Appendix A

Legislation and Policy Background Report

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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

Throughout the study, the 4 nominated high capacity vehicles will be compared to a reference vehicle operated by all *TransLink* bus service partners in South East Queensland, namely the:

- Two Door 12.5m Rigid Standard Route Bus.

The primary goal of this background report is to describe legislation, standards, land use and public transport plans and policies, and road and transport infrastructure programs which will impact on the future deployment and operation of the 4 high capacity vehicle types in South East Queensland. Some 54 documents have been reviewed by the authors to prepare this background report, broadly comprising of the following, and have been separately listed in the bibliography at Appendix B:

- Commonwealth and Queensland Transport Operations and Road Use Management Acts and Regulations,
- Commonwealth Disability and Commonwealth and Queensland Heavy Vehicle Standards,
- Queensland Dept of Transport and Main Roads Mass Concession, Restricted Access and Over-dimension Heavy Vehicle Schemes,
- The Edition 3 Australian Design Rules,
- Australian, Queensland DTMR and Austroads Road Design Standards,
- Queensland Land Use, Road Use Management, Transport Infrastructure Development and TransLink Infrastructure and Service Planning Policies,
- Queensland Regional, Integrated Regional Transport, Transport and Roads Investment, SEQ Infrastructure, TransLink Network and TransLink Strategic Plans,
- Queensland Transport Infrastructure, Busway and Road Planning and Design Manuals,
- TransLink Brisbane Transport and Private Operator Bus Contracts, and
- Bus Driver Awards.

1.2 Heavy Omnibus Legislation and Standards

Part 2 of this background report describes the plethora of Commonwealth and State Acts, Regulations, Vehicle Design Rules, Compliances and Standards which specify how high capacity omnibuses can be configured and constructed for safe conveyance of passengers, where, how and by whom they can be operated on public transport route and school services, and the dimensional, concessional, and axle mass limits which regulate how many passengers they can carry on Queensland roads. This Part also explores how Queensland road rules and road design standards impose restrictions on where routes and bus stops can be placed for high capacity omnibuses.

Part 2 summarises the mandatory legislative constraints with which high capacity vehicles must comply.

1.3 Planning and Policy Impacts on Future High Capacity Vehicle Deployment

Part 3 of this report explores contemporary State, Dept of Transport and Main Roads and TransLink regional land use, public transport and road plans, policies and funding programs to assess their support for and impacts on future deployment of high capacity vehicles. This Part also reviews other miscellaneous Acts and Regulations which define how, when, by whom and what constraints will apply to public transport planning and high capacity vehicle operations in South East Queensland over the coming 20 year horizon out to the year 2031.

The narratives provided in this Part attempt to present a broad overview of the vision, principles and objectives driving public transport development and reform in South East Queensland, and interpret the relevance of these to the future demand for high capacity vehicles.

Sections are included toward the end of Part 3 which assess high capacity vehicle opportunities and constraints under existing *TransLink* policies, operator contracts and driver awards. These sections serve as an introduction to later reports being prepared for the main body of the study.

1.4 Findings and Insights

The following is a brief preview of some of the more interesting findings and insights found during the document reviews undertaken for this report.

1 New axle mass limits proposed in the draft *Heavy Vehicle National Regulation* are highly favourable to future deployment of ultralow floor high capacity route buses, most notably the rear pusher type articulated buses. Provided axle mass limits are not exceeded, the Australian vehicle design rules and Queensland regulations provide considerable flexibility in the way high capacity route bus cabin layouts can be configured. Bus seating can be optionally maximised to reduce passenger standing on long trips or alternatively reduced to maximise mass transit total carrying capacity on short trips. The distance for which continuous passenger standing is permitted on urban route bus services has recently been extended to 20km.

2 14.5m rigid high capacity route buses are 2m over length relative to contemporary *Australian Design Rules*, and as such, are not permitted under existing State or Territory road use management regulations to be registered and driven on public roads. They are however permitted to operate route bus services in some States and Territories under short term concessional access permits issued by the road authority in each jurisdiction.

14.5m rigid buses have now been formally recognised in the new draft Heavy Vehicle National Regulation and classified as an over length special class of heavy vehicle, subject to the proposed new higher mass limit (HML) axle weight restrictions and HML area permits which effectively restrict the areas and roads on which these buses can be driven. HML area permits will replace the current Department of Transport and Main Roads (DTMR) gazetted concessional ccess permits expiring on 30 June 2012.

By 2013, after the *Heavy Vehicle National Law* has been enacted across all Australian States and Territories, only the *National Heavy Vehicle Regulator*, in consultation with individual State and

Territory road authorities, will be empowered to declare HML areas and routes on which 14.5m rigid buses will be permitted to operate. National HML area permits will enable Gold Coast school and route bus services operated with 14.5m rigid buses to continue across the Queensland-NSW border.

3 Road authorities such as DTMR have previously had the power under State and Territory legislation to arbitrarily set different heavy vehicle dimension and axle mass limits for special heavy vehicle types that currently include 14.5m rigid buses. Consequently, 14.5m rigid bus concessional wheelbase and rear overhang length limits now vary considerably between the 3 Eastern States and ACT, and 14.5m rigid route buses built to meet these concessional length limits in each jurisdiction are also significantly different. The draft *Heavy Vehicle National Regulation* has not yet resolved the uniform wheelbase and rear overhang limits for 14.5m buses.

4 The draft *Heavy Vehicle National Regulation* has lifted the overall height limit on double deck buses to 4.4m to enable higher interior head clearances on both passenger decks, but has to date neither recognised ultralow floor double deck buses as an emerging new category of Australian heavy route omnibus, nor proposed higher general axle mass limits for PWD accessible ultralow floor double deck buses, similar to those already given to other PWD accessible bus sizes. There are 8 bridges in South East Queensland with clearances equal to or less than 4.4m.

5 Double deck buses are currently exempted from the stringent ADR59 structural rollover strength requirements applicable to all other heavy omnibus types. Consequently ADR59 exemptions for closed roof double deck urban route and school buses are anticipated to cease in future.

6 None of the 4 subject high capacity buses selected for the study was considered appropriate candidates for the 30 DTMR steep incline - no standing *Notified Roads* located in South East Queensland. School and route bus services on DTMR *Notifed Roads* should be operated using 12.5m rigid ADR68 *Complying Buses* fitted with structurally anchored seats, seat belts and child constraints.

7 High capacity hybrid diesel-electric buses are becoming increasingly more popular in European, SE Asian and USA capital cities because of their considerably faster take off acceleration from stops, lower fuel consumption and exhaust emissions in stop-start traffic conditions, and quieter operation relative to comparable high capacity diesel buses. Diesel-overhead electric and diesel-L-ion battery or supercap electric buses travelling through noise sensitive route sectors in these overseas cities must under local planning laws operate by electric motor only whilst located in CBD office districts, residential suburbs and public road tunnels. Environmental noise immission laws, rather than heavy vehicle noise emission rules, may restrict high capacity diesel buses from entering noise sensitive commercial, residential, health and education precincts under proposed future Queensland EPA environmental noise planning limits. Only traffic noise generated on State main roads are exempted from these limits.

8 The Queensland Road Planning and Design Manual and national Austroads Guide to Road Design Manual used by DTMR and SEQ Local Governments to design indented bus bays only have drawings suitable for 12m rigid and 18m articulated buses, but no drawings for 14.5m rigid buses. Other documents, including the *Code of IDAS* and *TransLink Infrastructure Manual* will need to be amended for high capacity buses.

9 In late 2011, DTMR published *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland* in response to desired regional outcomes 8, 10 and 12 of the *South East Queensland Regional Plan 2009 – 2031. Connecting SEQ 2031* describes sweeping changes to both the structure and operation of the rail and bus network in South East Queensland called *UrbanLink,* which is based on the mass transit trunk and feeder operating concept.

The proposed *UrbanLink* backbone is comprised of high speed long haul railway *ExpressLink*, busway and transitway spines radiating out from the Brisbane CBD to surrounding regional and sub-regional transport nodes called hubs, complemented by the new *GoldLinQ* light rail and *CoastConnect* coastal bus sub-spines on the Gold and Sunshine Coasts, with each sub-spine connected by high frequency cross-country connector and local bus services to the high-speed heavy rail corridors to the Brisbane CBD. A new form of bus service, similar to the railway *ExpressLink* is also envisaged in *Connecting SEQ 2031* that will provide 6am – 9pm express bus services between major outlying rail and bus station hubs in Greater Brisbane to other major transport nodes in adjoining SEQ regions, and from country railway stations to places of high employment.

High capacity buses are considered the optimum vehicle for carrying the high passenger loads expected on new *UrbanLink* cross-city, high frequency trunk and cross-country bus services proposed to be operated between regional activity centres.

10 *UrbanLink* implementation will involve conversion of hundreds of existing *TransLink* single seat bus journeys to split trunk and local feeder journeys, so that existing buses can be freed up to deliver higher frequency local district feeder services with greater area coverage. The effect of this structural reform to the way the SEQ bus network currently operates will be a transfer of multiple combined local district passenger loads to the proposed new high frequency trunk rail and bus spines.

A large number of early works planning, design and construct programs has been sighted in the State's current infrastructure funding programs to extend Brisbane busways and create multiple new bus priority transitways and corridors for the new *UrbanLink* bus network. *Connecting SEQ 2031* indicates that the development of these corridors will be packaged with the staged conversion of existing single seat bus services to trunk and feeder bus services, but there appears to be no planning or programs currently in place to deliver the additional fleet needed to operate the new trunk services along these priority bus corridors.

2. Heavy Omnibus Legislation and Standards

2.1 High Capacity Vehicle Types

Representative examples of the 4 high capacity vehicles and standard reference vehicle discussed in this report are illustrated below in Figure 1 and

Figure 2 respectively.

Figure 1: Representative Examples of the 4 High Capacity Vehicle Types

2 Door 12 - 12.5m Double Deck Bus		
2 Door 14.5m Rigid Bus		
2 Door 18m Articulated Bus		
3 Door 18m Articulated Superbus		

Figure 2: Representative Examples of the Standard Reference Vehicle

2 Door 12.5m Rigid Urban Route Bus		

2.2 Heavy Omnibus Passenger Carrying Capacity

All road vehicles illustrated in Figure 1 and

Figure 2 are similarly classified as both heavy vehicles and omnibuses in the relevant Commonwealth and Queensland legislation. Key determinants of how, when, where, who can be transported, who can operate, who can drive, and for what distance are closely linked by legislature to the vehicle type, length and height, axle configuration and permitted axle load masses. Every heavy vehicle omnibus axle configuration has an empty vehicle weight (the tare mass), a legislated maximum load limit and chassis manufacturer designed gross vehicle mass (GVM) limit. The passenger carrying capacity of the bus is essentially governed through legislation by the difference between the permitted axle mass limits and their respective axle tare masses. Maximisation of passenger carrying capacity on high capacity vehicles is achieved in practice by deliberate placement of passenger seats, luggage racks and standee areas to distribute the live passenger and luggage loads across all axles up to their permitted maximum load limits.

The 4 subject high capacity vehicles have a higher combined standing and seated passenger carrying capacity than the standard reference 12.5m rigid urban route bus and their typical passenger capacity ranges have been tabulated below in Table 1. Variations arise between identical bus configuration types fuelled by compressed natural gas and diesel, the former having a lower registered carrying capacity due to permitted axle loads less the combined weight of roof mounted gas cylinders and stored maximum natural gas charges. Seated capacities indicated in Table 1 are for modern ultralow floor *Disability Discrimination Act (DDA)* compliant urban route buses equipped with 2 rear facing wheelchair spaces, each fitted with 3 to 4 side or forward facing flip-up passenger seats used as both seated and standee floor areas when wheelchair spaces are unoccupied.

Table 1: Typical Passenger Carrying Capacity of Standard and High Capacity Vehicles

Typical Passenger Capacity	2 Door 12.5m Rigid Bus (Reference)	2 Door 12 - 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Wheelchair	2	2	2	2	2
Seated	44 - 47	82 - 96	56 - 58	63 - 65	46 - 52
Standing	18 - 22	20 - 27	34 - 42	20 - 37	58 - 66
Total	62 - 69	109 - 111	92 - 98	85 - 100	110 - 112
Equivalent Median Standard 12.5m Buses		1.69	1.46	1.42	1.71

2.3 Heavy Vehicle Occupant Load Limits

Australian legislation and the national vehicle standards which limit the maximum passenger carrying capacity of heavy omnibuses specify the:

- Heavy Vehicle Occupant Load Limits: to be adopted for legal determination of live occupant and luggage loads,
- Heavy Vehicle Axle Mass Limits: which define the maximum axle mass (or weight) permitted on each heavy vehicle axle or axle group, and the combined maximum gross mass (or weight) permitted on all axles and axle groups for different heavy vehicle types,
- Heavy Omnibus Standee Floor Area Restrictions: which define the floor areas on heavy omnibuses where luggage may be stowed and where passengers are permitted and not permitted to stand, and
- Heavy Omnibus Configuration and Dimensional Limits: which define the permitted configuration and dimensions of different heavy omnibus body types.

The Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* specifies that all vehicles must comply with the *Australian Vehicle National Standards Rules 1999 (Cth)*. Buses over 5 tonne G*ross Vehicle Mass (GVM)* registered in Australia are described by *Australian Vehicle National Standard Rules* and *Australian Design Rules (ADRs)* as *Category ME Heavy Omnibuses*. ADR58/00 defines the maximum occupant capacity applicable to *Category ME* heavy school and route service omnibuses without dedicated heavy luggage spaces as 65kg per driver, crew member and passenger.

Under these *Rules*, the passenger loading condition to be applied in the determination of live occupant load is taken to be the weight distribution of the seated driver and passengers in all available bus manufacturer nominated seat positions, plus the uniform distribution of standee passengers (including a conductor or ticket inspection crew member if applicable) to all aisle way and allocated standing areas, excluding those standing areas preserved by ADR58/00 and ADR44/02 for exterior passenger entry/exit doors, emergency exits and interior or rear open exterior upper deck staircases on double deck heavy omnibuses. Where a dedicated heavy luggage space is provided for carriage of other than personal hand luggage on a heavy omnibus, a mass of 15kg per passenger (seated and standing), distributed evenly throughout the luggage space, must also be added to the live axle load assessment.

Up to permitted axle mass limits, total passenger carrying capacity on school and route omnibuses can be increased through bus manufacturer design by reducing the number of available passenger seats and dedicating more floor space to standees as has been applied to maximise the carrying capacity on the 3 door 18m articulated superbuses, but other legislative instruments (described later) limit the road types, distance and duration of school and route services on which passengers are permitted to stand. (Refer to Table 1 for a comparison of a typical 2 door 18m articulated route bus with high seating capacity, and a typical 3 door 18m articulated superbus with reduced seating capacity).

2.4 Heavy Vehicle Axle Mass Limits

Permitted axle mass limits in Queensland for the reference standard 12.5m route omnibus and 4 subject high capacity omnibuses have been contrasted below in Table 2 to Table 5 inclusive.

A new *Heavy Vehicle National Law Bill 2011* was introduced into Queensland Parliament on 15 November 2011 and is anticipated to be enacted by late 2012, together with a new *Heavy Vehicle (Mass, Dimension and Loading) National Regulation* currently in its final draft review stage. Similar heavy vehicle bills and regulations are expected to be enacted in all Australian States and Territories by 2013, heralding a single uniform set of heavy vehicle dimension and axle mass limits throughout Australia. Regulated axle mass limits for heavy omnibuses are currently specified in the Queensland *Transport Operations (Road Use Management – Mass, Dimensions and Loading) Regulation 2005*, last revised in July 2011, and these substantially mirror the new national general mass limits proposed for uniform national regulation.

Subject to specified ADR compliances for newly built heavy vehicles defined by the national regulation, the new national general axle mass limits will afford automatic cross border national licensing of all heavy omnibuses in all Australian States and Territories. New national higher mass limits prescribe the upper axle mass limits that individual State and Territory road managers such as the *Queensland Department of Transport and Main Roads (DTMR)* and the newly created *National Heavy Vehicle Regulator* may approve for special class oversize and/or over mass heavy vehicle types such as 14.5m rigid route buses operating in road authority defined areas or roads, and replace State and Territory Government gazetted *Controlled Access Permit* systems presently operated by each independent road manager. The new national higher mass limit permits are similarly intended to operate across State and Territory borders and where higher mass limits have been proposed in the national regulation, equate to an increased heavy omnibus passenger carrying capacity of 15 passengers/axle tonne increase.

The current version draft *National Heavy Vehicle Regulation* broadly differentiates heavy route omnibuses into 5 categories:

- Complying Buses – are heavy omnibuses which comply with Australian passenger safety standards ADR44/02, ADR59/00 and ADR68/00 and are fitted with power-train retarders. All existing *TransLink* route buses other than double deck buses must comply with ADR44/02 and ADR59/00, and most existing route buses fitted with automatic transmissions invariably have inbuilt power-train retarders. ADR68/00 however strictly applies to heavy omnibuses specifically designed for and operated with all passengers seated on structurally anchored, strongly built, crash-resistant passenger seats equipped with individual occupant seat belts or infant child restraints.

  Some 30 roads within *TransLink*'s SEQ public transport network boundaries are currently classified by DTMR as *Notified Roads,* considered too steep for school and route buses to safely navigate with standing passengers. Complying 12.5m rigid buses and high floor coaches would be considered suitable for operating school and rural route services on DTMR *Notified Roads,* but the roads identified in DTMR published maps are considered unsuitable for any of the 4 subject high capacity buses,
- Ultra-low Floor Route Buses – must have 2 axles, places for standees and a stairless entry for passengers. This definition deliberately excludes 14.5m rigid and double deck route buses,
- Ultra-low Floor Articulated Buses – must have passenger access and rotary movement between their articulated sections, places for standees and a stairless entry for passengers. These include all new model 18m articulated buses and articulated superbuses,
- Class 2 Restricted Access Buses - cover oversize, over mass 14.5m rigid route buses which are to use the new national axle higher mass limits, and
- Other Buses - cover double deck buses and most existing 10 year and older high floor 12.5m rigid route buses, coaches and articulated buses presently operating *TransLink* scheduled school and route bus services in South East Queensland.

Notwithstanding the general mass limits prescribed in the draft *National Heavy Vehicle Regulation* or the higher mass limits permitted by the *National Heavy Vehicle Regulator* in concert with individual State and Territory road authorities, the *Gross Vehicle Mass (GVM)* specified by the bus chassis manufacturer for each heavy vehicle axle, its road wheels and tyres may not be exceeded.

Table 2: Permitted Axle Mass Limits for 2 Door 12.5m Standard Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Buses)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Buses)
Rear Drive Axle with Dual Tyres	10t (High Floor) 11t (Ultra-Low Floor)	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	15t (High Floor) 16t (Complying or Ultra-low Floor)	No Higher Mass Limit Permitted	15t (High Floor) 16t (Complying or Ultra-low Floor)

Table 3: Permitted Axle Mass Limits for 2 Door 14.5m Extended Rigid Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Upper Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	Non-Compliant	No Higher Mass Upper Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Tandem Axle Group with Dual Drive Tyres and Single Steer Axle with Single Tyres	Non-Compliant	14t **	13t ** (Standing Permitted) 14t ** (Complying Bus)
Gross Mass	Non-Compliant	20t	19t (Standing Permitted) 20t (Complying Bus)

Table 4: Permitted Axle Mass Limits for 2 Door 12 - 12.5m Double Deck Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
<<< Single Steer Front Axle >>>			
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Drive Dual Tandem Axle Group Fitted with Two Tyres	16.5t **	17t **	16.5t **
Gross Mass	22.5t	23t	22.5t
<<< Twin Steer Front Axle >>>			
Twin Steer Front Axle with Single Tyres	10t (Non-Load Sharing) 11t (Load Sharing)	No Higher Mass Limit Permitted	10t (Non-Load Sharing) 11t (Load Sharing)
Rear Drive Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t
Gross Mass	20t	No Higher Mass Limit Permitted	20t (Non-Load Sharing) 21t (Load Sharing)

**S55 of the Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* stipulates that heavy omnibus axles in an axle group other than a twin steer axle group must relate to each other through a load-sharing suspension system with effective damping characteristics on all axles of the group such that no axle carries over 10% more than the mass it would carry if the load was divided equally.

Table 5: Permitted Axle Mass Limits for 2 and 3 Door 18m Articulated Buses

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limits	Draft Heavy Vehicle National Regulation General Mass Limits
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Mid Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Rear Axle with Single Steer Tyres (High Floor)	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	22t	No Higher Mass Limit Permitted	22t (High Floor) 26t (Ultra-low Floor)

2.5 Heavy Omnibus Standee Floor Area Restrictions

Urban route buses used for both seated and standee passenger loads require a minimum longitudinal 380mm aisle width under ADR58/00, where complying buses designed for and operated exclusively with seated passengers are afforded a reduced aisle width concession of 300mm. A similar 300mm reduced aisle width concession applies to the longitudinal aisles on the upper deck of a double deck bus where no standing passengers are permitted by Queensland road rules whilst the double deck bus is in motion. Notwithstanding these restrictions, for modern high capacity heavy route omnibuses with minimum ADR58/00 compliant urban route bus moulded seats with 400mm wide cushions laid out in double forward facing rows along either side of the centre aisle, greater aisle widths of around 450mm are readily achieved.

The national *Disability Standards for Accessible Public Transport 2002* specifies a minimum of two separate or preferably consolidated 1,300mm x 800mm wheelchair parking spaces on all urban route buses and an increased aisle width of 850mm from the wheelchair loading door and driver operated or manually assisted wheelchair ramp (normally installed at the front entry door) to both wheelchair parking spaces, other than between heavy omnibus wheel arches where the aisle width may be reduced (but only if necessary) to 750mm.

Up to the permitted axle mass limits, longer omnibuses with proportionately greater floor areas can accommodate more standees, however low floor bus aisles with a rear of rear door gradient over 1 in 12, and aisle way or flat floor spaces with head room clearances below 1,800mm for single deck buses, and 1,650mm for double deck buses, may not be used as operator allocated standee areas. Other doorway, aisle and standing area requirements called for in the national vehicle and disability standards include anti-slip steps and flooring, and provision of a suitable number of hand straps, hand grips and hand rails in all standee areas. Queensland road rules, described later, strictly prohibit non-complying route buses not meeting these ADR58/00 prescribed standee safety requirements from being operated on school or urban routes with other than fully seated passengers.

Each additional entry/exit door added to the left hand side of an omnibus passenger cabin above the compulsory minimum front entry/exit door specified by ADR58/00 reduces its available passenger floor space by approximately 0.7m^2 (namely 2 seat or 4 standee spaces) for a minimum 850mm wide single entry/exit door, and approximately 1.15m^2 (4 seat or 7 standee spaces) for a 1,200mm wide double entry/exit door. ADR58/00 does not permit installation of any passenger entry/exit doors on the right hand side of an omnibus other than for passenger emergency exit doors, and high capacity vehicles may not be used in Australia for centre platform station loading similar to that permitted by regulations for tram, rail bus, light rail vehicles and trains.

Interior and rear exterior open upper deck staircases are permitted on double deck buses but similarly encroach on available wheelchair, seated and standee passenger floor spaces. To compensate, ADR58/00 permits non-DDA compliant narrow 400mm wide straight or spiral stairways to the upper deck on a double deck bus.

ADR59/00 rollover body structural strength requirements apply to all single deck omnibuses operated in Australia, but do not currently apply to double deck buses. Upper deck seating capacity on double deck buses is however limited under ADR58/00 to any passenger loading condition that would cause a double deck bus to become unstable and roll on a transverse incline of 28º or higher. Such a loading condition can occur with a fully seated load on the upper deck and no passengers on the lower deck to lower the heavy vehicle centre of mass. Current exemption from body structural rollover compliance with ADR59/00 afforded exclusively to double deck heavy omnibuses is highly likely to change in coming years if their deployment on capital city route bus operations becomes as widespread as it was in the mid-decades of the last century before ADR59/00 compliance was legislated.

Whilst ADR58/00 must be universally applied to the determination of legal maximum passenger loading throughout Australia, most Australian urban route bus designers and capital city bus operators adopt an empirical (but unlegislated) standee comfort space of 5 – 6.25 standees/m^2 of allocated standing floor space to prevent excessive passenger crushing and aisle blockage to boarding and alighting passenger movements.

2.6 Heavy Omnibus Configuration and Dimension Limits

ADR43/04 sets forth the permitted configuration and dimensions applicable to Australian registered heavy omnibuses. These are summarised overleaf in Table 6.

14.5m rigid heavy route omnibuses are currently classified as oversize, over mass heavy vehicles in all Australian jurisdictions, do not comply with the ADR43/04 maximum rigid vehicle length limit, have been registered to date under special provisions of the *National Transport Commission Performance Based Standards Scheme,* and are presently only permitted to operate in Queensland under gazetted *Controlled Access Bus Class Permit No 127-TH-11,* expiring 30 June 2012. Permit 127-TH-11 is intended as a stopgap authorisation to operate 14.5m route buses on Queensland roads, and only allows their controlled access route operations on:

- Major State and Local Government controlled roads, franchise toll roads and motorways classified as *Regional Significant Roads* or higher in the *State Road Network of Queensland* road hierarchy, but excluding permit nominated regionally significant roads in SEQ to Mount Tamborine and Lamington National Park and Samford – Mt Glorious Road,
- Declared busways, and
- Permit nominated arterial, sub-arterial and local roads within Brisbane City Council local government boundaries.

Controlled Access Permit No 127-TH-11 currently enables the rear overhang of a 14.5m rigid school or route bus to be extended 1m beyond that allowed under ADR43/00 to the lesser of 70% of the front axle to rear overhang line (namely the vehicle wheelbase at 1/3 of the rear tandem axle separation distance) or 4.7m. Where the rear tandem tag axle steers as on all modern 14.5m rigid buses (refer Figure 3), the rear overhang is measured from the rear drive axle (i.e. by treating the rear steer axle as if it were non-existent), resulting in rear steered 14.5m rigid buses exhibiting a high rear end swing when departing from a bus stop or turning on full lock.

Figure 3: ADR/Regulation Defined Rear Overhang for a 14.5m Rigid Bus with Rear Steering Tag Axle

Table 6: ADR43/04 Permitted Heavy Omnibus Configuration and Dimensional Limits

Configuration or Dimension	2 Door 12.5m Rigid Bus (Reference)	2 Door 12 - 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Maximum Length	12.5m	12.5m	Non-Compliant	18m	18m
Maximum Height	4.3m	4.3m	4.3m	4.3m	4.3m
Maximum Width	2.5m	2.5m	2.5m	2.5m	2.5m
Outer Turning Circle	25m	25m	25m	24m	24m
Inner Turning Circle	Not Applicable	Not Applicable	Not Applicable	5.3m	5.3m
Rear Overhang	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	3.7m	3.7m
Full Load Minimum Ground Clearance Midway between Axle Pairs on Flat Roads	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle
Full Load Minimum Load Ground Clearance Midway between Axle Pairs over Road Apexes	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients

Controlled access 14.5m rigid heavy omnibuses built for New South Wales route operations have been permitted to date to extend their rear overhangs a further 200mm than in Queensland to the lesser of 70% of the front axle to rear overhang line or 4.9m. Consequently, a 14.5m rigid route bus built to Queensland controlled access permit limits can, with dual Queensland and New South Wales controlled access permits, operate school and route services crossing the border into NSW, but a 14.5m rigid bus built to NSW permit rules would not be permitted to hold dual permits and operate school and route services across the border into Queensland. Similarly, Victorian controlled access permit rules nominate a lower rear overhang than in Queensland or NSW of the lesser or 60% of the front axle to rear overhang line or 4.3m, similarly preventing NSW controlled access 14.5m rigid buses from entering Victoria. The draft *Heavy Vehicle National Regulation*, once enacted by all States and Territories, is intended to standardise all route bus length, height, width, front/rear overhang and axle mass limits throughout Australia.

The newly revised *Queensland Transport Operations (Mass, Dimension and Loading) Regulation 2005* and new draft *Heavy Vehicle National Regulation* adopt most of the earlier mentioned ADR43/04 permitted heavy omnibus configuration and dimension limits, but differ slightly in their treatment of high capacity buses:

- The Queensland regulation currently prohibits driving of any rigid heavy vehicle over 12.5m in length on Queensland roads, but the draft national regulation recognises heavy rigid omnibuses up to 14.5m long as Class 2 oversize rigid heavy omnibuses and specifies their permitted axle higher mass limits (HML), who is authorised, and the processes to be adopted to define future HML areas and routes in each road jurisdiction where 14.5m rigid omnibuses will be permitted to operate. The new draft regulation has to date not yet defined the permitted rear overhang for 14.5m rigid heavy omnibuses,
- The Queensland regulation does not permit higher gross mass limits for double deck buses with dual front load sharing steer axles and ultralow bottom deck floor heights capable of steplessly boarding passengers and wheelchairs. The national regulation recognises the former, but has not yet created a special heavy omnibus class for the emerging new types of ultralow floor double deck buses,
- The Queensland regulation does not differentiate between older high floor and modern ultralow floor “rear pusher” type 18m articulated buses, but the draft national regulation recognises older high floor and rear pusher ultralow floor articulated buses differently, and permits up to 4t higher gross axle mass limits on the latter,
- Both regulations now permit 100mm higher 4.4m high double deck buses, and
- Both regulations prevent the new *National Heavy Vehicle Regulator* and individual road authorities from granting arbitrary concessional mass and increased dimension limits to heavy omnibuses.

2.7 Performance Standards Affecting High Capacity Omnibuses

High capacity omnibuses need larger engines and transmissions to accelerate, maintain road speed and climb grades, and larger capacity compressed air braking systems and retarders to decelerate and descend inclines at a steady speed when fully loaded, than do their lower mass standard 12.5m rigid counterparts. This necessitates installation of larger and heavier onboard fuel storage tanks to power the vehicle and its various ancillary loads such as cabin ventilation, lighting and air conditioning, and to maintain vehicle operating range without twice daily refuelling. Increased relative mass and dimensions of HCVs also affect high capacity vehicle road performance relative to 12.5m standard buses and are discussed below.

2.7.1 Maximum Road Speed

ADR65/00 limits the maximum permitted road speed of a heavy omnibus to 100km/h, specifies that attainable road speed be automatically governed by a mechanical or electronic speed limiter, and stipulates that the power train design based on the bus chassis manufacturer’s maximum engine speed, overall transmission/differential gear reduction, tyre size and wheel revolutions per kilometre prevent a heavy omnibus from exceeding 100km/h.

These speed limiting conditions apply irrespective of whether a heavy omnibus is fully loaded or unloaded, and impact more significantly on the maximum road speed attainable by high capacity omnibuses than on smaller carrying capacity standard buses because of the relative change in live passenger and luggage weight between the unloaded and fully loaded conditions. In practice, the selection of engine size, automatic transmission and differential gear ratios needed for acceptable acceleration from urban bus stops, on hill starts and hill climbs limit the realisable maximum speed reached by a high capacity bus to 85 – 90km/h.

S140 of the Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* last revised in December 2011 now exempts Queensland high capacity omnibuses with a GVM over 14.5t (other than *Complying Buses*) that are fitted with hand grips or similar equipment for standing passengers from being fitted with ADR65/00 compliant speed limiting devices. It is unclear however whether this Queensland exemption will continue on after the national regulations take force.

2.7.2 Maximum External Vehicle Noise Emissions and EPA Permitted Environmental Noise Immissions

ADR83/00 limits the maximum permitted external noise emission within 7.5m of either side of a heavy omnibus passing at a speed of 50kph - 75% of its maximum road speed to 80dB(A) if fitted with an engine rated in the power range of 150 – 320kW. Engines in this rated power range are fitted on both the 12.5m route bus and the 4 subject high capacity route buses, but the latter have 30 – 45% larger and proportionately noisier engines. Consequently, 12.5m route buses can readily meet noise emission levels 5 to 10dB(A) below that set in ADR83/00, where high capacity omnibuses require elaborate engine noise encapsulation, exhaust muffling and radiator fan noise containment treatments to achieve noise emission levels below the ADR 80dB(A) threshold, the limit for which has been progressively falling over successive revisions of the standard.

Environmental nuisance noise imissions (namely nuisance noise levels reaching roadside property walls) are regulated in Queensland under Part 3 of the *Environmental Protection Act 1994* and the *Environmental Protection Regulation 2008*. The *Act* nominates the Queensland *Environmental Protection Agency (EPA)* and each *Local Government Authority* as responsible for the administration and enforcement of the noise immission regulations respectively, and the *Environmental Protection (Noise) Policy 2008* as setting the environmental noise acoustic quality objectives to be adopted throughout Queensland for new property development approvals and environmental noise planning levels. Traffic noise immissions from railways and main roads are exempted under the Act, but for non-main regional, arterial, sub-arterial and local roads passing through noise sensitive commercial and residential districts, the development approval planning noise levels are presently prescribed in the *Regulation* as:

- 63dB(A) at the $L_{10,18}$ level,
- 60dB(A) at the 1 hour continuous RMS A-weighted level ($L_{Aeq,1}$) between 10:00pm and 6:00am, and
- 80dB(A) for any single noise event maximum SPL.

The noise planning objectives of the Act, its Regulation and Policy aim to progressively ratchet down $L_{A1,1}$ hourly traffic noise immissions reaching private dwellings in future years to as low as 65dB(A) for all hours of the day, and $L_{Aeq,1}$ noise immission levels reaching prescribed noise sensitive public institutions such as schools, universities, childcare centres, hospitals and doctor surgeries to as low as 35dB(A).

Compliance with *EPA* regulated noise immission planning limits may in future prevent or limit the deployment of high capacity diesel omnibuses or enforce alternative use of low noise emission diesel-electric and hybrid buses in noise sensitive precincts. Noise immission compliances similar to those proposed by the *Environmental Protection (Noise) Policy* have already been implemented in many major European, South East Asian, Canadian and USA cities where high capacity overhead cable powered diesel-electric and hybrid omnibuses travelling through noise sensitive route sectors must operate by electric motor only whilst located in CBD office districts, residential suburbs and public road tunnels.

2.7.3 Upper Deck Level and Stairway Standee CCTV Monitoring on Double Deck Buses

Standing passengers are not permitted on the upper deck or stairways of a double deck bus when in motion. This will require double deck bus drivers to periodically observe regulated no standing areas on the vehicle before and after departing bus stops from a CCTV monitor mounted in the driver's cabin, and to use a pre-recorded or live voice *public address (PA)* announcement to direct passengers to sit. S31 of the *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010 and* ADR42/00 define the conditions under which a driver's visual display unit may be used on a heavy omnibus as a driving aid and where a permitted display unit may be mounted within the driver's visual field of view.

2.7.4 High Capacity Omnibus Standing and Overloading Restrictions

High capacity buses are traditionally designed and operated to minimise the number of standees or to reduce recurring incidents of overloading and missed passenger pick-ups. The *Transport Operations (Passenger Transport) Standard 2010* identifies any omnibus used for delivery of public passenger services as a *Relevant Vehicle* and prohibits a driver from operating a *Relevant Vehicle*:

- In an overloaded condition,
- Without an appropriate licence class and driver authorisation. An *MR (Medium Rigid)* class licence is needed to drive a standard 12.5m two axle rigid omnibus and a HR (heavy rigid) class licence to drive all 4 three axle high capacity omnibuses whose *gross vehicle masses (GVM)* exceed the prescribed 15t threshold. A HCV driver must continuously hold his/her open C class licence for 1 year before becoming eligible to hold an MR class licence, and must thereafter continuously hold both his/her C class licence and MR class licence for a period of 2 years and 1 year respectively before becoming eligible to hold a HR class licence. Driver licence requirements apply to all persons who drive a *Relevant Vehicle* (e.g. bus drivers, mechanics, cleaners, etc) on a road, but a driver authorisation is only mandated for a driver who actually operates a *Relevant Vehicle* on a public passenger service,
- With standing passengers in a bus fitted with seat belts, namely a *Complying Bus*, or *a Regional Classification Vehicle* with side facing seats (discussed later). The driver must additionally report any standing passenger allowed on a *Complying Bus* to his/her *Authorised Operator* at the end of each passenger service shift, or
- With standing passengers if not designed and constructed for such (to ADR58/00), on a long distance scheduled passenger service, a DTMR no standing passenger *Notified Road*, or if a scheduled school bus, for a distance of more than 20km**. The *Transport Operations (Passenger Transport) Standard* allows for 3 primary or pre-school children to occupy a single twin adult passenger seat for up to 90min, and an adult to nurse an infant on any scheduled school or route

omnibus not fitted with seat belts; but not on any *Complying Bus*, unless each child is individually restrained by a seat belt or in an approved infant child restraint.

(**The *Transport Operations (Passenger Transport) Standard* has only recently been amended to remove the no standee rule for school bus routes in excess of 20km. Prior to the amendment of this *Standard*, Brisbane Transport had to deploy articulated buses on its non-stop Route 142 to provide sufficient seating capacity for school children. Articulated buses were deployed on this route to provide additional seats, but the vehicle's total carrying capacity wasn't being fully utilised. With this restriction now removed, *TransLink* is free to allocate high capacity vehicles on any route other than a *Complying Bus* route operating on a DTMR *Notified Road*)

2.7.5 High Capacity Omnibus Scheduling for Mixed Bus Types

Because high capacity buses are permitted to board higher passenger loads, they may require bus type specific timetables if scheduled on mixed high capacity and standard 12.5m bus school or route services. The *Transport Operations (Passenger Transport) Standard 2010* stipulates that the driver of a scheduled school or route service must provide the passenger transport service in accordance with advertised schedules unless prevented from doing so by unforeseeable circumstances or schedules that are not realistically achievable. The *Authorised Operator* is obliged under the *Standard* to advertise timetables that are realistically achievable for the bus type and size allocated to a scheduled school or route service.

2.7.6 Prescribed Vehicle Regional Classification Requirements

The *Passenger Transport Standard* defines the prescribed vehicle classification of an omnibus as a *Local Classification Vehicle* if its operates a journey within a radius of 40km from the first passenger pick-up point, or if the journey is entirely within a single or contiguous urban area within a radius of 40km from the first passenger pick-up point. This classification applies to most existing heavy route omnibuses used for *TransLink* school and route bus services in SEQ.

If long haul trunk and spine express route services assigned to high capacity omnibuses as envisaged in *Connecting SEQ 2031* (discussed later) exceeded the 40km radius, but were less than 350km radius from the first passenger pick-up point, the prescribed vehicle classification of the high capacity bus would automatically revert to that of a *Regional Classification Vehicle* which must meet more stringent ADR safety compliances than a *Local Classification Vehicle*. The additional compliances specified for a *Regional Classification Vehicle* high capacity omnibus over those applicable to a *Local Classification* standard or high capacity route bus would include:

- Compliance with all non-route bus ADRs applicable to high and low back passenger seats,
- Installation of lap seat belts on side facing passenger seats complying with ADR4/00 and ADR5/00, and
- Provisions for light passenger luggage incapable of being held by hand, to be stored in overhead lockers or racks, but not in an aisle or any other floor space that would impede passenger egress to entry/exit doors or emergency exit doors. Where carriage of heavy passenger luggage was approved by *TransLink* or its *Authorised Operator*, it would either have to be placed in a passenger segregated luggage compartment or trailer, the latter of which would not be permitted under the draft *National Heavy Vehicle Regulation* on a 14.5m or 18m articulated route bus.

2.8 Queensland Road Rules Impacting High Capacity Bus Operations

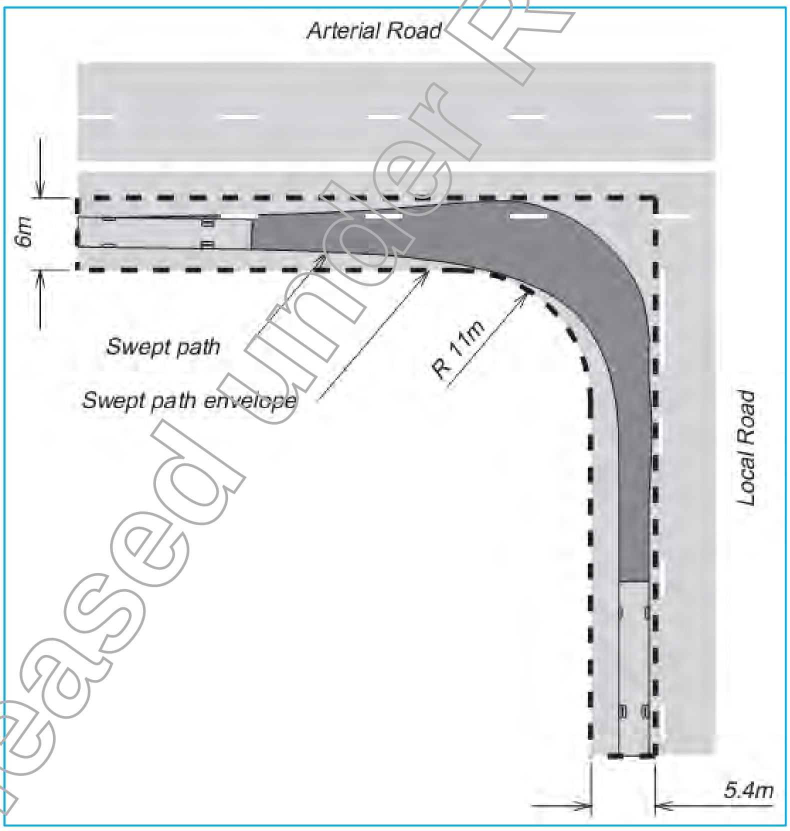
2.8.1 Heavy Omnibus Speed Limit

Notwithstanding the posted speed limit on any road or any exemption for fitment of speed limiting devices on high capacity omnibuses with a GVM over 14.5t, the Queensland *Transport Operations (Road Use Management – Road Rules) Regulation 2009* (hereinafter referred to as the *"Road Rules"*) prohibits the driver of a heavy omnibus with a GVM over 5t from travelling at a road speed greater than 100km/h.

2.8.2 Left and Right Turning Constraints on 14.5m Rigid Buses

Sections 27 through 34 inclusive of the *Road Rules* define how a long wheelbase heavy vehicle fitted with rear *Do Not Overtake Turning Vehicle Signs* may negotiate left and right hand turns from far side turning lanes at an intersection. The rules effectively limit left turns for a 14.5m over length bus to those from a two lane local road to a multilane major road where over length buses can safely and legally cross unidirectional traffic lanes as depicted in Figure 4, but similar left turn manoeuvres are not possible from a two lane local road into another two lane local road without either driving on the wrong side of the road or increasing the front steering locks to obtain a reduced swept path radius.

Figure 4: 14.5m Rigid Bus Left Turn from a Single Lane Local Road into a Two-Lane Arterial Road



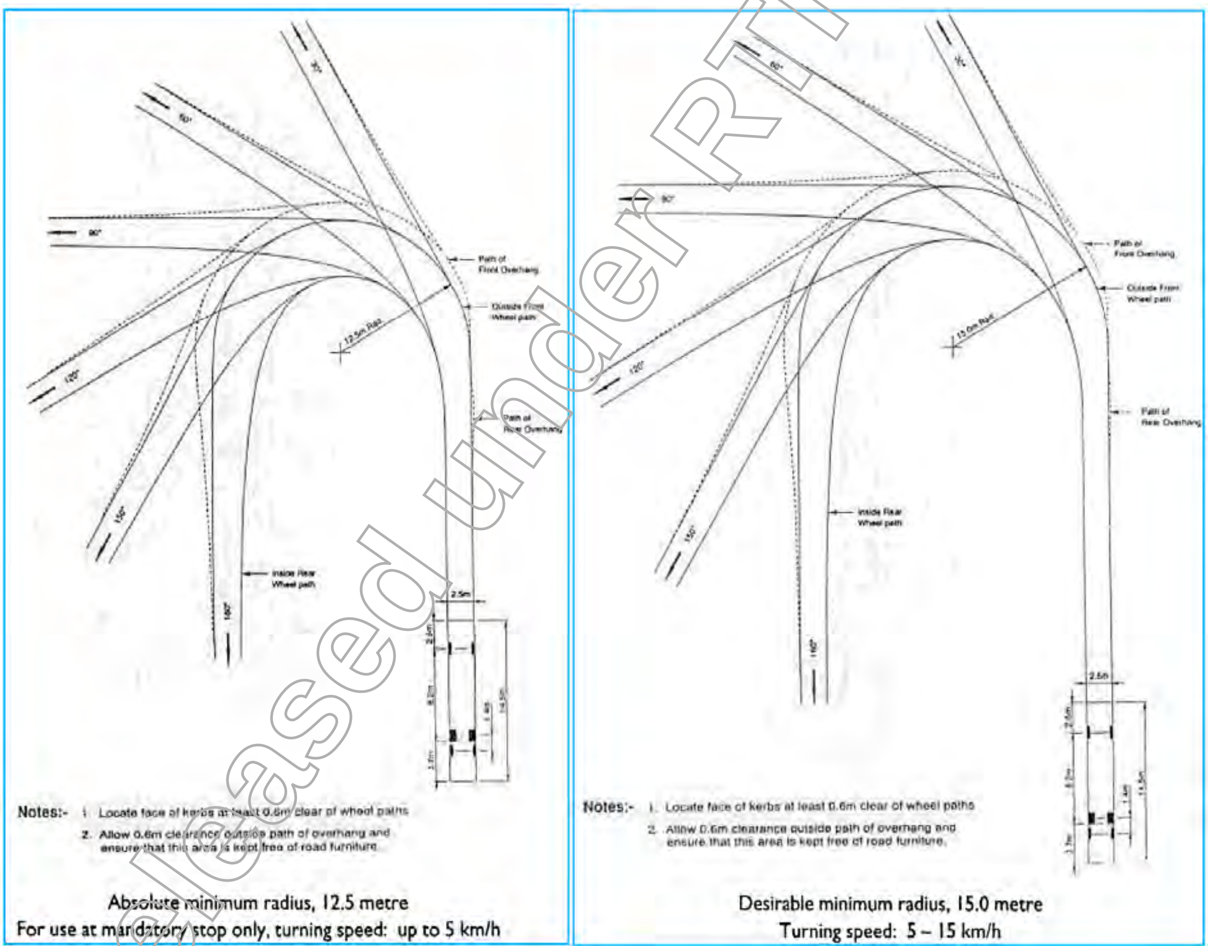
2.8.3 Turning Circle, Swept Path and Tail Swing on 14.5m Buses

ADR43/04 and the *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* specify that a heavy vehicle must be capable of turning left or right in a circle of not more than 25m diameter (12.5m radius) measured on the outer edge of its tyre track at ground level. This maximum regulated turning radius is applied by *Austroads* and all Australian road authorities to the design of minimum left turn kerb radii at intersections such as that depicted in Figure 4, which typically include an additional +R0.6m safety margin and range from R10m on local suburban road intersections up to R15m on major road intersections.

Neither vehicle standard specifies the vehicle road speed at which the regulated turning circle must be measured, but *Austroads* adopts a road design turning speed of 5km/h for 14.5m rigid bus turning circles of 12.5m radius (25m diameter) and recommends a greater turning circle of 15m radius (30m diameter) for road intersection design turning speeds up to 15km/h, as illustrated in Figure 5. At the latter 15km/h turning speed, the wall-to-wall swept path measured at the front right overhang of an over length 14.5m rigid bus is 32m (or R16m). These very large turning radii can be readily accomplished on a modern 14.5m rigid omnibus by setting the front steering wheel full lock stops to approximately 42°, but this effectively restricts operation to multilane main, arterial and sub-arterial roads, and in many cases, would prevent 14.5m rigid bus service routes from entering congested central business districts.

To enable tighter left turn and right turn cornering and full lock exiting from restricted length bus stops, 14.5m rigid bus operators increase their front steering full lock stop settings up to around 52° to achieve a greatly reduced wall-to-wall swept path radius of R12.5m, as illustrated in Figure 6.

Figure 5: Austroads 14.5m Long Rigid Bus Swept Paths Measured at 5km/h and 15km/h

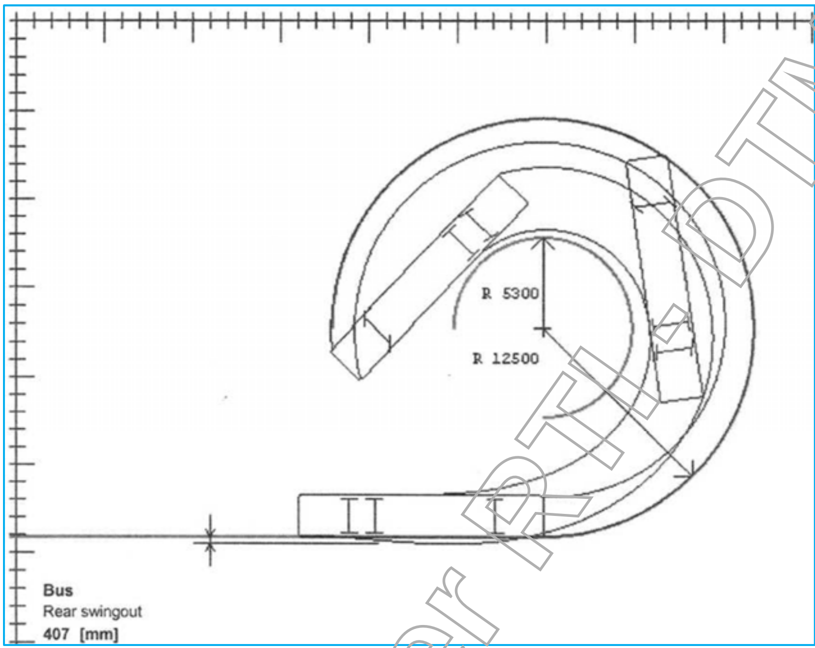


Whilst 14.5m rigid buses with increased front steering lock angles are fully compliant with the relevant ADR and Regulation, their reduced wall-to-wall turning radii may have the following unintended consequences if bus drivers do not exercise due care to prevent:

- Mid-body skirt kerb crossing or rear wheel kerb mounting during full lock left lane to left lane turns at intersections,

- Mid body skirt median crossing of median noses or rear wheel median nose mounting during full lock right lane turns at intersections,
- Rear tail swing in over kerbs on full lock right turn exiting from departure blocked left lane bus stops and zones, and
- Rear tail swing out into adjacent traffic lanes during full lock left and right turns.

Figure 6: 14.5m Rigid Bus Swept Path with Front Full Lock Stops Set for R12.5m Wall-to-Wall



These driving safety risks associated with setting increased front steering lock angles can be mitigated through appropriate management strategies for 14.5m rigid buses such as:

- Compulsory route assessments for all new 14.5m rigid bus services as currently enforced by the Road Traffic Authority of New South Wales,
- 14.5m rigid bus driver route orientation training,
- Positioning 14.5m rigid bus stops well clear of intersections where route left turns are scheduled,
- Preventing regulated parking zones immediately forward of straight left lane bus stop zones, and
- Constructing purpose built indented bus stops for 14.5m rigid buses with adequate run in and run out tapers.

2.8.4 Maximum Take Off Acceleration and Give Way to High Capacity Buses

S77 of the *Road Rules* states that all drivers must give way to a bus in the left lane or left line of traffic on a road in a built-up area where the speed limit is not more than 70km/h and the bus:

- Has stopped, is moving slowly or is stationary in a bus stop bay,
- Displays a rear *Give Way to Buses* sign and has activated its right direction turn indicator, or is
- About to re-enter or proceed ahead in the left lane or line of traffic in which the bus driver is already driving.

The give way to buses rule does not apply however to buses exiting bus stops and crossing lanes to right turn, buses pulling into traffic lanes on roads with posted speed limits above 70km/h, or relieve bus drivers from safely exiting bus stops without first checking in rear view mirrors that sufficient time has been given to oncoming traffic and sufficient gap length exists to safely re-enter the left line of traffic. The higher mass, slower acceleration and longer length of high capacity buses dictates that longer bus stop dwell times be allowed in high capacity bus service timetables for traffic lane re-entries during peak traffic periods.

2.8.5 Low Clearance Signs Affecting Double Deck High Capacity Buses

Notwithstanding the current 4.3m general heavy vehicle height limit or proposed new national extended 4.4m height limit permitted for double deck heavy omnibuses, s102 of the *Road Rules* prohibits the driver of a bus from driving past a *Low Clearance Sign* if the vehicle is higher than the height (in metres) indicated on the *Low Clearance Sign*.

The minimum clearance design height for all bridges constructed in Queensland is 4.6m. 14 low bridges with 4.8m or lower height clearance exist within *TransLink*'s SEQ route bus service boundaries and are listed in Table 7 below. Railway bridges Nos 1 and 2 in Table 7 would be considered impassable or marginal clearance heights respectively for single deck high floor route buses fitted with rooftop air conditioners and CNG cylinders, and bridge Nos 1 to 8 inclusive would be impassable to double deck buses.

Table 7: Low Clearance Bridges under 5m Height within TransLink Bus Route Service Boundaries

ID No	Bridge	Road	Suburb	Signed Clearance Height
1	Railway	Park Street	Milton	3.3m
2	Railway	Oxley Road	Corinda	3.6m
3	Railway	Annerley Road	Woolloongabba	3.8m
4	Railway	Muriel Avenue	Rocklea	3.8m
5	Railway	Cribb Street	Milton	3.9m
6	Pacific Motorway	Main Street	Beenleigh	4.0m
7	Railway	Countess Street	Petrie Terrace	4.4m
8	Hawthorne Street	Pacific Motorway Southbound Access On Ramp	Woolloongabba	4.4m
9	Linkfield Road	Gympie Arterial Road	Bald Hills	4.7m
10	Railway	Wynnum Road	Cannon Hill	4.7m
11	Pacific Motorway	Ipswich Road	Woolloongabba	4.7m
12	Anzac Avenue	Bruce Highway Exit to North Lakes	Murrumba Downs	4.8m
13	Kessels Road	Pacific Highway	Upper Mount Gravatt	4.8m
14	Watland Street	Old Pacific Highway Service Road	Slacks Creek	4.8m

2.8.6 No Buses Signs Affecting High Capacity Buses

S106 of the *Road Rules* prohibits the driver of a high capacity bus from driving past a *No Buses Sign* that has associated information on or with it indicating a mass or length, if the GVM or length of the bus exceeds the mass or length respectively indicated on the sign. *No Buses Signs* of this type normally only appear on unsealed or narrow rural roads and bridges or DTMR *Notified Roads* where 12.5m *Complying*

Buses would normally operate within *TransLink* network boundaries. These roads are considered unsuitable for the 4 subject high capacity vehicles.

2.8.7 Loading and Bus Zone Signs Affecting Long High Capacity Buses

Sections 179 and 183 of the *Road Rules* permit buses to stop in a signed loading zone for the sole purpose of dropping off and picking up passengers, and in a signed bus zone for any purpose whatsoever. Over length 14.5m and 18m articulated buses may not stop in these zones however if information displayed on zone signs preclude a bus of their specified type from stopping in the zone, or if the bus length exceeds the zone length and the driver cannot safely pull into the zone without double parking or blocking the left through lane of vehicular traffic, as prohibited by s189 of the *Road Rules*.

S195 of the *Road Rules* permits an over length high capacity bus to stop up to 20m behind and 10m ahead of a *Bus Stop Sign* if the driver can safely stop in a length of clear road or area to which a parking control sign applies or is approved by regulation, but is not occupied by a parked vehicle. S198 further permits an over length bus to obstruct bicycle paths, private vehicle and pedestrian accesses to footpath ramps whilst dropping off and picking up passengers.

2.9 Passenger Transport Regulations Affecting High Capacity Bus Operations

The *Transport Operations (Passenger Transport) Regulation 2005* governs public passenger transport operations on Queensland roads using buses, taxis, limousines, motorcycles and other vehicles. It deals primarily with operator and driver accreditation schemes and licensing of services. The following discusses where and how the passenger transport regulations would affect high capacity route buses differently to standard 12.5m rigid route buses. A *Relevant Vehicle,* as defined by the *Passenger Transport Regulation* and described herein, may be any of the 4 subject high capacity route bus types used to provide a public passenger service.

2.9.1 Driver Authorisations

S20B of the *Passenger Transport Regulation* requires the applicant for a *Relevant Vehicle* driver authorisation (new or 5 year renewal) to:

- Hold a prescribed licence of the appropriate class (HR) for the high capacity vehicle,
- Have continuously held an open C class or provisional licence for a car, truck or bus for at least 3 years, and
- Have passed a competency test approved by the chief executive (of DTMR) for the operation of the type of *Relevant Vehicle* the person intends to drive.

For a typical *TransLink* bus driver already possessing an MR class licence and driver authorisation to operate a standard 12.5m rigid route bus, attainment of the necessary prerequisites required for both a high capacity bus HR driver licence and driver authorisation would require a minimum 1 year lead time plus competency testing for each high capacity bus type in his/her authorised operator's bus fleet.

2.9.2 Driver Licence Suspension, Cancellation or Disqualification

S37 of the *Passenger Transport Regulation* states that if the driver licence of a person holding a driver authorisation is suspended, cancelled or disqualified from holding or obtaining a license, the person is automatically suspended, cancelled or disqualified from holding or obtaining a driver's authorisation for a corresponding period respectively. Depending on when in the 5 year renewal cycle of a high capacity vehicle driver authorisation a driver was to have his/her licence suspended, cancelled or disqualified, the prerequisite conditions for renewal would bar the bus driver from operating a high capacity bus for a period of up to 3 years, unless the driver was granted a provisional driver authorisation by the chief executive (of DTMR).

Where the continued livelihood of a bus driver was taken into account by the chief executive in the granting of a provisional driver authorisation and his/her authorised operator also had 12.5m rigid buses in its fleet, the conditions of the provisional driver authorisation may be limited to those applicable to an MR class licence only, still barring the affected driver from operating high capacity buses.

2.9.3 Market Entry Restrictions

Schedule 1 of the *Passenger Transport Regulation* limits provision of general route services other than those for dedicated school services to:

- Within cities and towns with a population of more than 7,500,
- On routes of not more than 40km between cities or towns, each having a population of more than 7,500, and
- Between villages with a population of 500 or more and a city or town with a population of greater than 7,500.

These market entry restrictions would conflict with the proposed new *UrbanLink* long haul trunk, cross-country and regional activity centre interconnect bus services described later in *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland*. These are service types best suited to future deployment of high capacity buses. Exceptions to market entry restrictions may be declared under the *Passenger Transport Act* by public notice or gazette issued by the chief executive (of DTMR).

2.10 Disability Standards Affecting High Capacity Buses

The *Disability Standards for Accessible Public Transport 2002* enforces the principle that *Equivalent Access* be provided for *Persons with Disabilities (PWD*s) to all public transport services. A public transport operator and provider (viz. *TransLink*) are mutually obligated to provide assistance to a *PWD* when requested and to vary the infrastructure, accesses to infrastructure and vehicle equipment and facilities that provide access to a public transport service such that an equivalent standard of amenity, availability, comfort, convenience, dignity, price and safety is maintained for *PWDs* to that afforded to other persons. The following disability standards may affect high capacity buses differently to standard 12.5m rigid buses.

2.10.1 Wheelchair Loading and Unloading

Non-slip, 800mm wide, 300kg rated wheelchair boarding devices are not called for under the *Disability Standards* for heavy buses operating dedicated school services, but are mandated on all other route buses and must be deployed if any passenger requests their use, whether a recognisable *PWD* or otherwise. Boarding ramps are normally installed at the front door of a route bus and may be of a type that is remotely powered and extended from the driver's seated position, or a type that needs to be manually pulled or flipped out onto the footpath kerb at the front door, necessitating that the driver leave his/her seat to assist the *PWD*.

Manually operated flip out ramps have become more prevalent on urban route service buses and are recognised by operators as more reliable, cheaper to install and easier to maintain. In addition to boarding device operations, a driver may be requested to assist a *PWD* with wheelchair pushing up boarding ramps and down bus aisles, and with stowage and retrieval of mobility appliances placed in luggage racks.

For a modern step-less entry ultralow floor bus, the vehicle will normally travel and stop with its compressed air front suspension raised to meet minimum ground clearance heights stipulated in ADR43/04 and the regulations, but must be lowered to near kerb height on the left hand side to board and alight persons with walking appliances, prams, wheelchairs, the visually impaired or blind. Inbuilt bus safety systems interlock the park or bus stop brakes whenever the wheelchair loading ramp is deployed, a door is opened or the bus suspension is not fully raised, and the bus cannot be moved off until all 3 safety conditions have been met.

The boarding ramp length and width necessitates both close spacing from and parallel alignment of the front door step to the kerb, and a near 90º wheelchair navigation path, which can be readily accommodated by 12.5m standard rigid buses at most bus stops constructed on left lane straight pull-in kerbs. Wheelchair loading and unloading challenges are however encountered with high capacity vehicles and include for:

- Double Deck Buses: 3.2 to 3.4m high double deck buses must be deliberately driven with a greater separation distance from kerbs than single deck buses to prevent accidental upper deck glazing, panel and roof strikes from shop awnings, traffic signs, posts, poles, tree branches and other high profile objects close to kerb lines. Double deck bus stop access is impacted by high profile obstructions in both the approach and departure paths, and these buses cannot be kneeled on the left side if high profile objects such as shop awnings and posts built to the kerb line exist within the bus stop zone.

  All wheel suspension kneeling may be necessary on a short wheelbase double deck bus to prevent excessive forward incline on wheelchair accessible bus aisles, and wheelchair kerb ramps similar to those provided for taxi and minibus wheelchair loading may prove necessary for double deck buses where wheelchairs have to boarded and unloaded to road because of high profile footpath furniture.

  Twin steer double deck buses such as Bus 343 under trial on the Gold Coast have narrower and longer aisle distances to reach wheelchair bays, and in combination with off-road wheelchair loading and/or all-wheel bus suspension kneeling, suffer longer dwell times at bus stops. Double deck buses may in some cases require larger onboard air storage tanks to speed up suspension raises and brake or auxiliary tank pressure recovery.

- 14.5m Rigid Buses: Over length 14.5m buses with increased steering lock settings suffer from excessive rear end swing into bus stops upon departure if full lock right turn outs are necessary to clear a vehicle (including another bus) parked in or immediately ahead of the bus stop. They are also impacted by non-parallel to kerb alignment in undersized straight and indented bus stops, and in indented bus stops with short turn-in or turn-out tapers designed to old road standards for short 12m rigid buses. Over length 14.5m rigid bus drivers, cognisant of rear end swing in due to forward path blockages, will deliberately space their buses up to 500mm out from the kerb to prevent swing in over the footpath, and kerb ramps may be needed at some existing short bus stops and indented bus bays to enable wheelchair loading off road.

- 18m Articulated Buses: Articulated buses are less susceptible to rear tail swing in, and with shorter front section wheelbases, can readily manoeuvre in close and parallel to kerbs in indented bus bays. However on existing short indented bus bays designed for 12m and 12.5m buses, articulated buses may be forced past the parallel section of kerb designated for front door passenger boarding into the turn out taper in order to clear the articulated trailer from the left through lane of traffic. This may result in wheelchair boarding over grassed, tiled or pebbled areas or from the road.

2.10.2 Hail and Ride PWD Pick Up/Set Down

Queensland *Road Rules* afford exclusive rights to urban route buses to park outside signed bus stop and bus zones across private driveways and pedestrian accesses, in front of fire hydrants, on bicycle lanes and in regulated clearway, loading, parking, taxi and other nominated vehicle zones if stopped solely and exclusively for the purpose of pick up or set down of passengers. The right to stop in these regulated zones does not apply if regulatory signs prohibit buses of a particular type from stopping.

A key purpose of this exclusive right of buses to stop virtually anywhere on an open kerb is to provide accessible public transport to the elderly, blind and persons with mobility disabilities where bus stops are separated by long distances or hilly terrain and where regulated bus zones have not been established close to aged people homes, hospitals, medical centres or similar facilities. Under the duty of customer care defined in the *Passenger Transport Regulations*, a route bus driver is arguably obligated and entitled by the *Road Rules* to pick up a *PWD* when hailed or to set down a *PWD* when requested to do so outside a designated bus stop when it is safe to do so, and such is understood to be common practice on *TransLink* route services operated in SEQ.

The opportunity to safely pick up and set down passengers outside regulated bus stops and zones is significantly curtailed by the availability of kerbside spaces available to 14.5m and 18m long high capacity buses in parking congested town centres and commercial business districts.

2.11 Transport Planning and Coordination Regulation

Part 2 of the Queensland *Transport Planning and Coordination Regulation 2005* defines IDAS local road standards to be applied on local government controlled roads that form part of a route used for a public transport service. Compliance with the *Code for IDAS* must be determined for all assessable developments granted under the Queensland *Sustainable Planning Regulation 2009*. The purpose of the *Code for IDAS* is to ensure that developer road works on local government roads do not have any significant adverse impact on the efficiency, safety and comfort of public passenger transport. The standards nominated by the *Code* override those published in the Queensland *Road Planning and Design Manual (RPDM)* and the national *Austroads Guide to Road Design (AGRD),* unless approved otherwise in Part 2 of the *Regulation*.

The following standards in Part 2 of the *Transport Planning and Coordination Regulation 2005* may restrict operation of high capacity buses vehicles on Local Government controlled roads approved under future *Controlled Access* or *HML Area Permits*:

- Lane Width on a Straight Undivided Two-Way Road: Lane widths of 3m on a straight undivided two-way local road would be unsuitable for operation of a 14.5m rigid and modern pusher type 18m ultra-low floor articulated bus if either the entry or egress intersection accessing the two-way local road had less than two lanes for left and right turns.
- Crossfall: Left lane crossfalls of 3 – 5% may not be suitable for 4.2 – 4.4m high double deck buses on narrow lane roads with trees, shop awnings, light poles, traffic signs and other high footpath furniture erected close to the kerb as can occur after a local government road widenings (for example in Milton Road, Auchenflower). Heavy loading on the upper deck of a double deck bus may cause a double deck bus to lean or oscillate leftward after crossing a side road intersection crown that has been elevated with successive layers of asphalt resurfacing.

- Indented Bus Bays: Indented bus bays prescribed by the *Regulation* for Local Government sub-arterial and higher order roads are required to comply with *RPDM* Chapter 20 and *AGRD* Parts 3 and 4 which provide indicative bay designs for either 12m rigid or 18m articulated buses, but no direction is given on which bus type and set down kerb length to design the bay for. For the proposed future high frequency *UrbanLink Bus Network* (discussed later), there will be an increased probability of closer running bus arrivals at indented bus bays, high capacity buses using indented bays and no overtaking lanes on congested road *TransitWays*. Unless *TransLink* and its service partners can positively verify that only low frequency standard rigid buses will use specific indented bays, it would be recommended that future indented bus bays be constructed for two 12.5m rigid buses with long run-out tapers to suit 14.5m rigid buses.
- Roundabouts: Whilst the general requirements for roundabouts on Local Government roads state that roundabout traffic islands must be designed in accordance with the *RPDM* and *AGRD* to clear the swept path of the design bus plus 0.6m clearance on each side, they do not specify for which design bus type. Modern steered tag axle 14.5m rigid and 18m pusher type ultralow floor articulated bus swept paths should be able to negotiate existing roundabouts at intersections on 4 lane two-way arterial and sub-arterial roads, but would experience difficulty negotiating non-flat top single lane two-way intersection roundabouts on most local roads.

3. Planning and Policy Impacts on Future Deployment of High Capacity Buses

This part reviews State, road and transport authority plans, policies and funding programs likely to impact on future demand for and deployment of high capacity buses in *South East Queensland (SEQ)* over the forthcoming 20 years out to 2031. Sweeping major changes are proposed to public transport delivery and related road and transport infrastructure during this period which tie in with State and Local Government regional planning for population growth, land use and redevelopment. Forthcoming changes affecting transport planning and funding priorities are broadly outlined in the following sections.

3.1 South East Queensland Regional Plan

The *South East Queensland Regional Plan 2009 – 2031* is the State's key long-term master plan for managing population growth, land use, new development and public infrastructure investment in SEQ over the forthcoming 20 year time horizon. The vision, strategic directions, principles and policies embodied in the *SEQ Regional Plan* prescribe the guidelines, strategic objectives and priorities to be adopted in all subordinate State and Local Authority road, transport and infrastructure plans and long-term infrastructure investment programs approved for the seven Local Government regions located in South East Queensland.

3.1.1 SEQ Regional Plan Vision and Strategic Directions

The overarching vision described in the *Regional Plan* for SEQ is for a region of interconnected communities with excellent accessibility to an extensive, integrated and efficient public transport system that contributes to reducing traffic congestion and greenhouse gas emissions.

Key strategic directions set out in the *SEQ Regional Plan* include restricting local planning schemes and development approvals to those that proactively reduce reliance on imported oil and private car dependency, with highest priority given to mixed-use (residential and employment precinct) transit oriented developments that support public transport through increased population density and close proximity to cities, major towns and defined activity centres with access to existing or proposed new public transport corridors. A core principle orchestrated in the strategic vision and principles is that reliable interconnected public transport services should be established prior to and lead development in regional activity centres to reinforce community travel habits that do not solely rely on private vehicle use.

3.1.2 Urban Footprint Development Concept

The *Regional Plan* envisages a new compact *Urban Footprint* land use for urban, rural, broadhectare, infill and remnant broadhectare areas located in SEQ, which incorporate a full range of urban uses, viz. residential housing, industry, business, infrastructure, community services, facilities and open spaces, underpinned by reliable, effective, high frequency public transportation. Priorities are assigned in the plan to those urban footprints which promote redevelopment in existing urban areas built around regional activity centres, established public transport nodes and corridors, and new public transport infrastructure which links regional activity centre transport nodes through a network of cross-city and inter-regional road, walking and cycling networks.

High capacity buses are well positioned to play a central role in providing cost-effective high frequency trunk and express services across the network of busways, cross-city and inter-regional roads with preserved bus corridors that will interconnect new activity centre transport nodes as they develop.

3.1.3 Regional Road, Public Transport and Infrastructure Priorities

Priorities have been ascribed to development in defined residential areas, regional activity centres, employment areas and identified population growth areas within each SEQ *Region.* The *Regional Plan* identifies specific future public transport nodes and corridors to be preserved and major public transport infrastructure projects to be included in all subordinate SEQ road, transport and infrastructure plans and funding programs, including but not limited to new busways, light rail track alignments, rail line duplications/extensions, bus/rail stations, tunnels, bridges, major road upgrades, pedestrian ways and cycle ways planned for identified high growth areas.

3.1.4 SEQ Regional Planning Principles and Policies

Future wide scale deployment of high capacity buses strongly supports the guiding principles and policies encompassed in the *SEQ Regional Plan* as follows:

- Sustainability Principle: High capacity buses offer the lowest cost per passenger-kilometre currently available for transporting heavy passenger loads at high frequency and reliability on mainline trunk corridors connecting distributed activity centre public transport nodes. They are also appropriately sized to deliver high capacity feeder and intermodal connecting services to and between major public transport nodes such as geographically disconnected light and heavy rail stations, regional airports and interstate transit centres,
- Reducing Greenhouse Gas Emission and Oil Supply Vulnerability Principles: High capacity buses consume the least imported fossil fuel and generate the lowest exhaust emission and greenhouse gas volumes per passenger-kilometre travelled. They also displace a greater number of private vehicles from public roads than any other currently known road based public transport mode, excepting the pushbike,
- Ecosystem Services Principle: *Ecosystem Services* are defined in the *SEQ Regional Plan* as public goods and services that benefit, sustain and support the human ecosystem. Provision of accessible public transport services and infrastructure to disconnected communities and social infrastructure is a linchpin element of the *Ecosystems Sustainability Framework for SEQ*.
- Rural Communities (Support) Principle: The *Regional Plan* attempts to redress the limited access, social and employment disadvantages of SEQ rural and small town communities to critical social infrastructure such as schools, hospitals, places of employment, shopping centres, etc. attributed to long separation distances from principal and major activity centres to places of residence, and a current general lack of existing available low cost public transport services. The *Regional Plan* identifies a number of key rural and public transport corridor mixed-use activity centres that are proposed to deliver higher order public infrastructure, community services, commercial activities, places of employment and improved public transport connectivity within SEQ. High capacity cross-country buses are anticipated to connect these key rural activity centres as they develop, and
- Social Planning and Addressing Disadvantage Principle: The *SEQ Regional Plan* forecasts an exponential growth of the aging population in SEQ over the next 2 decades and an urgent need for a broad choice of home, aged care and retirement accommodation options where aging persons can self commute to a hospital, medical centre, shopping centre or similar facility without needing to own and drive a private motor vehicle.

The plan identifies an emerging demand for highly interconnected public transport services that will encourage aged people, including those located in remote disadvantaged urban suburbs and rural communities, to continue living at home or in aged care facilities of their choice for the longest possible period, using a reliable public transport system that enables them to freely commute and "age in place". High capacity buses should play a primary role in providing cross-city and cross-country commuting services to social infrastructure including hospitals, medical centres and other professional services centres, enabling the elderly to "age in place".

3.1.5 Desired Regional Outcome 8 - Compact Settlement

Desired Regional Outcome 8 of the *Regional Plan* aims to prevent dispersed low-density population sprawl that has thus far dominated historical development in SEQ, to open up existing land parcels for redevelopment as new activity centres, and to only release new land parcels for compact high density mixed-use settlement where essential services and public infrastructure exists or can be provided at least cost to tax and ratepayers:

- Compact Development Principle: In addition to traditional utilities such as electricity, public lighting, telecommunications, water and sewerage reticulation; and essential public infrastructure such a roads, storm water drainage, footpaths, cycle ways, open spaces, etc, property developers will be required in future to focus their proposed developments within defined urban footprints and regional activity centres where public transport nodes and corridors already exist, or to suffer a high contribution penalty to the cost of creating new public transport services and infrastructure as a precondition of their development approvals.
- Containing Growth and Urban Character and Design Principles: These principles aim to constrain future growth by proactively discouraging new development outside defined urban footprints and in rural and broadhectare sites where public transport nodes, corridors and services do not already exist or are not already planned or committed to in published State or Local Government funding programs. Developers must either demonstrate current public transport programs exist and will be delivered prior to release of their new developments to market, or suffer the high cost penalty of having to contribute to any necessary new public transport infrastructure development. The latter option will be used as a strong disincentive to constrain unwanted sprawl, and developer agreement to payment of public transport infrastructure contributions will not guarantee unplanned development approvals.
- Activity Centres and Transit Corridors Principle: This principle commits State Government Departments, Statutory Authorities, Government Owned Corporations and Local Government Authorities (hereinafter called *State Government Entities*) to preparing detailed land use planning schemes and public infrastructure plans for defined *Principal, Major Regional, Specialist, Principal Rural and Major Rural* Activity *Centres* identified in the *SEQ Regional Plan* to guide land use, public transport and infrastructure delivery across SEQ. These defined regional activity centres are to be supported by quality public transport that will create compact, self-contained, diverse (mixed-use) communities interconnected by a network of public transport and active transport (walking and cycling) corridors.
- Integrated Land Use and Transport Planning Principle: This principle recognises the strong nexus that exists between land use and efficient public transport, and prescribes prerequisite conditions to be applied to future *Transit Oriented Development (TOD)* approvals in precincts located within close walking distance of a *High Frequency Priority (HFP)* or combined high frequency service transport node. *TOD Precincts* are to be built on a walking and cycling friendly core within 10 minutes walking distance of an existing or planned light or heavy rail station or bus station surrounded by high density residential, employment and other prescribed mixed land uses.

Under the *SEQ Regional Plan*, new *TOD Precincts* are to be geographically centred about existing or planned busway, bus and rail stations served by high frequency services on a dedicated transit corridor. Busway and bus station centric *TOD Precinct* nodes are proposed to be serviced by a combination of standard rigid local/feeder and high capacity trunk buses.

- Innovation and Technology (Support) Principle: This principle commits *State Government Entities* to providing reliable, high frequency public transport services to and infrastructure at activity centres dedicated by the State to research and development of science, health, education and training, innovation and technology which underpin the State's economy, future prosperity and international competitiveness.

3.1.6 Desired Regional Outcome 10 - Infrastructure

Desired Regional Outcome 10 of the *Regional Plan* addresses the need to plan, coordinate and deliver regional transport infrastructure and services in a timely manner commensurate with pace of predicted regional population growths, defined settlement patterns and desired community outcomes. Key principles relating to timely delivery of transport infrastructure include the:

- Demand Management Principle: This principle stipulates that all *State Government Entities* must strive to make best use of existing public infrastructure, and modify consumer behaviour rather than directing the State's limited resources toward development of other major new or upgraded infrastructure. In relation to public transport, the principle directs initiatives be taken to promote, intensify and encourage greater use of existing SEQ public transport infrastructure and increased public transport services to reduce public demand for imported oil and avoidable private motor vehicle journeys for both work and leisure.
- Protecting Key Sites and Corridors Principle: In relation to transport, this principle obligates all *State Government Entities* to identify, preserve, protect and manage key transport infrastructure sites and corridors located in SEQ. It further directs collocation where practicable of transport, energy, water, communications and other utilities in new generic infrastructure corridors and that preserved corridors be made available to the State emergency and police services.
- Social Infrastructure (Support) Principle: This principle states that new social infrastructure such as universities, hospitals, schools, aged care accommodation, etc. be located near safe, accessible, convenient public transport, pedestrian and cycle paths, and fully integrated with adjacent and compatible mixed land uses.

3.1.7 Desired Regional Outcome 12 – Integrated Transport

Desired Regional Outcome 12 of the *Regional Plan* describes the guiding principles and policies to be adopted by *Government Entity* road, transport and infrastructure planners and their funding programmers to realise highly connected accessible regions within SEQ based on an integrated transport system that is planned and managed to support compact urban growth and efficient travel; to connect people, places, goods and services; and promote public transport use, walking and cycling. *Outcome 12* sets the planning framework and guidelines for *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland.* Key principles and policies outlined in *Outcome 12* of the *SEQ Regional Plan* include the:

- Integrated Transport Planning Principle: This principle states simply that land use and transport planning shall be integrated, provide regional interconnectivity and greater levels of trip self-containment within each SEQ sub-region. Specific policy objectives and programs encompassed by this principle stipulate:

- o Construction of interconnected and coordinated rail and busway networks which provide high quality, dedicated passenger transport links across all SEQ urban areas,
- o Planning and implementation of new public transport routes, facilities, high frequency services and priority transit corridors that will ensure safe and convenient passenger accessibility, and support the interrelationship between land use and transport as defined within the *SEQ Regional Plan,*
- o Priority is to be afforded to public transport projects that support transit oriented communities and regional activity centres with interconnected public transport networks and services, safe cycling and walking routes,
- o Priority planning and development approvals by all land use authorities in urban areas are to be directed toward those developments which support walking, cycling and public transport,
- o Policy directions be developed to promote more compact forms of urban development, self-containment of passenger travel within SEQ sub-regions, continued development of new public transport spines for the Sunshine and Gold Coast Regions, and expanded use of the Brisbane rail and busway networks for *TOD Precincts*,
- o Urgent consideration be given to the capacity of the existing public transport network to cope with projected population growth in identified high growth areas, and
- o DTMR development of *Connecting SEQ 2031* and an *SEQ Infrastructure Plan and Program* in accordance with *Strategic Transport Network 2031* maps 22 to 24 inclusive for each region covered by the *SEQ Regional Plan*.

- Sustainable Travel and Improved Accessibility Principle: This principle asserts that sustainable travel choices must be provided in SEQ that support the accessibility needs of all community members, manage traffic congestion, and reduce private car dependency and transport generated pollution and greenhouse gas emissions. Specific policy objectives and programs encompassed by this principle include:
  - o New infrastructure, improved public transport services and service information that will actively support walking, cycling and public transport,
  - o Development and implementation of an *Urban Congestion Management Strategy* for SEQ,
  - o A *10 year Network Plan* to be developed for all public transport services operated in the *TransLink* service area, and
  - o Delivery of a high-quality public transport network in SEQ that supports increased urban densities around public transport nodes and along defined public transport corridors, community services and employment, reduces commuter travel time and loss of productive work time, and improves environmental outcomes and travel choices for people disadvantaged by their access to transport.
- Effective Transport Investment Principle: This principle states that investment in the public transport system shall be targeted to maximise use of existing infrastructure, minimise whole-of-life costs for new infrastructure, provide measurable community benefits, and reduce greenhouse gas emissions and vulnerability to future oil depletion. Specific policy objectives and programs encompassed by this principle target:
  - o Integration of transport infrastructure, public transport services and land use planning by deliberate sequencing of defined *Development Areas* to align with State and Local authority transport investment programs,

- o Development of new bus-priority and high-occupancy vehicle transit lanes in the SEQ road network that support public transport, and
- o Timely implementation of State approved transport projects contained in the *SEQIPP*, *TransLink Network Plan* and the Australian Government *AusLink* program.

- Transport System Efficiency Principle: This principle asserts that an efficient and integrated public transport system shall be implemented in SEQ. Specific policy objectives and programs encompassed by this principle state:
  - o The use of existing public transport assets and services in SEQ are to be maximised by a combination of cost-effective transport investments and policies, demand management and application of new *intelligent transport system (ITS)* technologies,
  - o Key existing and future transport sites and corridors are to be identified, protected and managed, and
  - o Public transport networks and roads are to be designed to provide improved connectivity between *SEQ Regional Plan* defined *Activity Centres.*

3.2 South East Queensland Integrated Transport Plan

Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland was published by DTMR in 2011 and sets out the 20 year forward plan for public transport network development across South East Queensland. It outlines when and where the SEQ public transport network will be augmented to address population growth and newly planned land uses and how it will achieve the desired outcomes prescribed by the *SEQ Regional Plan*. The plan repeats, but in significantly greater detail, the same vision, agenda and planning principles espoused in the *SEQ Regional Plan,* but with additional information pertinent to the future deployment of high capacity buses as follows.

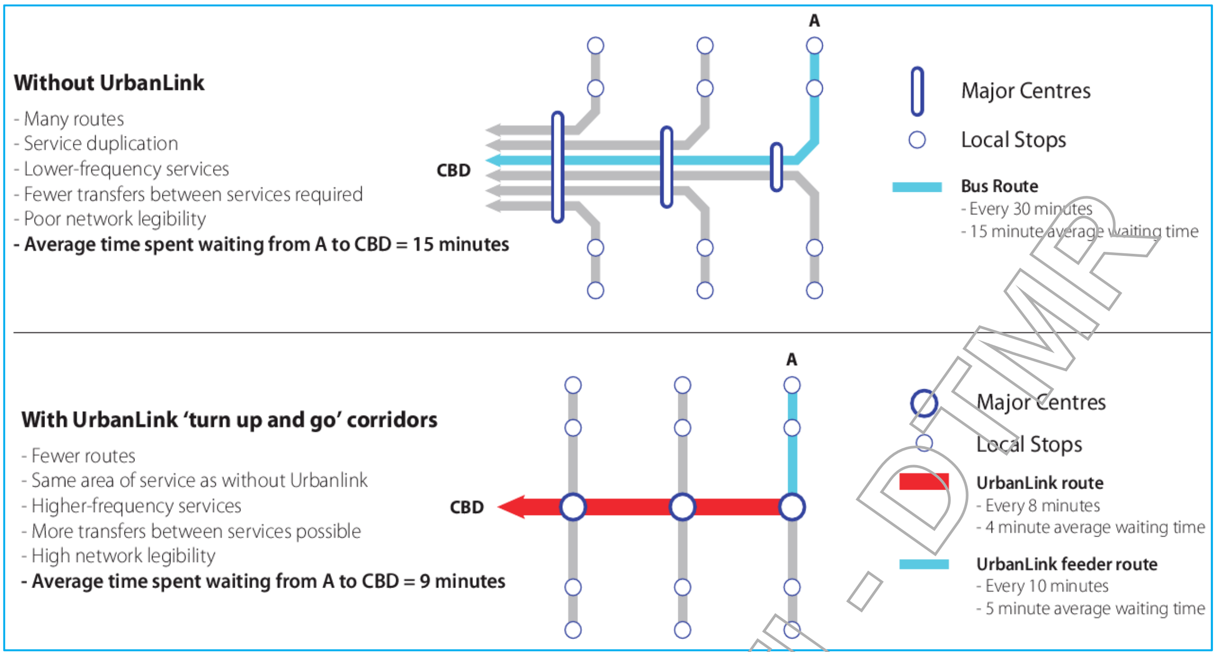
3.2.1 SEQ UrbanLink Network

Figure 8 presents a new *UrbanLink Network* envisaged to be rolled out across South East Queensland by 2031 under *Connecting SEQ 2031.* In close accord with the objectives of the *SEQ Regional Plan*, *UrbanLink* depicts a large number of geographically dispersed activity centre transport nodes interconnected by a network of existing and proposed new cross-city and cross-country high frequency bus services operating along priority busway and transitway corridors, the latter proposed for high density urban areas and known congested road corridors. The trunk and feeder concept proposed to underpin *UrbanLink* is illustrated overleaf in Figure 7.

The *UrbanLink* backbone comprises high speed priority railway, busway and transitway spines radiating out from the Brisbane CBD, the *Regional Plan* defined central principal activity centre transport node, to surrounding regional and sub-regional transport nodes, supported by the new *GoldLinQ* light rail and *CoastConnect* coastal bus sub-spines on the Gold and Sunshine Coasts, each connected by high frequency cross-country connector and local bus services to the long haul heavy rail corridors back to the Brisbane CBD.

UrbanLink is premised on all hours, 7 day, all stops, 10 to 15 minute (6am – 9pm) headway "turn up and go" trunk and feeder bus services operating to all major SEQ urban areas. It aspires to double the catchment of 15 minute walk and ride bus passengers by 2031, including those predicted to come from newly developed busway, bus and rail station centric *TOD Precinct* catchments. A new form of cross country bus service similar to the heavy railway *ExpressLink,* is also envisaged in *Connecting SEQ 2031* that will provide 6am – 9pm express bus services between major outlying rail and bus station hubs in Greater Brisbane to other major transport nodes in adjoining SEQ regions.

Figure 7: Trunk and Feeder Concept for 2031 UrbanLink Network



Connecting SEQ 2031 sets out ambitious public transport growth targets for *TransLink* heavy rail, light rail, bus and ferry services of 4.6% pa between 2006 and 2031, with 14% of all SEQ work and leisure trips targeted to be carried by the 4 modes in 2031. The trunk and feeder concept which underpins *UrbanLink* and achievement of the *Connecting SEQ 2031* passenger growth targets will invariably lead to:

- Increasing passenger loads and overloading on higher frequency local and spine feeder 12.5m standard bus services as the population and expected demand for public transport grows, and the supply of affordable car parking in major activity centres is constrained by local government parking regulations, increased parking charges and town centre planning schemes which reduce availability of both private under building and public car parking spaces,

- A progressive transfer of high passenger loads from local and spine feeder bus services (currently operating one seat terminus-to-terminus) to long haul trunk bus services travelling along the major bus spines from outlying transport hubs, sub-regional stations and park n' rides,

- Predicted high passenger boarding loads from intermodal transfer *UrbanLink* bus services not currently operating between the new coastal strip LRT and CoastConnect sub-spines and hinterland railway stations, and

- High passenger loads expected on the new *UrbanLink* cross-city and cross-country bus services proposed to be operated between regional activity centres as called for in the *Regional Plan* and planned for staged implementation under *Connecting SEQ 2031.*

In the past 7 years, Brisbane Transport has pressed some 30 new two door articulated buses and 128 two door 14.5m rigid buses into service, primarily to address growing passenger demand, long standing periods, overcrowding and passenger stranding at inner suburb bus stops by their lower capacity standard 12.5m rigid route buses. Other Australian capital city operators have witnessed similar gradual upward creep in passenger loads toward the maximum carrying capacity of their standard 12.5m route buses, and like Brisbane Transport have been confronted with the choice of either increasing service frequencies, drivers and standard route bus strengths deployed on high demand services, or to strategically retire off their older high floor 12.5m rigid buses and replace them with new ultralow floor high capacity buses before national disability compliances fall due.

If the new *UrbanLink Network* is implemented as envisaged by *Connecting SEQ 2031*, standard rigid 12.5m route buses are anticipated to be progressively relegated to operating shorter, higher frequency local, BUZ, spine feeder, one-seat terminus-to-terminus and low to moderate demand cross-city and cross-country bus services, and a growing demand will transpire for high capacity vehicles to take over the new coastal sub-spine to heavy rail intermodal transfers, high frequency priority and high capacity demand cross-city and cross-country interconnect services.

3.2.2 Predicted UrbanLink Bus Network and Services Demand

Connecting SEQ 2031 predicts that:

- By 2031, buses will need to carry half of all passenger journeys in SEQ to achieve its 2031 target; namely double the modal share of passenger trips currently being transported by bus,
- Between 2006 and 2031, daily bus passenger boardings will increase by 250%; namely 940,000 additional boardings per day above present daily boarded loads, and
- By 2031, kilometres travelled by combined regional operator bus fleets in the region will increase by nearly 200% over current total distance travelled.

Connecting SEQ 2031 highlights that the *UrbanLink Bus Network* will progressively transition in new cross-town connector bus routes as outer regional activity centres develop, and new cross-regional interconnector bus routes to deliver anywhere-to-anywhere travel between SEQ regions and sub-regions.

Connecting SEQ 2031 declares the rail network illustrated in Figure 8 as the preferred long haul mass transit spine for all SEQ regions and sub-regions lying outside greater Brisbane. It describes conceptual staging scenarios in which *UrbanLink* and cross-country bus services initially plug the discontinuities in the heavy and light rail long-haul spines, then transition to *UrbanLink* local and feeder bus services connecting dispersed activity centres to the rail backbone spines at the major railway station nodes depicted on Figure 9. The plan acknowledges that bus services similar to *ExpressLink* will be required in both the lead up to and beyond 2031 to transport commuters from outer town and city suburbs to major centres of employment, and will fill a similar role to *ExpressLink* rail services in those regional and sub-regional areas where rail services will not exist.

High capacity buses are considered the optimum future vehicle types to service these high peak demand bus services.

3.2.3 UrbanLink Activity Centres Access Hierarchy

Connecting SEQ 2031 defines a hierarchy of 3 new activity centre public transport nodes (called *Hubs*), all of which are to be provided with *UrbanLink* 7 day a week, 15 minute (6am – 9pm) or lower headway bus services and high quality transport infrastructure to deal with predicted peak passenger interchange demands:

- Regional Hubs: These first tier hubs will form the key termini and interchange points for most public transport trunk services operated in their respective regions. They are to be established in the *SEQ Regional Plan* defined principal activity centres of Brisbane CBD, Ipswich Central, Southport and Maroochydore,
- Sub-Regional Hubs: These second tier hubs are to be directly connected to first tier *Regional Hubs* by high speed, high frequency *UrbanLink* bus corridors and will be the secondary interchange points for multiple high frequency local and sub-regional feeder bus services. They are to be established at *SEQ Regional Plan* defined principal and major regional activity centres and will support hub-centric *TOD Precincts* and intensified mixed-use development, as well as direct bus access to adjoining areas of employment, education, health and services, and

- District Hubs: These third tier hubs will form transport interchange points in areas of significant employment and will be directly linked to the two higher tier transport hubs. They are to be established in *Regional Plan* defined specialist activity centres and enterprise opportunity areas.

Figure 8: 2031 Indicative UrbanLink Bus Network Map

Figure 9: 2031 Indicative Rail Network with UrbanLink, ExpressLink, CoastLink and Light Rail

3.2.4 UrbanLink Priority Transit Corridors

Connecting SEQ 2031 nominates and maps priority transit corridors predominantly comprising of motorway T2 and T3 lanes, new bus only *TransitWay* lanes and arterial and inner city road bus only left lanes.

Priority transit corridors are to be created for the new *UrbanLink Network* in each of the 7 SEQ Local Government jurisdictions where an immediate opportunity exists to increase mixed-use public transport supported development of at least 40 dwellings/hectare or 80 jobs/hectare in accordance with *SEQ Regional Plan Desired Outcome 8*.

Under the plan, construction of new priority *TransitWay* bus corridors is to be packaged up with *UrbanLink* bus service rollouts and will, in many cases, ultimately determine the staging and pace of new *UrbanLink* bus service implementations. *TransitWay* single lane bus corridors will incorporate indented bus stops to enable overtaking by non-stopping *UrbanLink* buses, and it is crucial therefore that new *TransitWay* indented bus stops be long enough for 18m articulated and 14.5m rigid buses, and their run out tapers extended to prevent excessive tail swing into bus stops.

3.2.5 Priority UrbanLink Network Reform and Infrastructure Projects

Connecting SEQ 2031 identifies timely completion of the following major network reforms and transport infrastructure projects as crucial to the roll out of the new *2031 UrbanLink Network*:

- Extension of the Northern Busway to Bracken Ridge with interim on-road priority treatments beyond Chermside,
- Extension of the Eastern Busway to Capalaba with interim on-road priority treatments beyond Carandale,
- Extension of the South Eastern Busway to Springwood,
- Two-way extension of the Gold Coast light rail northward to Helensvale Railway Station and southward to Coolangatta, the latter by 2031,
- Development of new strategic park n' rides in locations selected away from *TOD Precincts*, transit hubs and priority transit corridors, and sited at an average radial distance of 10km from the Brisbane CBD and 3km from other defined activity centres identified in the *SEQ Regional Plan*,
- Progressive transformation of the existing *TransLink* one seat terminus-to-terminus network to a trunk and feeder *UrbanLink* network,
- Progressive expansion in both coverage and frequency of all existing *TransLink* local bus services,
- Completion of the priority *Transitway* corridors shown on the indicative *UrbanLink* map in Figure 8, and
- Completion of the Sunshine Coast *CoastConnect* bus (and later heavy rail) corridor between Maroochydore and Caloundra via Mooloolaba and Kawana Town Centre.

3.3 Queensland Infrastructure Plan and SEQ Infrastructure Plan and Program

The annual *Queensland Infrastructure Plan 2011* and long term *South East Queensland Infrastructure Plan and Program 2010 - 2031* (*SEQIPP*) outline State Government investment priorities for regionally significant infrastructure. The *SEQIPP* details forward construction programs between 2010 and 2014, and future infrastructure development and upgrades planned over a 20 year time horizon out to 2031.

SEQIPP transport infrastructure investment priorities closely align with those directed by the *SEQ Regional Plan, Connecting SEQ 2031 Integrated Transport Plan* and *Queensland Infrastructure Plan,* but *SEQIPP* transport infrastructure priorities additionally take into account the interdependencies that exist between coordinated delivery of public transport and other regionally significant infrastructure projects such as new hospitals, schools and roads, and State Treasury budget constraints on the bottom line total cost of all SEQ infrastructure development programs.

Approved *SEQIPP* 2010 – 2014 bus transport programs include:

- Brisbane public transport corridor preservations (ongoing),
- *CoastLink* Creekside Boulevard to Kawana Town Centre corridor preservations (ongoing),
- Future stage investigation and planning for the Eastern Busway (2010/11 – 2013/14),
- Future stage investigation and planning for the Northern Busway from Kedron to Chermside Busway Station (2011/12),
- Future stage investigation and planning for the Northern Busway from Kedron to Carsedine and Fitzgibbon Busway Stations (2013/14), and
- Design of interim high occupancy vehicle lanes from Kedron to Bracken Ridge (2011/12).

Look ahead indicative *SEQIPP* 2015 – 2031 bus transport funding programs include:

- *CoastConnect* bus corridor design and construction (2014/15 – 2019/20),
- Nerang-Broadbeach Road upgrades incorporating priority *TransitWay* bus lanes (2014/15 – 2019/20),
- Gold Coast LRT – Gold Coast University Hospital to Broadbeach (2020/21 – 2025/26),
- Eastern Busway – Bennetts Road to Capalaba design and construction (2020/21 – 2025/26),
- Northern Busway – Kedron to Bracken Ridge design and construction (2020/21 – 2025/26),
- South East Busway – Eight Mile Plains to Rochedale and Rochedale to Springwood design and construction (2020/21 – 2025/26), and
- Redland Bus Priority Measures design and construction (2026/27 – 2030/31).

3.4 Queensland Transport and Roads Investment Program

The Que*ensland Transport and Roads Investment Program 2011/12 to 2014/15* details the Queensland Department of Transport and Main Road's 4 year rolling maintenance and infrastructure investment program for the State's transport and road networks. The program is reviewed annually to take into account unforseen funding priorities such as urgent road, rail and bridge reconstruction following floods and other natural disasters which may cancel, suspend or delay less urgent planned capital transport infrastructure projects.

Currently approved major bus transport investment programs in South East Queensland include:

- *TransLink* Station Upgrades (2011/12 - $44M, 2012/13 - $35M),
- State-wide Public Transport Infrastructure Disability Compliance Upgrades (2011/12 - $1.935M, 2012/13 - $1.935M),
- Western Bus Priority Corridor and Northwest Transport Corridor Planning,
- Logan Central Station Upgrade,
- State Wide Bus Station and Stop Infrastructure Grants (2011/12 - $3M, 2012/13 - $3M),

- Transport Infrastructure Development Schemes (2011/12 - $8M),
- Construction of Carindale Station and new Eastern Busway Approaches (2012/13 - $50M),
- Northern Busway Planning and Land Acquisitions – Kedron to Bracken Ridge (2012/13 - $28.518M), and
- Brisbane CBD and Cultural Centre/Melbourne Street Tunnel 14.5m Rigid Bus Access Improvements (2011/12 - $5M, 2012/13 - $5M).

Look ahead indicative major SEQ bus transport investment programs in 2013/14 and 2014/15 include:

- TransLink Station Upgrades ($80.15M),
- State-wide Public Transport Infrastructure Disability Compliance Upgrades ($3.870M),
- State-wide Bus Station and Bus Stop Infrastructure Grants ($6M),
- Construction of Carindale Station and Eastern Busway Approaches ($60M),
- Construction of South East Busway - Eight Miles Plains to Rochedale ($23.32M),
- Construction of CoastConnect ($25.978M), and
- Northern Busway Planning and Land Acquisitions – Kedron to Bracken Ridge (2012/13 - $39.1M).

3.5 TransLink Public Transport Infrastructure Manual

The *TransLink Public Transport Infrastructure Manual* was last revised in June 2007 when standard 12.5m rigid and 18m high floor articulated route buses were in common use in SEQ, and as for the Queensland *Road Planning and Design Manual* and national *Austroads Guide to Road Design,* has not yet been updated for emerging new 14.5m rigid, rear pusher ultralow floor articulated and double deck high capacity buses.

The principles and key considerations applicable to bus stop zones, shelters, seating, furniture, landscaping, hardstand areas, boarding points, stop markers, accesses, walkways and national disability standard tactile ground surface indicators and wheelchair boarding areas are still considered relevant to high capacity vehicles. Premium and Signature bus stop dimensions suit all high capacity vehicles and incorporate 35m nominal or longer hard stand areas suitable for two standard 12.5m rigid or double deck buses with half bus length parking separations, two extended 14.5m rigid buses or a standard rigid or double deck bus parked nose to tail with a 14.5m or 18m articulated bus at adequate separation distances, and clear hardstand areas suitable for potential future all door passenger boarding and alighting.

Likely revisions required to the manual would include:

- New Shelter Type Definitions: for indented bus stops on future *Transitways*,
- Hard Stand Length: Intermediate stop hard stand lengths extended for 18m articulated and superbus stopping on proposed new *UrbanLink* cross city and cross country routes,
- Front Door Boarding Access Lighting Illuminance Level: Increase to 150 lux, as specified in the national disability standards for bus stops,
- Indented Bus Bay Length and Taper Redefinitions: Intermediate stop indented bus bay lengths and tapers increased for 14.5m rigid bus stopping on proposed new *UrbanLink* routes, including

departure paths clearances from regulated parking or other occupiable zones to prevent hard lock turn outs into left traffic lanes,

- Mandating High Capacity Bus Zone Separation Distances: from left lane route turns and right turn lane crossings approaching intersections, and
- Compulsory *TransLink* Route Assessment Guidelines: for proposed new double deck and 14.5m bus controlled access and HML routes. These guidelines are required to indentify whole of route operating constraints, not just those applicable to designated bus stops and zones.

3.6 Transport Operations (Passenger Transport) Act

The *Transport Operations (Passenger Transport) Act 1994 (TOPTA)*, last revised in January 2012, is intended to achieve the provision of best possible public passenger transport services at reasonable cost to the community and government.

3.6.1 Objectives

The overall objectives of this Act that potentially relate to the application of high capacity vehicles are to:

- Enable the effective planning and efficient management of public passenger transport in the State, and
- Provide a system of public passenger transport in the State that:
  - is responsive to community needs,
  - offers an attractive alternative to private motor vehicle transport in a way that reduces the overall environmental, economic and social costs of passenger transport,
  - addresses the challenges of future growth,
  - provides public passenger services at a reasonable cost to the community and government, and
  - promotes the personal safety of persons using public passenger transport.

3.6.2 Definition of a Vehicle

TOPTA defines a bus as a motor vehicle with a seating capacity for 9 or more passengers, excluding the driver. It defines public transport as a bus or ferry being used for a general route service.

3.6.3 Operator Accreditation

S14 (*Operator Accreditation Standards*) of *TOPTA* states that bus operators should:

- Have the capacity to ensure the appropriate operation and maintenance of public passenger vehicles; and
- Comply with all relevant vehicle design, safety and operational requirements.

In the context of future HCV deployment, not all *TransLink* operators have the capacity to operate or maintain high capacity buses.

3.6.4 Driver Authorisation

Chapter 4 of *TOPTA* refers to *Driver Authorisation*, which is a qualification a driver must obtain and continue to maintain whilst operating vehicles providing public passenger services. The purpose of the driver authorisation is to ensure that drivers of public passenger vehicles are responsible while in the act of driving, and capable of safely operating a public passenger vehicle of the relevant category. More detailed information about heavy vehicle licensing requirements is presented in Section 3.6.4.1 below.

Bus drivers are required to obtain a driver authorisation for scheduled route bus services, as opposed to other categories of driver authorisation such as those for taxi and limousine drivers. In addition to having the correct licence for the vehicle type, driver authorisation also obliges drivers to submit to a medical assessment and prove their eligibility to work in Australia. There are no additional requirements for high capacity vehicle drivers other than those relating to licence class.

3.6.4.1 Heavy Vehicle Licences

According to the DTMR website, bus drivers must pass a practical driving test if they want to upgrade their existing licence to a heavy vehicle (class MR, HR or HC) licence and may also be required to pass a heavy vehicle road rules test. Table 8 shows the licence classes applicable to all bus types presently operated on the *TransLink* network. In general, licence classes broadly align with bus gross vehicle masses.

Table 8: Queensland Licence Classes

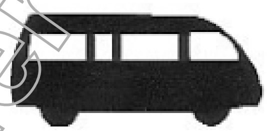
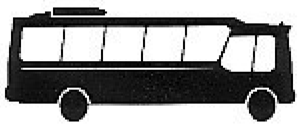
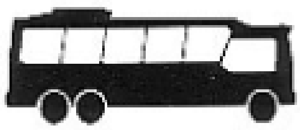
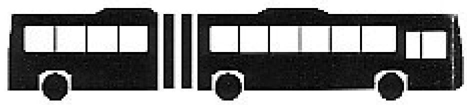
Licence Class	Vehicle Description	Example *TransLink* Bus Currently in Operation
LR (Light Rigid)	A **light rigid** bus more than 4.5 tonne GVM, but not more than 8 tonne GVM, built to carry more than 12 adults including the driver	 Minibus
MR (Medium Rigid)	A **medium rigid** bus more than 8 tonne GVM, with not more than two axles.	 12.5m Rigid
HR (Heavy Rigid)	A **heavy rigid or articulated** bus more than 15 tonne GVM, with at least three axles.	 14.5m Rigid 12 – 12.5m Double Deck  18m Articulated 18m Superbus

Table 9 sets out the minimum periods that a driver is required to hold a particular class of licence before becoming eligible to progress to the next higher class of licence. Each particular class of licence must have been held for a minimum holding period within the last five years when applying for the next higher class. The holding period may be a single continuous period or made up of a number of individual periods, however times when a licence is suspended or expired cannot be included when calculating minimum holding periods.

Table 9: Queensland Licence Class Holding Periods

Class of Licence Held	Minimum Holding Period	Next Eligible Class of Licence
C (car)	At least 1 year	LR or MR
C (car)	At least 2 years	HR
LR or MR	At least 1 year	HR

A *TransLink* bus operator cannot assign a 12.5m standard rigid bus driver with an MR class licence to operate a high capacity vehicle. The bus driver must either already hold the relevant HR license or wait for the minimum MR licence holding period to expire before he/she can upgrade an MR licence to a HR licence before progressing to operate a high capacity vehicle.

Section 41 of *TOPTA* states that a service contract may establish performance levels for the quality and type of public passenger vehicles and current version *TransLink* 3G contracts contain similar provisions. Bus operator 3G contracts are discussed later in Section 3.17.

3.6.5 Special Events

Section 67B of *TOPTA* asserts that a special event declaration may be made only if *TransLink* considers, amongst other criteria, that the provision of transport services to or from the special event is likely to rely on an increased use of vehicles by *TransLink*. If *TransLink* had more high capacity vehicles operating in its network, the impact of a special event on existing network capacity could arguably be reduced and/or might, in some cases, negate the need to declare the special event or provide additional bus services. The assignment of high capacity buses to special event services would also reduce the cost to special event organisers and patrons of providing any additional services.

3.6.6 Fare Evasion

Chapter 11 of *TOPTA* covers fare evasion offenses and responsibilities, and specifically states that a person must not evade payment of a fare lawfully required for the person's use or hire of a public passenger vehicle. This is important in the context of considering various measures to reduce bus stop dwell times on high capacity vehicles, such as through all door boarding. There is nothing in the legislation that prevents all door boarding on any *TransLink* bus and the responsibility to pay the correct fare falls upon the passenger. A bus driver or other authorised person such as a Transit Officer, is only authorised under *TOPTA* to enforce payment of fares.

A driver is authorised to check tickets under the legislation, and therefore has a role to play in managing fare evasion. However it is not known in practice how a bus driver would validate fare payment using go cards. This will be explored further in later reports.

3.6.7 Prevention of Boarding on Full Buses

Section 143AH of *TOPTA* empowers a bus driver or an authorised officer to direct a person to leave or not enter a public passenger vehicle, or compartment of the vehicle, if:

- the person is about to enter, or has just entered the vehicle, or a compartment of the vehicle, that already appears to have its full complement of passengers, and
- the driver or authorised person tells the person in a general way, that the vehicle or compartment is full and that the person cannot board the vehicle, or compartment, or remain on the vehicle, or in the compartment, and
- the person then fails to leave, or not to enter the vehicle or compartment.

The deployment of high capacity vehicles will reduce the probability of drivers having to give such directions which occasionally lead to serious conflicts or altercations between drivers and passengers. More information about management of full buses is discussed later in Section 3.16.

3.6.8 Demand Management

Section 147 of *TOPTA* states that the Minister for Transport and Main Roads may authorise a local government to carry out, under a local law, demand management measures to encourage the use of public passenger transport. The Act defines demand management strategies such as pricing on parking, bus priority and high occupancy vehicle measures. While the *Act* does not clearly define high occupancy vehicle measures, it is assumed these measures apply to bus only, T2 and T3 high occupancy vehicle lanes, but could be interpreted as any other measures to facilitate the introduction of high occupancy buses, such as larger bus stop bays or alternative kerbside allocations.

3.7 TMR Information Bulletins – Vehicle

Vehicle information bulletins issued by DTMR on its website are designed to provide plain English explanations of the *TOPTA* standards and regulations. These have no specific requirements applicable to high capacity buses that differ from those applicable to standard 12.5m buses used for general route or school services.

3.8 Transport Operations (TransLink Transit Authority) Act

The main purpose of the *Transport Operations (TransLink Transit Authority) Act 2008* is to deliver best possible mass transit services at reasonable cost to the community and government in *TransLink's* South East Queensland network area, while keeping government regulation to a minimum. The *TTA Act* does not quantify the definition of mass transit services in terms of bus passenger carrying capacity, but defines it simply as general route services for the carriage of large numbers of passengers.

The objectives of the *TTA Act* are not dissimilar to those expressed in *TOPTA* (see Section 3.6.1), but enable the effective operational planning and efficient management of mass transit services, as opposed to public passenger transport services for *TOPTA*. The *TTA Act* has an additional objective beyond those stated in *TOPTA*, namely to help the government achieve its congestion management priorities relating to road transport.

Most of the provisions in the *TTA Act* focus on the establishment and statutory responsibilities of the TTA, its Board, CEO and employment office. Other than referencing the *Special Event* provisions already discussed for *TOPTA* in Section 3.6.5 and the State Government's congestion management agenda, the *TTA Act* makes no direct mention of high capacity vehicles.

Chapter 5A of the *TTA Act* clarifies that the chief executive officer of *TransLink* may give a direction with the Transport Minister's approval, to second essential public transport infrastructure to allow any operator of a relevant service for the infrastructure to use the infrastructure on stated conditions fixed by the chief executive, but not to change the infrastructure in any way that would restrict its future use. Before giving the direction, the chief executive must undertake consultation with the infrastructure asset owner and be satisfied there is no other reasonable and practicable alternative to the direction that will secure its use. The asset owner may claim compensation from the State for costs incurred by the asset owner in complying with the direction, but failure to comply with the direction attracts a penalty of up to 1,665 penalty units.

Under the provisions of Chapter 5A, the CEO of *TransLink* may declare a road as an essential piece of public transport infrastructure and direct the road asset owner, such as DTMR or an SEQ local government authority to provide bus priority and/or upgrade bus stops to enable the deployment of high capacity vehicles.

3.9 Transport Operations (TransLink Transit Authority) Regulation

There are no references to or implications for high capacity buses in the current version of the *Transport Operations (TransLink Transit Authority) Regulation 2008.*

3.10 Disability Discrimination Act

The federal *Disability Discrimination Act 1992 (DDA)* provides protection for anyone in Australia against discrimination based on a disability. It encourages everyone to be involved in implementing the *DDA* and to share in the overall benefits to the community and economy that flow from participation by the widest range of people. Discrimination occurs when a person with a disability is treated less favourably than a person without a disability. The *Act* makes is unlawful to discriminate in the provision of access to transport premises, vehicles, services and facilities.

The compliance requirements of the *DDA* for bus stops and heavy vehicles are the same, regardless of vehicle size and carrying capacity. However there are some indirect *DDA* considerations for high capacity vehicles if they are to be deployed on future school bus services. These are set out in the *Disability Standards for Accessible Public Transport (Transport Standards)* and discussed below.

3.10.1 Disability Standards for Accessible Public Transport (Transport Standards)

The Australian Government released the *Disability Standards for Accessible Public Transport* in October 2002. The disability *Transport Standards* establish minimum accessibility requirements for the providers and operators of public transport conveyances (DDA terminology for vehicles), infrastructure and premises. They encompass a wide range of compliance specifications for public transport facilities, bus stops and buses including:

- Wheelchair access paths, manoeuvring areas, ramps and vehicle boarding devices,
- Allocated spaces, doorways, controls, symbols, signs, waiting areas, boarding points, surfaces, hand and grab rails,
- Doorways and doors, lifts, stairs, toilets and tactile ground surface indicators (*TGSIs*),
- Alarms, lighting, controls, furniture and fittings,
- Street furniture, gateways, payment of fares and hearing augmentation systems, and
- Information provision, booked services, food and drink services, stowage of belongings and priority access arrangements.

The *Transport Standards* further specify levels of service, measures and actions that public transport operators and providers must take to discharge their obligations under the *DDA* and how public transport by bus, taxi, tram, train, ferry and commercial aircraft is to be made ‘accessible’. The *Standards* apply to all new transport conveyances (vehicles) and infrastructure introduced into service after 23 October 2002. A progressively staged timetable for compliance over a 20 to 30 year period applies to conveyances (vehicles) and infrastructure built before this date.

Both vehicles and bus stops need to meet the DDA compliance targets shown in Table 10 but an operator or provider may apply to the *Australian Human Rights Commission (AHRC)* for an exemption from compliance with the *Standards*. Exemptions may be subject to conditions that are set by the *AHRC* but are often only temporary or limited to a short term of not more than five years. Exemptions have primarily been granted to small regional bus service operators and members of the *Australasian Railway Association*.

A dedicated school bus service is defined in the *Transport Standards* as a service operated to transport primary or secondary students to or from school or for other school activity purposes. These services are excluded from 26 physical access parts of the *Transport Standards* and have been summarised at Appendix A.

Table 10: DDA Compliance Targets

Compliance Year	Compliance Target
2007	25%
2012	50%
2017	75%
2022	100%

The exclusions set out in Appendix A effectively mean that dedicated *TransLink* school buses and coaches are excluded from most physical access requirements in the *Transport Standards* and are not required to provide:

- A boarding device for persons using mobility aids,
- Handrails or grab rails,
- Allocated spaces for people with mobility aids,
- Wide step and aisle wheelchair manoeuvring areas,
- Automatic or power-assisted doors, and
- Doorways of a minimum width necessary to assist people with mobility impairments.

These exemptions now look destined to cease within the 20 – 25 year life cycle of a *TransLink* operator school bus or coach. Historically, the exclusion of dedicated school buses from the physical access parts of the *Transport Standards* was in response to identified high costs of retrofit to existing school buses and coaches. Parts of the *Standards* not excluded only provided a small degree of accessibility, primarily to students with a visual impairment and covered by the low cost signage, illumination and information specifications in the *Standards*.

Part 34 of the *Transport Standards* however obliges the Federal Minister for Infrastructure and Transport, in consultation with the Attorney-General, to review the efficiency and effectiveness of the *Standards* every five years after coming into effect. The first review was undertaken in 2007, and the final report on the review was released by the Australian Government on 3 June 2011. The consultant who conducted the review for the relevant Ministries was tasked to undertake an analysis for one of the key recommendations in the final report, namely a '*RIS Analysis of Dedicated School Bus Exclusion Options*'.

The RIS analysis estimated that the cost of enforcing dedicated school buses to comply with the *Standards* would be $1.265 billion over 20 years (at 1998 prices, Attorney-General's Department, 1999), which would in the main be incurred by a large number of small bus operators. These costs were deemed to be extremely high, and it was further argued by disaffected school bus service operators that:

- They were small business people, generally operating older and often second-hand vehicles, which were turned over infrequently,
- There was little or no demand for accessible services, and the cost could not be justified by the limited demand,
- It was unlikely that there would be accessible pathways between bus stops and PWD residences so accessible transport improvements to buses would not be utilised, and
- Existing bus stops were generally unformed, sometimes comprising merely a space for the school bus to pull over on the roadside (Attorney General's Department, 1999).

It was also noted on the Attorney-General's Department website that another reason for excluding dedicated school buses was in response to issues associated with operating ultralow floor buses on 'difficult terrain' (Attorney-General's Department, 2006).

The *RIS* analysis concluded that paratransit solutions would be more cost effective than upgrading school buses and recommended that school buses be considered in State and Territory Action Plans, with a view to further considering options for making school bus services fully accessible in the future. In spite of this suggestion, recent Action Plans released by most State and Territory Governments have not progressed the issue, and it appears that the majority of stakeholders consider the current exclusions for dedicated school buses to be an ongoing full exclusion from the *Standards*.

Exclusions for dedicated school bus services raise concerns about the operator practice of allowing other passengers to board school services. In rural and regional areas, it is common practice for non-school students to also use dedicated school services to get into town. It is currently not clear if, by allowing other adult passengers on a school bus service, the service remains a dedicated school service or reverts to a general access service. If dedicated school bus services that provide a service to other patrons are considered to be providing a general access service, operators may be forced in future to cease the practice to avoid being subject to the numerous accessibility requirements defined in the *Transport Standards*.

Arguments about a lack of suitable bus stop infrastructure ignore the fact that bus stop infrastructure in most SEQ regions needs to be upgraded for general route services operating side-by-side with school services. The underlying reasoning behind the current exclusions was not that they provide ongoing relief to bus operators from compliance with the *Transport Standards*, but rather that further assessment and consideration be given by States and Territories to making dedicated school bus services fully accessible in the future. The final *RIS* report considered two options:

- Option 1: status quo, maintaining the current school bus exclusions in the *Standards,* or
- Option 2: removing the exclusions from the *Transport Standards* that currently applied only to dedicated school bus services over an extended time period.

The final recommendation of the analysis was that Option 2 should be adopted on the basis that it was the best cost minimisation approach. The Option 2 approach presented the best way forward in terms of allowing the *Standards* to fulfil their purpose, while minimising compliance costs for government and the bus industry.

Following close consideration of the final review report and its recommendations, the Australian Government announced its response on 3 June 2011. The response contained 15 recommendations, the most relevant being...

<u>Recommendation 14:</u> *"Phased application of dedicated school bus services to physical access requirements in the Transport Standards, commencing in 2029 and being fully required by 2044.*

The Government supports this recommendation in principle.

The Review found that the current exclusions to the physical access provisions of dedicated school buses limit the current and future provision of services for students with a disability. The Government recognises the importance of providing students with a disability every opportunity to participate in community life, including being able to travel alongside students without disability on dedicated school bus services. The Government also considers there is merit in examining the potential consequences of this recommendation on existing complaints-based mechanisms of compliance.

The Government proposes that the Australian Transport Council considers the most appropriate mechanism to progress this recommendation, noting that the Review concludes that a full RIS would be required in light of the potential cost impact on school bus operators and providers. As part of the further analysis, there would be merit in examining the number of second-hand accessible buses that may currently be available for purchase by dedicated school bus operators given accessible buses have been in service since 1995 and, if possible, the scope to commence earlier or to shorten the phase-in requirements".

3.10.2 Disability (Access to Premises Buildings) Standards

The *Disability (Access to Premises Buildings) Standards 2010* commenced on 1 May 2011. Part H2 of the *Premises Standards* specifically relates to buildings associated with public transport services. This component has been transferred from the *Transport Standards*. Part H2 covers all public transport buildings including railway stations, bus interchanges and ferry terminals and would also apply to underground bus stations such as King George Square, Lutwyche and Queen Street Bus Stations. These standards will be reviewed in future reports being delivered under this study.

3.11 TransLink Strategic Plan

The *TransLink Strategic Plan 2011-2015* contains 5 pillars (or strategic priorities) with a underlying theme of providing 'value for money'. Of the 17 measures and targets established under the 5 pillars, those listed in Table 11 overleaf relate directly or indirectly to the future deployment of high capacity vehicles on *TransLink* school and route bus services.

3.12 TransLink Network Plans

TransLink Network Plans (*TNPs)* are developed annually as a strategic platform to articulate *TransLink*'s vision for making travel easy. The overarching goal of network planning is to simplify the network; making public transport easier for customers to use and to understand for their entire journeys. Each *TNP* reflects on *TransLink*'s achievements over the past year, identifies public transport trends and challenges, and sets out a plan for shaping the network for the future.

Table 11: TransLink Strategic Pillars, Measures and Targets

Pillar	Measure	2010/11 Actual	2014/15 Target
Quality Customer Experience	1.1 - Customer Satisfaction	70/100	75/100
Manage the Network	4.1 - Cost Recovery	22.5%	30.2%
	4.2 - Mode Share	7% (2006)	8.7%
	4.3 - Patronage	178.6 Million	193.1 Million
	4.4 - Capacity Enhancement	308,000 weekly seats	TBA
Financial Sustainability	5.2 - Subsidy per Passenger Trip	$6.06	$6.10
	5.3 - Average Revenue per Passenger Trip	$1.76	$2.64
	5.4 - Revenue Leakage (via Fare Evasion)	NA	TBA
	5.5 - Cost per Seat Capacity	$8,636 (Target)	$9,567 (Target)

3.12.1 TransLink Network Plan 2011

3.12.1.1 Strategic Objectives

Key challenges outlined in *TNP 2011* included:

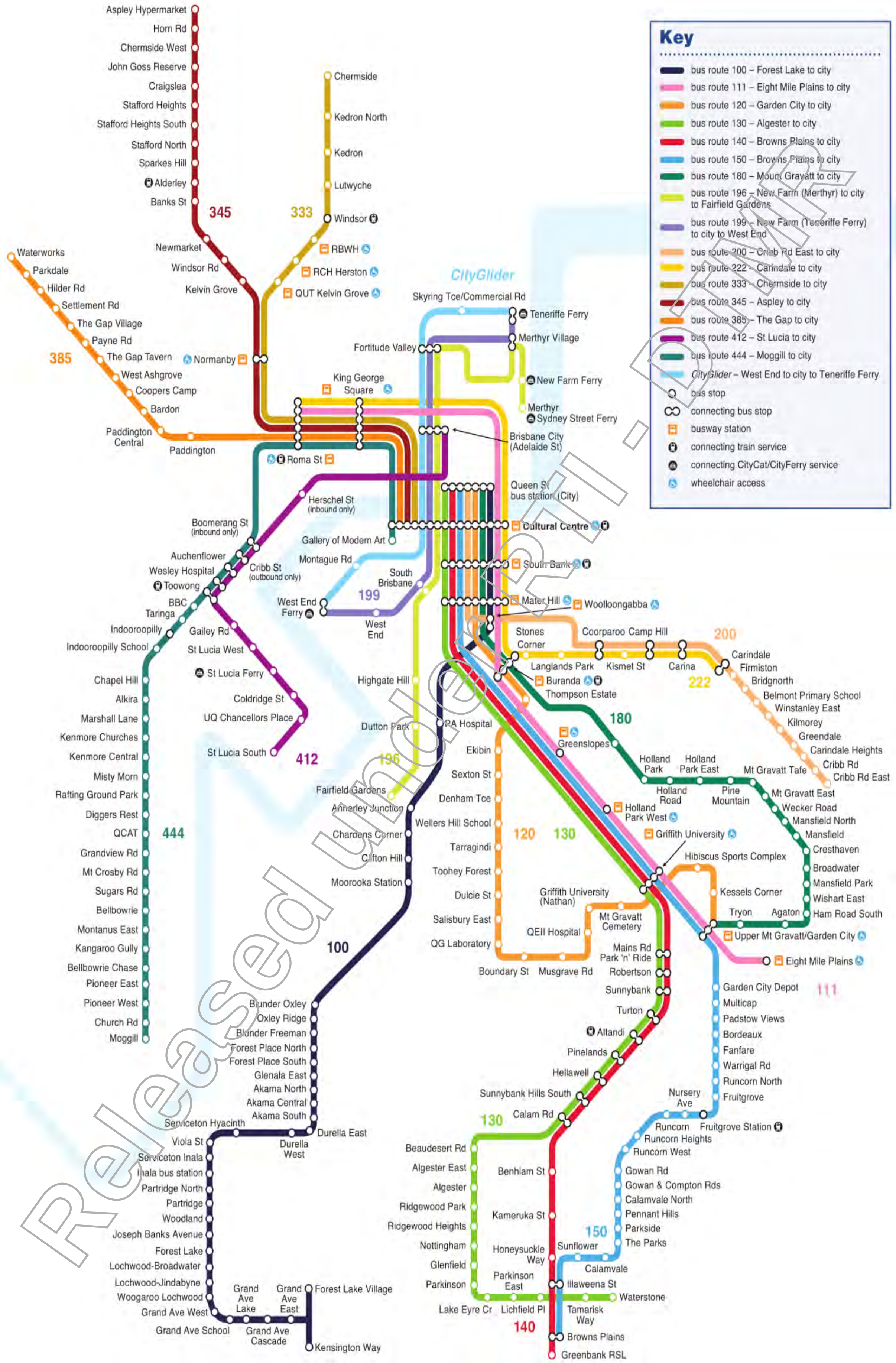
- Congestion: A key issue for the State and Local Governments in South East Queensland is the growing traffic congestion on SEQ roads. Traffic congestion poses significant threats to the SEQ region and impacts on its overall productivity due to increased freight costs and lost productive work time. Congestion also poses a considerable threat to the region's air shed and living environment from engine exhaust emissions and noise pollution generated by vehicles driving slowly and idling in traffic for long periods. *TransLink* aims to lead, plan, develop and promote public transport services to alleviate growing traffic congestion on SEQ roads.
- Value for Money: As the lead public transport agency in South East Queensland, *TransLink* has a responsibility to ensure public transport is an affordable and viable alternative to private motor vehicle travel. Whilst tasked to offer affordable transport options to its customers, *TransLink* must also secure the long-term financial sustainability of the SEQ public transport system and facilitate future growth of the public transport network.
- Maintaining the Transport Fleet: To ensure it can continue to meet the growing capacity demand on its network, *TransLink* invests annually in new railway rolling stock and bus fleet capacity. Its current capacity is 201 three-car heavy rail train sets and a fleet of 2,312 buses servicing the entire network, however in order to meet future projected capacities, *TransLink* will be adding 6 additional new three-car train sets to its network by December 2011, and working with its service providers to identify and replace buses in accordance with its ongoing *Bus Replacement Schedule*.

3.12.1.2 Capacity Enhancement

A notable focus of *TNP 2011* has been network capacity enhancement and *TransLink* set a target of 305,000 additional weekly bus seats in 2011. By close of year, *TransLink* had exceeded its target, delivering an extra 308,000 weekly seats in the year, distributed across its SEQ bus network as follows:

- 110,000 additional weekly seats on Brisbane buses,
- 11,000 additional weekly seats on Sunshine Coast buses,

Figure 10: TransLink High Frequency Bus Network in Brisbane



- 10,000 additional weekly seats on Gold Coast buses, and
- 17,000 additional weekly seats on Redcliffe, North Lakes, Caboolture, Logan and Ipswich buses.

It is understood the capacity growth target set for 2012 is 318,000 additional weekly seats.

3.12.1.3 High Frequency Priority Bus Routes

TransLink currently operates 18 high frequency priority bus routes in the SEQ Region, most of which are illustrated on the schematic route maps for greater Brisbane in Figure 10 below, which excludes the Logan City to Brisbane CBD high frequency superbus Route 555.

TNP 2011 also references the expanding busway network, with new busway extensions to Langlands Park and Kedron being completed in FY2011/12. DTMR bus corridor planning is currently underway to further expand the greater Brisbane busway network northward, southward and eastward where indicated on Figure 11.

Figure 11: Existing and Proposed Busway Network in Brisbane

3.12.2 TransLink Network Plan 2009

A review has been conducted on unpublished *TransLink Network Plan 2009*. *TNP 2009* is a more comprehensive planning document than the later version *TNP 2010* and *TNP 2011* summary plans and contains detailed *TransLink* policies and network strategies not included in later editions. *TNP 2009* makes the following specific references relevant to high capacity vehicles.

3.12.2.1 Passenger Comfort

TNP 2009 discusses *TransLink*'s commitment to passenger comfort and defines it as providing sufficient capacity to cater for growing demand using modern, air-conditioned, clean vehicles and continuing to work towards access compliance with the *Disability Discrimination Act 1992.*

3.12.2.2 Strategic Objectives

TNP 2009 addresses the top seven challenges for *TransLink* in South East Queensland and cites increased public transport capacity as a key response to meeting growing passenger demand and managing overcrowding. Capacity has become a prominent issue for SEQ public transport, especially in the greater Brisbane region. This has been partly due to a rapid increase in public transport take up since *TransLink* began managing public transport throughout SEQ in 2004. Some overcrowding can be reasonably expected in the capital city region and it will never be practicable to provide all peak hour passengers with a bus seat.

Service capacity needs to be continuously expanded so passengers can be assured of a comfortable ride, particularly on long service trips. To boost services along existing high-demand transport corridors, *TransLink* has established improved forward planning and procurement processes to allow early ordering of additional new buses and trains. With inner city Brisbane continuing as the major employment centre and transport hub for passenger transfers between buses, trains and ferries in the SEQ Region, meeting service capacity in the capital city has become a top priority. Planning is currently underway to investigate more capacity for both rail and bus services travelling to inner city Brisbane.

TNP 2009 further references the need to provide environmentally sustainable travel through more efficient use of resources. Public transport is considered at least 10 times more efficient in terms of fuel and energy consumption per passenger-kilometre and a considerably more efficient use of road space than single occupant motor vehicles.

3.12.2.3 Bus Priority

TNP 2009 acknowledges the role of local and State road authorities in delivering the "priority" for its *High Frequency Priority (*HFP) services, and strongly encourages both SEQ Local Governments and DTMR to invest in bus priority and high occupancy vehicle lane projects for new *TransLink* nominated HFP bus service corridors. To maximise the people-carrying capacity of roads, buses must be given priority access to busy activity centres through congested sections of the road network. This can be achieved by way of bus priority at signalised road intersections, bus only lanes and shared motorway high occupancy vehicle (T2 and T3) transit lanes, where buses can share lanes with other vehicles carrying two or more persons. The benefits of bus priority road treatments by these various road authorities include:

- Faster bus travel times which reduce bus fuel consumption, air pollution and greenhouse gas emissions,
- Improved reliability by reducing daily variations in service running times, allowing buses to meet their timetables more consistently, and
- More people carried in far fewer vehicles.

DTMR has prepared a *HOV Network Strategy* for South East Queensland and coordinated development of the *TransLink* HFP network has been a key input to the HOV strategic planning and funding prioritisation processes.

3.12.2.4 Service Categories

TNP 2009 defined future services on the *TransLink* network under the following 4 categories:

- High Frequency Priority (HFP): covering high frequency services provided by both bus and rail,
- Local: covering local and district bus services,
- Peak Only: covering extra bus and rail services needed to boost peak capacity and to provide direct trips for commuters during peaks, and
- Regional Links: covering inter-city rail services on the Ipswich, Gold Coast and Sunshine Coast railway lines.

3.12.2.5 High Frequency Priority Network

TNP 2009 focussed on rollout of *TransLink*'s then new high frequency priority (HFP) network, a 'turn up and go' service network for which passengers would not need timetables. *TransLink*'s 2009/10 strategy was to develop the new network of high frequency priority services that would form the backbone of South East Queensland's future trunk and feeder public transport system, (namely, the new *UrbanLink* network described in *Connecting SEQ 2031)*.

The initial high frequency network concept developed in *TNP 2009* operated at a headway of 15 minutes or better between 6am and 9pm each day of the week. Based on the trunk and feeder operating concept, the high frequency priority network used a combination of fast, very frequent, high capacity trunk bus services connecting with less frequent local feeder bus services that essentially provided transport only to local district destinations. A feature of the high frequency network was its capability for trunk bus services to operate as limited-stop and express services, leading to shorter overall journey times for customers. Converting existing bus routes to limited stop and express trunk routes created an ideal niche for high capacity buses, eliminating their perceived weakness of excessive dwell times at interchange and intermediate bus stops along the route.

While HCVs have been identified as prime candidates for deployment to HFP trunk routes, they could equally well be deployed on many existing peak-only and school bus routes, most of which have limited passenger turnover en route and operate for short periods of very high load demand. *TNP 2009* presented a schematic HFP map for each of TransLink's seven sub-regions, showing indicative routes targeted for implementation out to 2020. The HFP map developed for the greater Brisbane HFP network appears overleaf in Figure 12, and since 2010, the skeleton of the future HFP network envisaged in *TNP 2009* and shown on the map has already begun to take shape.

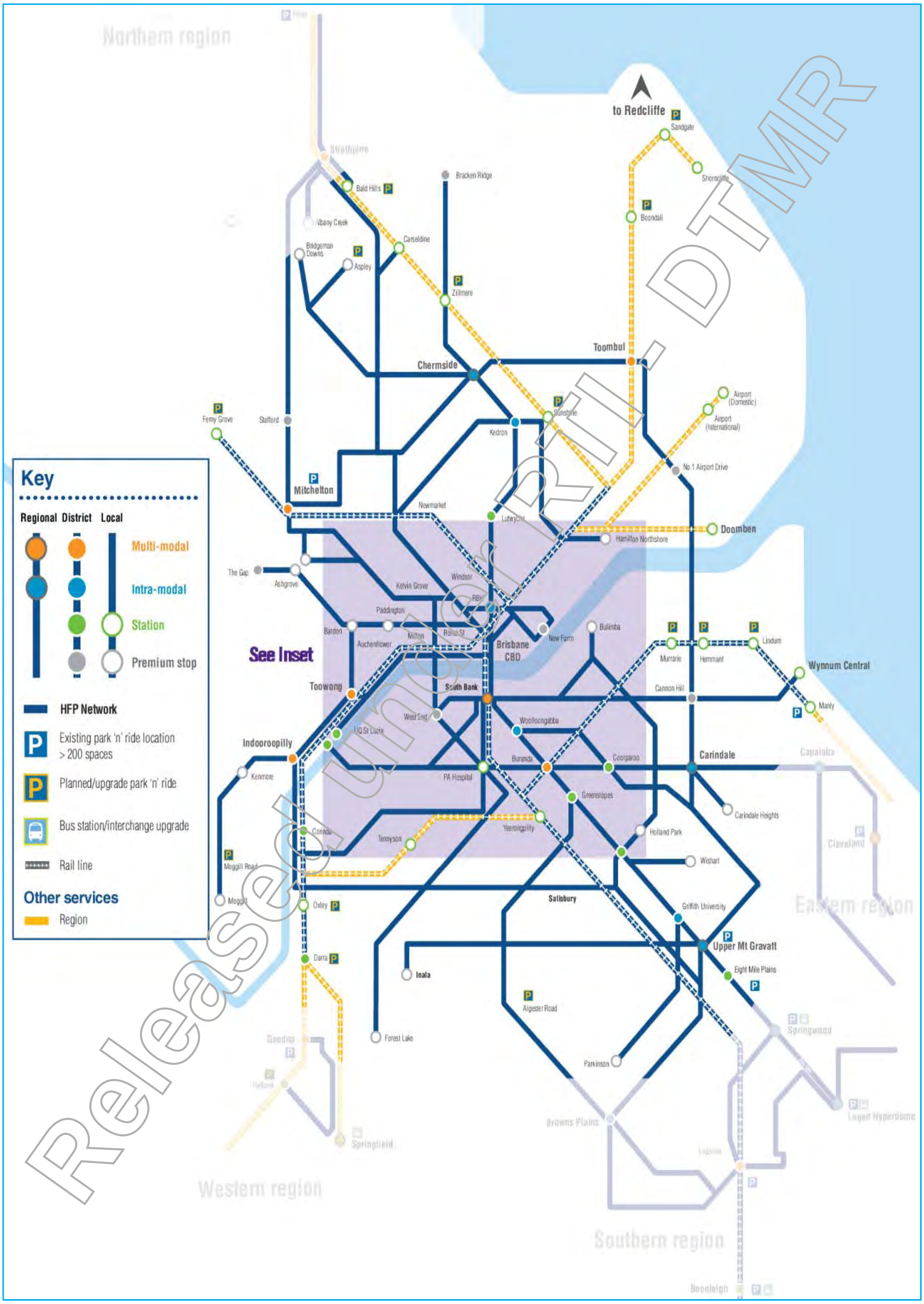
3.12.2.6 Bus Fleet Vehicle Mix and Specifications

TNP 2009 discussed expanding and enhancing the bus fleet, and developing standard bus specifications that allowed greater portability of the fleet across the network. This included refining the bus fleet vehicle mix to ensure it better met operational requirements by:

- Increasing the provision of higher capacity buses on high demand corridors such as busway and HFP routes, through targeted deployment of 14.5m rigid and 18m articulated buses,
- Development of *TransLink* standard bus specifications to provide consistent high-quality vehicles across the network, and

- Use of midibuses in areas of weak demand, provided only that such satisfied the national *DDA* accessibility standards.

Figure 12: Indicative HFP Network for Brisbane Envisaged in TNP 2009



Fleet improvement initiatives highlighted in *TNP 2009* included:

- Trial of hybrid diesel-electric buses,
- Trial of high capacity buses,
- Phase out of minibuses, and
- Development of a fleet strategy to promote innovation in development of clean, modern vehicle types.

TNP 2009 committed *TransLink* to make the bus fleet more environmentally sustainable through continued support for use of compressed natural gas on Brisbane Transport buses and trial of other alternative fuel technologies which burned less fuel and produced lower carbon equivalent emissions per passenger kilometre, favouring high capacity buses.

3.12.2.7 Bus Depots

TNP 2009 made reference to bus depots, citing new depots would be needed for the bus fleet to expand and meet expected future growth demand. Ill considered siting of bus depots can significantly affect the level of wasted bus dead running time to and from depots and termini whilst not carrying passengers. *TransLink* proposed in *TNP 2009* to become more proactive in locating, developing and managing bus depot rollouts as availability of land suitable for new depots became increasingly scarce. *TransLink* proposed in the plan to partner with bus operators and Local Governments in SEQ to investigate opportunities to strategically manage new depot rollouts with the aim of:

- Reducing overall network operating costs,
- Improving resource use, including depot sharing between operators,
- Responding to land use intents in local areas, including provision of adjoining park ‘n ride and kiss ‘n ride facilities for local residents,
- Ensuring long-term stability of the network, and
- Ensuring future growth could be accommodated as efficiently as possible.

3.13 TransLink Service Planning Policy

The *TransLink Service Planning Policy,* endorsed by *TransLink* senior management in 2011, does not specifically mention the bus fleet or high capacity vehicles, but contained the policy statement, extracted below, linking supply (of services) to demand (from land use) which favoured future high capacity bus deployment on HFP trunk services.

<u>Policy Statement</u>

Deliver an effective match between public transport services and land uses in the *TransLink* area.

<u>Policy Narrative</u>

The viability of TransLink Public Transport Services is determined by the demand generated by urban land uses from within the catchment of stops and stations. To improve the ability of Public Transport to compete with car based transportation, TransLink will utilise the following tools to assess the provision of Public Transport Services in the TransLink area:

- *The link between land use and the type and frequency of public transport that can be reasonably provided is to be as detailed in the TransLink Standards of Service relative to Land Use Density* (refer Table 12 below), and

- *Lower-density urban development (below 10 dwellings per hectare) is difficult to serve with mass transit. The minimum residential densities for Public Transport Services in new and existing urban areas are to be as detailed in the TransLink Level of Service relative to Land Use Density* (refer Table 13 below).

The policy links dwelling and job density to service frequency and not to a specific vehicle type or capacity, however the planning policy clarifies that the *TransLink* network shall provide a mix of service types to cater for the type of trip, time of day, day of week, frequency and origin/destination needs of communities across the *TransLink* service area. In effect, this aligns services generally with the typical service characteristics summarised in Table 14.

Table 12: TransLink Standards of Service Relative to Land Use Density

	Density	Typical Development Type	Public Transport Service Type
TransLink Mass Transit Services	High-density 40 dwellings/ha or more 100 residents or jobs/ha	City Centre, Activity Centre, Specialist Activity Centre or Urban (as per TOD Guide prepared by DIP)	HFP services
TransLink Mass Transit Services	Medium-density 30 dwellings/ha or more 50 residents or jobs/ha	Suburban and Neighbourhood (as per TOD Guide prepared by DIP)	HFP services on major corridors Infill by feeder services
TransLink Mass Transit Services	Low-density 15 to 29 dwellings/ha 20 residents/ha or 10 jobs/ha	New urban development areas* Business parks	Feeder services on hourly frequencies Some access to HFP and peak only services
TransLink Mass Transit Services	Low-density 10 to 14 dwellings/ha	Existing urban areas*	Feeder services on hourly frequencies Some access to HFP and peak services
	Low-density and Non-urban Fewer than 10 dwellings/ha in existing urban areas and 15 dwellings/ha in new urban development areas	Older subdivisions Hectare subdivisions Rural towns Isolated villages	Does not generally support mass transit services Park 'n ride to facilitate access to the public transport network Flexible transport (provided by Local Government or DTMR) may be appropriate Inter-regional service may connect centres

It is generally considered that lower demand would not warrant assignment of high capacity vehicles to local feeder services. There may however be some potential in the future to deploy HCVs on selected *NightLink* services, notably the more popular 3am *NightLink* services departing city entertainment districts just after lock-out.

Table 13: TransLink Level of Service Relative to Land Use Density

Net Residential Density	Approximate Lot Size (m^2)	Minimum Public Transport Level of Service
0 to 9 dwellings/ha	900m^2 or greater	Flexible transport (not provided by TransLink)
10 to 14 dwelling/ha	600 to 700m^2	Local or feeder services (in existing urban areas only)*
15 to 19 dwellings/ha	400 to 500m^2	Local or feeder services
20 dwellings/ha or more	300m^2 or less	HFP and feeder services

The *TransLink Service Planning Policy* does not reference school services as a specific service type and these are covered by a separate policy.

Table 14: TransLink Typical Service Characteristics

	High Frequency Priority (HFP)	High Frequency Priority Express	Peak Express	Regional	Local Feeder	NightLink After Hours
Public Transport Type	Bus, rail and ferry	Bus and rail	Bus and rail	Rail	Bus	Bus and rail
Key Function	Increase patronage	Increase patronage	Provide extra capacity to cater for peak-period commuter travel	Increase patronage and provide high speed links between regional areas	Provide coverage across the entire urban area and meet minimum service standards (2)	Supplement taxi services and provide safe late-night travel
Core Attribute	'Turn up and go' high frequency all day	'Turn up and go' high frequency all day with limited stops	Peak period express services Monday to Friday	Inter-region link	Provides access to HFP routes and local attractors	Secure late night services
Frequency	15 minutes or better all day	15 minutes or better all day	30 minutes or better peak only and where required	10 to 60 minutes all day	60 or better minutes all day	60 minutes or better Friday and Saturday nights
Minimum Hours of Operation	6.00am – 9.00pm 7 days	As required	Peak only	9.00am – 5.00pm weekdays / Saturdays; 9.00am – 4.00pm Sundays	9.00am – 5.00pm weekdays / Saturdays; 9.00am – 4.00pm Sundays	Set down on demand 1.00am – 5.00am Saturday and Sunday mornings
Stop Spacing	400m to 1.6 km	800m to 1.6km	400m to 2km with a section of the route running express	3 to 20km	400 to 800m	400m to 2km (note: set down on demand)

3.14 TransLink Infrastructure Planning Policy

The *TransLink Infrastructure Planning Policy,* endorsed by *TransLink* senior management in 2011, makes no specific mention of the bus fleet or high capacity vehicles, but addresses the future network capacity.

TransLink's priority in this regard has been to optimise existing capacity by implementing better network designs and alternative servicing strategies to yield improved efficiencies, before resorting to design and construction of additional new infrastructure capacity. Where it has been identified that new infrastructure is both warranted and justifiable, *TransLink* endeavours to match the type of public transport infrastructure to the long-term capacity requirements of the network, based on the following 4 assessment criteria:

- Support for Land Use Development: modal selection must be based on the desired role of the public transport network in supporting the overall development of an urban area, not simply as an bolt-on extension to the existing transport system,
- Right Mode for the Task: consideration must be given to current and future origins and destinations of trips using the nearest transport corridor and nodes, so that the mode of transport selected best meets the maximum number of passenger needs at an affordable cost,
- Minimisation of Overall Journey Time: public transport travel times must be competitive with private car travel times in peak periods, and
- Business Case Justification: must ensure cost-benefit realisation and contribution to delivery on *TransLink's* long term strategic objectives.

Modal Selection

Table 15 summarises current *TransLink* guidelines for planning different public transport delivery modes. Ranges shown reflect different assumptions for dwell time and in the case of trains, the number of cars per train set. Peak-hour factor and passenger loading assumptions used to derive this table reflect *Transit Capacity* and *Quality of Service Manual* recommendations. Highest observed values only have been listed.

Table 15: Modal Selection Thresholds

	Passenger Capacity in Peak Directions (passengers/hr)		Average Travel Speed (km/hr)	
	Low	High	Low	High
Bus in Mixed Traffic	500	1,000	6	10
CBD Bus Lane	1,500	4,000	6	14
On Street Light Rail with Signal Priority	2,600	5,000	13	24
Light Rail with Exclusive Right of Way	6,000	16,000	42	55
Bus on High Occupancy Vehicle (HOV) Lane	500	1,500	55	87
Busway with Passing, including Stations	2,000	12,000	56	72
Suburban Rail	7,000	24,000	32	81
Long Distance Commuter Rail	2,000	7,000	56	89
Metro Rail	10,000	60,000		

3.14.1 Bus Station and Stop Hierarchy

Policy Statement 2 of the *TransLink Infrastructure Planning Policy* indicates generally that stations and stops in the *TransLink* area will provide for easy and safe circulation of passengers and vehicles. Table 16 outlines the current *TransLink Station and Stop Hierarchy*.

TransLink defines different categories of functionality for its station and stop facilities as follows:

- Local Facility: is a local facility sited and designed primarily to cater for the transport needs of the immediate surrounding community. The primary means of access to a local station or stop is walking via local footpaths and roads,
- District Facility: is a station located at a significant attractor in the network. These stations have a good standard of passenger facilities. Services to district facilities are primarily a mix of express and all-stops HFP trunk services, but some feeder services also operate from the station, and
- Regional Facility: is a major station or interchange with a very high standard of passenger facilities located at a major attractor such as a regional shopping centre, or where two or more HFP services converge in the network.

Table 16: TransLink Stop and Station Hierarchy

Functionality			Category	Typical location criteria*	PT Mode
Local			Regular Stop	low patronage no interchanging between services outer suburban or low density areas low frequency services	Bus
Local			Intermediate Stop	moderate patronage no interchanging between services often located within suburban areas low to moderate frequency services	Bus
Local	District		Premium Stop	moderate to high patronage limited interchanging between services often located along major corridors moderate to high frequency services	Bus Busway Light Rail Ferry
Local	District		Standard Station	moderate to high patronage limited interchanging between services key point of transfer between services of the same mode often located along public transport corridors such as rail lines or busways moderate to high frequency services	Bus Busway Light Rail Heavy Rail Metro Rail Ferry
	District	Regional	Intra-modal Station	high to very high patronage high level of interchanging key point of transfer between services of the same mode often located at major district or regional attractions, or at strategic places within the network high frequency services	Bus Busway Light Rail Heavy Rail Metro Rail
	District	Regional	Multi-modal Station	high to very high patronage high level of interchanging key point of transfer between services of both the same and different modes often located at major district or regional attractions, or at strategic places within the network high frequency services	Bus Busway Light Rail Suburban Rail Long-distance commuter Rail Metro Rail

In future, high capacity buses are more likely to use *District* and *Regional* facilities. Under the *TransLink Infrastructure Planning Policy,* bus stations and stops are classified according to the service frequency and patronage hierarchy presented in Table 17.

Table 17: Service Frequency and Patronage Hierarchy

Frequency Levels	For the purpose of this policy, frequency of services (in the peak) at stops or stations will typically be as follows: • Low: Local Services - greater than 60 minutes • Moderate: Local Services - 15 to 30 minutes • High: High Frequency Priority (HFP) Services - 10 to 15 minutes • Very High: High Frequency Priority (HFP) Services - greater than 10 minutes
Patronage Levels	For the purpose of this policy, patronage levels (in the peak) at stops or stations will typically be as follows: • Low: 0 to 250 passengers per hour • Moderate: 250 to 2,500 passengers per hour • High: 2,500 to 20,000 passengers per hour • Very High: greater than 20,000 passengers per hour

There is no existing capacity requirement that marries specific vehicle sizes to bus station and stop service frequencies and patronage demand.

3.14.2 Bus Depots

Policy Statement 4 of the *TransLink Infrastructure Planning Policy* states simply that bus depots and train stabling shall contribute to an efficient network. The location and capacity of bus depots have significant influence over the operating efficiency of the *TransLink* mass transit bus network. The following criteria are applied when planning new, or upgrading existing bus depots:

- Efficiency: Depot location selection to minimise vehicle dead running time and distance and maximise network operating efficiencies. This normally translates to siting depots close to where the majority of bus routes originate in the morning and terminate in the evening,
- Capacity: Sufficient depot capacity to be provided to accommodate future growth as efficiently as possible and to ensure the long term stability of the bus network,
- Utilisation: Adequate space to be provided to ensure efficient and effective bus operations and maintenance. Depot infrastructure is to be readily accessible to bus drivers and other depot staff and provide an appropriate level of amenity, and
- Impacts: Depot locations should minimise operational and maintenance impacts on surrounding communities.

The current policy acknowledges that more detailed bus depot strategies will be necessary to inform future planning for new or upgraded existing bus depot infrastructure.

3.14.3 Mass Transit Definition

Under the *Transport Operations (TransLink Transit Authority) Act 2008, TransLink* is responsible for delivery of mass transit services in South East Queensland. *TransLink*'s service and infrastructure planning policies define mass transit as follows...

"For the purpose of this policy, mass transit is an urban public transport system which provides regular scheduled bus, light rail, rail or ferry services. Mass transit only operates where the carrying capacity of

the transport mode is 24 seats or greater. Mass transit is generally provided to areas that have a density of 10 dwellings per hectare or greater".

This definition distinguishes the service capacity to be provided by *TransLink* from the service capacity to be provided by DTMR under their respective public transport charters within SEQ, and defines the minimum carrying capacity of their respective passenger transport vehicles.

3.15 Draft Service Augmentation Policy

The 2004 *TransLink Network Plan* proposed that services carrying more than 30 passengers per in-service hour be considered for augmentation. Since public release of this document, the policy has never been formally amended.

While not yet officially endorsed by *TransLink* senior management, informal agreement has been reached on a new draft policy position defining when services should be augmented going forward into the future. The draft policy is set to replace the former policy contained in the 2004 *TransLink Network Plan,* and is likely to be incorporated into the *Service Planning Policy*. Its position is summarised as follows...

"A service may be considered for a capacity upgrade if the maximum passenger load equals or exceeds 90% of the legal passenger carrying capacity of the vehicle for a continuous period of 20 minutes or longer. When considering capacity upgrades, the service must consistently meet or exceed the above thresholds to warrant a permanent capacity upgrade, taking into account seasonal fluctuations in demand".

The new draft policy does not imply that service augmentation necessarily means plugging additional services into a persistently loaded route, but allows for the qualifying service to be augmented by a vehicle capacity upgrade where such would more cost-effectively resolve overcrowding and missed passenger boardings without adding additional services. It is understood that the *TransLink* Strategy and Planning Team is keen to upgrade netBi functionality that would enable load profiles to be generated for individual services against their scheduled times, so that thresholds could be set to detect extended periods of overloading and thereby target services for which high capacity buses or additional services would be needed.

The earlier *TNP 2004* policy made no reference to either vehicle capacity or passenger turnover. The latter determines the magnitude and duration of transient passenger load peaks along the route, and is affected by the service type and distribution of surrounding land uses at scheduled bus stops. By way of example, the current Route 199 BUZ has the highest passenger boardings of any *TransLink* bus route. But because the 199 route services numerous mixed land uses on its high density corridor in both the peak and contra-peak travel directions, the service experiences a very high passenger turnover.

In contrast to the Route 199 BUZ, most school, university and peak express rocket services have only one or a few high passenger offloading stops and therefore experience only limited passenger turnover en route. Consequently, whilst the total number of passenger boardings on the 199 BUZ greatly exceeds the carrying capacity of HCVs along its entire route length, these vehicles would not reach full capacity for any significant period of time as a consequence of high passenger churn.

3.16 Driver Full Bus Reports

In the absence of having load profile functionality in its current version of netBi, Brisbane Transport has chosen to prioritise its service crowding mitigation initiatives by requesting bus drivers to report when buses appear full. Historically, full buses were reported when drivers finished their shifts at home depots and this necessitated drivers being diligent in both recalling and recording the affected service(s) and where on their routes overloading was encountered.

More recently, Brisbane Transport has resorted to using its bus two-way radio system which enables instant driver reporting at the push of a button on the in-vehicle mobile radio when the driver observes the bus is full. Electronic bus full data captured by mobile radio not only reports the full bus and service number, but additionally records the GPS coordinates of the vehicle to show where along the route the bus first became full. It is unknown whether drivers also manually record where, further along the route, the bus was no longer full, taking into consideration that the boarded passenger status on high turnover routes may fluctuate repeatedly between fully and partially loaded.

A recognised problem with full bus reports, be they manual or electronic, is they rely on the subjective judgement of the bus driver. A bus driver is authorised and obligated under *TOPTA* to prevent passengers boarding a bus that is considered full, and while the driver might know the legal carrying capacity stamped on the compliance plate of the vehicle being driven, he/she would not know how many passengers were actually boarded without conducting a head count. Accurate touch on and touch off electronic ticketing data could be used to calculate boarded load in real time, but is not currently provided to the bus driver and is only passed to *TransLink* for post-service evaluation and planning purposes.

It is understood that the popular high frequency BUZ route buses are amongst those most frequently reported full by bus drivers, but their assessments fail to consider high passenger turnover and service frequency (i.e. passenger waiting time between services), or whether preceding or following services along common corridor route segments may have had surplus boarding capacity. It is considered therefore that reliance solely on driver subjective assessment of passenger loads in deciding which services should be augmented with higher capacity buses or additional services is not a sustainable long term proposition for prioritising future *TransLink* service augmentations.

3.17 TransLink 3G Bus Contracts

3.17.1 Private Operator 3G Contracts

14 private bus operators presently hold *3G (Third Generation)* operating contracts with *TransLink*. The following sections review the current 3G contract and discuss selected clauses and schedules of the contract with direct or indirect implications for the future deployment of high capacity vehicles.

3.17.1.1 Vehicle Standards

3G contracts define a vehicle as a bus used, or which may be used by or for the operator to perform the services under the contract. This definition is the same as that found in *TOPTA*. 3G contracts further state the operator will comply with all State and Commonwealth Government laws in relation to vehicle accessibility and emission standards, and in particular, with the *Disability Standards for Accessible Public Transport 2002* and accompanying guidelines implemented under the *Disability Discrimination Act 2002 (Cth)*.

Schedule 7 of the private bus operator 3G contract provides a list of vehicle standards but most of the standards relate only to vehicle cleanliness and safety. There is no mention in the contract standards that vehicles should, for instance, be fitted with:

- Air conditioning,
- Two entry/exit doors, or

- Changeable electronic destination and route numeral signs, save that one destination sign must be fitted on the front of the bus.

No mention appears in the 3G contract about vehicle passenger carrying capacity, except in respect of reference to the *TOPTA* bus definition which basically defines a bus as having 9 or more passenger seats.

Under the 3G contract, *TransLink* must approve the purchase of new buses required by an operator to provide the services. If the operator chooses to purchase a bus that is considered to exceed *TransLink*'s minimum specifications, the operator must self-fund the difference between the cost of a vehicle that would have met the minimum specifications to provide the services and the vehicle that the operator has elected to purchase. For example, where a standard 12.5m route bus would be sufficient to provide route and school services in the operator's contract area, but the operator elects to purchase a coach to operate its own private tours, *TransLink* will only pay the cost of a standard route bus. In a similar vein, *TransLink* will not compensate the operator for any additional depreciation and running costs associated with a vehicle it elects to procure which exceeds the minimum specifications needed to deliver the contract services.

3.17.1.2 Livery

The 3G contract outlines *TransLink*'s branding requirements in relation to bus livery. An operator must ensure that its vehicles exhibit *TransLink*'s trademark and name in accordance with *TransLink* standards and guidelines for their proper use, and *TransLink* may direct an operator to change the livery of its vehicles to accord with the standards and guidelines. *TransLink* will pay to an operator the actual and reasonable cost incurred by it for any changes made to the livery of existing vehicles, but not for livery changes to vehicles made during their normal refurbishment or maintenance, or on a new vehicle.

If *TransLink* chooses to assign existing high capacity vehicles to routes that have a unique service brand necessitating an update of service branding elements in the fleet livery (such as say for new HFP routes), the cost of livery changes would be claimable back from *TransLink* by operators under current 3G contract conditions.

3.17.1.3 Fuel Costs

Schedule 8 - Indexation of the 3G contract states vehicle fuel costs will be paid to operators by *TransLink,* based on the actual cost of fuel and using *FuelTrack* to determine the indexation factor.

TransLink does not presently specify the bus fuel type or propulsion system to be used by the operator, nor the manufacturer, model or size of vehicle to be used, however as the receiver of all passenger ticket revenue generated by the services, high capacity buses placed on heavily loaded routes would realise the lowest fuel consumption and highest revenue generation per passenger-kilometre travelled.

3.17.1.4 Contract Payments

3G contract clauses indicate that there will be no change to the contract payments made to an operator by reason of a reduction in the level of service provided in accordance with the base kilometres specified in the contract, unless otherwise mutually agreed. These clauses exist to assure operators that they would not be financially disadvantaged as a consequence of any *TransLink* decision during the life of the contract to reduce the base kilometres below those which existed when operators first joined the *TransLink* network in 2004.

These clauses place potential constraints on the future deployment of high capacity vehicles. For instance, two articulated buses may be considered equivalent to three standard rigid buses in terms of total carrying capacity. If *TransLink* chose to substitute two articulated buses in place of three standard rigid buses on a route to improve the economic performance of particular services, the operator's base kilometres would be reduced by one third, but at no realisable saving to *TransLink*.

In the 8 year period that has elapsed since 2004, total operator base kilometres have increased by an average of 64.53% and the opportunity exists to reduce or contain further growth in travelled kilometres through greater high capacity bus utilisation, provided that new base kilometres are not locked in at their increased levels in the next round 4G contracts. In practice, *TransLink* will be more likely in future to selectively deploy high capacity vehicles on high demand routes in lieu of increasing services and kilometres. This approach would be expected to help constrain growth in base kilometres, rather than reduce existing kilometres.

3.17.1.5 Performance Management Framework

Schedule 10 of the 3G contract outlines the performance management framework for delivery of services and includes penalties for the following items of relevance to high capacity buses:

- On-time Running: The number of buses departing from agreed scheduled locations no more than 1 minute earlier than scheduled, and no more than 5 minutes later than scheduled, must be less than 5% of the total agreed scheduled departures for a day. (It is understood that these thresholds may have subsequently been revised by *TransLink*), and
- Missed Trips: The number of trips removed from the daily schedule must be no greater than 0.5% of the total trips scheduled for the day.

It could be argued by operators that they should be exempted from the above performance management framework penalties if the deployment of higher capacity vehicles failed to account for additional running time in the schedule to cover longer dwell times and generally slower acceleration from stops due to the higher mass of HCVs.

Another performance measure nominated in the schedule sets a target of 1 accident per 100,000km. A high capacity vehicle longer or higher than a standard 12.5m rigid bus may be expected to have a higher rate of accidents per 100,000km, based simply on the fact that it takes up more road and air space than its 12.5m counterpart, calling for greater driver diligence, concentration and care to manoeuvre and avoid accidents.

3.17.1.6 Private Charters and Tours

Some SEQ bus operators run private charter and tour services outside their standing 3G route and school service contracts with *TransLink*. In these instances, *TransLink* pays that proportion of the vehicle running cost associated with operating its own scheduled services, and the operator picks up the remaining cost expended on its own private charter and tour operations. Operators in the private charter business generally prefer to buy high floor coaches with more seats than low floor standard 12.5m route buses and with luggage stowage compartments below the main passenger deck. They predominantly operate their private charter services in *TransLink* scheduled service off-peak periods.

This arrangement has proven to be cost effective for both the private charter operators and *TransLink*, as the operators can utilise their high floor coaches on school routes during the peaks which often demand higher seating capacity, and coaches do not currently need to be *DDA* compliant. In effect, *TransLink* only pays for the vehicle to be operated on school routes, and the vehicle's initial procurement and ongoing running costs are cross-subsidised by private charter operations in circumstances where operating school bus services alone would be financially unviable.

For ultralow floor buses used on urban routes, *TransLink* arguably pays for a portion of its mass transit fleet to sit idle and underutilised in depots during off-peak periods, as most operators with ultralow floor bus fleets do not operate private charter businesses. The current exemption from DDA compliance for new buses used exclusively on school services looks set to expire after 2029, presenting *TransLink* with a dilemma of deciding to continue authorising purchase of coaches by operators in the tour business, or directing they purchase ultralow floor buses, given the typical 20 to 25 year life cycle of buses and coaches in SEQ.

It is unlikely a high capacity 14.5m rigid or 18m low-floor articulated bus could be used by an operator for charter services, but some operators might consider using low floor double deck buses for their charter services, where the lower deck could be partially partitioned off for luggage storage. Where this option was unacceptable to charter operators, this might mean that *TransLink* would need to pay up to 100% of the cost of a new high capacity vehicle and to shore up its return on investment by operating high capacity vehicles on other services where high demand warranted such. The cross-city and cross-country route services envisioned in *Connecting SEQ 2031* could be one future avenue to absorb this excess network capacity.

3.17.1.7 New Vehicle Funding

3G contracts state that an operator may be eligible for financial assistance under a guideline such as the *Accessible Bus Program Guideline.* These guidelines are now considered to be out-of-date as they only strictly relate to urban regional bus operators who hold a service contract with the Department of Transport and Main Roads. The guidelines do not apply to *TransLink* school and route service bus operators.

TransLink does however indirectly fund its operator new vehicle purchases through an operating lease arrangement. Under this lease arrangement, *TransLink* pays the annual lease instalments for each newly procured bus over a number of years, and the mutually agreed residual value is paid out by the operator upon termination of the lease period. The lease agreement is sufficient to enable operators to source finance for their ongoing fleet renewal programs with *TransLink* assurance provided both as initial lessee and financial guarantor.

It is understood that *TransLink* pays 125% of the lease cost of a standard 12.5m rigid bus for a 14.5m rigid bus and 150% for an articulated bus, and the lease cost ratios are based on the relative seating capacities of the 3 vehicle types. Notwithstanding this financial agreement, Brisbane Transport planners argue that their 14.5m rigid buses are equivalent to articulated buses in terms of their total carrying capacity.

3.17.1.8 Replacement Vehicles

Schedule 7 of the 3G contract stipulates that the maximum age of an operator's vehicles must not exceed 25 years and the average age of an operator's fleet must be no greater than 13 years. Schedules 4 and 5 of the operating contract specify vehicle register details that operators are to provide to *TransLink* annually for their existing fleets, proposed vehicle acquisitions and replacements. Any existing buses or coaches proposed to be removed from service and/or replaced must be negotiated annually with *TransLink*.

Current 3G contracts do not require private operators to advise *TransLink* of the each vehicle's total carrying capacity, only their seated capacity. The compliance plate installed in each bus details the vehicle's designed (legal) carrying capacity and whilst this information may be recorded by private operators, it is not currently collected through their respective fleet registers by *TransLink*. The Brisbane

Transport fleet register is the only register that records both seated and total carrying capacity for each vehicle and bus subgroup.

3.17.1.9 Spare Vehicles

While the 3G private operator contract is silent on the percentage of the bus fleet to be held as spares, *TransLink* adopts bus industry best practice of around 10%, namely one spare vehicle for every 10 vehicles demanded during the highest weekday peak.

3.17.2 Brisbane Transport 3G Contract

It is understood that the conditions contained in the Brisbane Transport 3G contract are broadly similar to those in private operator 3G contracts, but the former includes the following additional provisions in regard to the Brisbane Transport bus fleet:

- *TransLink,* Brisbane City Council and Brisbane Transport are to agree each year on new fleet orders and the fleet mix of 12.5m rigid, 14.5m rigid and 18m articulated buses before orders are placed with the Council's bus chassis and body manufacturers, and
- *TransLink,* Brisbane City Council and Brisbane Transport are to agree each year on the planned fleet growth and replacement program.

It is further understood that *TransLink* has agreed to fund 125 equivalent rigid bus purchases per annum up until the end of FY2011/12, subject to annual agreement upon the fleet composition and bus replacement program. All vehicles procured under this arrangement have to date been CNG or diesel engine, air conditioned, ultralow floor, PWD accessible, two door route buses. A total of 128 new 14.5m rigid buses and 30 new 18m articulated high capacity buses have been procured under the agreed replacement program to date.

3.17.3 Brisbane City Council - Volgren Joint Venture

The current Brisbane City Council administration announced commitments to procure 400 and later 500 new buses during their last two terms in office. These commitments were made without *TransLink*'s prior agreement to fund either the new bus procurements or their deployment on scheduled school and route services. In recognition of this, it is understood the current Brisbane Transport 3G contract held with Brisbane City Council contains new provisions to ensure similar forward commitments cannot be made by Council without *TransLink*'s prior consultation and approval.

In 2008, Brisbane City Council announced it had entered into a 10 year joint venture with Australian aluminium bus body manufacturer Volgren Australia, to construct a new $19 million bus build factory at Trade Coast Central, Eagle Farm. It is understood Council donated a 2.54 hectare site valued at $6.7 million to Volgren to establish the new factory, which later opened in December 2009. Brisbane Transport bus body fabrication staff from the Council's Brisbane Transport Bus Workshops at Toowong were transferred to the new enterprise under the joint venture agreement, resulting in the closure of the Toowong bus body construction line previously used to fabricate and assemble new Council buses. It is understood the Volgren factory has the capacity to produce up to 200 buses per annum and the joint venture, executed in 2008, has a further 6 years to run.

Volgren has publically confirmed its Brisbane facility could build GM-Allison based hybrid diesel/electric rigid buses similar to those presently being trialled in Melbourne, and had the capability to also manufacture hybrid articulated buses. Brisbane City Council is however currently only placing orders for new diesel rigid buses to replace its older high floor diesel route buses located in depots which have no close proximity to existing high pressure natural gas pipelines. It is further understood that Brisbane City Council is reluctant to make further acquisitions of 18m articulated buses and considers the 14.5m rigid bus to be the equivalent of an articulated bus in terms of total carrying capacity and considerable cheaper to build, maintain and operate.

3.18 High Capacity Vehicle Scheduling Constraints

3.18.1 Depot Related Scheduling Constraints

Practical scheduling constraints prevent assignment of high capacity vehicle types to particular bus routes. These relate to:

- Intra-depot Constraints: Not all existing bus depots have the facilities, or would through appropriate modifications, be suitable candidates to park, maintain, wash and refuel high capacity vehicles. There may also exist road access or bus stop infrastructure limitations on bus routes operated from particular depots that prevent service delivery using high capacity buses. (Examples of typical depot related high capacity vehicle constraints are later described in the SIP business case study found at Section 3.18.5), and
- Inter-depot Constraints: Large operators with multiple depot sites attempt to limit assignment of bus routes to one or the two best depots which minimise their resident fleet average dead running time. This practice provides a bonus advantage in that drivers stationed at multiple depots do not need to be fully acquainted with every route on the operator's network. This is particularly important in the case of *TransLink*'s largest bus operator, Brisbane Transport, which has over 200 bus routes in the greater Brisbane area serviced by 1,250 buses from 9 separate depots.

With the advent of the *TransLink* go card, when a driver logs onto his/her vehicle DCU, stops are listed in sequential order for the route about to be driven, so driver reliance on prior knowledge of routes has arguably become less critical and the current Brisbane Transport Award pays its drivers more for operating services from multiple depots.

Notwithstanding this apparent flexibility, the inability to globally optimise scheduling between depots obviates potential interlining of services that would maximise operating efficiencies and further reduce dead running. The HASTUS and AUSTRICS scheduling systems used by most *TransLink* operators apply business rules established by each operator which effectively thwart opportunities for *TransLink* to further improve network efficiency. Example A below illustrates how depot siloing business rules can affect efficient interlining of two hypothetical services operated from different depots.

> Example A: Say Brisbane Transport Route 111, operated out of Garden City Bus Depot, shared a common terminus with Route 222 at Roma Street Busway Station. Because Route 222 is only operated out of Carina Bus Depot, it cannot be interlined with Route 111 under HASTUS business rules, because drivers stationed at Garden City Bus Depot are not expected to be familiar with routes operated exclusively by Carina Bus Depot bus drivers. Because these services can't be interlined under HASTUS business rules, the hypothetical Route 111 bus must leave the busway to start at another origin stop in the CBD which can be interlined with a route operated out of Garden City Bus Depot.

A cost effective method known to reduce dead running cost is to assign designated vehicle types to turn back high frequency routes. This practice allows, for instance, an inbound HFP high capacity bus to arrive at its CBD terminus, take a short recovery period without repositioning, then return back along the same route in the outbound direction. In a more complicated but equally cost effective interlining scenario, two converging high frequency routes operated from the same home depot and sharing a common terminus can facilitate interlining of both services for a minimum layover period. This is illustrated by Example B below.

> Example B: Say BUZ Routes 345 and 385 share the same terminus at the Gallery of Modern Arts and operate out of the same bus depot so HASTUS business rules permit their interlining. The buses can be scheduled to operate every 10 minutes (5 minutes combined) during the peaks and every 15 minutes during the off-peak (every 7.5 minutes combined). By interlining these two separate routes, the interlined recovery time becomes 5 minutes in the peaks and 7.5 minutes in the off-peak without incurring any bus dead running distance or driver paid time for repositioning of either bus.

Under the two hypothetical scenarios presented above, the opportunities to interline are constrained to those which can be accommodated by drivers and buses operating out of the same home depot.

3.18.2 Livery Constraints

Creation of special fleet subgroups with their own distinctive livery reduces bus interchangeability between depots, prevents substitution of similar bus sizes between services, increases the whole-of-fleet spare bus ratio and essentially de-optimises fleet utilisation and route scheduling. Utilisation can however be optimised for fleet sub-groups with a distinctive livery if operated all day on high frequency routes with a minimum of spare buses held in depot as in the case of, for example, the Brisbane *CityGlider.* Unlike other similar size buses without a distinct livery, a scheduler could not interline a *CityGlider* bus with say a peak hour *Rocket* service, as the redeployment of the *CityGlider* vehicle on another route would erode the service brand and only serve to confuse customers, but the continuous all day demand for the *CityGlider* service renders the need for interlining unnecessary.

Unlike standard rigid 12.5m buses, high capacity buses are further constrained by their relatively smaller sub-group strengths, standby spare bus reserves and the limited number of routes to which they can be scheduled. If further sub-grouped by a distinct livery for other than all day, high priority, high frequency services, high capacity buses may be found sidelined in depots for long off-peak periods each day.

3.18.3 Meeting Minimum Depot Fuel Quotas

Many operators have diesel (or natural gas) supply contracts in place with bulk fuel delivery vendors which specify minimum fuel storage top up thresholds for tanker deliveries and/or minimum weekly, fortnightly or monthly accounting period consumption thresholds which will attract bulk fuel discounts. These fuel supply arrangements, while intended to achieve economies of scale for best fuel price, indirectly result in buses with high kilometre routes being deliberately stationed at particular depots so minimum depot fuel order thresholds are reached, albeit that the selection of the vehicles' home depot may be considered suboptimal from both a scheduling and dead running perspective than other available depots. High capacity buses operating high frequency limited stop and express routes for long periods of the day consume fuel at considerably higher rates per day than smaller capacity 12.5m buses, and are tempting targets for operators to selectively place at depots where attainment of minimum fuel quotas is a priority consideration.

3.18.4 Assessing Load Profile and Turnover for HCV Deployment

If selection of high capacity bus routes is based solely on driver reported or netBi measured load profiles, such may result in high capacity vehicles being inefficiently deployed to infrequent, low passenger turnover routes with resulting network de-optimisation if such routes don't share common termini with other routes, limiting interlining opportunities to reduce layover time and dead running needed to reposition trip origins. The challenge when selecting target routes for high capacity vehicles will be to contrast the cost per passenger-kilometre of augmenting low frequency crowded routes with low passenger turnover against the cost of augmenting high frequency routes with high passenger turnover along the route.

The latter routes are generally considered better candidates for cost-effective deployment of a dedicated high capacity vehicle fleet, however due to their high frequency, turn back contra-peak operation and servicing of multiple destinations, these routes may have the desired high patronage turnover but demand may not necessarily justify use of high capacity vehicles throughout the day.

3.18.5 Service Improvement Program Business Case – High Capacity Vehicle Deployment (Gateway 2)

This section describes a recent *TransLink* business case to reallocate high capacity vehicles to specific bus routes that consistently delivered full standing loads. The business case highlights the issues that were considered and constraints encountered when allocating high capacity vehicles to other bus routes.

As part of its 20 February 2012 *Service Improvement Program*, *TransLink* reallocated high capacity vehicles to operate on specific Brisbane bus routes for the first time. The objective of this project was to achieve a more functional and efficient utilisation of the Brisbane Transport high capacity bus fleet. By reallocating 14.5m rigid and 18m articulated high capacity vehicles to known congested routes, *TransLink* sought to proactively manage increased passenger demand without increasing peak bus service numbers.

Specific routes were selected largely on the basis of driver full bus reports and the project proposed an increase in weekly capacity on the network of 2,640 seats to address the growth in passenger demand. The Brisbane bus routes selected by the project team have been summarised below in Table 18.

Table 18: Proposed Deployment of High Capacity Vehicles on Brisbane Bus Routes

Route	To/From	Operations Proposal
66	Woolloongabba to Royal Brisbane Womens Hospital via Busway	Operate using articulated (18 metre) buses, 5 days a week (inbound and outbound)
109	UQ Lakes to CBD via Inner Busway	Operate using 18 metre articulated buses, 5 days a week (inbound and outbound), and 14.5 metre vehicles on Saturday and Sunday.
111	Eight Miles Plains to CBD via South East Busway	Operate using 18 metre articulated buses, 7 days a week (inbound and outbound)
130	Calamvale to CBD via Mains Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
139	Sunnybank to University of Queensland via South East Busway	Operate using 14.5 metre vehicles, 5 days a week (inbound and outbound)
140	Brown Plains to CBD via Mains Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
150	Browns Plains to CBD via Warrigal Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
P137 and P142	Sunnybank and Browns Plains to CBD	Additionally routes 137 and 142 to be allocated exclusively to 14.5 metre vehicles
160	Garden City to Queen Street Bus Station	Operate using 18 metre articulated buses, 5 days a week (inbound and outbound)
169	Eight Mile Plains to University of Queensland via Busway	Operate using 14.5 metre vehicles 7 days a week (inbound and outbound)

Most the routes listed in Table 18 are considered to be all hour high frequency priority weekday routes, with the exception of Routes P137 and P142 which are limited stop, peak only routes. Some of the above listed routes incurred additional running time allocations, but it is unclear from the business case if this was justified by increased traffic congestion or in anticipation of future higher passenger loads and longer dwell times at bus stops. Full implementation required some operational platform adjustments at Queen Street and Browns Plains Bus Stations to accommodate the longer high capacity vehicle reallocations.

The business case supported withdrawal of high capacity vehicles from selected routes and their reallocation to specific HFP routes with known consistently high or full standing loads. This resulted in the need to augment some of the services on the routes from which the high capacity vehicles were drawn to ensure their commuters received a level of service commensurate with that which existed before the higher capacity vehicles were redeployed. The following routes were identified by the project for supplementary augmentation:

- Route 135: Two additional trips at 7:30 and 8:00 am to compensate passengers who previously had access to articulated vehicles on Route 135 trips commencing at 7:17am and 7:46am,
- Route 136: One additional trip at 7:13am to compensate passengers who previously had access to articulated vehicles on the 6:58am trip, and
- Route 155: One additional trip at 7:25am to compensate passengers who previously had access to articulated vehicles on the 7:35am trip.

It is understood at present that there is no documented *TransLink* policy which explicitly states that redeployment of higher capacity vehicles to better match supply to passenger demand should result in maintenance of the current level of capacity, and the HFP routes listed in Table 19 were excluded from the reallocation of higher capacity vehicles for the reasons indicated.

Table 19: Routes Excluded from Redeployment of High Capacity Vehicles

Route	Reason for being Excluded from HCV Project
412	Route 412 cannot be allocated as a Higher Capacity Route as it originates from the Toowong Bus Depot which currently does not accommodate high capacity vehicles. Additionally Brisbane Transport has advised that Stop 16 Adelaide Street cannot accommodate 14.5 metre vehicles (a shared stop with Route 109)
385	Route 385 is unsuitable as a Higher Capacity Route as the alignment it operates on cannot facilitate 14.5 metre vehicles, in particular along Coopers Camp Road. Additionally the bus stops at Bardon and Paddington are not set up to handle 14.5 metre vehicles
333 345	Both these bus services operate from the Virginia Bus Depot which currently does not accommodate higher capacity vehicles. KGS stop cannot accommodate 14.5 metre or articulated vehicles. Would result in excessive dead running associated with repositioning vehicles
196	Considering the current level of service and the alternative bus routes in the corridor (199 and CityGlider), Rroute 196 is not being considered as a Higher Capacity Route at this time
120	Route 120 was transitioned to a HFP route in June 2011. Currently there is insufficient demand for higher capacity vehicles on this route
200 and 222	Route 222 was upgraded to a full HFP route in June 2011. It has provided additional capacity throughout the Old Cleveland Road corridor resulting in a reduction in overcrowding on route 200. Currently there is no need to introduce Higher Capacity Vehicles on Routes 200 or 222 as both are not at capacity
180 and 100	These routes will be transitioned to HFP status on 31st October. TTA will monitor their performance and consider allocating higher capacity vehicles if demand warrants

3.19 Passenger Vehicle Transportation Award 2010

Fair Work Australia introduced the Commonwealth *Passenger Vehicle Transportation Award* on 1 January 2010. Subsequent amendments to the *Award* took effect on 21 June 2011. This modern national award replaced previous State specific awards (referred to as *Division 2B State Awards*) and has transitional arrangements in place effective up till 1 July 2014. The Commonwealth award applies throughout Australia to employees in the passenger transportation industry, defined by the *Award* as the transport of passengers by motor vehicle, limousine, hire car, bus, coach, electric tram, monorail or light rail vehicle. The *Award* does not apply to employees who are already covered by a modern enterprise award or an enterprise instrument commonly known as an *Enterprise Bargaining Agreement*.

Neither the making of this award nor the operation of its transitional arrangements was intended to result in a reduction in the net take-home pay of employees. The *Award* contains the minimum conditions of employment for employees and the monetary obligations imposed on their employers, but discharge of monetary obligations does not preclude any voluntary or employee negotiated over-award payments. Bus operators, for instance, may freely choose to provide monetary benefits above the minimum employee entitlements specified by the *Award*.

An employer and individual employee may agree to vary the application of certain provisions of the *Award* to meet the genuine needs of the employer and individual employee. The terms the employer and the individual employee may agree to vary are confined to:

- Arrangements for when work is to be performed,
- Overtime rates,
- Penalty rates,
- Allowances, and
- Leave loading.

It is understood that several *TransLink* bus operators have chosen to adopt the modern federal award, while most others have chosen to retain *Enterprise Bargaining Agreements* with their employees that were already in operation before the new federal award replaced existing State awards.

3.19.1 High Capacity Vehicle Allowance

Clause 15.1(b) of the *Passenger Vehicle Transportation Award 2010* stipulates that an employee required to drive an articulated bus during a shift will be paid an additional $10.00 allowance for that shift. This amounts to a 1.56% loading on the standard weekly rate defined in the *Award* for a Grade 3 employee earning $640/week. The award does not provide a precise definition of an articulated bus, but is reasonably assumed to exclude 14.5m rigid and double deck buses. It is understood that Brisbane Transport currently pays its bus drivers a 15% loading on shifts that include the driving of articulated buses, but it is unknown if this loading also currently applies to 14.5m rigid buses.

It is also uncertain whether bus drivers on the federal *Award* are paid the additional 1.56% for all shifts, regardless of whether an articulated or other high capacity vehicle was actually deployed on their respective shifts. Given allowances may be varied above the minimum set by the federal *Award*, some operators may choose for instance to pay all drivers who hold a HR class licence (refer Section 3.6.4.1) a high capacity bus shift allowance, as this would be an easier method of calculating the allowance payment when vehicle allocations are regularly changed on the day of operation.

We are also uncertain if other *TransLink* operators such as Thompson Bus Services, Surfside Bus Lines and Logan City Bus Service pay their high capacity vehicle drivers a HCV allowance or a pay loading, and forthcoming stakeholder interviews will attempt to ascertain this information.

3.19.2 Minimum Wage Rates for Drivers

The minimum wage rates for full-time adult drivers and other employees are prescribed in the federal *Award* for Grade 2 to Grade 6 employees inclusive. The *Award* also covers pay and conditions for part-time and casual employees and both are assumed to work less than 38 hours per week. Casual drivers attract an additional 25% loading over rates prescribed for full-time drivers of a similar grade.

The federal *Award* provides definitions for each grade of employee as summarised in Table 20 below. Grade 3 and higher drivers may operate heavy omnibuses and there is no distinction in these 4 *Award* classifications specifically given to drivers of high capacity buses.

Table 20: Driver Grades Defined in Passenger Vehicle Transportation Award

Grade	Description
Grade 2	A driver of a passenger vehicle with a carrying capacity of less than 25 school children to and/or from a school
Grade 3	An employee engaged in driving a passenger vehicle with a carrying capacity of 25 or more school children to and/or from school, or employee engaged in driving a passenger vehicle with a carrying capacity of less than 25 passengers on a specified route service which operates regularly between fixed terminals
Grade 4	Employees who efficiently operate passenger vehicles and issue tickets, balance and account for tickets and revenue, practice basic customer relations when providing information to passengers and the general public, inspect and monitor general conditions of the passenger vehicle, perform basic mechanical support duties and report and record information
Grade 5	An employee who - performs the duties of a driver with a sound understanding of operational work practices and procedures, performs activities of increasing complexity with some scope to exercise initiative in the application of established work procedures, may instruct other employees including on-the-job training, operates special services with a sound knowledge of the routes of other depots, instructs new drivers in route and passenger vehicle operations, inducts new drivers to aspects of depot operations and information, communicates with all types of customers with an advanced degree of courtesy and accuracy of information, and carries out duties associated with passenger surveys and service monitoring
Grade 6	Employees who are classified as supervisors and/or trainers and who perform more complex activities, which may require the exercise of knowledge and initiative in the application and establishment of work procedures. An employee at this level performs the duties of driver, plus as required, provides training, supervision, inducting and monitoring of trainee drivers, drives routes in other depots to cover vehicle schedules and assists in preparing rosters and amendments. This employee is required to have a customer service focus and is also required to provide support to operations officers at special events including supervision and coordination of transport movements, and is responsible for routine probationary service monitoring and assessment of new drivers

Most bus drivers operating *TransLink* urban routes would fall within the definition of Grade 4 employees or higher, given they already collect fares and issue tickets. Additional allowances are paid to drivers who supervise trainee drivers, but it is not known at this stage if this includes trainees on high capacity vehicles.

It would appear that minimum wage rates for junior bus drivers (aged 20 and under) are not applicable to bus drivers in Queensland, as the new Queensland driver licensing regime requires persons under 23 years of age to hold a learner's permit for 1 year, then a P1 licence for 1 year, a P2 licence for 2 years, and an open C or similar class license for another year before becoming eligible for a heavy vehicle licence.

3.19.3 Vehicle Allowance

The federal *Award* provides for employers to pay a vehicle allowance of $0.74/km however it does not provide a definition for the vehicle allowance and it is not clear if this applies to urban bus drivers or long distance coach drivers. This matter will also be clarified during stakeholder interviews.

3.19.4 Medical Examination Allowance

Bus drivers are expected to cover their own costs of obtaining a heavy vehicle licence and this expense is not normally covered by the operator but the federal *Award* provides for drivers to claim a *Medical Examination Allowance*. A medical examination is required by any employee applying for or renewing a heavy omnibus *Driver Authorisation* in Queensland and it is likely the *Medical Examination Allowance* would only apply to existing licence holders who need to apply for or renew their authorisations during work hours.

3.19.5 Fatigue Management

The *Award* sets out various rules on maximum hours of work which have presumably been aligned with those in the national heavy vehicle fatigue management regulations which will take precedence under future law. While there are no known fatigue management rules that would apply specifically to high capacity route bus drivers, HCV deployment in lieu of standard buses could reduce maximum HCV driver hours if considered necessary to contribute to improved driver fatigue management by bus operators.

Appendix A

Current DDA Exemptions for School Buses

Transport Standards Part	Comments
3.2 Access for passengers in wheelchairs	Requires that passengers with mobility aids must be able to enter and exit a conveyance (vehicle) and position their aids in allocated spaces, with or without the requested assistance of the bus driver
6.2 Boarding ramps	Specifies that a boarding ramp must comply with the relevant Australian Standard
6.3 Minimum allowable width (ramps)	-
6.4 Slope of external boarding ramps	Specifies the slope of boarding ramps, for both assisted and unassisted wheelchair access
8.2 When boarding devices must be provided	-
8.3 Use of boarding devices	Specifies that a boarding device must be provided at all designated bus stops
8.4 Hail-and-ride services	Specifies the use of boarding devices for Hail-and-ride services
8.5 Width and surface of boarding devices	-
8.6 Maximum load to be supported by boarding device	-
8.7 Signals requesting use of boarding device	-
8.8 Notification by passenger of need for boarding device	-
9.1 Minimum size for allocated space	-
9.4 Number of allocated spaces to be provided in buses	-
9.7 Consolidation of allocated parking spaces on vehicles	Suggests that allocated spaces should be consolidated
9.9 Use of allocated space for other purposes	Specifies that allocated spaces can be used for other purposes when not occupied
9.11 Movement of mobility aid in allocated space	Specifies that an allocated space must constrain movement of a mobility aid towards the front and sides of a conveyance (vehicle)
10.1 Compliance with Australian Standard (surfaces)	Specifies the ground and floor surface properties on conveyances (vehicles)
11.3 Handrails on steps	-
11.4 Handrails above access paths	-
11.5 Compliance with Australian Standards (grab rails)	Specifies that grab rails must comply with the relevant Australian Standard
11.6 Grab rails to be provided where fares are to be paid	-
11.7 Grab rails to be provided in allocated spaces	-
12.1 Doors on access paths	Requires that any doors along an access path not present a barrier to independent travel
12.4 Clear opening of doorways	-
12.6 Automatic or power-assisted doors	-
14.1 Stairs not to be sole means of access	-

Appendix B

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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by *TransLink Transit Authority (TransLink)* to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

Throughout the study, the 4 nominated high capacity vehicles will be compared to a reference vehicle operated by all *TransLink* bus service partners in South East Queensland, namely the:

- Two Door 12.5m Rigid Standard Route Bus.

The primary goal of this background report is to describe legislation, standards, land use and public transport plans and policies, and road and transport infrastructure programs which will impact on the future deployment and operation of the 4 high capacity vehicle types in South East Queensland. Some 54 documents have been reviewed by the authors to prepare this background report, broadly comprising of the following, and have been separately listed in the bibliography at Appendix B:

- Commonwealth and Queensland Transport Operations and Road Use Management Acts and Regulations,
- Commonwealth Disability and Commonwealth and Queensland Heavy Vehicle Standards,
- Queensland Dept of Transport and Main Roads Mass Concession, Restricted Access and Over-dimension Heavy Vehicle Schemes,
- The Edition 3 Australian Design Rules,
- Australian, Queensland DTMR and Austroads Road Design Standards,
- Queensland Land Use, Road Use Management, Transport Infrastructure Development and TransLink Infrastructure and Service Planning Policies,
- Queensland Regional, Integrated Regional Transport, Transport and Roads Investment, SEQ Infrastructure, TransLink Network and TransLink Strategic Plans,
- Queensland Transport Infrastructure, Busway and Road Planning and Design Manuals,
- TransLink Brisbane Transport and Private Operator Bus Contracts, and
- Bus Driver Awards.

1.2 Heavy Omnibus Legislation and Standards

Part 2 of this background report describes the plethora of Commonwealth and State Acts, Regulations, Vehicle Design Rules, Compliances and Standards which specify how high capacity omnibuses can be configured and constructed for safe conveyance of passengers, where, how and by whom they can be operated on public transport route and school services, and the dimensional, concessional, and axle mass limits which regulate how many passengers they can carry on Queensland roads. This Part also explores how Queensland road rules and road design standards impose restrictions on where routes and bus stops can be placed for high capacity omnibuses.

Part 2 summarises the mandatory legislative constraints with which high capacity vehicles must comply.

1.3 Planning and Policy Impacts on Future High Capacity Vehicle Deployment

Part 3 of this report explores contemporary State, Dept of Transport and Main Roads and Translink regional land use, public transport and road plans, policies and funding programs to assess their support for and impacts on future deployment of high capacity vehicles. This Part also reviews other miscellaneous Acts and Regulations which define how, when, by whom and what constraints will apply to public transport planning and high capacity vehicle operations in South East Queensland over the coming 20 year horizon out to the year 2031.

The narratives provided in this Part attempt to present a broad overview of the vision, principles and objectives driving public transport development and reform in South East Queensland, and interpret the relevance of these to the future demand for high capacity vehicles.

Sections are included toward the end of Part 3 which assess high capacity vehicle opportunities and constraints under existing *TransLink* policies, operator contracts and driver awards. These sections serve as an introduction to later reports being prepared for the main body of the study.

1.4 Findings and Insights

The following is a brief preview of some of the more interesting findings and insights found during the document reviews undertaken for this report.

1. New axle mass limits proposed in the draft *Heavy Vehicle National Regulation* are highly favourable to future deployment of ultralow floor high capacity route buses, most notably the rear pusher type articulated buses. Provided axle mass limits are not exceeded, the Australian vehicle design rules and Queensland regulations provide considerable flexibility in the way high capacity route bus cabin layouts can be configured. Bus seating can be optionally maximised to reduce passenger standing on long trips or alternatively reduced to maximise mass transit total carrying capacity on short trips. The distance for which continuous passenger standing is permitted on urban route bus services has recently been extended to 20km.

2 14.5m rigid high capacity route buses are 2m over length relative to contemporary *Australian Design Rules*, and as such, are not permitted under existing State or Territory road use management regulations to be registered and driven on public roads. They are however permitted to operate route bus services in some States and Territories under short term concessional access permits issued by the road authority in each jurisdiction.

14.5m rigid buses have now been formally recognised in the new draft Heavy Vehicle National Regulation and classified as an over length special class of heavy vehicle, subject to the proposed new higher mass limit (HML) axle weight restrictions and HML area permits which effectively restrict the areas and roads on which these buses can be driven. HML area permits will replace the current Department of Transport and Main Roads (DTMR) gazetted concessional ccess permits expiring on 30 June 2012.

By 2013, after the *Heavy Vehicle National Law* has been enacted across all Australian States and Territories, only the *National Heavy Vehicle Regulator*, in consultation with individual State and Territory road authorities, will be empowered to declare HML areas and routes on which 14.5m rigid buses will be permitted to operate. National HML area permits will enable Gold Coast school and route bus services operated with 14.5m rigid buses to continue across the Queensland-NSW border.

3 Road authorities such as DTMR have previously had the power under State and Territory legislation to arbitrarily set different heavy vehicle dimension and axle mass limits for special heavy vehicle types that currently include 14.5m rigid buses. Consequently, 14.5m rigid bus concessional wheelbase and rear overhang length limits now vary considerably between the 3 Eastern States and ACT, and 14.5m rigid route buses built to meet these concessional length limits in each jurisdiction are also significantly different. The draft *Heavy Vehicle National Regulation* has not yet resolved the uniform wheelbase and rear overhang limits for 14.5m buses.

4 The draft *Heavy Vehicle National Regulation* has lifted the overall height limit on double deck buses to 4.4m to enable higher interior head clearances on both passenger decks, but has to date neither recognised ultralow floor double deck buses as an emerging new category of Australian heavy route omnibus, nor proposed higher general axle mass limits for PWD accessible ultralow floor double deck buses, similar to those already given to other PWD accessible bus sizes. There are 8 bridges in South East Queensland with clearances equal to or less than 4.4m.

5 Double deck buses are currently exempted from the stringent ADR59 structural rollover strength requirements applicable to all other heavy omnibus types. Consequently ADR59 exemptions for closed roof double deck urban route and school buses are anticipated to cease in future.

6 None of the 4 subject high capacity buses selected for the study was considered appropriate candidates for the 30 DTMR steep incline - no standing *Notified Roads* located in South East Queensland. School and route bus services on DTMR *Notifed Roads* should be operated using 12.5m

rigid ADR68 *Complying Buses* fitted with structurally anchored seats, seat belts and child constraints.

7 High capacity hybrid diesel-electric buses are becoming increasingly more popular in European, SE Asian and USA capital cities because of their considerably faster take off acceleration from stops, lower fuel consumption and exhaust emissions in stop-start traffic conditions, and quieter operation relative to comparable high capacity diesel buses. Diesel-overhead electric and diesel-L-ion battery or supercap electric buses travelling through noise sensitive route sectors in these overseas cities must under local planning laws operate by electric motor only whilst located in CBD office districts, residential suburbs and public road tunnels. Environmental noise immission laws, rather than heavy vehicle noise emission rules, may restrict high capacity diesel buses from entering noise sensitive commercial, residential, health and education precincts under proposed future Queensland EPA environmental noise planning limits. Only traffic noise generated on State main roads are exempted from these limits.

8 The Queensland Road Planning and Design Manual and national Austroads Guide to Road Design Manual used by DTMR and SEQ Local Governments to design indented bus bays only have drawings suitable for 12m rigid and 18m articulated buses, but no drawings for 14.5m rigid buses. Other documents, including the *Code of IDAS* and *TransLink Infrastructure Manual* will need to be amended for high capacity buses.

9 In late 2011, DTMR published *Connecting SEQ 2031 - An Integrated Regional Transport Plan for South East Queensland* in response to desired regional outcomes 8, 10 and 12 of the *South East Queensland Regional Plan 2009 - 2031. Connecting SEQ 2031* describes sweeping changes to both the structure and operation of the rail and bus network in South East Queensland called *UrbanLink*, which is based on the mass transit trunk and feeder operating concept.

The proposed *UrbanLink* backbone is comprised of high speed long haul railway, busway and transitway spines radiating out from the Brisbane CBD to surrounding regional and sub-regional transport nodes called hubs, complemented by the new *GoldLinQ* light rail and *CoastConnect* coastal bus sub-spines on the Gold and Sunshine Coasts, with each sub-spine connected by high frequency cross-country connector and local bus services to the high-speed heavy rail corridors to the Brisbane CBD. A new form of bus service, called *ExpressLink*, is also envisaged in *Connecting SEQ 2031* that will provide 6am - 9pm express bus services between major outlying rail and bus station hubs in Greater Brisbane to other major transport nodes in adjoining SEQ regions, and from country railway stations to places of high employment.

High capacity buses are considered the optimum vehicle for carrying the high passenger loads expected on new *UrbanLink* cross-city, high frequency trunk and *ExpressLink* cross-country bus services proposed to be operated between regional activity centres.

10 *UrbanLink* implementation will involve conversion of hundreds of existing *TransLink* single seat bus journeys to split trunk and local feeder journeys, so that existing buses can be freed up to deliver

higher frequency local district feeder services with greater area coverage. The effect of this structural reform to the way the SEQ bus network currently operates will be a transfer of multiple combined local district passenger loads to the proposed new high frequency trunk rail and bus spines.

A large number of early works planning, design and construct programs has been sighted in the State's current infrastructure funding programs to extend Brisbane busways and create multiple new bus priority transitways and corridors for the new *UrbanLink* bus network. *Connecting SEQ 2031* indicates that the development of these corridors will be packaged with the staged conversion of existing single seat bus services to trunk and feeder bus services, but there appears to be no planning or programs currently in place to deliver the additional fleet needed to operate the new trunk services along these priority bus corridors.

2. Heavy Omnibus Legislation and Standards

2.1 High Capacity Vehicle Types

Representative examples of the 4 high capacity vehicles and standard reference vehicle discussed in this report are illustrated below in Figure 1 and Figure 2 respectively.

Figure 1: Representative Examples of the 4 High Capacity Vehicle Types

2 Door 12 – 12.5m Double Deck Bus		
2 Door 14.5m Rigid Bus		
2 Door 18m Articulated Bus		
3 Door 18m Articulated Superbus		

Figure 2: Representative Examples of the Standard Reference Vehicle

2 Door 12.5m Rigid Urban Route Bus		

2.2 Heavy Omnibus Passenger Carrying Capacity

All road vehicles illustrated in Figure 1 and Figure 2 are similarly classified as both heavy vehicles and omnibuses in the relevant Commonwealth and Queensland legislation. Key determinants of how, when, where, who can be transported, who can operate, who can drive, and for what distance are closely linked by legislature to the vehicle type, length and height, axle configuration and permitted axle load masses. Every heavy vehicle omnibus axle configuration has an empty vehicle weight (the tare mass), a legislated maximum load limit and chassis manufacturer designed gross vehicle mass (GVM) limit. The passenger carrying capacity of the bus is essentially governed through legislation by the difference between the permitted axle mass limits and their respective axle tare masses. Maximisation of passenger carrying capacity on high capacity vehicles is achieved in practice by deliberate placement of passenger seats, luggage racks and standee areas to distribute the live passenger and luggage loads across all axles up to their permitted maximum load limits.

The 4 subject high capacity vehicles have a higher combined standing and seated passenger carrying capacity than the standard reference 12.5m rigid urban route bus and their typical passenger capacity ranges have been tabulated below in Table 1. Variations arise between identical bus configuration types fuelled by compressed natural gas and diesel, the former having a lower registered carrying capacity due to permitted axle loads less the combined weight of roof mounted gas cylinders and stored maximum natural gas charges. Seated capacities indicated in Table 1 are for modern ultralow floor *Disability Discrimination Act (DDA)* compliant urban route buses equipped with 2 rear facing wheelchair spaces, each fitted with 3 to 4 side or forward facing flip-up passenger seats used as both seated and standee floor areas when wheelchair spaces are unoccupied.

Table 1: Typical Passenger Carrying Capacity of Standard and High Capacity Vehicles

Typical Passenger Capacity	2 Door 12.5m Rigid Bus (Reference)	2 Door 12 – 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Wheelchair	2	2	2	2	2
Seated	44 - 47	82 - 96	56 - 58	63 - 65	46 - 52
Standing	18 - 22	20 - 27	34 - 42	20 - 37	58 - 66
Total	62 - 69	109 - 111	92 - 98	85 - 100	110 - 112

Equivalent Median Standard 12.5m Buses	1.69	1.46	1.42	1.71

2.3 Heavy Vehicle Occupant Load Limits

Australian legislation and the national vehicle standards which limit the maximum passenger carrying capacity of heavy omnibuses specify the:

- **Heavy Vehicle Occupant Load Limits**: to be adopted for legal determination of live occupant and luggage loads,
- **Heavy Vehicle Axle Mass Limits:** which define the maximum axle mass (or weight) permitted on each heavy vehicle axle or axle group, and the combined maximum gross mass (or weight) permitted on all axles and axle groups for different heavy vehicle types,
- **Heavy Omnibus Standee Floor Area Restrictions:** which define the floor areas on heavy omnibuses where luggage may be stowed and where passengers are permitted and not permitted to stand, and
- **Heavy Omnibus Configuration and Dimensional Limits:** which define the permitted configuration and dimensions of different heavy omnibus body types.

The Queensland *Transport Operations (Road Use Management - Vehicle Standards and Safety) Regulation 2010* specifies that all vehicles must comply with the *Australian Vehicle National Standards Rules 1999 (Cth)*. Buses over 5 tonne *Gross Vehicle Mass (GVM)* registered in Australia are described by *Australian Vehicle National Standard Rules* and *Australian Design Rules (ADRs)* as *Category ME Heavy Omnibuses*. ADR58/00 defines the maximum occupant capacity applicable to *Category ME* heavy school and route service omnibuses without dedicated heavy luggage spaces as 65kg per driver, crew member and passenger.

Under these *Rules*, the passenger loading condition to be applied in the determination of live occupant load is taken to be the weight distribution of the seated driver and passengers in all available bus manufacturer nominated seat positions, plus the uniform distribution of standee passengers (including a conductor or ticket inspection crew member if applicable) to all aisle way and allocated standing areas, excluding those standing areas preserved by ADR58/00 and ADR44/02 for exterior passenger entry/exit doors, emergency exits and interior or rear open exterior upper deck staircases on double deck heavy omnibuses. Where a dedicated heavy luggage space is provided for carriage of other than personal hand luggage on a heavy omnibus, a mass of 15kg per passenger (seated and standing), distributed evenly throughout the luggage space, must also be added to the live axle load assessment.

Up to permitted axle mass limits, total passenger carrying capacity on school and route omnibuses can be increased through bus manufacturer design by reducing the number of available passenger seats and dedicating more floor space to standees as has been applied to maximise the carrying capacity on the 3 door 18m articulated superbuses, but other legislative instruments (described later) limit the road types, distance and duration of school and route services on which passengers are permitted to stand. (Refer to Table 1 for a comparison of a typical 2 door 18m articulated route bus with high seating capacity, and a typical 3 door 18m articulated superbus with reduced seating capacity).

2.4 Heavy Vehicle Axle Mass Limits

Permitted axle mass limits in Queensland for the reference standard 12.5m route omnibus and 4 subject high capacity omnibuses have been contrasted below in Table 2 to **S55 of the Queensland *Transport Operations (Road Use Management - Vehicle Standards and Safety) Regulation 2010* stipulates that heavy omnibus axles in an axle group other than a twin steer axle group must relate to each other through a load-sharing suspension system with effective damping characteristics on all axles of the group such that no axle carries over 10% more than the mass it would carry if the load was divided equally.

Table 5 inclusive.

A new *Heavy Vehicle National Law Bill 2011* was introduced into Queensland Parliament on 15 November 2011 and is anticipated to be enacted by late 2012, together with a new *Heavy Vehicle (Mass, Dimension and Loading) National Regulation* currently in its final draft review stage. Similar heavy vehicle bills and regulations are expected to be enacted in all Australian States and Territories by 2013, heralding a single uniform set of heavy vehicle dimension and axle mass limits throughout Australia. Regulated axle mass limits for heavy omnibuses are currently specified in the Queensland *Transport Operations (Road Use Management - Mass, Dimensions and Loading) Regulation 2005*, last revised in July 2011, and these substantially mirror the new national general mass limits proposed for uniform national regulation.

Subject to specified ADR compliances for newly built heavy vehicles defined by the national regulation, the new national general axle mass limits will afford automatic cross border national licensing of all heavy omnibuses in all Australian States and Territories. New national higher mass limits prescribe the upper axle mass limits that individual State and Territory road managers such as the *Queensland Department of Transport and Main Roads (DTMR)* and the newly created *National Heavy Vehicle Regulator* may approve for special class oversize and/or over mass heavy vehicle types such as 14.5m rigid route buses operating in road authority defined areas or roads, and replace State and Territory Government gazetted *Controlled Access Permit* systems presently operated by each independent road manager. The new national higher mass limit permits are similarly intended to operate across State and Territory borders and where higher mass limits have been proposed in the national regulation, equate to an increased heavy omnibus passenger carrying capacity of 15 passengers/axle tonne increase.

The current version draft *National Heavy Vehicle Regulation* broadly differentiates heavy route omnibuses into 5 categories:

- **Complying Buses** - are heavy omnibuses which comply with Australian passenger safety standards ADR44/02, ADR59/00 and ADR68/00 and are fitted with power-train retarders. All existing *TransLink* route buses other than double deck buses must comply with ADR44/02 and ADR59/00, and most existing route buses fitted with automatic transmissions invariably have inbuilt power-train retarders. ADR68/00 however strictly applies to heavy omnibuses specifically designed for and operated with all passengers seated on structurally anchored, strongly built, crash-resistant passenger seats equipped with individual occupant seat belts or infant child restraints.

  Some 30 roads within *TransLink*'s SEQ public transport network boundaries are currently classified by DTMR as *Notified Roads*, considered too steep for school and route buses to safely navigate with standing passengers. Complying 12.5m rigid buses and high floor coaches would be considered suitable for operating school and rural route services on DTMR *Notified Roads*, but the roads identified in DTMR published maps are considered unsuitable for any of the 4 subject high capacity buses,

- **Ultra-low Floor Route Buses** - must have 2 axles, places for standees and a stairless entry for passengers. This definition deliberately excludes 14.5m rigid and double deck route buses,
- **Ultra-low Floor Articulated Buses** - must have passenger access and rotary movement between their articulated sections, places for standees and a stairless entry for passengers. These include all new model 18m articulated buses and articulated superbuses,
- **Class 2 Restricted Access Buses** - cover oversize, over mass 14.5m rigid route buses which are to use the new national axle higher mass limits, and
- **Other Buses** - cover double deck buses and most existing 10 year and older high floor 12.5m rigid route buses, coaches and articulated buses presently operating *TransLink* scheduled school and route bus services in South East Queensland.

Notwithstanding the general mass limits prescribed in the draft *National Heavy Vehicle Regulation* or the higher mass limits permitted by the *National Heavy Vehicle Regulator* in concert with individual State and Territory road authorities, the *Gross Vehicle Mass (GVM)* specified by the bus chassis manufacturer for each heavy vehicle axle, its road wheels and tyres may not be exceeded.

Table 2: Permitted Axle Mass Limits for 2 Door 12.5m Standard Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Buses)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Buses)
Rear Drive Axle with Dual Tyres	10t (High Floor) 11t (Ultra-Low Floor)	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	15t (High Floor) 16t (Complying or Ultra-low Floor)	No Higher Mass Limit Permitted	15t (High Floor) 16t (Complying or Ultra-low Floor)

Table 3: Permitted Axle Mass Limits for 2 Door 14.5m Extended Rigid Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Upper Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	Non-Compliant	No Higher Mass Upper Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Tandem Axle Group with Dual Drive Tyres and Single Steer Axle with Single Tyres	Non-Compliant	14t **	13t ** (Standing Permitted) 14t ** (Complying Bus)
Gross Mass	Non-Compliant	20t	19t (Standing Permitted) 20t (Complying Bus)

Table 4: Permitted Axle Mass Limits for 2 Door 12 – 12.5m Double Deck Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
<<< Single Steer Front Axle >>>			
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Drive Dual Tandem Axle Group Fitted with Two Tyres	16.5t **	17t **	16.5t **
Gross Mass	22.5t	23t	22.5t
<<< Twin Steer Front Axle >>>			

Twin Steer Front Axle with Single Tyres	10t (Non-Load Sharing) 11t (Load Sharing)	No Higher Mass Limit Permitted	10t (Non-Load Sharing) 11t (Load Sharing)
Rear Drive Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t
Gross Mass	20t	No Higher Mass Limit Permitted	20t (Non-Load Sharing) 21t (Load Sharing)

**S55 of the Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* stipulates that heavy omnibus axles in an axle group other than a twin steer axle group must relate to each other through a load-sharing suspension system with effective damping characteristics on all axles of the group such that no axle carries over 10% more than the mass it would carry if the load was divided equally.

Table 5: Permitted Axle Mass Limits for 2 and 3 Door 18m Articulated Buses

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limits	Draft Heavy Vehicle National Regulation General Mass Limits
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Mid Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Rear Axle with Single Steer Tyres (High Floor)	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	22t	No Higher Mass Limit Permitted	22t (High Floor) 26t (Ultra-low Floor)

2.5 Heavy Omnibus Standee Floor Area Restrictions

Urban route buses used for both seated and standee passenger loads require a minimum longitudinal 380mm aisle width under ADR58/00, where complying buses designed for and operated exclusively with seated passengers are afforded a reduced aisle width concession of 300mm. A similar 300mm reduced aisle width concession applies to the longitudinal aisles on the upper deck of a double deck bus where no standing passengers are permitted by Queensland road rules whilst the double deck bus is in motion. Notwithstanding these restrictions, for modern high capacity heavy route omnibuses with minimum ADR58/00 compliant urban route bus moulded seats with 400mm wide cushions laid out in double forward facing rows along either side of the centre aisle, greater aisle widths of around 450mm are readily achieved.

The national *Disability Standards for Accessible Public Transport 2002* specifies a minimum of two separate or preferably consolidated 1,300mm x 800mm wheelchair parking spaces on all urban route buses and an increased aisle width of 850mm from the wheelchair loading door and driver operated or manually assisted wheelchair ramp (normally installed at the front entry door) to both wheelchair parking spaces, other than between heavy omnibus wheel arches where the aisle width may be reduced (but only if necessary) to 750mm.

Up to the permitted axle mass limits, longer omnibuses with proportionately greater floor areas can accommodate more standees, however low floor bus aisles with a rear of rear door gradient over 1 in 12, and aisle way or flat floor spaces with head room clearances below 1,800mm for single deck buses, and 1,650mm for double deck buses, may not be used as operator allocated standee areas. Other doorway, aisle and standing area requirements called for in the national vehicle and disability standards include anti-slip steps and flooring, and provision of a suitable number of hand straps, hand grips and hand rails in all standee areas. Queensland road rules, described later, strictly prohibit non-complying route buses not meeting these ADR58/00 prescribed standee safety requirements from being operated on school or urban routes with other than fully seated passengers.

Each additional entry/exit door added to the left hand side of an omnibus passenger cabin above the compulsory minimum front entry/exit door specified by ADR58/00 reduces its available passenger floor space by approximately 0.7m^2 (namely 2 seat or 4 standee spaces) for a minimum 850mm wide single entry/exit door, and approximately 1.15m^2 (4 seat or 7 standee spaces) for a 1,200mm wide double entry/exit door. ADR58/00 does not permit installation of any passenger entry/exit doors on the right hand side of an omnibus other than for passenger emergency exit doors, and high capacity vehicles may not be used in Australia for centre platform station loading similar to that permitted by regulations for tram, rail bus, light rail vehicles and trains.

Interior and rear exterior open upper deck staircases are permitted on double deck buses but similarly encroach on available wheelchair, seated and standee passenger floor spaces. To compensate, ADR58/00 permits non-DDA compliant narrow 400mm wide straight or spiral stairways to the upper deck on a double deck bus.

ADR59/00 rollover body structural strength requirements apply to all single deck omnibuses operated in Australia, but do not currently apply to double deck buses. Upper deck seating capacity on double deck buses is however limited under ADR58/00 to any passenger loading condition that would cause a double deck bus to become unstable and roll on a transverse incline of 28° or higher. Such a loading condition can occur with a fully seated load on the upper deck and no passengers on the lower deck to lower the heavy vehicle centre of mass. Current exemption from body structural rollover compliance with ADR59/00 afforded exclusively to double deck heavy omnibuses is highly likely to change in coming years if their deployment on capital city route bus operations becomes as widespread as it was in the mid-decades of the last century before ADR59/00 compliance was legislated.

Whilst ADR58/00 must be universally applied to the determination of legal maximum passenger loading throughout Australia, most Australian urban route bus designers and capital city bus operators adopt an empirical (but unlegislated) standee comfort space of 5 - 6.25 standees/m^2 of allocated standing floor space to prevent excessive passenger crushing and aisle blockage to boarding and alighting passenger movements.

2.6 Heavy Omnibus Configuration and Dimension Limits

ADR43/04 sets forth the permitted configuration and dimensions applicable to Australian registered heavy omnibuses. These are summarised overleaf in Table 6.

14.5m rigid heavy route omnibuses are currently classified as oversize, over mass heavy vehicles in all Australian jurisdictions, do not comply with the ADR43/04 maximum rigid vehicle length limit, have been registered to date under special provisions of the *National Transport Commission Performance Based Standards Scheme*, and are presently only permitted to operate in Queensland under gazetted *Controlled Access Bus Class Permit No 127-TH-11*, expiring 30 June 2012. Permit 127-TH-11 is intended as a stopgap authorisation to operate 14.5m route buses on Queensland roads, and only allows their controlled access route operations on:

- Major State and Local Government controlled roads, franchise toll roads and motorways classified as *Regional Significant Roads* or higher in the *State Road Network of Queensland* road hierarchy, but excluding permit nominated regionally significant roads in SEQ to Mount Tamborine and Lamington National Park and Samford - Mt Glorious Road,
- Declared busways, and
- Permit nominated arterial, sub-arterial and local roads within Brisbane City Council local government boundaries.

Controlled Access Permit No 127-TH-11 currently enables the rear overhang of a 14.5m rigid school or route bus to be extended 1m beyond that allowed under ADR43/00 to the lesser of 70% of the front axle to rear overhang line (namely the vehicle wheelbase at 1/3 of the rear tandem axle separation distance) or 4.7m. Where the rear tandem tag axle steers as on all modern 14.5m rigid buses (refer

Figure 3), the rear overhang is measured from the rear drive axle (i.e. by treating the rear steer axle as if it were non-existent), resulting in rear steered 14.5m rigid buses exhibiting a high rear end swing when departing from a bus stop or turning on full lock.

Figure 3: ADR/Regulation Defined Rear Overhang for a 14.5m Rigid Bus with Rear Steering Tag Axle

Table 6: ADR43/04 Permitted Heavy Omnibus Configuration and Dimensional Limits

Configuration or Dimension	2 Door 12.5m Rigid Bus (Reference)	2 Door 12 - 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Maximum Length	12.5m	12.5m	Non-Compliant	18m	18m
Maximum Height	4.3m	4.3m	4.3m	4.3m	4.3m
Maximum Width	2.5m	2.5m	2.5m	2.5m	2.5m
Outer Turning Circle	25m	25m	25m	24m	24m
Inner Turning Circle	Not Applicable	Not Applicable	Not Applicable	5.3m	5.3m
Rear Overhang	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	3.7m	3.7m
Full Load Minimum Ground Clearance Midway between Axle Pairs on Flat Roads	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle
Full Load Minimum Load Ground Clearance Midway between Axle Pairs over Road Apexes	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients

Controlled access 14.5m rigid heavy omnibuses built for New South Wales route operations have been permitted to date to extend their rear overhangs a further 200mm than in Queensland to the lesser of 70% of the front axle to rear overhang line or 4.9m. Consequently, a 14.5m rigid route bus built to Queensland controlled access permit limits can, with dual Queensland and New South Wales controlled access permits, operate school and route services crossing the border into NSW, but a 14.5m rigid bus built to NSW permit rules would not be permitted to hold dual permits and operate school and route services across the border into Queensland. Similarly, Victorian controlled access permit rules nominate a lower rear overhang than in Queensland or NSW of the lesser or 60% of the front axle to rear overhang line or 4.3m, similarly preventing NSW controlled access 14.5m rigid buses from entering Victoria. The draft *Heavy Vehicle National Regulation*, once enacted by all States and Territories, is intended to standardise all route bus length, height, width, front/rear overhang and axle mass limits throughout Australia.

The newly revised *Queensland Transport Operations (Mass, Dimension and Loading) Regulation 2005* and new draft *Heavy Vehicle National Regulation* adopt most of the earlier mentioned ADR43/04 permitted heavy omnibus configuration and dimension limits, but differ slightly in their treatment of high capacity buses:

- The Queensland regulation currently prohibits driving of any rigid heavy vehicle over 12.5m in length on Queensland roads, but the draft national regulation recognises heavy rigid omnibuses up to 14.5m long as Class 2 oversize rigid heavy omnibuses and specifies their permitted axle higher mass limits (HML), who is authorised, and the processes to be adopted to define future HML areas and routes in each road jurisdiction where 14.5m rigid omnibuses will be permitted to operate. The new draft regulation has to date not yet defined the permitted rear overhang for 14.5m rigid heavy omnibuses,

- The Queensland regulation does not permit higher gross mass limits for double deck buses with dual front load sharing steer axles and ultralow bottom deck floor heights capable of steplessly boarding passengers and wheelchairs. The national regulation recognises the former, but has not yet created a special heavy omnibus class for the emerging new types of ultralow floor double deck buses,
- The Queensland regulation does not differentiate between older high floor and modern ultralow floor "rear pusher" type 18m articulated buses, but the draft national regulation recognises older high floor and rear pusher ultralow floor articulated buses differently, and permits up to 4t higher gross axle mass limits on the latter,
- Both regulations now permit 100mm higher 4.4m high double deck buses, and
- Both regulations prevent the new *National Heavy Vehicle Regulator* and individual road authorities from granting arbitrary concessional mass and increased dimension limits to heavy omnibuses.

2.7 Performance Standards Affecting High Capacity Omnibuses

High capacity omnibuses need larger engines and transmissions to accelerate, maintain road speed and climb grades, and larger capacity compressed air braking systems and retarders to decelerate and descend inclines at a steady speed when fully loaded, than do their lower mass standard 12.5m rigid counterparts. This necessitates installation of larger and heavier onboard fuel storage tanks to power the vehicle and its various ancillary loads such as cabin ventilation, lighting and air conditioning, and to maintain vehicle operating range without twice daily refuelling. Increased relative mass and dimensions of HCVs also affect high capacity vehicle road performance relative to 12.5m standard buses and are discussed below.

2.7.1 Maximum Road Speed

ADR65/00 limits the maximum permitted road speed of a heavy omnibus to 100km/h, specifies that attainable road speed be automatically governed by a mechanical or electronic speed limiter, and stipulates that the power train design based on the bus chassis manufacturer's maximum engine speed, overall transmission/differential gear reduction, tyre size and wheel revolutions per kilometre prevent a heavy omnibus from exceeding 100km/h.

These speed limiting conditions apply irrespective of whether a heavy omnibus is fully loaded or unloaded, and impact more significantly on the maximum road speed attainable by high capacity omnibuses than on smaller carrying capacity standard buses because of the relative change in live passenger and luggage weight between the unloaded and fully loaded conditions. In practice, the selection of engine size, automatic transmission and differential gear ratios needed for acceptable acceleration from urban bus stops, on hill starts and hill climbs limit the realisable maximum speed reached by a high capacity bus to 85 - 90km/h.

S140 of the Queensland *Transport Operations (Road Use Management - Vehicle Standards and Safety) Regulation 2010* last revised in December 2011 now exempts Queensland high capacity omnibuses with a GVM over 14.5t (other than *Complying Buses*) that are fitted with hand grips or similar equipment for standing passengers from being fitted with ADR65/00 compliant speed limiting devices. It is unclear however whether this Queensland exemption will continue on after the national regulations take force.

2.7.2 Maximum External Vehicle Noise Emissions and EPA Permitted Environmental Noise Immissions

ADR83/00 limits the maximum permitted external noise emission within 7.5m of either side of a heavy omnibus passing at a speed of 50kph - 75% of its maximum road speed to 80dB(A) if fitted with an engine rated in the power range of 150 - 320kW. Engines in this rated power range are fitted on both the 12.5m route bus and the 4 subject high capacity route buses, but the latter have 30 - 45% larger and proportionately noisier engines. Consequently, 12.5m route buses can readily meet noise emission levels 5 to 10dB(A) below that set in ADR83/00, where high capacity omnibuses require elaborate engine noise encapsulation, exhaust muffling and radiator fan noise containment treatments to achieve noise emission levels below the ADR 80dB(A) threshold, the limit for which has been progressively falling over successive revisions of the standard.

Environmental nuisance noise imissions (namely nuisance noise levels reaching roadside property walls) are regulated in Queensland under Part 3 of the *Environmental Protection Act 1994* and the *Environmental Protection Regulation 2008*. The *Act* nominates the Queensland *Environmental Protection Agency (EPA)* and each *Local Government Authority* as responsible for the administration and enforcement of the noise immission regulations respectively, and the *Environmental Protection (Noise) Policy 2008* as setting the environmental noise acoustic quality objectives to be adopted throughout Queensland for new property development approvals and environmental noise planning levels. Traffic noise immissions from railways and main roads are exempted under the Act, but for non-main regional, arterial, sub-arterial and local roads passing through noise sensitive commercial and residential districts, the development approval planning noise levels are presently prescribed in the *Regulation* as:

- 63dB(A) at the $L_{10,18}$ level,
- 60dB(A) at the 1 hour continuous RMS A-weighted level ($L_{Aeq,1}$) between 10:00pm and 6:00am, and
- 80dB(A) for any single noise event maximum SPL.

The noise planning objectives of the Act, its Regulation and Policy aim to progressively ratchet down $L_{A1,1}$ hourly traffic noise immissions reaching private dwellings in future years to as low as 65dB(A) for all hours of the day, and $L_{Aeq,1}$ noise immission levels reaching prescribed noise sensitive public institutions such as schools, universities, childcare centres, hospitals and doctor surgeries to as low as 35dB(A).

Compliance with *EPA* regulated noise immission planning limits may in future prevent or limit the deployment of high capacity diesel omnibuses or enforce alternative use of low noise emission diesel-electric and hybrid buses in noise sensitive precincts. Noise immission compliances similar to those proposed by the *Environmental Protection (Noise) Policy* have already been implemented in many major European, South East Asian, Canadian and USA cities where high capacity overhead cable powered diesel-electric and hybrid omnibuses travelling through noise sensitive route sectors must operate by electric motor only whilst located in CBD office districts, residential suburbs and public road tunnels.

2.7.3 Upper Deck Level and Stairway Standee CCTV Monitoring on Double Deck Buses

Standing passengers are not permitted on the upper deck or stairways of a double deck bus when in motion. This will require double deck bus drivers to periodically observe regulated no standing areas on the vehicle before and after departing bus stops from a CCTV monitor mounted in the driver's cabin, and to use a pre-recorded or live voice *public address (PA)* announcement to direct passengers to sit. S31 of the *Transport Operations (Road Use Management - Vehicle Standards and Safety) Regulation 2010* and ADR42/00 define the conditions under which a driver's visual display unit may be used on a heavy omnibus as a driving aid and where a permitted display unit may be mounted within the driver's visual field of view.

2.7.4 High Capacity Omnibus Standing and Overloading Restrictions

High capacity buses are traditionally designed and operated to minimise the number of standees or to reduce recurring incidents of overloading and missed passenger pick-ups. The *Transport Operations (Passenger Transport) Standard 2010* identifies any omnibus used for delivery of public passenger services as a *Relevant Vehicle* and prohibits a driver from operating a *Relevant Vehicle*:

- In an overloaded condition,
- Without an appropriate licence class and driver authorisation. An *MR (Medium Rigid)* class licence is needed to drive a standard 12.5m two axle rigid omnibus and a HR (heavy rigid) class licence to drive all 4 three axle high capacity omnibuses whose *gross vehicle masses (GVM)* exceed the prescribed 15t threshold. A HCV driver must continuously hold his/her open C class licence for 1 year before becoming eligible to hold an MR class licence, and must thereafter continuously hold both his/her C class licence and MR class licence for a period of 2 years and 1 year respectively before becoming eligible to hold a HR class

licence. Driver licence requirements apply to all persons who drive a *Relevant Vehicle* (e.g. bus drivers, mechanics, cleaners, etc) on a road, but a driver authorisation is only mandated for a driver who actually operates a *Relevant Vehicle* on a public passenger service,

- With standing passengers in a bus fitted with seat belts, namely a *Complying Bus*, or a *Regional Classification Vehicle* with side facing seats (discussed later). The driver must additionally report any standing passenger allowed on a *Complying Bus* to his/her *Authorised Operator* at the end of each passenger service shift, or
- With standing passengers if not designed and constructed for such (to ADR58/00), on a long distance scheduled passenger service, a DTMR no standing passenger *Notified Road*, or if a scheduled school bus, for a distance of more than 20km**. The *Transport Operations (Passenger Transport) Standard* allows for 3 primary or pre-school children to occupy a single twin adult passenger seat for up to 90min, and an adult to nurse an infant on any scheduled school or route omnibus not fitted with seat belts; but not on any *Complying Bus*, unless each child is individually restrained by a seat belt or in an approved infant child restraint.

(**The *Transport Operations (Passenger Transport) Standard* has only recently been amended to remove the no standee rule for school bus routes in excess of 20km in length. Prior to the amendment of this clause in the *Standard*, Brisbane Transport had to deploy articulated buses on non-stop Route 142 to provide sufficient seating capacity for school children. Articulated buses were deployed on this route to provide additional seats, but the vehicle's total carrying capacity wasn't being fully utilised. With this restriction now removed, *TransLink* is free to allocate high capacity vehicles on any route other than a *Complying Bus* route operating on a DTMR *Notified Road*)

2.7.5High Capacity Omnibus Scheduling for Mixed Bus Types

Because high capacity buses are permitted to board higher passenger loads, they may require bus type specific timetables if scheduled on mixed high capacity and standard 12.5m bus school or route services. The *Transport Operations (Passenger Transport) Standard 2010* stipulates that the driver of a scheduled school or route service must provide the passenger transport service in accordance with advertised schedules unless prevented from doing so by unforeseeable circumstances or schedules that are not realistically achievable. The *Authorised Operator* is obliged under the *Standard* to advertise timetables that are realistically achievable for the bus type and size allocated to a scheduled school or route service.

2.7.6Prescribed Vehicle Regional Classification Requirements

The *Passenger Transport Standard* defines the prescribed vehicle classification of an omnibus as a *Local Classification Vehicle* if its operates a journey within a radius of 40km from the first passenger pick-up point, or if the journey is entirely within a single or contiguous urban area within a radius of 40km from the first passenger pick-up point. This classification applies to most existing heavy route omnibuses used for *TransLink* school and route bus services in SEQ.

If long haul trunk and spine express route services assigned to high capacity omnibuses as envisaged in *Connecting SEQ 2031* (discussed later) exceeded the 40km radius, but were less than 350km radius from the first passenger pick-up point, the prescribed vehicle classification of the high capacity bus would automatically revert to that of a *Regional Classification Vehicle* which must meet more stringent ADR safety compliances than a *Local Classification Vehicle*. The additional compliances specified for a *Regional Classification Vehicle* high capacity omnibus over those applicable to a *Local Classification* standard or high capacity route bus would include:

- Compliance with all non-route bus ADRs applicable to high and low back passenger seats,
- Installation of lap seat belts on side facing passenger seats complying with ADR4/00 and ADR5/00, and
- Provisions for light passenger luggage incapable of being held by hand, to be stored in overhead lockers or racks, but not in an aisle or any other floor space that would impede passenger egress to entry/exit doors or emergency exit doors. Where carriage of heavy passenger luggage was approved by *TransLink* or its *Authorised Operator*, it would either have to be placed in a passenger segregated luggage compartment or trailer, the latter of which would not be permitted under the draft *National Heavy Vehicle Regulation* on a 14.5m or 18m articulated route bus.

2.8 Queensland Road Rules Impacting High Capacity Bus Operations

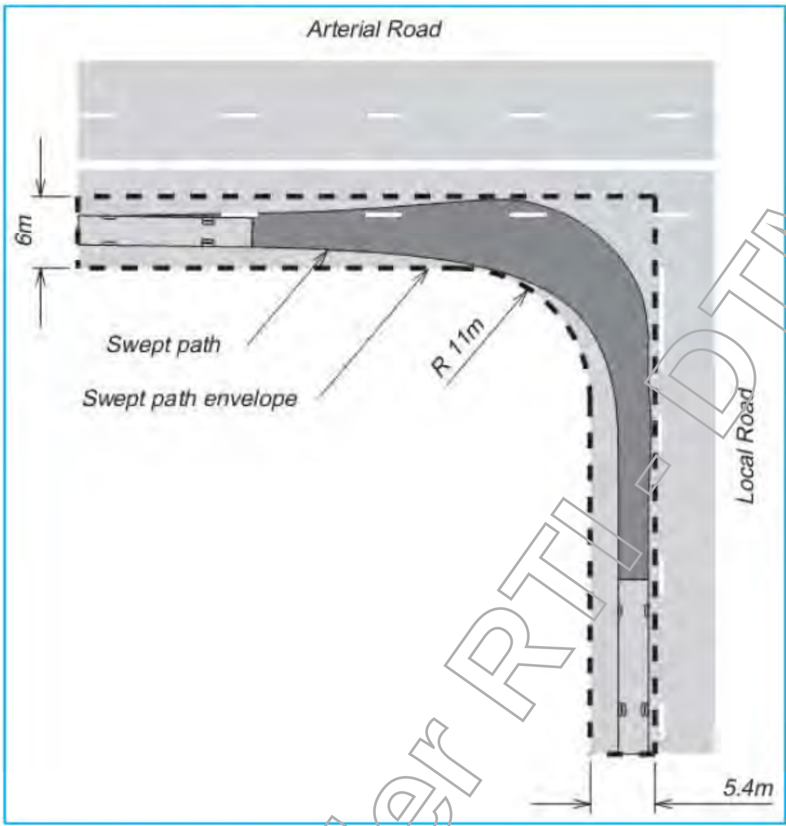
2.8.1 Heavy Omnibus Speed Limit

Notwithstanding the posted speed limit on any road or any exemption for fitment of speed limiting devices on high capacity omnibuses with a GVM over 14.5t, the Queensland *Transport Operations (Road Use Management – Road Rules) Regulation 2009* (hereinafter referred to as the *"Road Rules")* prohibits the driver of a heavy omnibus with a GVM over 5t from travelling at a road speed greater than 100km/h.

2.8.2 Left and Right Turning Constraints on 14.5m Rigid Buses

Sections 27 through 34 inclusive of the *Road Rules* define how a long wheelbase heavy vehicle fitted with rear *Do Not Overtake Turning Vehicle Signs* may negotiate left and right hand turns from far side turning lanes at an intersection. The rules effectively limit left turns for a 14.5m over length bus to those from a two lane local road to a multilane major road where over length buses can safely and legally cross unidirectional traffic lanes as depicted in Figure 4, but similar left turn manoeuvres are not possible from a two lane local road into another two lane local road without either driving on the wrong side of the road or increasing the front steering locks to obtain a reduced swept path radius.

Figure 4: Left Turn of a 14.5m Rigid Bus from a Single Lane Local Road into a Two-Lane Arterial Road



2.8.3 Turning Circle, Swept Path and Tail Swing on 14.5m Buses

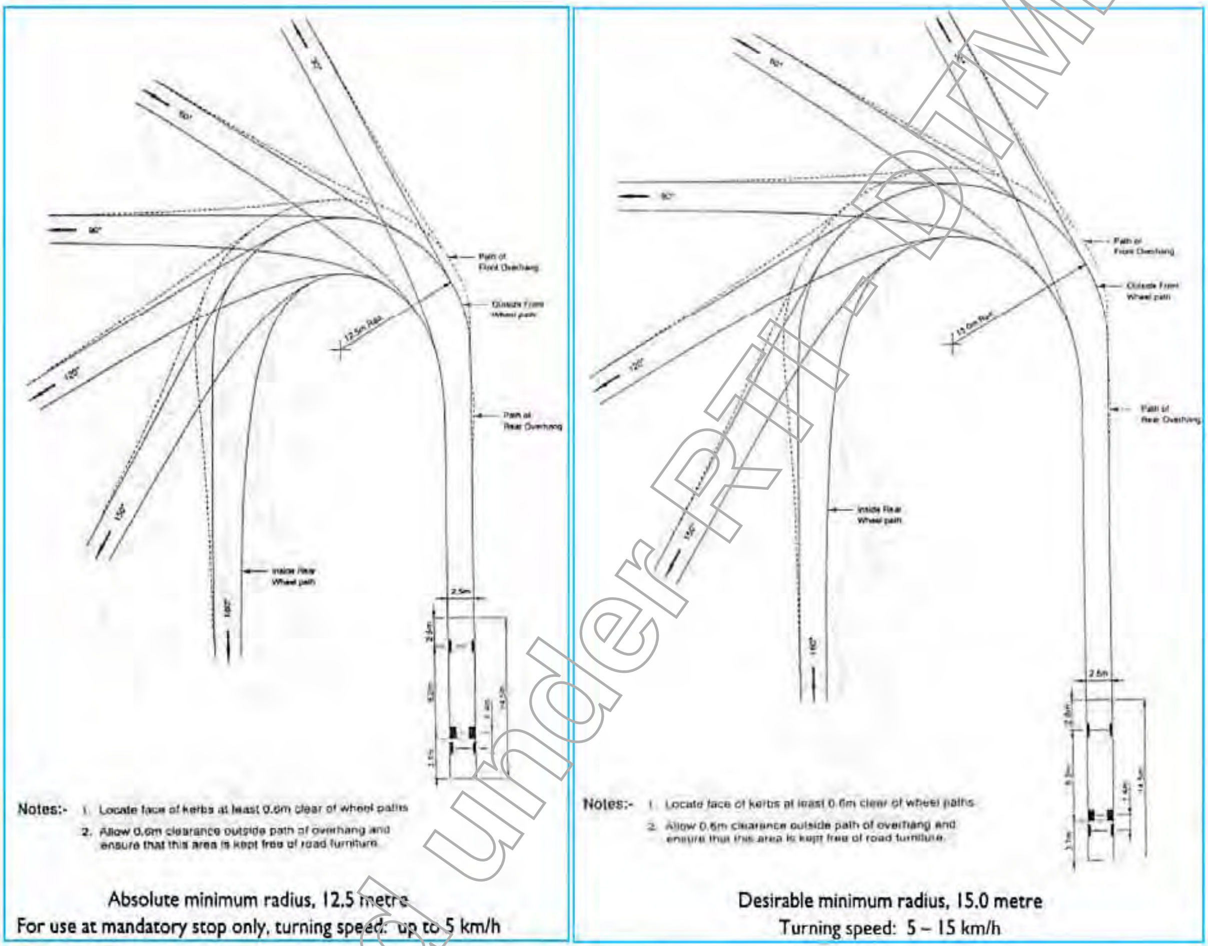
ADR43/04 and the *Transport Operations (Road Use Management - Vehicle Standards and Safety) Regulation 2010* specify that a heavy vehicle must be capable of turning left or right in a circle of not more than 25m diameter (12.5m radius) measured on the outer edge of its tyre track at ground level. This maximum regulated turning radius is applied by *Austroads* and all Australian road authorities to the design of minimum left turn kerb radii at intersections such as that depicted in Figure 4, which typically include an additional +R0.6m safety margin and range from R10m on local suburban road intersections up to R15m on major road intersections.

Neither vehicle standard specifies the vehicle road speed at which the regulated turning circle must be measured, but *Austroads* adopts a road design turning speed of 5km/h for 14.5m rigid bus turning circles of 12.5m radius (25m diameter) and recommends a greater turning circle of 15m radius (30m diameter) for road intersection design turning speeds up to 15km/h, as illustrated in

Figure 5. At the latter 15km/h turning speed, the wall-to-wall swept path measured at the front right overhang of an over length 14.5m rigid bus is 32m (or R16m). These very large turning radii can be readily accomplished on a modern 14.5m rigid omnibus by setting the front steering wheel full lock stops to approximately 42°, but effectively restricts operation to multilane main, arterial and sub-arterial roads and in many cases, would prevent 14.5m rigid bus service routes from entering congested central business districts.

To enable tighter left turn and right turn cornering and full lock exiting from restricted length bus stops, 14.5m rigid bus operators increase their front steering full lock stop settings up to around 52° to achieve a greatly reduced wall-to-wall swept path radius of R12.5m, as illustrated in Figure 6.

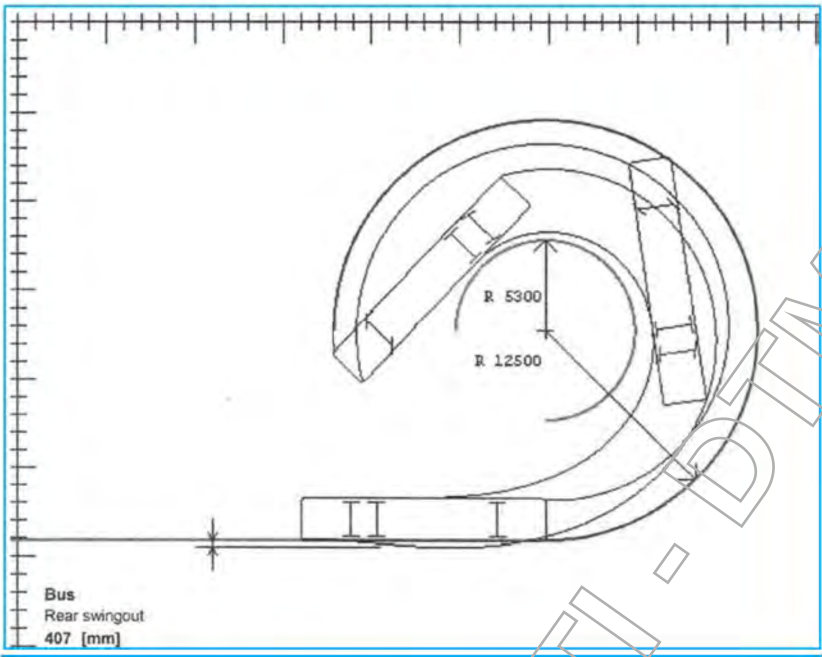
Figure 5: Austroads 14.5m Long Rigid Bus Swept Paths Measured at 5km/h and 15km/h



Whilst 14.5m rigid buses with increased front steering lock angles are fully compliant with the relevant ADR and Regulation, their greatly reduced wall-to-wall turning radii may have the following unintended consequences if bus drivers do not exercise due care to prevent:

- Mid body skirt kerb crossing or rear wheel kerb mounting during full lock left lane to left lane turns at intersections,
- Mid body skirt median crossing of median noses or rear wheel median nose mounting during full lock right lane turns at intersections,
- Rear tail swing in over kerbs on full lock right turn exiting from departure blocked left lane bus stops and zones, and
- Rear tail swing out into adjacent traffic lanes during full lock left and right turns.

Figure 6: Swept Path of a 14.5m Rigid Bus with its Front Full Lock Stops Set for R12.5m Wall-to-Wall



These driving safety risks associated with setting increased front steering lock angles can be mitigated through appropriate management strategies for 14.5m rigid buses such as:

- Compulsory route assessments for all new 14.5m rigid bus services as currently enforced by the Road Traffic Authority in New South Wales,
- 14.5m rigid bus driver route orientation training,
- Positioning 14.5m rigid bus stops well clear of intersections where route left turns are scheduled,
- Preventing regulated parking zones immediately forward of straight left lane bus stop zones, and
- Constructing purpose built indented bus stops for 14.5m rigid buses with adequate run in and run out tapers.

2.8.4 Maximum Take Off Acceleration and Give Way to High Capacity Buses

S77 of the *Road Rules* states that all drivers are to give way to a bus in the left lane or left line of traffic on a road in a built-up area where the speed limit is not more than 70km/h and the bus:

- Has stopped, is moving slowly or is stationary in a bus stop bay,
- Displays a rear *Give Way to Buses* sign and has activated its right direction turn indicator, or is
- About to re-enter or proceed ahead in the left lane or line of traffic in which the bus driver is already driving.

The give way to buses rule does not apply however to buses exiting bus stops and crossing lanes to right turn, buses pulling into traffic lanes on roads with posted speed limits above 70km/h, nor relieve bus drivers from safely exiting bus stops without first checking in rear view mirrors that sufficient time has been given to oncoming traffic and sufficient gap length exists to safely re-enter the left line of traffic. The higher mass, slower acceleration and longer length of high capacity buses dictates that longer bus stop dwell times be allowed in high capacity bus service timetables for traffic lane re-entries during peak traffic periods.

2.8.5 Low Clearance Signs Affecting Double Deck High Capacity Buses

Notwithstanding the current 4.3m general heavy vehicle height limit or proposed new national extended 4.4m height limit permitted for double deck heavy omnibuses, s102 of the *Road Rules* prohibits the driver of a bus from driving past a *Low Clearance Sign* if the vehicle is higher than the height (in metres) indicated on the *Low Clearance Sign.*

The minimum clearance design height for all bridges constructed in Queensland is 4.6m. 14 low clearance bridges with 4.8m or lower height clearances exist within *TransLink*'s route bus service boundaries and are listed in Table 7 below. Railway bridges Nos 1 and 2 in Table 7 would be considered impassable or marginal clearance heights respectively for single deck high floor route buses fitted with rooftop air conditioners and CNG cylinders, and bridge Nos 1 to 8 inclusive would be impassable to double deck buses.

Table 7: Low Clearance Bridges under 5m Height within TransLink Bus Route Service Boundaries

ID No	Bridge	Road	Suburb	Signed Clearance Height
1	Railway	Park Street	Milton	3.3m
2	Railway	Oxley Road	Corinda	3.6m
3	Railway	Annerley Road	Woolloongabba	3.8m
4	Railway	Muriel Avenue	Rocklea	3.8m
5	Railway	Cribb Street	Milton	3.9m
6	Pacific Motorway	Main Street	Beenleigh	4.0m
7	Railway	Countess Street	Petrie Terrace	4.4m
8	Hawthorne Street	Pacific Motorway Southbound Access On Ramp	Woolloongabba	4.4m
9	Linkfield Road	Gympie Arterial Road	Bald Hills	4.7m
10	Railway	Wynnum Road	Cannon Hill	4.7m
11	Pacific Motorway	Ipswich Road	Woolloongabba	4.7m
12	Anzac Avenue	Bruce Highway Exit to North Lakes	Murrumba Downs	4.8m
13	Kessels Road	Pacific Highway	Upper Mount Gravatt	4.8m
14	Watland Street	Old Pacific Highway Service Road	Slacks Creek	4.8m

2.8.6 No Buses Signs Affecting High Capacity Buses

S106 of the *Road Rules* prohibits the driver of a high capacity bus from driving past a *No Buses Sign* that has associated information on or with it indicating a mass or length, if the GVM or length of the bus exceeds the mass or length respectively indicated on the sign. *No Buses Signs* of this type normally only appear on unsealed or narrow rural roads and bridges or DTMR *Notified Roads* where 12.5m *Complying Buses* would normally operate within *TransLink* network boundaries. These roads are considered unsuitable for the 4 subject high capacity vehicles.

2.8.7 Loading and Bus Zone Signs Affecting Long High Capacity Buses

Sections 179 and 183 of the *Road Rules* permit buses to stop in a signed loading zone for the sole purpose of dropping off and picking up passengers and in a signed bus zone for any purpose whatsoever. Over length high capacity 14.5m and 18m articulated buses may not stop in these zones however if information on zone signs precludes a bus of their specified type is not permitted to stop in the zone, or if the bus length exceeds the zone length and the driver cannot safely pull into the zone without double parking or blocking the left through line of vehicular traffic, prohibited by s189 of the *Road Rules*.

S195 of the *Road Rules* permits an over length high capacity bus to stop up to 20m behind and 10m ahead of a *Bus Stop Sign* if the driver can safely stop in a length of clear road or area to which a parking control sign applies or is approved by regulation, but is not occupied by a parked vehicle. S198 further permits an over length bus to obstruct bicycle paths, private vehicle and pedestrian accesses to footpath ramps whilst dropping off and picking up passengers.

2.9 Passenger Transport Regulations Affecting High Capacity Bus Operations

The *Transport Operations (Passenger Transport) Regulation 2005* governs public passenger transport operations on Queensland roads using buses, taxis, limousines, motorcycles and other vehicles. It deals primarily with operator and driver accreditation schemes and licensing of services. The following discusses where and how the passenger transport regulations would affect high capacity route buses differently to standard 12.5m rigid route buses. A *Relevant Vehicle*, as defined by the *Passenger Transport Regulation* and described herein, may be any of the 4 subject high capacity route bus types used to provide a public passenger service.

2.9.1 Driver Authorisations

S20B of the *Passenger Transport Regulation* requires the applicant for a *Relevant Vehicle* driver authorisation (new or 5 year renewal) to:

- Hold a prescribed licence of the appropriate class (HR) for the high capacity vehicle,

- Have continuously held an open C class or provisional licence for a car, truck or bus for at least 3 years, and
- Have passed a competency test approved by the chief executive (of DTMR) for the operation of the type of *Relevant Vehicle* the person intends to drive.

For a typical *TransLink* bus driver already possessing an MR class licence and driver authorisation to operate a standard 12.5m rigid route bus, attainment of the necessary prerequisites required for both a high capacity bus HR driver licence and driver authorisation would require a minimum 1 year lead time plus competency testing for each high capacity bus type in his/her authorised operator's bus fleet.

2.9.2Driver Licence Suspension, Cancellation or Disqualification

S37 of the *Passenger Transport Regulation* states that if the driver licence of a person holding a driver authorisation is suspended, cancelled or disqualified from holding or obtaining a license, the person is automatically suspended, cancelled or disqualified from holding or obtaining a driver's authorisation for a corresponding period respectively. Depending on when in the 5 year renewal cycle of a high capacity vehicle driver authorisation a driver was to have his/her licence suspended, cancelled or disqualified, the prerequisite conditions for renewal would bar the bus driver from operating a high capacity bus for a period of up to 3 years, unless the driver was granted a provisional driver authorisation by the chief executive (of DTMR).

Where the continued livelihood of a bus driver was taken into account by the chief executive in the granting of a provisional driver authorisation and his/her authorised operator also had 12.5m rigid buses in its fleet, the conditions of the provisional driver authorisation may be limited to those applicable to an MR class licence only, still barring the affected driver from operating high capacity buses.

2.9.3Market Entry Restrictions

Schedule 1 of the *Passenger Transport Regulation* limits provision of general route services other than those for dedicated school services to:

- Within cities and towns with a population of more than 7,500,
- On routes of not more than 40km between cities or towns, each having a population of more than 7,500, and
- Between villages with a population of 500 or more and a city or town with a population of greater than 7,500.

These market entry restrictions would conflict with the proposed new *UrbanLink* long haul trunk and *ExpressLink* cross-country and regional activity centre interconnect bus services described later in *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland*. These are service types best suited to future deployment of high capacity buses. Exceptions to market entry restrictions may be declared under the *Passenger*

Transport Act by public notice or gazette issued by the chief executive (of DTMR).

2.10 Disability Standards Affecting High Capacity Buses

The *Disability Standards for Accessible Public Transport 2002* enforces the principle that *Equivalent Access* be provided for *Persons with Disabilities (PWDs)* to all public transport services. A public transport operator and provider (viz. *TransLink*) are mutually obligated to provide assistance to a *PWD* when requested and to vary the infrastructure, accesses to infrastructure and vehicle equipment and facilities that provide access to a public transport service such that an equivalent standard of amenity, availability, comfort, convenience, dignity, price and safety is maintained for *PWDs* to that afforded to other persons. The following disability standards may affect high capacity buses differently to standard 12.5m rigid buses.

2.10.1 Wheelchair Loading and Unloading

Non-slip, 800mm wide, 300kg rated wheelchair boarding devices are not called for under the *Disability Standards* for heavy buses operating dedicated school services, but are mandated on all other route buses and must be deployed if any passenger requests their use, whether a recognisable *PWD* or otherwise. Boarding ramps are normally installed at the front door of a route bus and may be of a type that is remotely powered and extended from the driver's seated position, or a type that needs to be manually pulled or flipped out onto the footpath kerb at the front door, necessitating that the driver leave his/her seat to assist the *PWD*.

Manual flip out ramps have become more prevalent on urban route service buses and are recognised by operators as more reliable, cheaper to install and easier to maintain. In addition to boarding device operations, a driver may be requested to assist a *PWD* with wheelchair pushing up boarding ramps and bus aisles, and with stowage and retrieval of mobility appliances placed in luggage racks.

For a modern step-less entry ultralow floor bus, the vehicle will normally travel and stop with it's compressed air front suspension raised to meet minimum ground clearance heights stipulated in ADR43/04 and the regulations, but must be lowered to near kerb height on the left hand side to board and alight persons with walking appliances, prams, wheelchairs, the visually impaired or blind. Inbuilt bus safety systems interlock the park or bus stop brakes whenever the wheelchair loading ramp is deployed, a door is opened or the bus suspension is not fully raised, and the bus cannot be moved off until all 3 safety conditions have been met.

The boarding ramp length and width necessitates both close spacing from and parallel alignment of the front door step to the kerb, and a near 90° wheelchair navigation path, which can be readily accommodated by 12.5m standard rigid buses at most bus stops constructed on left lane straight pull-in kerbs. Wheelchair loading and unloading challenges are however encountered with high capacity vehicles and include for:

- Double Deck Buses: 3.2 - 3.4m high double deck buses must be deliberately driven with a greater separation distance from kerbs than single deck buses to prevent accidental upper deck glazing, panel and roof strikes from shop awnings, traffic signs, posts, poles, tree branches and other high profile objects close to kerb lines. Double deck bus stop access is impacted by high profile obstructions in both the approach and departure paths, and these buses cannot be kneeled on the left side if high profile objects such as shop awnings and posts built to the kerb line exist within the bus stop zone.

  All wheel suspension kneeling may be necessary on a short wheelbase double deck bus to prevent excessive forward incline on wheelchair accessible bus aisles, and wheelchair kerb ramps similar to those provided for taxi and minibus wheelchair loading may prove necessary for double deck buses where wheelchairs have to boarded and unloaded to road because of high profile footpath furniture.

  Twin steer double deck buses such as Bus 343 under trial on the Gold Coast have narrower and longer aisle distances to reach wheelchair bays, and in combination with off-road wheelchair loading and/or all-wheel bus suspension kneeling, suffer longer dwell times at bus stops. Double deck buses may in some cases require larger onboard air storage tanks to speed up suspension raises and brake or auxiliary tank pressure recovery.

- 14.5m Rigid Buses: Over length 14.5m buses with increased steering lock settings suffer from excessive rear end swing into bus stops upon departure if full lock right turn outs are necessary to clear a vehicle (including another bus) parked in or immediately ahead of the bus stop. They are also impacted by non-parallel to kerb alignment in undersized straight and indented bus stops, and in indented bus stops with short turn-in or turn-out tapers designed to old road standards for short 12m rigid buses. Over length 14.5m rigid bus drivers, cognisant of rear end swing in due to forward path blockages, will deliberately space their buses up to 500mm out from the kerb to prevent swing in over the footpath, and kerb ramps may be needed at some existing short bus stops and indented bus bays to enable wheelchair loading off road.

- 18m Articulated Buses: Articulated buses are less susceptible to rear tail swing in, and with shorter front section wheelbases, can readily manoeuvre in close and parallel to kerbs in indented bus bays. However on existing short indented bus bays designed for 12m and 12.5m buses, articulated buses may be forced past the parallel section of kerb designated for front door passenger boarding into the turn out taper in order to clear the articulated trailer from the left through lane of traffic. This may result in wheelchair boarding over grassed, tiled or pebbled areas or from the road.

2.10.2 Hail and Ride PWD Pick Up/Set Down

Queensland *Road Rules* afford exclusive rights to urban route buses to park outside signed bus stop and bus zones across private driveways and pedestrian accesses, in front of fire hydrants, on bicycle lanes and in regulated clearway, loading, parking, taxi and other nominated vehicle zones if stopped solely and exclusively for the purpose of pick up or set down of passengers.

The right to stop in these regulated zones does not apply if regulatory signs prohibit buses of a particular type from stopping.

A key purpose of this exclusive right of buses to stop virtually anywhere on an open kerb is to provide accessible public transport to the elderly, blind and persons with mobility disabilities where bus stops are separated by long distances or hilly terrain and where regulated bus zones have not been established close to aged people homes, hospitals, medical centres or similar facilities. Under the duty of customer care defined in the *Passenger Transport Regulations*, a route bus driver is arguably obligated and entitled by the *Road Rules* to pick up a *PWD* when hailed or to set down a *PWD* when requested to do so outside a designated bus stop when it is safe to do so, and such is understood to be common practice on *TransLink* route services operated in SEQ.

The opportunity to safely pick up and set down passengers outside regulated bus stops and zones is significantly curtailed by the availability of kerbside spaces available to 14.5m and 18m long high capacity buses in parking congested town centres and commercial business districts.

2.11 Transport Planning and Coordination Regulation

Part 2 of the Queensland *Transport Planning and Coordination Regulation 2005* defines IDAS local road standards to be applied on local government controlled roads that form part of a route used for a public transport service. Compliance with the *Code for IDAS* must be determined for all assessable developments granted under the Queensland *Sustainable Planning Regulation 2009*. The purpose of the *Code for IDAS* is to ensure that developer road works on local government roads do not have any significant adverse impact on the efficiency, safety and comfort of public passenger transport. The standards nominated by the *Code* override those published in the Queensland *Road Planning and Design Manual (RPDM)* and the national *Austroads Guide to Road Design (AGRD)*, unless approved otherwise in Part 2 of the *Regulation*.

The following standards in Part 2 of the *Transport Planning and Coordination Regulation 2005* may restrict operation of high capacity buses vehicles on Local Government controlled roads approved under future *Controlled Access* or *HML Area Permits*:

- Lane Width on a Straight Undivided Two-Way Road: Lane widths of 3m on a straight undivided two-way local road would be unsuitable for operation of a 14.5m rigid and modern pusher type 18m ultra-low floor articulated bus if either the entry or egress intersection accessing the two-way local road had less than two lanes for left and right turns.
- Crossfall: Left lane crossfalls of 3 - 5% may not be suitable for 4.2 - 4.4m high double deck buses on narrow lane roads with trees, shop awnings, light poles, traffic signs and other high footpath furniture erected close to the kerb as can occur after a local government road widenings (for example in Milton Road, Auchenflower). Heavy loading on the upper deck of a double deck bus may cause a double deck bus to lean or oscillate leftward after crossing a side road intersection crown that has been elevated with successive layers of asphalt resurfacing.

- Indented Bus Bays: Indented bus bays prescribed by the Regulation for Local Government sub-arterial and higher order roads are required to comply with *RPDM* Chapter 20 and *AGRD* Parts 3 and 4 which provide indicative bay designs for either 12m rigid or 18m articulated buses, but no direction is given on which bus type and set down kerb length to design the bay for. For the proposed future high frequency *UrbanLink Bus Network* (discussed later), there will be an increased probability of closer running bus arrivals at indented bus bays, high capacity buses using indented bays and no overtaking lanes on congested road *TransitWays*. Unless *TransLink* and its service partners can positively verify that only low frequency standard rigid buses will use specific indented bays, it would be recommended that future indented bus bays be constructed for two 12.5m rigid buses with long run-out tapers to suit 14.5m rigid buses.

- Roundabouts: Whilst the general requirements for roundabouts on Local Government roads state that roundabout traffic islands must be designed in accordance with the *RPDM* and *AGRD* to clear the swept path of the design bus plus 0.6m clearance on each side, they do not specify for which design bus type. Modern steered tag axle 14.5m rigid and 18m pusher type ultralow floor articulated bus swept paths should be able to negotiate existing roundabouts at intersections on 4 lane two-way arterial and sub-arterial roads, but would experience difficulty negotiating non-flat top single lane two-way intersection roundabouts on most local roads.

3. Planning and Policy Impacts on Future Deployment of High Capacity Buses

This part reviews State, road and transport authority plans, policies and funding programs likely to impact on future demand for and deployment of high capacity buses in *South East Queensland (SEQ)* over the forthcoming 20 years out to 2031. Sweeping major changes are proposed to public transport delivery and related road and transport infrastructure during this period which tie in with State and Local Government regional planning for population growth, land use and redevelopment. Forthcoming changes affecting transport planning and funding priorities are broadly outlined in the following sections.

3.1 South East Queensland Regional Plan

The *South East Queensland Regional Plan 2009 – 2031* is the State's key long-term master plan for managing population growth, land use, new development and public infrastructure investment in SEQ over the forthcoming 20 year time horizon. The vision, strategic directions, principles and policies embodied in the *SEQ Regional Plan* prescribe the guidelines, strategic objectives and priorities to be adopted in all subordinate State and Local Authority road, transport and infrastructure plans and long-term infrastructure investment programs approved for the seven Local Government regions located in South East Queensland.

3.1.1 SEQ Regional Plan Vision and Strategic Directions

The overarching vision described in the *Regional Plan* for SEQ is for a region of interconnected communities with excellent accessibility to an extensive, integrated and efficient public transport system that contributes to reducing traffic congestion and greenhouse gas emissions.

Key strategic directions set out in the *SEQ Regional Plan* include restricting local planning schemes and development approvals to those that proactively reduce reliance on imported oil and private car dependency, with highest priority given to mixed-use (residential and employment precinct) transit oriented developments that support public transport through increased population density and close proximity to cities, major towns and defined activity centres with access to existing or proposed new public transport corridors. A core principle orchestrated in the strategic vision and principles is that reliable interconnected public transport services should be established prior to and lead development in regional activity centres to reinforce community travel habits that do not solely rely on private vehicle use.

3.1.2 Urban Footprint Development Concept

The *Regional Plan* envisages a new compact *Urban Footprint* land use for urban, rural, broadhectare, infill and remnant broadhectare areas located in SEQ, which incorporate a full range of urban uses, viz. residential housing, industry, business, infrastructure, community services, facilities and open spaces, underpinned by reliable, effective, high frequency public transportation. Priorities are assigned in the plan to those urban footprints which promote redevelopment in existing urban areas built around regional activity centres, established public transport nodes and corridors, and new public transport infrastructure which links regional activity centre transport nodes through a network of cross-city and inter-regional road, walking and cycling networks.

High capacity buses are well positioned to play a central role in providing cost-effective high capacity high frequency trunk and express services across the network of busways, cross-city and inter-regional roads with preserved bus corridors that will interconnect new activity centre transport nodes as they develop.

3.1.3 Regional Road, Public Transport and Infrastructure Priorities

Priorities have been ascribed to development in defined residential areas, regional activity centres, employment areas and identified population growth areas within each SEQ *Region*. The *Regional Plan* identifies specific future public transport nodes and corridors to be preserved and major public transport infrastructure projects to be included in all subordinate SEQ road, transport and infrastructure plans and funding programs, including but not limited to new busways, light rail track alignments, rail line duplications/extensions, bus/rail stations, tunnels, bridges, major road upgrades, pedestrian ways and cycle ways planned for identified high growth areas.

3.1.4 SEQ Regional Planning Principles and Policies

Future wide scale deployment of high capacity buses strongly supports the guiding principles and policies encompassed in the *SEQ Regional Plan* as follows:

- Sustainability Principle: High capacity buses offer the lowest cost per passenger-kilometre currently available for transporting heavy passenger loads at high frequency and reliability on mainline trunk corridors connecting distributed activity centre public transport nodes. They are also appropriately sized to deliver high capacity feeder and intermodal connecting services to and between major public transport nodes such as geographically disconnected light and heavy rail stations, regional airports and interstate transit centres,
- Reducing Greenhouse Gas Emission and Oil Supply Vulnerability Principles: High capacity buses consume the least imported fossil fuel and generate the lowest exhaust emission and greenhouse gas volumes per passenger-kilometre travelled. They also displace a greater number of

private vehicles from public roads than any other currently known road based public transport mode, excepting the pushbike,

- Ecosystem Services Principle: *Ecosystem Services* are defined in the *SEQ Regional Plan* as public goods and services that benefit, sustain and support the human ecosystem. Provision of accessible public transport services and infrastructure to disconnected communities and social infrastructure is a linchpin element of the *Ecosystems Sustainability Framework for SEQ*.

- Rural Communities (Support) Principle: The *Regional Plan* attempts to redress the limited access, social and employment disadvantages of SEQ rural and small town communities to critical social infrastructure such as schools, hospitals, places of employment, shopping centres, etc. attributed to long separation distances from principal and major activity centres to places of residence, and a current general lack of existing available low cost public transport services. The *Regional Plan* identifies a number of key rural and public transport corridor mixed-use activity centres that are proposed to deliver higher order public infrastructure, community services, commercial activities, places of employment and improved public transport connectivity within SEQ. High capacity cross-country buses are anticipated to connect these key rural activity centres as they develop, and

- Social Planning and Addressing Disadvantage Principle: The *SEQ Regional Plan* forecasts an exponential growth of the aging population in SEQ over the next 2 decades and an urgent need for a broad choice of home, aged care and retirement accommodation options where aging persons can self commute to a hospital, medical centre, shopping centre or similar facility without needing to own and drive a private motor vehicle.

  The plan identifies an emerging demand for highly interconnected public transport services that will encourage aged people, including those located in remote disadvantaged urban suburbs and rural communities, to continue living at home or in aged care facilities of their choice for the longest possible period, using a reliable public transport system that enables them to freely commute and "age in place". High capacity buses should play a primary role in providing cross-city and cross-country commuting services to social infrastructure including hospitals, medical centres and other professional services centres, enabling the elderly to "age in place".

3.1.5Desired Regional Outcome 8 – Compact Settlement

Desired Regional Outcome 8 of the *Regional Plan* aims to prevent dispersed low-density population sprawl that has thus far dominated historical development in SEQ, to open up existing land parcels for redevelopment as new activity centres, and to only release new land parcels for compact high density mixed-use settlement where essential services and public infrastructure exists or can be provided at least cost to tax and ratepayers:

- Compact Development Principle: In addition to traditional utilities such as electricity, public lighting, telecommunications, water and sewerage reticulation; and essential public infrastructure such a roads, storm water drainage, footpaths, cycle ways, open spaces, etc, property developers will be required in future to focus their proposed developments within defined urban footprints and regional activity centres where public transport nodes and corridors already exist, or to suffer a high contribution penalty to the cost of creating new public transport services and infrastructure as a precondition of their development approvals.

- Containing Growth and Urban Character and Design Principles: These principles aim to constrain future growth by proactively discouraging new development outside defined urban footprints and in rural and broadhectare sites where public transport nodes, corridors and services do not already exist or are not already planned or committed to in published State or Local Government funding programs. Developers must either demonstrate current public transport programs exist and will be delivered prior to release of their new developments to market, or suffer the high cost penalty of having to contribute to any necessary new public transport infrastructure development. The latter option will be used as a strong disincentive to constrain unwanted sprawl, and developer agreement to payment of public transport infrastructure contributions will not guarantee unplanned development approvals.

- Activity Centres and Transit Corridors Principle: This principle commits State Government Departments, Statutory Authorities, Government Owned Corporation and Local Government Authorities (hereinafter called *State Government Entities*) to preparing detailed land use planning schemes and public infrastructure plans for defined *Principal, Major Regional, Specialist, Principal Rural* and *Major Rural* Activity *Centres* identified in the *SEQ Regional Plan* to guide land use, public transport and infrastructure delivery across SEQ. These defined regional activity centres are to be supported by quality public transport that will create compact, self-contained, diverse (mixed-use) communities interconnected by a network of public transport and active transport (walking and cycling) corridors.

- Integrated Land Use and Transport Planning Principle: This principle recognises the strong nexus that exists between land use and efficient public transport, and prescribes prerequisite conditions to be applied to future *Transit Oriented Development (TOD)* approvals in precincts located within close walking distance of a *High Frequency Priority (HFP)* or combined high frequency service transport node. *TOD Precincts* are to be built on a walking and cycling friendly core within 10 minutes walking distance of an existing or planned light or heavy rail station or bus station surrounded by high density residential, employment and other prescribed mixed land uses.

  Under the *SEQ Regional Plan*, new *TOD Precincts* are to be geographically centred about existing or planned busway, bus and rail stations served by high frequency services on a dedicated transit corridor. Busway and bus station centric *TOD Precinct* nodes are proposed to be serviced by a combination of standard rigid local/feeder and high capacity trunk buses.

- Innovation and Technology (Support) Principle: This principle commits *State Government Entities* to providing reliable, high frequency public transport services to and infrastructure at activity centres dedicated by the State to research and development of science, health, education and training, innovation and technology which underpin the State's economy, future prosperity and international competitiveness.

3.1.6 Desired Regional Outcome 10 – Infrastructure

Desired Regional Outcome 10 of the *Regional Plan* addresses the need to plan, coordinate and deliver regional transport infrastructure and services in a timely manner commensurate with pace of predicted regional population growths, defined settlement patterns and desired community outcomes. Key principles relating to timely delivery of transport infrastructure include the:

- Demand Management Principle: This principle stipulates that all *State Government Entities* must strive to make best use of existing public infrastructure, and modify consumer behaviour rather than directing the State's limited resources toward development of other major new or upgraded infrastructure. In relation to public transport, the principle directs initiatives be taken to promote, intensify and encourage greater use of existing SEQ public transport infrastructure and increased public transport services to reduce public demand for imported oil and avoidable private motor vehicle journeys for both work and leisure.
- Protecting Key Sites and Corridors Principle: In relation to transport, this principle obligates all *State Government Entities* to identify, preserve, protect and manage key transport infrastructure sites and corridors located in SEQ. It further directs collocation where practicable of transport, energy, water, communications and other utilities in new generic infrastructure corridors and that preserved corridors be made available to the State emergency and police services.
- Social Infrastructure (Support) Principle: This principle states that new social infrastructure such as universities, hospitals, schools, aged care accommodation, etc. be located near safe, accessible, convenient public transport, pedestrian and cycle paths, and fully integrated with adjacent and compatible mixed land uses.

3.1.7 Desired Regional Outcome 12 – Integrated Transport

Desired Regional Outcome 12 of the *Regional Plan* describes the guiding principles and policies to be adopted by *Government Entity* road, transport and infrastructure planners and their funding programmers to realise highly connected accessible regions within SEQ based on an integrated transport system that is planned and managed to support compact urban growth and efficient travel; to connect people, places, goods and services; and promote public transport use, walking and cycling. *Outcome 12* sets the planning framework and guidelines for *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland*. Key principles and policies outlined in *Outcome 12* of the *SEQ Regional Plan* include the:

- Integrated Transport Planning Principle: This principle states simply that land use and transport planning shall be integrated, provide regional interconnectivity and greater levels of trip self-containment within each SEQ sub-region. Specific policy objectives and programs encompassed by this principle stipulate:

- o Construction of interconnected and coordinated rail and busway networks which provide high quality, dedicated passenger transport links across all SEQ urban areas,
- o Planning and implementation of new public transport routes, facilities, high frequency services and priority transit corridors that will ensure safe and convenient passenger accessibility, and support the interrelationship between land use and transport as defined within the *SEQ Regional Plan*,
- o Priority is to be afforded to public transport projects that support transit oriented communities and regional activity centres with interconnected public transport networks and services, safe cycling and walking routes,
- o Priority planning and development approvals by all land use authorities in urban areas are to be directed toward those developments which support walking, cycling and public transport,
- o Policy directions be developed to promote more compact forms of urban development, self-containment of passenger travel within SEQ sub-regions, continued development of new public transport spines for the Sunshine and Gold Coast Regions, and expanded use of the Brisbane rail and busway networks for *TOD Precincts*,
- o Urgent consideration be given to the capacity of the existing public transport network to cope with projected population growth in identified high growth areas, and
- o DTMR development of *Connecting SEQ 2031* and an *SEQ Infrastructure Plan and Program* in accordance with *Strategic Transport Network 2031* maps 22 to 24 inclusive for each region covered by the *SEQ Regional Plan*.

- Sustainable Travel and Improved Accessibility Principle: This principle asserts that sustainable travel choices must be provided in SEQ that support the accessibility needs of all community members, manage traffic congestion, and reduce private car dependency and transport generated pollution and greenhouse gas emissions. Specific policy objectives and programs encompassed by this principle include:

  - o New infrastructure, improved public transport services and service information that will actively support walking, cycling and public transport,
  - o Development and implementation of an *Urban Congestion Management Strategy* for SEQ,
  - o A *10 year Network Plan* to be developed for all public transport services operated in the *TransLink* service area, and
  - o Delivery of a high-quality public transport network in SEQ that supports increased urban densities around public transport nodes and along defined public transport corridors, community services and employment, reduces commuter travel time and loss of productive

work time, and improves environmental outcomes and travel choices for people disadvantaged by their access to transport.

- Effective Transport Investment Principle: This principle states that investment in the public transport system shall be targeted to maximise use of existing infrastructure, minimise whole-of-life costs for new infrastructure, provide measurable community benefits, and reduce greenhouse gas emissions and vulnerability to future oil depletion. Specific policy objectives and programs encompassed by this principle target:
    - o Integration of transport infrastructure, public transport services and land use planning by deliberate sequencing of defined *Development Areas* to align with State and Local authority transport investment programs,
    - o Development of new bus-priority and high-occupancy vehicle transit lanes in the SEQ road network that support public transport, and
    - o Timely implementation of State approved transport projects contained in the *SEQIPP*, *TransLink Network Plan* and the Australian Government *AusLink* program.
- Transport System Efficiency Principle: This principle asserts that an efficient and integrated public transport system shall be implemented in SEQ. Specific policy objectives and programs encompassed by this principle state:
    - o The use of existing public transport assets and services in SEQ are to be maximised by a combination of cost-effective transport investments and policies, demand management and application of new *intelligent transport system (ITS)* technologies,
    - o Key existing and future transport sites and corridors are to be identified, protected and managed, and
    - o Public transport networks and roads are to be designed to provide improved connectivity between *SEQ Regional Plan* defined *Activity Centres*.

3.2 South East Queensland Integrated Transport Plan

Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland was published by DTMR in 2011 and sets out the 20 year forward plan for public transport network development across South East Queensland. It outlines when and where the SEQ public transport network will be augmented to address population growth and newly planned land uses and how it will achieve the desired outcomes prescribed by the *SEQ Regional Plan*. The plan repeats, but in significantly greater detail, the same vision agenda and planning principles in the *SEQ Regional Plan*, but with additional information pertinent to the future deployment of high capacity buses as follows.

3.2.1SEQ UrbanLink Network

Connecting SEQ 2031 sets out ambitious public transport growth targets for *TransLink* heavy rail, light rail, bus and ferry services of 4.6% pa between 2006 and 2031, with 14% of all SEQ work and leisure trips targeted to be carried by the 4 modes in 2031. The trunk and feeder concept which underpins *UrbanLink* and achievement of the *Connecting SEQ 2031* passenger growth targets will invariably lead to:

- Increasing passenger loads and overloading on higher frequency local and spine feeder 12.5m standard bus services as the population and expected demand for public transport grows, and the supply of affordable car parking in major activity centres is constrained by local government parking regulations, increased parking charges and town centre planning schemes which reduce availability of both private building and public car park spaces,
- A progressive transfer of high passenger loads from local and spine feeder bus services (currently operating one seat terminus-to-terminus) to long haul trunk bus services travelling along the major bus spines from outlying transport hubs, sub-regional stations and park n' rides,
- Predicted high passenger boarding loads from intermodal transfer *UrbanLink* bus services not currently operating between the new coastal strip LRT and CoastConnect sub-spines and hinterland railway stations, and
- High passenger loads expected on the new *UrbanLink* cross-city and *ExpressLink* cross-country bus services proposed to be operated between regional activity centres as called for in the *Regional Plan* and planned for staged implementation under *Connecting SEQ 2031*.

In the past 7 years, Brisbane Transport has pressed some 30 new two door articulated buses and 128 two door 14.5m rigid buses into service, primarily to address growing passenger demand, long standing periods, overcrowding and passenger stranding at inner suburb bus stops by their lower capacity standard 12.5m rigid route buses. Other Australian capital city operators have witnessed similar gradual upward creep in passenger loads toward the maximum carrying capacity of their standard 12.5m route buses, and like Brisbane Transport have been confronted with the choice of either increasing service frequencies, drivers and standard route bus strengths deployed on high demand services, or to strategically retire off their older high floor 12.5m rigid buses and replace them with new ultralow floor high capacity buses before national disability compliances fall due.

If the new *UrbanLink Network* is implemented as envisaged by *Connecting SEQ 2031*, standard rigid 12.5m route buses are anticipated to be progressively relegated to operating shorter, higher frequency local, BUZ, spine feeder, one-seat terminus-to-terminus and low to moderate demand cross-city and cross-country *ExpressLink* services, and a growing demand will transpire for high capacity vehicles to take over the new coastal sub-spine to heavy rail intermodal transfers, high frequency priority and high capacity demand cross-city and cross-country interconnect services.

3.2.2 Predicted UrbanLink Bus Network and Services Demand

Connecting SEQ 2031 predicts that:

- By 2031, buses will need to carry half of all passenger journeys in SEQ to achieve its 2031 target; namely double the modal share of passenger trips currently being transported by bus,
- Between 2006 and 2031, daily bus passenger boardings will increase by 250%; namely 940,000 additional boardings per day above present daily boarded loads, and
- By 2031, kilometres travelled by the combined regional operator bus fleets in the region will increase by nearly 200% over current total distance travelled.

Connecting SEQ 2031 highlights that the *UrbanLink Bus Network* will progressively transition in new cross-town connector bus routes as outer regional activity centres develop, and new cross-regional interconnector bus routes to deliver anywhere-to-anywhere travel between SEQ regions and sub-regions.

Connecting SEQ 2031 declares the rail network illustrated in **Error! Reference source not found.** as the preferred long haul mass transit spine for all SEQ regions and sub-regions lying outside greater Brisbane. It describes conceptual staging scenarios in which *UrbanLink* and *ExpressLink* trunk bus services initially plug the discontinuities in the heavy and light rail long-haul spines, then transition across to *UrbanLink* and *ExpressLink* local and feeder bus services connecting dispersed activity centres to the rail backbone spines at the major railway station nodes depicted on **Error! Reference source not found.**. The plan acknowledges that *ExpressLink* bus services will be required in both the lead up to and beyond 2031 to transport commuters from outer town and city suburbs to major centres of employment, and will fill a similar role to *ExpressLink* rail services in those regional and sub-regional areas where rail services won't exist.

High capacity buses are considered the optimum future vehicle types to service high peak demand *ExpressLink* bus services.

3.2.3UrbanLink Activity Centres Access Hierarchy

*Connecting SEQ 2031*defines a hierarchy of 3 new activity centre public transport nodes (called *Hubs*), all of which are to be provided with *UrbanLink* 7 day a week, 15 minute (6am - 9pm) or lower headway bus services and high quality transport infrastructure to deal with predicted peak passenger interchange demands:

- Regional Hubs: These first tier hubs will form the key termini and interchange points for most public transport trunk services operated in their respective regions. They are to be established in the *SEQ Regional Plan* defined principal activity centres of Brisbane CBD, Ipswich Central, Southport and Maroochydore,
- Sub-Regional Hubs: These second tier hubs are to be directly connected to first tier *Regional Hubs* by high speed, high frequency *UrbanLink* bus corridors and will be the secondary interchange points for multiple high frequency local and sub-regional feeder bus services. They are to be established at *SEQ Regional Plan* defined principal and major regional activity centres and will support hub-centric *TOD Precincts* and

intensified mixed-use development, as well as direct bus access to adjoining areas of employment, education, health and services, and

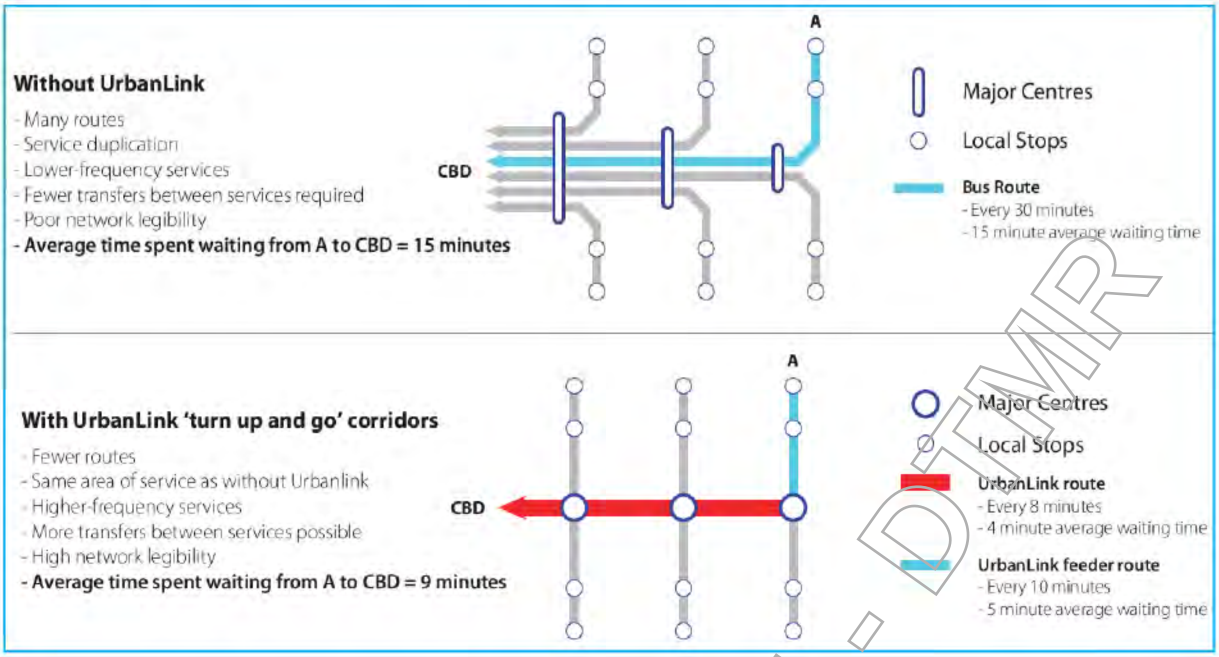
- District Hubs: These third tier hubs will form transport interchange points in areas of significant employment and will be directly linked to the two higher tier transport hubs. They are to be established in *Regional Plan* defined specialist activity centres and enterprise opportunity areas.

Figure 8 presents a new *UrbanLink Network* envisaged to be rolled out across South East Queensland by 2031 under *Connecting SEQ 2031.* In close accord with the objectives of the *SEQ Regional Plan*, *UrbanLink* depicts a large number of geographically dispersed activity centre transport nodes interconnected by a network of existing and proposed new cross-city and cross-country high frequency bus services operating along priority busway and transitway corridors, the latter proposed for high density urban areas and known congested road corridors. The trunk and feeder concept proposed to underpin *UrbanLink* is illustrated overleaf in Figure 7.

The *UrbanLink* backbone comprises high speed priority railway, busway and transitway spines radiating out from the Brisbane CBD, the *Regional Plan* defined central principal activity centre transport node, to surrounding regional and sub-regional transport nodes, supported by the new *GoldLinQ* light rail and *CoastConnect* coastal bus sub-spines on the Gold and Sunshine Coasts, each connected by high frequency cross-country connector and local bus services to the long haul heavy rail corridors back to the Brisbane CBD.

UrbanLink is premised on all hours, 7 day, all stops, 10 to 15 minute (6am - 9pm) headway "turn up and go" trunk and feeder bus services operating to all major SEQ urban areas. It aspires to double the catchment of 15 minute walk and ride bus passengers by 2031, including those predicted to come from newly developed busway, bus and rail station centric *TOD Precinct* catchments. A new form of bus service, *the ExpressLink*, is also envisaged in *Connecting SEQ 2031* that will provide 6am - 9pm express bus services between major outlying rail and bus station hubs in Greater Brisbane to other major transport nodes in adjoining SEQ regions.

Figure 7: Trunk and Feeder Concept for 2031 UrbanLink Network



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- District Hubs: These third tier hubs will form transport interchange points in areas of significant employment and will be directly linked to the two higher tier transport hubs. They are to be established in *Regional Plan* defined specialist activity centres and enterprise opportunity areas.

Figure 8: 2031 Indicative UrbanLink Bus Network Map

Figure 9: 2031 Indicative Rail Network with UrbanLink, ExpressLink, CoastLink and Light Rail Services

3.2.6 UrbanLink Priority Transit Corridors

Connecting SEQ 2031 nominates and maps priority transit corridors predominantly comprising of motorway T2 and T3 lanes, new bus only *TransitWay* lanes and arterial and inner city road bus only left lanes.

Priority transit corridors are to be created for the new *UrbanLink Network* in each of the 7 SEQ Local Government jurisdictions where an immediate opportunity exists to increase mixed-use public transport supported development of at least 40 dwellings/hectare or 80 jobs/hectare in accordance with *SEQ Regional Plan Desired Outcome 8.*

Under the plan, construction of new priority *TransitWay* bus corridors is to be packaged up with *UrbanLink* bus service rollouts and will, in many cases, ultimately determine the staging and pace of new *UrbanLink* bus service implementations. *TransitWay* single lane bus corridors will incorporate indented bus stops to enable overtaking by non-stopping *UrbanLink* and *ExpressLink* buses, and it is crucial therefore that new *TransitWay* indented bus stops be long enough for 18m articulated and 14.5m rigid buses, and their run out tapers extended to prevent excessive tail swing into bus stops.

3.2.7Priority UrbanLink Network Reform and Infrastructure Projects

Connecting SEQ 2031 identifies timely completion of the following major network reforms and transport infrastructure projects as crucial to the roll out of the new *2031 UrbanLink Network:*

- Extension of the Northern Busway to Bracken Ridge with interim on-road priority treatments beyond Chermside,
- Extension of the Eastern Busway to Capalaba with interim on-road priority treatments beyond Carandale,
- Extension of the South Eastern Busway to Springwood,
- Two-way extension of the Gold Coast light rail northward to Helensvale Railway Station and southward to Coolangatta, the latter by 2031,
- Development of new strategic park n' rides in locations selected away from *TOD Precincts*, transit hubs and priority transit corridors, and sited at an average radial distance of 10km from the Brisbane CBD and 3km from other defined activity centres identified in the *SEQ Regional Plan*,
- Progressive transformation of the existing *TransLink* one seat terminus-to-terminus network to a trunk and feeder *UrbanLink* network,
- Progressive expansion in both coverage and frequency of all existing *TransLink* local bus services,
- Completion of the priority Transitway corridors shown on the indicative UrbanLink map in Figure 8, and
- Completion of the Sunshine Coast *CoastConnect* bus (and later heavy rail) corridor between Maroochydore and Caloundra via Mooloolaba and Kawana Town Centre.

3.3 Queensland Infrastructure Plan and SEQ Infrastructure Plan and Program

The annual *Queensland Infrastructure Plan 2011* and long term *South East Queensland Infrastructure Plan and Program 2010 - 2031* (*SEQIPP*) outline State

Government investment priorities for regionally significant infrastructure. The *SEQIPP* details forward construction programs between 2010 and 2014, and future infrastructure development and upgrades planned over the 20 year time horizon to 2031.

SEQIPP transport infrastructure investment priorities closely align with those directed by the *SEQ Regional Plan, Connecting SEQ 2031 Integrated Transport Plan* and *Queensland Infrastructure Plan,* but *SEQIPP* transport infrastructure priorities additionally take into account the interdependencies that exist between coordinated delivery of public transport and other regionally significant infrastructure projects such as new hospitals, schools and roads, and State Treasury budget constraints on the bottom line total cost of all SEQ infrastructure development programs.

Approved SEQIPP 2010 - 2014 bus transport programs include:

- Brisbane public transport corridor preservations (ongoing),
- *CoastLink* Creekside Boulevard to Kawana Town Centre corridor preservations (ongoing),
- Future stage investigation and planning for the Eastern Busway (2010/11 - 2013/14),
- Future stage investigation and planning for the Northern Busway from Kedron to Chermside Busway Station (2011/12),
- Future stage investigation and planning for the Northern Busway from Kedron to Carsedine and Fitzgibbon Busway Stations (2013/14), and
- Design of interim high occupancy vehicle lanes from Kedron to Bracken Ridge (2011/12).

Look ahead indicative SEQIPP 2015 - 2031 bus transport funding programs include:

- *CoastConnect* bus corridor design and construction (2014/15 - 2019/20),
- Nerang-Broadbeach Road upgrades incorporating priority *TransitWay* bus lanes (2014/15 - 2019/20),
- Gold Coast LRT - Gold Coast University Hospital to Broadbeach (2020/21 - 2025/26),
- Eastern Busway - Bennetts Road to Capalaba design and construction (2020/21 - 2025/26),
- Northern Busway - Kedron to Bracken Ridge design and construction (2020/21 - 2025/26),
- South East Busway - Eight Mile Plains to Rochedale and Rochedale to Springwood design and construction (2020/21 - 2025/26), and
- Redland Bus Priority Measures design and construction (2026/27 - 2030/31).

3.4 Queensland Transport and Roads Investment Program

The *Queensland Transport and Roads Investment Program 2011/12 to 2014/15* details the Queensland Department of Transport and Main Road's 4 year rolling maintenance and infrastructure investment program for the State's transport and road networks. The program is reviewed annually to take into account unforseen funding priorities such as urgent road, rail and bridge reconstruction following floods and other natural disasters which may cancel, suspend or delay less urgent planned capital transport infrastructure projects.

Currently approved major bus transport investment programs in South East Queensland include:

- *TransLink* Station Upgrades (2011/12 - $44M, 2012/13 - $35M),
- State-wide Public Transport Infrastructure Disability Compliance Upgrades (2011/12 - $1.935M, 2012/13 - $1.935M),
- Western Bus Priority Corridor and Northwest Transport Corridor Planning,
- Logan Central Station Upgrade,
- State Wide Bus Station and Stop Infrastructure Grants (2011/12 - $3M, 2012/13 - $3M),
- Transport Infrastructure Development Schemes (2011/12 - $8M),
- Construction of Carindale Station and new Eastern Busway Approaches (2012/13 - $50M),
- Northern Busway Planning and Land Acquisitions - Kedron to Bracken Ridge (2012/13 - $28.518M), and
- Brisbane CBD and Cultural Centre/Melbourne Street Tunnel 14.5m Rigid Bus Access Improvements (2011/12 - $5M, 2012/13 - $5M).

Look ahead indicative major SEQ bus transport investment programs in 2013/14 and 2014/15 include:

- TransLink Station Upgrades ($80.15M),
- State-wide Public Transport Infrastructure Disability Compliance Upgrades ($3.870M),
- State-wide Bus Station and Bus Stop Infrastructure Grants ($6M),
- Construction of Carindale Station and Eastern Busway Approaches ($60M),
- Construction of South East Busway - Eight Miles Plains to Rochedale ($23.32M),
- Construction of CoastConnect ($25.978M), and
- Northern Busway Planning and Land Acquisitions - Kedron to Bracken Ridge (2012/13 - $39.1M).

3.5 TransLink Public Transport Infrastructure Manual

The *TransLink Public Transport Infrastructure Manual* was last revised in June 2007 when standard 12.5m rigid and 18m high floor articulated route buses were in common use in SEQ, and as for the Queensland *Road Planning and Design Manual* and national *Austroads Guide to Road Design*, has not yet been updated for emerging new 14.5m rigid, rear pusher ultralow floor articulated and double deck high capacity buses.

The principles and key considerations applicable to bus stop zones, shelters, seating, furniture, landscaping, hardstand areas, boarding points, stop markers, accesses, walkways and national disability standard tactile ground surface indicators and wheelchair boarding areas are still considered relevant to high capacity vehicles. Premium and Signature bus stop dimensions suit all high capacity vehicles and incorporate 35m nominal or longer hard stand areas suitable for two standard 12.5m rigid or double deck buses with half bus length parking separations, two extended 14.5m rigid buses or a standard rigid or double deck bus parked nose to tail with a 14.5m or 18m articulated bus at adequate separation distances, and clear hardstand areas suitable for potential future all door passenger boarding and alighting.

Likely revisions required to the manual would include:

- New Shelter Type Definitions: for indented bus stops on future *Transitways*,
- Hard Stand Length: Intermediate stop hard stand lengths extended for 18m articulated and superbus stopping on proposed new *UrbanLink* and *ExpressLink* cross city and cross country routes,
- Front Door Boarding Access Lighting Illuminance Level: Increase to 150 lux, as specified in the national disability standards for bus stops,
- Indented Bus Bay Length and Taper Redefinitions: Intermediate stop indented bus bay lengths and tapers increased for 14.5m rigid bus stopping on proposed new *UrbanLink* and *ExpressLink* routes, including departure paths clearances from regulated parking or other occupiable zones to prevent hard lock turn outs into left traffic lanes,
- Mandating High Capacity Bus Zone Separation Distances: from left lane route turns and right turn lane crossings approaching intersections, and
- Compulsory *TransLink* Route Assessment Guidelines: for proposed new double deck and 14.5m bus controlled access and HML routes. These guidelines are required to indentify whole of route operating constraints, not just those applicable to designated bus stops and zones.

3.6 Transport Operations (Passenger Transport) Act

The *Transport Operations (Passenger Transport) Act 1994 (TOPTA)*, last revised in January 2012, is intended to achieve the provision of best possible public passenger transport services at reasonable cost to the community and government.

3.6.1Objectives

The overall objectives of this Act that potentially relate to the application of high capacity vehicles are to:

- Enable the effective planning and efficient management of public passenger transport in the State, and
- Provide a system of public passenger transport in the State that:
  - is responsive to community needs,
  - offers an attractive alternative to private motor vehicle transport in a way that reduces the overall environmental, economic and social costs of passenger transport,
  - addresses the challenges of future growth,
  - provides public passenger services at a reasonable cost to the community and government, and
  - promotes the personal safety of persons using public passenger transport.

3.6.2Definition of a Vehicle

TOPTA defines a bus as a motor vehicle with a seating capacity for 9 or more passengers, excluding the driver. It defines public transport as a bus or ferry being used for a general route service.

3.6.3Operator Accreditation

S14 (*Operator Accreditation Standards*) of *TOPTA* states that bus operators should:

- Have the capacity to ensure the appropriate operation and maintenance of public passenger vehicles; and
- Comply with all relevant vehicle design, safety and operational requirements.

In the context of future HCV deployment, not all *TransLink* operators have the capacity to operate or maintain high capacity buses.

3.6.4Driver Authorisation

Chapter 4 of *TOPTA* refers to *Driver Authorisation*, which is a qualification a driver must obtain and continue to maintain whilst operating vehicles providing public passenger services. The purpose of the driver authorisation is to ensure that drivers of public passenger vehicles are responsible while in the act of driving, and capable of safely operating a public passenger vehicle of the relevant category. More detailed information about heavy vehicle licensing requirements is presented in Section 3.6.4.1 below.

Bus drivers are required to obtain a driver authorisation for scheduled route bus services, as opposed to other categories of driver authorisation such those for taxi and limousine drivers. In addition to having the correct licence for the vehicle type, driver authorisation also obliges drivers to submits to a medical assessment and prove their eligibility to work in Australia. There are no additional requirements for high capacity vehicle drivers other than those relating to licence class.

3.6.4.1 Heavy Vehicle Licences

According to the DTMR website, bus drivers must pass a practical driving test if they want to upgrade their existing licence to a heavy vehicle (class MR, HR or HC) licence and may also be required to pass a heavy vehicle road rules test. Table 8 shows the licence classes applicable to all bus types presently operated on the *TransLink* network. In general, licence classes broadly align with bus gross vehicle masses.

Table 8: Queensland Licence Classes

Licence Class	**Vehicle Description**	**Example *TransLink* Bus Currently in Operation**
LR (Light Rigid)	A light rigid bus more than 4.5 tonne GVM, but not more than 8 tonne GVM, built to carry more than 12 adults including the driver	 **Minibus**
MR (Medium Rigid)	A medium rigid bus more than 8 tonne GVM, with not more than two axles.	 **12.5m Rigid**
HR (Heavy Rigid)	A heavy rigid or articulated bus more than 15 tonne GVM, with at least three axles.	 **14.5m Rigid** **12 – 12.5m Double Deck**  **18m Articulated** **18m Superbus**

Table 9 sets out the minimum periods that a driver is required to hold a particular class of licence before becoming eligible to progress to the next higher class of licence. Each particular class of licence must have been held for a minimum holding period within the last five years when applying for the next higher class. The holding period may be a single continuous period or made up of a number of individual periods, however times when a licence is suspended or expired cannot be included when calculating minimum holding periods.

Table 9: Queensland Licence Class Holding Periods

Class of Licence Held	Minimum Holding Period	Next Eligible Class of Licence
C (car)	At least 1 year	LR or MR
C (car)	At least 2 years	HR
LR or MR	At least 1 year	HR

A *TransLink* bus operator cannot assign a 12.5m standard rigid bus driver with an MR class licence to operate a high capacity vehicle. The bus driver must either already hold the relevant HR license or wait for the minimum MR licence holding period to expire before he/she can upgrade an MR licence to a HR licence before progressing to operate a high capacity vehicle. A breakdown of licence classes held by existing *TransLink* bus operators is presented in Table 10 below.

Table 10: Licence Classes Held by Existing TransLink Bus Operators

Operator	MR Licence Holders	HR Licence Holders
Brisbane Transport	X	X
Bribie Island Coaches	X	X
Brisbane Bus Lines	X	X
Buslink Queensland	X	X
Caboolture Bus Lines	X	X
Logan City Bus Service	X	X
Hornibrook Bus Lines	X	X
Kangaroo Bus Lines	X	X
Mt Gravatt Bus Service	X	X
Park Ridge Transit	X	X
Sunshine Coast Sunbus	X	X
Surfside Bus Lines	X	X
Thompson Bus Service	X	X
Veolia Brisbane Pty Ltd	X	X
Westside Bus Company	X	X
Total	X	X
Percentage (%)	X	X

Column 'HR Licence Holders' in Table 10 effectively indicates the maximum number of high capacity vehicles that could be deployed in any given operator's network over the short term (of at least 12 months).

Section 41 of *TOPTA* states that a service contract may establish performance levels for the quality and type of public passenger vehicles and current version *TransLink* 3G contracts contain similar provisions. Bus operator 3G contracts are discussed later in Section 3.18.

3.6.5Special Events

Section 67B of *TOPTA* asserts that a special event declaration may be made only if *TransLink* considers, amongst other criteria, that the provision of transport services to or from the special event is likely to rely on an increased use of vehicles by *TransLink*. If *TransLink* had more high capacity vehicles operating in its network, the impact of a special event on existing network capacity could arguably be reduced and/or might, in some cases, negate the need to declare the special event or provide additional bus services. The assignment of high capacity buses to special event services would also reduce the cost to special event organisers and patrons of providing any additional services.

3.6.6Fare Evasion

Chapter 11 of *TOPTA* covers fare evasion offenses and responsibilities, and specifically states that a person must not evade payment of a fare lawfully required for the person's use or hire of a public passenger vehicle. This is important in the context of considering various measures to reduce bus stop dwell times on high capacity vehicles, such as through all door boarding. There is nothing in the legislation that prevents all door boarding on any *TransLink* bus and the responsibility to pay the correct fare falls upon the passenger. A bus driver or other authorised person such as a Transit Officer, is only authorised under *TOPTA* to enforce payment of fares.

A driver is authorised to check tickets under the legislation, and therefore has a role to play in managing fare evasion. However it is not known in practice how a bus driver would check for validate fare payment using go cards. This will be explored further in later reports.

3.6.7Prevention of Boarding on Full Buses

Section 143AH of *TOPTA* empowers a bus driver or an authorised officer to direct a person to leave or not enter a public passenger vehicle, or compartment of the vehicle, if:

- the person is about to enter, or has just entered the vehicle, or a compartment of the vehicle, that already appears to have its full complement of passengers, and
- the driver or authorised person tells the person in a general way, that the vehicle or compartment is full and that the person cannot board the vehicle, or compartment, or remain on the vehicle, or in the compartment, and
- the person then fails to leave, or not to enter the vehicle or compartment.

The deployment of high capacity vehicles will reduce the probability of drivers having to give such directions which occasionally lead to serious conflicts or altercations between drivers and passengers. More information about management of full buses is discussed later in Section 3.17.

3.6.8Demand Management

Section 147 of *TOPTA* states that the Minister for Transport and Main Roads may authorise a local government to carry out, under a local law, demand management measures to encourage the use of public passenger transport. The Act defines demand management strategies such as pricing on parking, bus priority and high occupancy vehicle measures. While the *Act* does not clearly define high occupancy vehicle measures, it is assumed this measure applies to bus only, T2 and T3 high occupancy vehicle lanes, but could be interpreted as any other measures to facilitate the introduction of high occupancy buses, such as larger bus stops or alternative kerbside allocations.

3.7 TMR Information Bulletins – Vehicle

Vehicle information bulletins issued by DTMR on its website are designed to provide plain English explanations of the *TOPTA* standards and regulations. These have no specific requirements applicable to high capacity buses that differ from those applicable to standard 12.5m buses used for general route or school services.

3.8 Transport Operations (TransLink Transit Authority) Act

The main purpose of the *Transport Operations (TransLink Transit Authority) Act 2008* is to deliver best possible mass transit services at reasonable cost to the community and government in *TransLink's* South East Queensland network area, while keeping government regulation to a minimum. The *TTA Act* does not quantify the definition of mass transit services in terms of bus passenger carrying capacity, but defines it simply as general route services for the carriage of large numbers of passengers.

The objectives of the *TTA Act* are not dissimilar to those expressed in *TOPTA* (see Section 3.6.1), but enable the effective operational planning and efficient management of mass transit services, as opposed to public passenger transport services for *TOPTA*. The *TTA Act* has an additional objective beyond those stated in *TOPTA*, namely to help the government achieve its congestion management priorities relating to road transport.

Most of the provisions in the *TTA Act* focus on the establishment and statutory responsibilities of the TTA, its Board, CEO and employment office. Other than referencing the *Special Event* provisions already discussed for *TOPTA* in Section 3.6.5 and the State Government's congestion management agenda, the *TTA Act* makes no direct mention of high capacity vehicles.

Chapter 5A of the *TTA Act* clarifies that the chief executive officer of *TransLink* may give a direction with the Transport Minister's approval, to second essential public transport infrastructure to allow any operator of a relevant service for the infrastructure to use the infrastructure on stated conditions fixed by the chief executive, but not to change the infrastructure in any way that would restrict its future use. Before giving the direction, the chief executive must undertake consultation with the infrastructure asset owner and be satisfied there is no other reasonable and practicable alternative to the direction that will secure its use. The asset owner may claim compensation from the State for costs incurred by the asset owner in complying with the direction, but failure to comply with the direction attracts a penalty of up to 1,665 penalty units.

Under the provisions of Chapter 5A, the CEO of *TransLink* may declare a road as an essential piece of public transport infrastructure and direct the road asset owner, such as DTMR or a SEQ local government authority, to provide bus priority and/or upgrade bus stops to enable the deployment of high capacity vehicles.

3.9 Transport Operations (TransLink Transit Authority) Regulation

There are no references to or implications for high capacity buses in the current version of the *Transport Operations (TransLink Transit Authority) Regulation 2008*.

3.10 Disability Discrimination Act

The federal *Disability Discrimination Act 1992 (DDA)* provides protection for anyone in Australia against discrimination based on a disability. It encourages everyone to be involved in implementing the *DDA* and to share in the overall benefits to the community and economy that flow from participation by the widest range of people. Discrimination occurs when a person with a disability is treated less favourably than a person without a disability. The *Act* makes is unlawful to discriminate in the provision of access to transport premises, vehicles, services and facilities.

The compliance requirements of the *DDA* for bus stops and heavy vehicles are the same, regardless of vehicle size and carrying capacity. However there are some indirect *DDA* considerations for high capacity vehicles if they are to be deployed on future school bus services. These are set out in the *Disability Standards for Accessible Public Transport (Transport Standards)* and discussed below.

3.10.1 Disability Standards for Accessible Public Transport (Transport Standards)

The Australian Government released the *Disability Standards for Accessible Public Transport* in October 2002. The disability *Transport Standards* establish minimum accessibility requirements for the providers and operators of public transport conveyances (DDA terminology for vehicles), infrastructure and premises. They encompass a wide range of compliance specifications for public transport facilities, bus stops and buses including:

- Wheelchair access paths, manoeuvring areas, ramps and vehicle boarding devices,

- Allocated spaces, doorways, controls, symbols, signs, waiting areas, boarding points, surfaces, hand and grab rails,
- Doorways and doors, lifts, stairs, toilets and tactile ground surface indicators (*TGSIs*),
- Alarms, lighting, controls, furniture and fittings,
- Street furniture, gateways, payment of fares and hearing augmentation systems, and
- Information provision, booked services, food and drink services, stowage of belongings and priority access arrangements.

The *Transport Standards* further specify levels of service, measures and actions that public transport operators and providers must take to discharge their obligations under the *DDA* and how public transport by bus, taxi, tram, train, ferry and commercial aircraft is to be made 'accessible'. The *Standards* apply to all new transport conveyances (vehicles) and infrastructure introduced into service after 23 October 2002. A progressively staged timetable for compliance over a 20 to 30 year period applies to conveyances (vehicles) and infrastructure built before this date.

Both vehicles and bus stops need to meet the DDA compliance targets shown in Table 11 but an operator or provider may apply to the *Australian Human Rights Commission (AHRC)* for an exemption from compliance with the *Standards*. Exemptions may be subject to conditions that are set by the *AHRC* but are often only temporary or limited to a short term of not more than five years. Exemptions have primarily been granted to small regional bus service operators and providers and to members of the *Australasian Railway Association.*

A dedicated school bus service is defined in the *Transport Standards* as a service operated to transport primary or secondary students to or from school or for other school activity purposes. These services are excluded from 26 physical access parts of the *Transport Standards* and have been summarised at Appendix A.

Table 11: DDA Compliance Targets

Compliance Year	Compliance Target
2007	25%
2012	50%
2017	75%
2022	100%

The exclusions set out in Appendix A effectively mean that dedicated *TransLink* school buses and coaches are excluded from most physical access requirements in the *Transport Standards* and are not required to provide:

- A boarding device for persons using mobility aids,
- Handrails or grab rails,

- Allocated spaces for people with mobility aids,
- Wide step and aisle wheelchair manoeuvring areas,
- Automatic or power-assisted doors, and
- Doorways of a minimum width necessary to assist people with mobility impairments.

These exemptions now look destined to cease within the 20 - 25 year life cycle of a *TransLink* operator school bus or coach. Historically, the exclusion of dedicated school buses from the physical access parts of the *Transport Standards* was in response to identified high costs of retrofit to existing school buses and coaches. Parts of the *Standards* not excluded only provided a small degree of accessibility, primarily to students with a visual impairment and covered by the low cost signage, illumination and information specifications in the *Standards*.

Part 34 of the *Transport Standards* however obliges the Federal Minister for Infrastructure and Transport, in consultation with the Attorney-General, to review the efficiency and effectiveness of the *Standards* every five years after coming into effect. The first review was undertaken in 2007, and the final report on the review was released by the Australian Government on 3 June 2011. The consultant who conducted the review for the relevant Ministries was tasked to undertake an analysis for one of the key recommendations in the final report, namely a '*RIS Analysis of Dedicated School Bus Exclusion Options*'.

The RIS analysis estimated that the cost of enforcing dedicated school buses to comply with the *Standards* would be $1.265 billion over 20 years (at 1998 prices, Attorney-General's Department, 1999), which would in the main be incurred by a large number of small bus operators. These costs were deemed to be extremely high, and it was further argued by disaffected school bus service operators that:

- They were small business people, generally operating older and often second-hand vehicles, which were turned over infrequently,
- There was little or no demand for accessible services, and the cost could not be justified by the limited demand,
- It was unlikely that there would be accessible pathways between bus stops and PWD residences so accessible transport improvements to buses would not be utilised, and
- Existing bus stops were generally unformed, sometimes comprising merely a space for the school bus to pull over on the roadside (Attorney General's Department, 1999).

It was also noted on the Attorney-General's Department website that another reason for excluding dedicated school buses was in response to issues associated with operating ultralow floor buses on 'difficult terrain' (Attorney-General's Department, 2006).

The *RIS* analysis concluded that paratransit solutions would be more cost effective than upgrading school buses and recommended that school buses be considered in State and Territory Action Plans, with a view to further considering options for making school bus services fully accessible in the future. In spite of this suggestion, recent Action Plans released by most State and Territory Governments have not progressed the issue, and it appears that the majority of stakeholders consider the current exclusions for dedicated school buses to be an ongoing full exclusion from the *Standards*.

Exclusions for dedicated school bus services raise concerns about the operator practice of allowing other passengers to board school services. In rural and regional areas, it is common practice for non-school students to also use dedicated school services to get into town. It is currently not clear if, by allowing other adult passengers on a school bus service, the service remains a dedicated school service or reverts to a general access service. If dedicated school bus services that provide a service to other patrons are considered to be providing a general access service, operators may be forced in future to cease the practice to avoid being subject to the numerous accessibility requirements defined in the *Transport Standards*.

Arguments about a lack of suitable bus stop infrastructure ignore the fact that bus stop infrastructure in most SEQ regions needs to be upgraded for general route services operating side-by-side with school services. The underlying reasoning behind the current exclusions was not that they provide ongoing relief to bus operators from compliance with the *Transport Standards*, but rather that further assessment and consideration be given by States and Territories to making dedicated school bus services fully accessible in the future. The final *RIS* report considered two options:

- Option 1: status quo, maintaining the current school bus exclusions in the *Standards*, or
- Option 2: removing the exclusions from the *Transport Standards* that currently applied only to dedicated school bus services over an extended time period.

The final recommendation of the analysis was that Option 2 should be adopted on the basis that it was the best cost minimisation approach. The Option 2 approach presented the best way forward in terms of allowing the *Standards* to fulfil their purpose, while minimising compliance costs for government and the bus industry.

Following close consideration of the final review report and its recommendations, the Australian Government announced its response on 3 June 2011. The response contained 15 recommendations, the most relevant being...

Recommendation 14: "*Phased application of dedicated school bus services to physical access requirements in the Transport Standards, commencing in 2029 and being fully required by 2044.*

The Government supports this recommendation in principle.

The Review found that the current exclusions to the physical access provisions of dedicated school buses limit the current and future provision of services for students with a disability. The Government recognises the importance of providing students with a disability every opportunity to participate in community life, including being able to travel alongside students without disability on dedicated school bus services. The Government also considers *there is merit in examining the potential consequences of this recommendation on existing complaints-based mechanisms of compliance.*

The Government proposes that the Australian Transport Council considers the most appropriate mechanism to progress this recommendation, noting that the Review concludes that a full RIS would be required in light of the potential cost impact on school bus operators and providers. As part of the further analysis, there would be merit in examining the number of second-hand accessible buses that may currently be available for purchase by dedicated school bus operators given accessible buses have been in service since 1995 and, if possible, the scope to commence earlier or shorten the phase-in requirements".

3.10.2 Disability (Access to Premises Buildings) Standards

The *Disability (Access to Premises Buildings) Standards 2010* commenced on 1 May 2011. Part H2 of the *Premises Standards* specifically relates to buildings associated with public transport services. This component has been transferred from the *Transport Standards*. Part H2 covers all public transport buildings including railway stations, bus interchanges and ferry terminals and would also apply to underground bus stations such as King George Square, Lutwyche and Queen Street Bus Stations. These standards will be reviewed in future reports being delivered under this study.

3.11 TransLink Strategic Plan

The *TransLink Strategic Plan 2011-2015* contains a number of pillars (or strategic priorities) with a underlying theme of providing 'value for money'. Of the 17 measures and targets established under the 5 pillars, those listed in

Table 12 relate directly or indirectly to the future deployment of high capacity vehicles on *TransLink* school and route bus services.

Table 12: TransLink Strategic Pillars, Measures and Targets

Pillar	Measure	2010/11 Actual	2014/15 Target
Quality Customer Experience	1.1 - Customer Satisfaction	70/100	75/100
Manage the Network	4.1 - Cost Recovery	22.5%	30.2%
	4.2 - Mode Share	7% (2006)	8.7%
	4.3 - Patronage	178.6 Million	193.1 Million
	4.4 - Capacity Enhancement	308,000 weekly seats	TBA
Financial Sustainability	5.2 - Subsidy per Passenger Trip	$6.06	$6.10
	5.3 - Average Revenue per Passenger Trip	$1.76	$2.64
	5.4 - Revenue Leakage (via Fare Evasion)	NA	TBA
	5.5 - Cost per Seat Capacity	$8,636 (Target)	$9,567 (Target)

3.12 TransLink Network Plans

TransLink Network Plans (TNPs) are developed annually as a strategic platform to articulate *Translink*'s vision for making travel easy. The overarching goal of network planning is to simplify the network; making public transport easier for customers to use and to understand for their entire journeys. Each *TNP* reflects on *TransLink*'s achievements over the past year, identifies public transport trends and challenges, and sets out a plan for shaping the network for the future.

3.12.1 TransLink Network Plan 2011

3.12.1.1 Strategic Objectives

Key challenges outlined in *TNP 2011* included:

- Congestion: A key issue for the State and Local Governments in South East Queensland is the growing traffic congestion on SEQ roads. Traffic congestion poses significant threats to the SEQ region and impacts on its overall productivity due to increased freight costs and lost productive work time. Congestion also poses a considerable threat to the region's air shed and living environment from engine exhaust emissions and noise pollution generated by vehicles driving slowly and idling in traffic for long periods. *TransLink* aims to lead, plan, develop and promote public transport services to alleviate growing traffic congestion on SEQ roads.
- Value for Money: As the lead public transport agency in South East Queensland, *TransLink* has a responsibility to ensure public transport is an affordable and viable alternative to private motor vehicle travel. Whilst tasked to offer affordable transport options to its customers, *TransLink* must also secure the long-term financial sustainability of the SEQ public transport system and facilitate future growth of the public transport network.
- Maintaining the Transport Fleet: To ensure it can continue to meet the growing capacity demand on its network, *TransLink* invests annually in new railway rolling stock and bus fleet capacity. Its current capacity is 201 three-car heavy rail train sets and a fleet of 2,312 buses servicing the entire network, however in order to meet future projected capacities, *TransLink* will be adding 6 additional new three-car train sets to its network by December 2011, and working with its service providers to identify and replace buses in accordance with its ongoing *Bus Replacement Schedule*.

3.12.1.2 Capacity Enhancement

A notable focus of *TNP 2011* has been network capacity enhancement and *TransLink* set a target of 305,000 additional weekly bus seats in 2011. By close of year, *TransLink* had exceeded its target, delivering an extra 308,000 weekly seats in the year, distributed across its SEQ bus network as follows:

- 110,000 additional weekly seats on Brisbane buses,
- 11,000 additional weekly seats on Sunshine Coast buses,

- 10,000 additional weekly seats on Gold Coast buses, and
- 17,000 additional weekly seats on Redcliffe, North Lakes, Caboolture, Logan and Ipswich buses.

It is understood the capacity growth target set for 2012 is 318,000 additional weekly seats.

3.12.1.3 High Frequency Priority Bus Routes

TransLink currently operates 18 high frequency priority bus routes in the SEQ Region, most of which are illustrated on the schematic route maps for greater Brisbane in **Error! Not a valid bookmark self-reference.** below, which excludes the Logan City to Brisbane CBD high frequency superbus Route 555.

TNP 2011 also references the expanding busway network, with new busway extensions to Langlands Park and Kedron being completed in FY2011/12. DTMR bus corridor planning is currently underway to further expand the greater Brisbane busway network northward, southward and eastward where indicated on

Figure 11: Existing and Proposed Busway Network in Brisbane

3.12.2 TransLink Network Plan 2009

A review has been conducted on unpublished *TransLink Network Plan 2009*. *TNP 2009* is a more comprehensive planning document than the later version *TNP 2010* and *TNP 2011* summary plans and contains detailed *TransLink* policies and network strategies not included in later editions. *TNP 2009* makes the following specific references relevant to high capacity vehicles.

3.12.2.1 Passenger Comfort

TNP 2009 discusses *TransLink*'s commitment to passenger comfort and defines it as providing sufficient capacity to cater for growing demand using modern, air-conditioned, clean vehicles and continuing to work towards access compliance with the *Disability Discrimination Act 1992*.

3.12.2.2 Strategic Objectives

TNP 2009 addresses the top seven challenges for *TransLink* in South East Queensland and cites increased public transport capacity as a key response to meeting growing passenger demand and managing overcrowding. Capacity has become a prominent issue for SEQ public transport, especially in the greater Brisbane region. This has been partly due to a rapid increase in public transport take up since *TransLink* began managing public transport throughout SEQ in 2004. Some overcrowding can be reasonably expected in the capital city region and it will never be practicable to provide all peak hour passengers with a bus seat.

Service capacity needs to be continuously expanded so passengers can be assured of a comfortable ride, particularly on long service trips. To boost services along existing high-demand transport corridors, *TransLink* has established improved forward planning and procurement processes to allow early ordering of additional new buses and trains. With inner city Brisbane continuing as the major employment centre and transport hub for passenger transfers between buses, trains and ferries in the SEQ Region, meeting service capacity in the capital city has become a top priority. Planning is currently underway to investigate more capacity for both rail and bus services travelling to inner city Brisbane.

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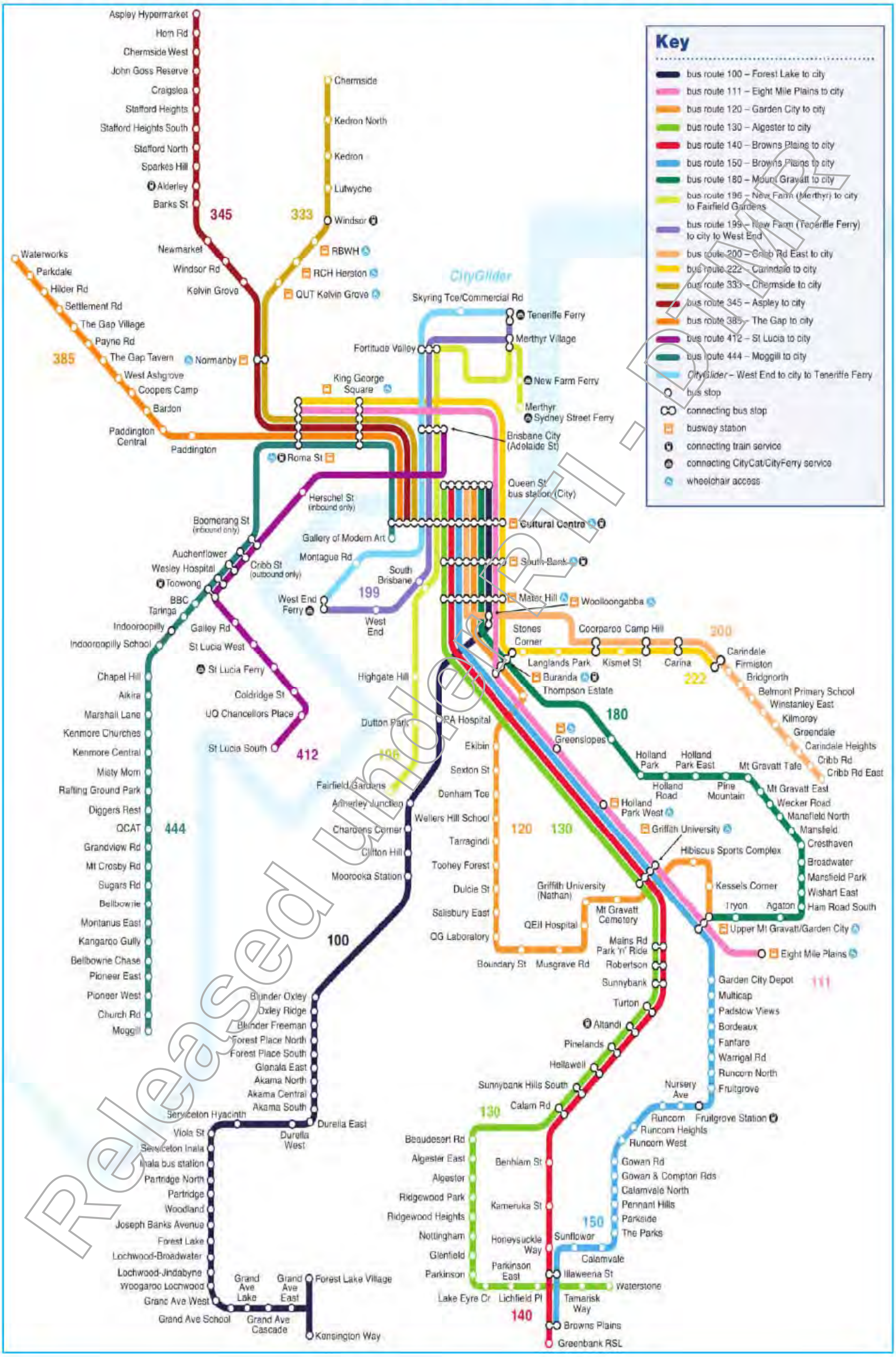
Figure 10: TransLink High Frequency Bus Network in Brisbane



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TNP 2009 addresses the top seven challenges for *TransLink* in South East Queensland and cites increased public transport capacity as a key response to meeting growing passenger demand and managing overcrowding. Capacity has become a prominent issue for SEQ public transport, especially in the greater Brisbane region. This has been partly due to a rapid increase in public transport take up since *TransLink* began managing public transport throughout SEQ in 2004. Some overcrowding can be reasonably expected in the capital city region and it will never be practicable to provide all peak hour passengers with a bus seat.

Service capacity needs to be continuously expanded so passengers can be assured of a comfortable ride, particularly on long service trips. To boost services along existing high-demand transport corridors, *TransLink* has established improved forward planning and procurement processes to allow early ordering of additional new buses and trains. With inner city Brisbane continuing as the major employment centre and transport hub for passenger transfers between buses, trains and ferries in the SEQ Region, meeting service capacity in the capital city has become a top priority. Planning is currently underway to investigate more capacity for both rail and bus services travelling to inner city Brisbane.

TNP 2009 further references the need to provide environmentally sustainable travel through more efficient use of resources. Public transport is considered at least 10 times more efficient in terms of fuel and energy consumption per passenger-kilometre and a considerably more efficient use of road space than single occupant motor vehicles.

3.12.3.3 Bus Priority

TNP 2009 acknowledges the role of local and State road authorities in delivering the "priority" for its *High Frequency Priority (HFP)* services, and strongly encourages both SEQ Local Governments and DTMR to invest in bus priority and high occupancy vehicle lane projects for new *TransLink* nominated HFP bus service corridors. To maximise the people-carrying capacity of roads, buses must be given priority access to busy activity centres through congested sections of the road network. This can be achieved by way of bus priority at signalised road intersections, bus only lanes and shared motorway high occupancy vehicle (T2 and T3) transit lanes, where buses can share lanes with other vehicles carrying two or more persons. The benefits of bus priority road treatments by these various road authorities include:

- Faster bus travel times which reduce bus fuel consumption, air pollution and greenhouse gas emissions,
- Improved reliability by reducing daily variations in service running times, allowing buses to meet their timetables more consistently, and
- More people carried in far fewer vehicles.

DTMR has prepared a *HOV Network Strategy* for South East Queensland and coordinated development of the *TransLink* HFP network has been a key input to the HOV strategic planning and funding prioritisation processes.

3.12.3.4 Service Categories

TNP 2009 defined future services on the *TransLink* network under the following 4 categories:

- High Frequency Priority (HFP): covering high frequency services provided by both bus and rail,
- Local: covering local and district bus services,
- Peak Only: covering extra bus and rail services needed to boost peak capacity and to provide direct trips for commuters during peaks, and
- Regional Links: covering inter-city rail services on the Ipswich, Gold Coast and Sunshine Coast railway lines.

3.12.3.5 High Frequency Priority Network

TNP 2009 focussed on rollout of *TransLink*'s then new high frequency priority (HFP) network, a 'turn up and go' service network for which passengers would not need timetables. *TransLink*'s 2009/10 strategy was to develop the new network of high frequency priority services that would form the backbone of South East Queensland's future trunk and feeder public transport system, (namely, the new *UrbanLink* network described in *Connecting SEQ 2031*).

The initial high frequency network concept developed in *TNP 2009* operated at a headway of 15 minutes or better between 6am and 9pm each day of the week. Based on the trunk and feeder operating concept, the high frequency priority network used a combination of fast, very frequent, high capacity trunk bus services connecting with less frequent local feeder bus services that essentially provided transport only to local district destinations. A feature of the high frequency network was its capability for trunk bus services to operate as limited-stop and express services, leading to shorter overall journey times for customers. Converting existing bus routes to limited stop and express trunk routes created an ideal niche for high capacity buses, eliminating their perceived weakness of excessive dwell times at interchange and intermediate bus stops along the route.

3.12.3.6 While HCVs have been identified as prime candidates for deployment to HFP trunk routes, they could equally well be deployed on many existing peak-only and school routes, most of which have limited passenger turnover en route and operate for short periods of very high load demand. *TNP 2009* presented a schematic HFP map for each of *TransLink*'s seven sub-regions, showing indicative routes targeted for implementation out to 2020. The HFP map developed for the greater Brisbane HFP network appears below in Bus Fleet Vehicle Mix and Specifications

TNP 2009 discussed expanding and enhancing the bus fleet, and developing standard bus specifications that allowed greater portability of the fleet across the network. This included refining the bus fleet vehicle mix to ensure it better met operational requirements by:

- Increasing the provision of higher capacity buses on high demand corridors such as busway and HFP routes, through targeted deployment of 14.5m rigid and 18m articulated buses,

- Development of *TransLink* standard bus specifications to provide consistent high-quality vehicles across the network, and
- Use of midibuses in areas of weak demand, provided only that such satisfied the national *DDA* accessibility standards.

Fleet improvement initiatives highlighted in *TNP 2009* included:

- Trial of hybrid diesel-electric buses,
- Trial of high capacity buses,
- Phase out of minibuses, and
- Development of a fleet strategy to promote innovation in development of clean, modern vehicle types.

TNP 2009 committed *TransLink* to make the bus fleet more environmentally sustainable through continued support for use of compressed natural gas on Brisbane Transport buses and trial of other alternative fuel technologies which burned less fuel and produced lower carbon equivalent emissions per passenger kilometre, favouring high capacity buses.

Figure 12, and since 2010, the skeleton of the future HFP network envisaged in TNP shown on the map has already begun taking shape.

3.12.3.7 Bus Fleet Vehicle Mix and Specifications

TNP 2009 discussed expanding and enhancing the bus fleet, and developing standard bus specifications that allowed greater portability of the fleet across the network. This included refining the bus fleet vehicle mix to ensure it better met operational requirements by:

- Increasing the provision of higher capacity buses on high demand corridors such as busway and HFP routes, through targeted deployment of 14.5m rigid and 18m articulated buses,

- Development of *TransLink* standard bus specifications to provide consistent high-quality vehicles across the network, and
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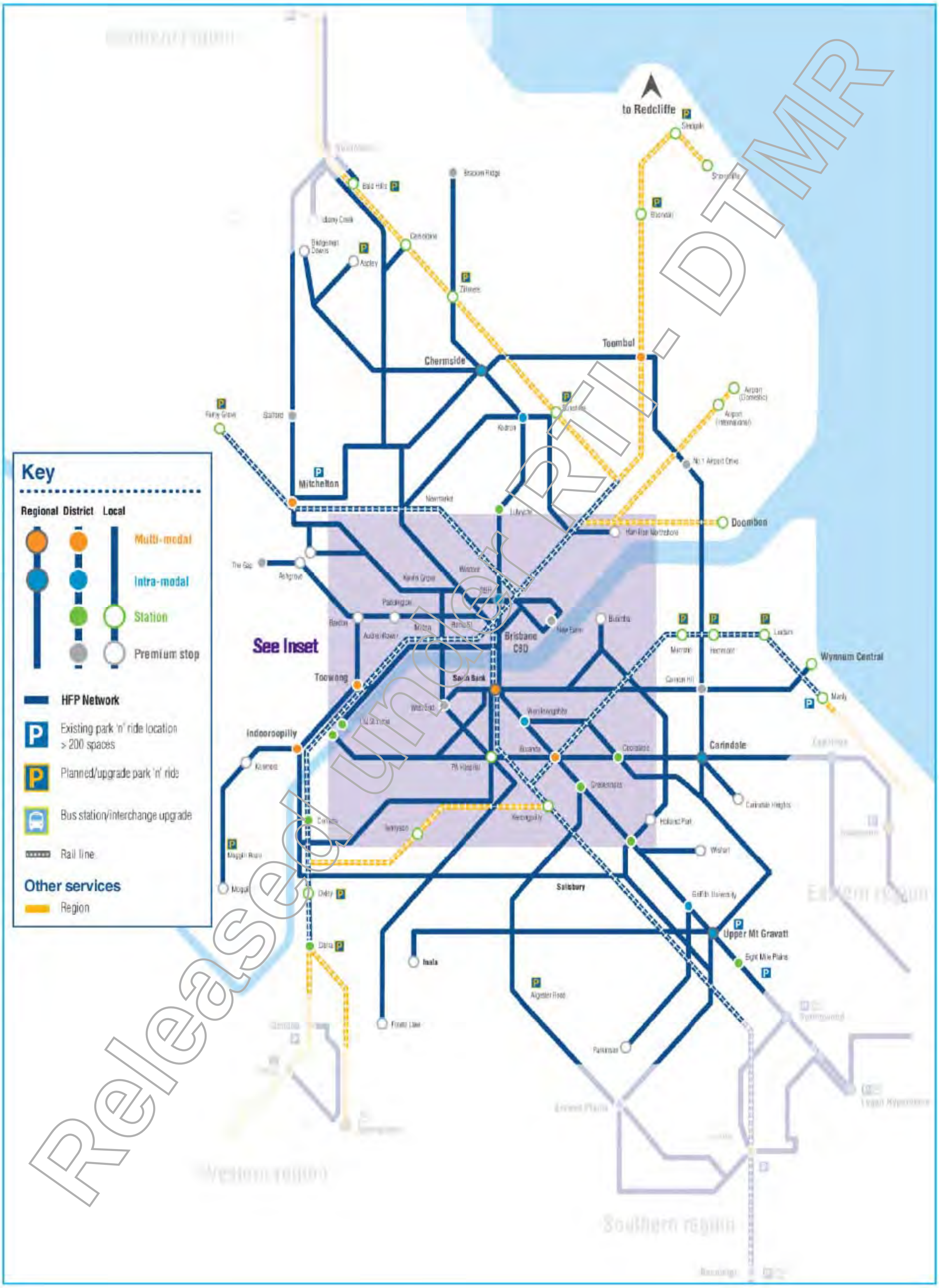
Brisbane Transport buses and trial of other alternative fuel technologies which burned less fuel and produced lower carbon equivalent emissions per passenger kilometre, favouring high capacity buses.

Figure 12: Indicative HFP Network for Brisbane



3.12.3.8 Bus Depots

TNP 2009 made reference to bus depots, citing new depots would be needed for the bus fleet to expand and meet expected future growth demand. Ill considered siting of bus depots can significantly affect the level of wasted bus dead running time to and from depots and termini whilst not carrying passengers. *TransLink* proposed in *TNP 2009* to become more proactive in locating, developing and managing bus depot rollouts as availability of land suitable for new depots became increasingly scarce. *TransLink* proposed in the plan to partner with bus operators and Local Governments in SEQ to investigate opportunities to strategically manage new depot rollouts with the aim of:

- Reducing overall network operating costs,
- Improving resource use, including depot sharing between operators,
- Responding to land use intents in local areas, including provision of adjoining park 'n ride and kiss 'n ride facilities for local residents,
- Ensuring long-term stability of the network, and
- Ensuring future growth could be accommodated as efficiently as possible.

3.13 TransLink Service Planning Policy

The *TransLink Service Planning Policy*, endorsed by *TransLink* senior management in 2011, does not specifically mention the bus fleet or high capacity vehicles, but contained the policy statement, extracted below, linking supply (of services) to demand (from land use) which favoured future high capacity bus deployment on HFP trunk services.

<u>Policy Statement</u>

Deliver an effective match between public transport services and land uses in the *TransLink* area.

<u>Policy Narrative</u>

The viability of TransLink Public Transport Services is determined by the demand generated by urban land uses from within the catchment of stops and stations. To improve the ability of Public Transport to compete with car based transportation, TransLink will utilise the following tools to assess the provision of Public Transport Services in the TransLink area:

- *The link between land use and the type and frequency of public transport that can be reasonably provided is to be as detailed in the TransLink Standards of Service relative to Land Use Density* (refer
- *This policy links dwelling and job density to service frequency, not to a specific vehicle type or capacity, however the planning policy clarifies that the TransLink network shall provide a mix of service types to cater for the type of trip, time of day, day of week, frequency and origin/destination needs of communities across the TransLink service area. In effect, this aligns services generally with the typical service characteristics summarised in Table 15.*

- *Table 13* below), and
- *Lower-density urban development (below 10 dwellings per hectare) is difficult to serve with mass transit. The minimum residential densities for Public Transport Services in new and existing urban areas are to be as detailed in the TransLink Level of Service relative to Land Use Density* (refer
- The *TransLink Service Planning Policy does not reference school services as a separate service type. These are covered by a separate policy discussed later in Section 3.15.*

- *Table 14* below).

This policy links dwelling and job density to service frequency, not to a specific vehicle type or capacity, however the planning policy clarifies that the TransLink network shall provide a mix of service types to cater for the type of trip, time of day, day of week, frequency and origin/destination needs of communities across the *TransLink* service area. In effect, this aligns services generally with the typical service characteristics summarised in Table 15.

Table 13: TransLink Standards of Service Relative to Land Use Density

	Density	Typical Development Type	Public Transport Service Type
TransLink Mass Transit Services	**High-density** 40 dwellings/ha or more 100 residents or jobs/ha	City Centre, Activity Centre, Specialist Activity Centre or Urban (as per TOD Guide prepared by DIP)	HFP services
	Medium-density 30 dwellings/ha or more 50 residents or jobs/ha	Suburban and Neighbourhood (as per TOD Guide prepared by DIP)	HFP services on major corridors Infill by feeder services
	Low-density 15 to 29 dwellings/ha 20 residents/ha or 10 jobs/ha	New urban development areas* Business parks	Feeder services on hourly frequencies Some access to HFP and peak only services
	Low-density 10 to 14 dwellings/ha	Existing urban areas*	Feeder services on hourly frequencies Some access to HFP and peak services
	Low-density and Non-urban Fewer than 10 dwellings/ha in	Older subdivisions Hectare subdivisions Rural towns Isolated villages	Does not generally support mass transit services

	existing urban areas and 15 dwellings/ha in new urban development areas		Park 'n ride to facilitate access to the public transport network Flexible transport (provided by Local Government or DTMR) may be appropriate Inter-regional service may connect centres

It is generally considered that lower demand would not warrant assignment of high capacity vehicle to local feeder services. There may however be some potential in the future to deploy HCVs on selected NightLink services, notably the more popular 3am NightLink services departing city entertainment districts just after lock-out.

The *TransLink Service Planning Policy* does not reference school services as a separate service type. These are covered by a separate policy discussed later in Section 3.15.

Table 14: TransLink Level of Service Relative to Land Use Density

Net Residential Density	**Approximate Lot Size (m²)**	**Minimum Public Transport Level of Service**
0 to 9 dwellings/ha	900m² or greater	Flexible transport (not provided by TransLink)
10 to 14 dwelling/ha	600 to 700m²	Local or feeder services (in existing urban areas only)*
15 to 19 dwellings/ha	400 to 500m²	Local or feeder services
20 dwellings/ha or more	300m² or less	HFP and feeder services

Table 15: TransLink Typical Service Characteristics

	High Frequency Priority (HFP)	High Frequency Priority Express	Peak Express	Regional	Local Feeder	NightLink After Hours
Public Transport Type	Bus, rail and ferry	Bus and rail	Bus and rail	Rail	Bus	Bus and rail
Key Function	Increase patronage	Increase patronage	Provide extra capacity to cater for peak-period commuter travel	Increase patronage and provide high speed links between regional areas	Provide coverage across the entire urban area and meet minimum service standards (2)	Supplement taxi services and provide safe late-night travel
Core Attribute	'Turn up and go' high frequency all day	'Turn up and go' high frequency all day with limited stops	Peak period express services Monday to Friday	Inter-region link	Provides access to HFP routes and local attractors	Secure late night services
Frequency	15 minutes or better all day	15 minutes or better all day	30 minutes or better peak only and where required	10 to 60 minutes all day	60 or better minutes all day	60 minutes or better Friday and Saturday nights
Minimum Hours of Operation	6.00am – 9.00pm 7 days	As required	Peak only	9.00am – 5.00pm weekdays / Saturdays; 9.00am – 4.00pm Sundays	9.00am – 5.00pm weekdays / Saturdays; 9.00am – 4.00pm Sundays	Set down on demand 1.00am – 5.00am Saturday and Sunday mornings
Stop Spacing	400m to 1.6 km	800m to 1.6km	400m to 2km with a section of the route running express	3 to 20km	400 to 800m	400m to 2km (note: set down on demand)

3.14 TransLink Infrastructure Planning Policy

The *TransLink Infrastructure Planning Policy*, endorsed by *TransLink* senior management in 2011, makes no specific mention of the bus fleet or high capacity vehicles, but addresses the future network capacity.

TransLink's priority in this regard has been to optimise existing capacity by implementing better network designs and alternative servicing strategies to yield improved efficiencies, before resorting to design and construction of additional new infrastructure capacity. Where it has been identified that new infrastructure is both warranted and justifiable, *TransLink* endeavours to match the type of public transport infrastructure to the long-term capacity requirements of the network, based on the following 4 assessment criteria:

- Support for Land Use Development: modal selection must be based on the desired role of the public transport network in supporting the overall development of an urban area, not simply as an bolt-on extension to the existing transport system,
- Right Mode for the Task: consideration must be given to current and future origins and destinations of trips using the nearest transport corridor and nodes, so that the mode of transport selected best meets the maximum number of passenger needs at an affordable cost,
- Minimisation of Overall Journey Time: public transport travel times must be competitive with private car travel times in peak periods, and
- Business Case Justification: must ensure cost-benefit realisation and contribution to delivery on *TransLink's* long term strategic objectives.

3.14.1 Modal Selection

Table 16 summarises current *TransLink* guidelines for planning different public transport delivery modes. Ranges shown reflect different assumptions for dwell time and in the case of trains, the number of cars per train set. Peak-hour factor and passenger loading assumptions used to derive this table reflect *Transit Capacity and Quality of Service Manual* recommendations. Highest observed values only have been listed.

Table 16: Modal Selection Thresholds

	Passenger Capacity in Peak Directions (passengers/hr)		Average Travel Speed (km/hr)	
	Low	High	Low	High
Bus in Mixed Traffic	500	1,000	6	10
CBD Bus Lane	1,500	4,000	6	14
On Street Light Rail with Signal	2,600	5,000	13	24
Light Rail with Exclusive Right of	6,000	16,000	42	55
Bus on High Occupancy Vehicle	500	1,500	55	87
Busway with Passing, including	2,000	12,000	56	72
Suburban Rail	7,000	24,000	32	81
Long Distance Commuter Rail	2,000	7,000	56	89
Metro Rail	10,000	60,000		

3.14.2 Bus Station and Stop Hierarchy

Policy Statement 2 of the *TransLink Infrastructure Planning Policy* indicates generally that stations and stops in the *TransLink* area will provide for easy and safe circulation of passengers and vehicles. Table 17 outlines the current *TransLink Station and Stop Hierarchy*.

TransLink defines different categories of functionality for its station and stop facilities as follows:

- Local Facility: is a local facility sited and designed primarily to cater for the transport needs of the immediate surrounding community. The primary means of access to a local station or stop is walking via local footpaths and roads,
- District Facility: is a station located at a significant attractor in the network. These stations have a good standard of passenger facilities. Services to district facilities are primarily a mix of express and all-stops HFP trunk services, but some feeder services also operate from the station, and
- Regional Facility: is a major station or interchange with a very high standard of passenger facilities located at a major attractor such as a regional shopping centre, or where two or more HFP services converge in the network.

Table 17: TransLink Stop and Station Hierarchy

Functionality	Category	Typical location criteria*	PT Mode
	Regular Stop	low patronage no interchanging between services outer suburban or low density areas low frequency services	Bus
	Intermediate Stop	moderate patronage no interchanging between services often located within suburban areas low to moderate frequency services	Bus
Local	**Premium Stop**	moderate to high patronage limited interchanging between services often located along major corridors moderate to high frequency services	Bus Busway Light Rail Ferry
District	**Standard Station**	moderate to high patronage limited interchanging between services key point of transfer between services of the same mode often located along public transport corridors such as rail lines or busways moderate to high frequency services	Bus Busway Light Rail Heavy Rail Metro Rail Ferry
Regional	**Intra-modal Station**	high to very high patronage high level of interchanging key point of transfer between services of the same mode often located at major district or regional attractions, or at strategic places within the network	Bus Busway Light Rail Heavy Rail Metro Rail

				high frequency services	
			Multi-modal Station	high to very high patronage high level of interchanging key point of transfer between services of both the same and different modes often located at major district or regional attractions, or at strategic places within the network high frequency services	Bus Busway Light Rail Suburban Rail Long-distance commuter Rail Metro Rail

In future, high capacity buses are more likely to use *District* and *Regional* facilities. Under the *TransLink Infrastructure Planning Policy*, bus stations and stops are classified according to the service frequency and patronage hierarchy presented in Table 18.

Table 18: Service Frequency and Patronage Hierarchy

Frequency Levels	For the purpose of this policy, frequency of services (in the peak) at stops or stations will typically be as follows: • **Low:** Local Services - greater than 60 minutes • **Moderate:** Local Services - 15 to 30 minutes • **High:** High Frequency Priority (HFP) Services - 10 to 15 minutes • **Very High:** High Frequency Priority (HFP) Services - greater than 10 minutes
Patronage Levels	For the purpose of this policy, patronage levels (in the peak) at stops or stations will typically be as follows: • **Low:** 0 to 250 passengers per hour • **Moderate:** 250 to 2,500 passengers per hour • **High:** 2,500 to 20,000 passengers per hour • **Very High:** greater than 20,000 passengers per hour

There is no existing capacity requirement that marries specific vehicle sizes to bus station and stop service frequencies and patronage demand.

3.14.3 Bus Depots

Policy Statement 4 of the *TransLink Infrastructure Planning Policy* states simply that bus depots and train stabling shall contribute to an efficient network. The location and capacity of bus depots have significant influence over the operating efficiency of the *TransLink* mass transit bus network. The following criteria are applied when planning new, or upgrading existing bus depots:

- Efficiency: Depot location selection to minimise vehicle dead running time and distance and maximise network operating efficiencies. This normally translates to siting depots close to where the majority of bus routes originate in the morning and terminate in the evening,

- Capacity: Sufficient depot capacity to be provided to accommodate future growth as efficiently as possible and to ensure the long term stability of the bus network,
- Utilisation: Adequate space to be provided to ensure efficient and effective bus operations and maintenance. Depot infrastructure is to be readily accessible to bus drivers and other depot staff and provide an appropriate level of amenity, and
- Impacts: Depot locations should minimise operational and maintenance impacts on surrounding communities.

The current policy acknowledges more detailed bus depot strategies will be necessary to inform future planning for new, or upgrade of existing bus depot infrastructure.

3.14.4 Mass Transit Definition

Under the *Transport Operations (TransLink Transit Authority) Act 2008*, *TransLink* is responsible for delivery of mass transit services in South East Queensland. *TransLink*'s service and infrastructure planning policies define mass transit as follows...

"For the purpose of this policy, mass transit is an urban public transport system which provides regular scheduled bus, light rail, rail or ferry services. Mass transit only operates where the carrying capacity of the transport mode is 24 seats or greater. Mass transit is generally provided to areas that have a density of 10 dwellings per hectare or greater".

This definition distinguishes the service capacity to be provided by *TransLink* from the service capacity to be provided by DTMR under their respective public transport charters within SEQ, and defines the minimum carrying capacity of their respective passenger transport vehicles.

3.15 TransLink School Policy

To be supplied by TransLink – it is understood this policy specifies that only low floor vehicles should be purchased for school services, except if the services have to operate on E3 (notified roads). This is intended to allow greater optimisation between school and urban bus networks.

3.16 Draft Service Augmentation Policy

The 2004 *TransLink Network Plan* proposed that services carrying more than 30 passengers per in-service hour be considered for augmentation. Since public release of this document, the policy has never been formally amended.

While not yet officially endorsed by *TransLink* senior management, informal agreement has been reached on a new draft policy position defining when services should be augmented going forward into the future. The draft policy is set to replace the former policy contained in the 2004 *TransLink Network Plan*, and is likely to be incorporated into the *Service Planning Policy*. Its position is summarised as follows...

"A service may be considered for a capacity upgrade if the maximum passenger load equals or exceeds 90% of the legal passenger carrying capacity of the vehicle for a continuous period of 20 minutes or longer. When considering capacity upgrades, the service must consistently meet or exceed the above thresholds to warrant a permanent capacity upgrade, taking into account seasonal fluctuations in demand".

The new draft policy does not imply that service augmentation necessarily means plugging additional services into a persistently loaded route, but allows for the qualifying service to be augmented by a vehicle capacity upgrade where such would more cost-effectively resolve overcrowding and missed passenger boardings without adding additional services. It is understood that the *TransLink* Strategy and Planning Team is keen to upgrade netBi functionality that would enable load profiles to be generated for individual services against their scheduled times, so that thresholds could be set to detect extended periods of overloading and thereby target services for which high capacity buses or additional services would be needed.

The earlier *TNP 2004* policy made no reference to either vehicle capacity or passenger turnover. The latter determines the magnitude and duration of transient passenger load peaks along the route, and is affected by the service type and distribution of surrounding land uses at scheduled bus stops. By way of example, the current Route 199 BUZ has the highest passenger boardings of any *TransLink* bus route. But because the 199 route services numerous mixed land uses on its high density corridor in both the peak and contra-peak travel directions, the service experiences a very high passenger turnover.

In contrast to the Route 199 BUZ, most school, university and peak express rocket services have only one or a few high passenger offloading stops and therefore experience only limited passenger turnover en route. Consequently, whilst the total number of passenger boardings on the 199 BUZ greatly exceeds the carrying capacity of HCVs along its entire route length, these vehicles would not reach full capacity for any significant period of time as a consequence of high passenger churn.

3.17 Driver Full Bus Reports

In the absence of having load profile functionality in its current version of netBi, Brisbane Transport has chosen to prioritise its service crowding mitigation initiatives by requesting bus drivers to report when buses appear full. Historically, full buses were reported when drivers finished their shifts at home depots and this necessitated drivers being diligent in both recalling and recording the affected service(s) and where on their routes overloading was encountered.

More recently, Brisbane Transport has resorted to using its bus two-way radio system which enables instant driver reporting at the push of a button on the in-vehicle mobile radio when the driver observes the bus is full. Electronic bus full data captured by mobile radio not only reports the full bus and service number, but additionally records the GPS coordinates of the vehicle to show where along the route the bus first became full. It is unknown whether drivers also manually record where, further along the route, the bus was no longer full, taking into consideration that the boarded passenger status on high turnover routes may fluctuate repeatedly between fully and partially loaded.

A recognised problem with full bus reports, be they manual or electronic, is they rely on the subjective judgement of the bus driver. A bus driver is authorised and obligated under *TOPTA* to prevent passengers boarding a bus that is considered full, and while the driver might know the legal carrying capacity stamped on the compliance plate of the vehicle being driven, he/she would not know how many passengers were actually boarded without conducting a head count. Accurate touch on and touch off electronic ticketing data could be used to calculate boarded load in real time, but is not currently provided to the bus driver and is only passed to *TransLink* for post-service evaluation and planning purposes.

It is understood that the popular high frequency BUZ route buses are amongst those most frequently reported full by bus drivers, but their assessments fail to consider high passenger turnover and service frequency (i.e. passenger waiting time between services), or whether preceding or following services along common corridor route segments may have had surplus boarding capacity. It is considered therefore that reliance solely on driver subjective assessment of passenger loads in deciding which services should be augmented with higher capacity buses or additional services is not a sustainable long term proposition for prioritising future *TransLink* service augmentations.

3.18 TransLink 3G Bus Contracts

3.18.1 Private Operator 3G Contracts

14 private bus operators presently hold *3G (Third Generation)* operating contracts with *TransLink*. The following sections review the current 3G contract and discuss selected clauses and schedules of the contract with direct or indirect implications for the future deployment of high capacity vehicles.

3.18.1.1 Vehicle Standards

3G contracts define a vehicle as a bus used, or which may be used by or for the operator to perform the services under the contract. This definition is the same as that found in *TOPTA*. 3G contracts further state the operator will comply with all State and Commonwealth Government laws in relation to vehicle accessibility and emission standards, and in particular, with the *Disability Standards for Accessible Public Transport 2002* and accompanying guidelines implemented under the *Disability Discrimination Act 2002 (Cth)*.

Schedule 7 of the private bus operator 3G contract provides a list of vehicle standards but most of the standards relate only to vehicle cleanliness and safety. There is no mention in the contract standards that vehicles should, for instance, be fitted with:

- Air conditioning,
- Two entry/exit doors, or

- Changeable electronic destination and route numeral signs, save that one destination sign must be fitted on the front of the bus.

No mention appears in the 3G contract about vehicle passenger carrying capacity, except in respect of reference to the *TOPTA* bus definition which basically defines a bus as having 9 or more passenger seats.

Under the 3G contract, *TransLink* must approve the purchase of new buses required by an operator to provide the services. If the operator chooses to purchase a bus that is considered to exceed *TransLink*'s minimum specifications, the operator must self-fund the difference between the cost of a vehicle that would have met the minimum specifications to provide the services and the vehicle that the operator has elected to purchase. For example, where a standard 12.5m route bus would be sufficient to provide route and school services in the operator's contract area, but the operator elects to purchase a coach to operate its own private tours, *TransLink* will only pay the cost of a standard route bus. In a similar vein, *TransLink* will not compensate the operator for any additional depreciation and running costs associated with a vehicle it elects to procure which exceeds the minimum specifications needed to deliver the contract services.

3.18.1.2 Livery

The 3G contract outlines *TransLink*'s branding requirements in relation to bus livery. An operator must ensure that its vehicles exhibit *TransLink*'s trademark and name in accordance with *TransLink* standards and guidelines for their proper use, and *TransLink* may direct an operator to change the livery of its vehicles to accord with the standards and guidelines. *TransLink* will pay to an operator the actual and reasonable cost incurred by it for any changes made to the livery of existing vehicles, but not for livery changes to vehicles made during their normal refurbishment or maintenance, or on a new vehicle.

If *TransLink* chooses to assign existing high capacity vehicles to routes that have a unique service brand necessitating an update of service branding elements in the fleet livery (such as say for new HFP routes), the cost of livery changes would be claimable back from *TransLink* by operators under current 3G contract conditions.

3.18.1.3 Fuel Costs

Schedule 8 – Indexation of the 3G contract states vehicle fuel costs will be paid to operators by *TransLink*, based on the actual cost of fuel and using *FuelTrack* to determine the indexation factor.

TransLink does not presently specify the bus fuel type or propulsion system to be used by the operator, nor the manufacturer, model or size of vehicle to be used, however as the receiver of all passenger ticket revenue generated by the services, high capacity buses placed on heavily loaded routes would realise the lowest fuel consumption and highest revenue generation per passenger-kilometre travelled.

3.18.1.4 Contract Payments

3G contract clauses indicate that there will be no change to the contract payments made to an operator by reason of a reduction in the level of service provided in accordance with the base kilometres specified in the contract, unless otherwise mutually agreed. These clauses exist to assure operators that they would not be financially disadvantaged as a consequence of any *TransLink* decision during the life of the contract to reduce the base kilometres below those which existed when operators first joined the *TransLink* network in 2004.

These clauses place potential constraints on the future deployment of high capacity vehicles. For instance, two articulated buses may be considered equivalent to three standard rigid buses in terms of total carrying capacity. If *TransLink* chose to substitute two articulated buses in place of three standard rigid buses on a route to improve the economic performance of particular services, the operator's base kilometres would be reduced by one third, but at no realisable saving to *TransLink*.

In the 8 year period that has elapsed since 2004, total operator base kilometres have increased by an average of 64.53% and the opportunity exists to reduce or contain further growth in travelled kilometres through greater high capacity bus utilisation, provided that new base kilometres are not locked in at their increased levels in the next round 4G contracts. In practice, *TransLink* will be more likely in future to selectively deploy high capacity vehicles on high demand routes in lieu of increasing services and kilometres. This approach would be expected to help constrain growth in base kilometres, rather than reduce existing kilometres.

3.18.1.5 Performance Management Framework

Schedule 10 of the 3G contract outlines the performance management framework for delivery of services and includes penalties for the following items of relevance to high capacity buses:

- On-time Running: The number of buses departing from agreed scheduled locations no more than 1 minute earlier than scheduled, and no more than 5 minutes later than scheduled, must be less than 5% of the total agreed scheduled departures for a day. (It is understood that these thresholds may have subsequently been revised by *TransLink*), and
- Missed Trips: The number of trips removed from the daily schedule must be no greater than 0.5% of the total trips scheduled for the day.

It could be argued by operators that they should be exempted from the above performance management framework penalties if the deployment of higher capacity vehicles failed to account for additional running time in the schedule to cover longer dwell times and generally slower acceleration from stops due to the higher mass of HCVs.

Another performance measure nominated in the schedule sets a target of 1 accident per 100,000km. A high capacity vehicle longer or higher than a standard 12.5m rigid bus may be expected to have a higher rate of accidents per 100,000km, based simply on the fact that it takes up more road and air space than its 12.5m counterpart, calling for greater driver diligence, concentration and care to manoeuvre and avoid accidents.

3.18.1.6 Private Charters and Tours

Some SEQ bus operators run private charter and tour services outside their standing 3G route and school service contracts with *TransLink*. In these instances, *TransLink* pays that proportion of the vehicle running cost associated with operating its own scheduled services, and the operator picks up the remaining cost expended on its own private charter and tour operations. Operators in the private charter business generally prefer to buy high floor coaches with more seats than low floor standard 12.5m route buses and with luggage stowage compartments below the main passenger deck. They predominantly operate their private charter services in *TransLink* scheduled service off-peak periods.

This arrangement has proven to be cost effective for both the private charter operators and *TransLink*, as the operators can utilise their high floor coaches on school routes during the peaks which often demand higher seating capacity, and coaches do not currently need to be *DDA* compliant. In effect, *TransLink* only pays for the vehicle to be operated on school routes, and the vehicle's initial procurement and ongoing running costs are cross-subsidised by private charter operations in circumstances where operating school bus services alone would be financially unviable.

For ultralow floor buses used on urban routes, *TransLink* arguably pays for a portion of its mass transit fleet to sit idle and underutilised in depots during off-peak periods, as most operators with ultralow floor bus fleets do not operate private charter businesses. The current exemption from DDA compliance for new buses used exclusively on school services looks set to expire after 2029, presenting *TransLink* with a dilemma of deciding to continue authorising purchase of coaches by operators in the tour business, or directing they purchase ultralow floor buses, given the typical 20 to 25 year life cycle of buses and coaches in SEQ.

It is unlikely a high capacity 14.5m rigid or 18m low-floor articulated bus could be used by an operator for charter services, but some operators might consider using low floor double deck buses for their charter services, where the lower deck could be partially partitioned off for luggage storage. Where this option was unacceptable to charter operators, this might mean that *TransLink* would need to pay up to 100% of the cost of a new high capacity vehicle and to shore up its return on investment by operating high capacity vehicles on other services where high demand warranted such. The *ExpressLink* cross-city and cross-country route services envisioned in *Connecting SEQ 2031*could be one future avenue to absorb this excess network capacity.

3.18.1.7 New Vehicle Funding

3G contracts state that an operator may be eligible for financial assistance under a guideline such as the *Accessible Bus Program Guideline.* These guidelines are now considered to be out-of-date as they only strictly relate to urban regional bus operators who hold a service contract with the Department of Transport and Main Roads. The guidelines do not apply to *TransLink* school and route service bus operators.

TransLink does however indirectly fund its operator new vehicle purchases through an operating lease arrangement. Under this lease arrangement, *TransLink* pays the annual lease instalments for each newly procured bus over a number of years, and the mutually agreed residual value is paid out by the operator upon termination of the lease period. The lease agreement is sufficient to enable operators to source finance for their ongoing fleet renewal programs with *TransLink* assurance provided both as initial lessee and financial guarantor.

While the 3G contract remains silent on specific lease terms and conditions entered into with individual bus operators, it is understood the typical operating lease terms and residuals shown below in Table 19 generally apply to most bus operators. *TransLink* only commences paying lease instalments when the bus or coach is placed in service, not when the operator orders or takes possession of a new vehicle from its manufacturer.

Table 19: Typical TransLink Leasing Details

Vehicle Type	Annual Lease Cost	Lease Period	Residual Value
12.5m Rigid - Private Operator	$	X years	X%
12.5m Rigid - Brisbane Transport	$	X years	X%
14.5m Rigid - Brisbane Transport	$	X years	X%
18m Articulated - Private Operator	$	X years	X%
18m Articulated - Brisbane Transport	$	X years	X%
12.5m Double Deck Bus - Private Operator	$	X years	X%

It is understood that *TransLink* pays 125% of the lease cost of a standard 12.5m rigid bus for a 14.5m rigid bus and 150% for an articulated bus, and the lease cost ratios are based on the relative seating capacities of the 3 vehicle types. Notwithstanding this financial agreement, Brisbane Transport planners argue that their 14.5m rigid buses are equivalent to articulated buses in terms of their total carrying capacity.

3.18.1.8 Replacement Vehicles

Schedule 7 of the 3G contract stipulates that the maximum age of an operator's vehicles must not exceed 25 years and the average age of an operator's fleet must be no greater than 13 years. Schedules 4 and 5 of the operating contract specify vehicle register details that operators are to provide to *TransLink* annually for their existing fleets, proposed vehicle acquisitions and replacements. Any existing buses or coaches proposed to be removed from service and/or replaced must be negotiated annually with *TransLink*.

Current 3G contracts do not require private operators to advise *TransLink* of the each vehicle's total carrying capacity, only their seated capacity. The compliance plate installed in each bus details the vehicle's designed (legal) carrying capacity and whilst this information may be recorded by private operators, it is not currently collected through their respective fleet registers by *TransLink*. The Brisbane Transport fleet register is the only register that records both seated and total carrying capacity for each vehicle and bus subgroup.

Table 20 below summarises the average carrying capacities of the *TransLink* bus fleet.

Table 20: Capacity of TransLink Bus Fleet

Operator	Average Seats	Average Standees	Average Total Capacity	Low-floor	Vehicle type
Brisbane Transport	X	X	X	x	X
Bribie Island Coaches	X	X	X	x	X
Brisbane Bus Lines	X	X	X	x	X
Buslink Queensland	X	X	X	x	x
Caboolture Bus Lines	X	X	X	x	x
Logan City Bus Service	X	X	X	x	x
Hornibrook Bus Lines	X	X	X	x	x
Kangaroo Bus Lines	X	X	X	x	x
Mt Gravatt Bus Service	X	X	X	x	x
Park Ridge Transit	X	X	X	x	x
Sunshine Coast Sunbus	X	X	X	x	x
Surfside Bus Lines	X	X	X	x	x
Thompson Bus Service	X	X	X	x	x
Veolia Brisbane Pty Ltd	X	X	X	x	x
Westside Bus Company	X	X	X	x	x
Total	X	X	X	x	x
Percentage (%)	X	X	X	x	x

There are currently x vehicles (x%) in the *TransLink* fleet classified as high capacity vehicles. X% of these are ultralow floor. Assuming *TransLink*'s peak vehicle requirement is 90% of the total fleet, the bus fleet could at any given time accommodate x seated passengers and an additional y standing passengers.

3.18.1.9 Spare Vehicles

While the 3G private operator contract is silent on the percentage of the bus fleet to be held asr spares, *TransLink* adopts bus industry best practice of around 10%, namely one spare vehicle for every 10 vehicles demanded during the highest weekday peak.

3.18.2 Brisbane Transport 3G Contract

It is understood that the conditions contained in the Brisbane Transport 3G contract are broadly similar to those in private operator 3G contracts, but the former includes the following additional provisions in regard to the Brisbane Transport bus fleet:

- *TransLink*, Brisbane City Council and Brisbane Transport are to agree each year on new fleet orders and the fleet mix of 12.5m rigid, 14.5m rigid and 18m articulated buses before orders are placed with the Council's bus chassis and body manufacturers, and
- *TransLink*, Brisbane City Council and Brisbane Transport are to agree each year on the planned fleet growth and replacement program.

It is further understood that *TransLink* has agreed to fund 125 equivalent rigid bus purchases per annum up until the end of FY2011/12, subject to annual agreement upon the fleet composition and bus replacement program. All vehicles procured under this arrangement have to date been CNG or diesel engine, air conditioned, ultralow floor, PWD accessible, two door route buses. A total of 128 new 14.5m rigid buses and 30 new 18m articulated high capacity buses have been procured under the agreed replacement program to date.

3.18.3 Brisbane City Council - Volgren Joint Venture

The current Brisbane City Council administration announced commitments to procure 400 and later 500 new buses during their last two terms in office. These commitments were made without *TransLink*'s prior agreement to fund either the new bus procurements or their deployment on scheduled school and route services. In recognition of this, it is understood the current Brisbane Transport 3G contract held with Brisbane City Council contains new provisions to ensure similar forward commitments cannot be made by Council without *TransLink*'s prior consultation and approval.

In 2008, Brisbane City Council announced it had entered into a 10 year joint venture with Australian aluminium bus body manufacturer Volgren Australia, to construct a new $19 million bus build factory at Trade Coast Central, Eagle Farm. It is understood Council donated a 2.54 hectare site valued at $6.7 million to Volgren to establish the new factory, which later opened in December 2009. Brisbane Transport bus body fabrication staff from the Council's Brisbane Transport Bus Workshops at Toowong were transferred to the new enterprise under the joint venture agreement, resulting in the closure of the Toowong bus body construction line previously used to fabricate and assemble new Council buses. It is understood the Volgren factory has the capacity to produce up to 200 buses per annum and the joint venture, executed in 2008, has a further 6 years to run.

Volgren has publically confirmed its Brisbane facility could build GM-Allison based hybrid diesel/electric rigid buses similar to those presently being trialled in Melbourne, and had the capability to also manufacture hybrid articulated buses. Brisbane City Council is however currently only placing orders for new diesel rigid buses to replace its older high floor diesel route buses located in depots which have no close proximity to existing high pressure natural gas pipelines. It is further understood that Brisbane City Council is reluctant to make further acquisitions of 18m articulated buses and considers the 14.5m rigid bus to be the equivalent of an articulated bus in terms of total carrying capacity and considerable cheaper to build, maintain and operate.

3.19 High Capacity Vehicle Scheduling Constraints

3.19.1 Depot Related Scheduling Constraints

Practical scheduling constraints prevent assignment of high capacity vehicle types to particular bus routes. These relate to:

- Intra-depot Constraints: Not all existing bus depots have the facilities, or would through appropriate modifications, be suitable candidates to park, maintain, wash and refuel high capacity vehicles. There may also exist road access or bus stop infrastructure limitations on bus routes operated from particular depots that prevent service delivery using high capacity buses. (Examples of typical depot related high capacity vehicle constraints are later described in the SIP business case study found at Section 3.19.5), and
- Inter-depot Constraints: Large operators with multiple depot sites attempt to limit assignment of bus routes to one or the two best depots which minimise their resident fleet average dead running time. This practice provides a bonus advantage in that drivers stationed at multiple depots do not need to be fully acquainted with every route on the operator's network. This is particularly important in the case of *TransLink*'s largest bus operator, Brisbane Transport, which has over 200 bus routes in the greater Brisbane area serviced by 1,250 buses from 9 separate depots.

With the advent of the *TransLink* go card, when a driver logs onto his/her vehicle DCU, stops are listed in sequential order for the route about to be driven, so driver reliance on prior knowledge of routes has arguably become less critical and the current Brisbane Transport Award pays its drivers more for operating services from multiple depots.

Notwithstanding this apparent flexibility, the inability to globally optimise scheduling between depots obviates potential interlining of services that would maximise operating efficiencies and further reduce dead running. The HASTUS and AUSTRICS scheduling systems used by most *TransLink* operators apply business rules established by each operator which effectively thwart opportunities for *TransLink* to further improve network efficiency. Example A below illustrates how depot siloing business rules can affect efficient interlining of two hypothetical services operated from different depots.

Example A: Say Brisbane Transport Route 111, operated out of Garden City Bus Depot, shared a common terminus with Route 222 at Roma Street Busway Station. Because Route 222 is only operated out of Carina Bus Depot, it cannot be interlined with Route 111 under HASTUS business rules, because drivers stationed at Garden City Bus Depot are not expected to be familiar with routes operated exclusively by Carina Bus Depot bus drivers. Because these services can't be interlined under HASTUS business rules, the hypothetical Route 111 bus must leave the busway to start at another origin stop in the CBD which can be interlined with a route operated out of Garden City Bus Depot.

A cost effective method known to reduce dead running cost is to assign designated vehicle types to turn back high frequency routes. This practice allows, for instance, an inbound HFP high capacity bus to arrive at its CBD terminus, take a short recovery period without repositioning, then return back along the same route in the outbound direction. In a more complicated but equally cost effective interlining scenario, two converging high frequency routes operated from the same home depot and sharing a common terminus can facilitate interlining of both services for a minimum layover period. This is illustrated by Example B below.

Example B: Say BUZ Routes 345 and 385 share the same terminus at the Gallery of Modern Arts and operate out of the same bus depot so HASTUS business rules permit their interlining. The buses can be scheduled to operate every 10 minutes (5 minutes combined) during the peaks and every 15 minutes during the off-peak (every 7.5 minutes combined). By interlining these two separate routes, the interlined recovery time becomes 5 minutes in the peaks and 7.5 minutes in the off-peak without incurring any bus dead running distance or driver paid time for repositioning of either bus.

Under the two hypothetical scenarios presented above, the opportunities to interline are constrained to those which can be accommodated by drivers and buses operating out of the same home depot.

3.19.2 Livery Constraints

Creation of special fleet subgroups with their own distinctive livery reduces bus interchangeability between depots, prevents substitution of similar bus sizes between services, increases the whole-of-fleet spare bus ratio and essentially de-optimises fleet utilisation and route scheduling. Utilisation can however be optimised for fleet sub-groups with a distinctive livery if operated all day on high frequency routes with a minimum of spare buses held in depot as in the case of, for example, the Brisbane *CityGlider*. Unlike other similar size buses without a distinct livery, a scheduler could not interline a *CityGlider* bus with say a peak hour *Rocket* service, as the redeployment of the *CityGlider* vehicle on another route would erode the service brand and only serve to confuse customers, but the continuous all day demand for the *CityGlider* service renders the need for interlining unnecessary.

Unlike standard rigid 12.5m buses, high capacity buses are further constrained by their relatively smaller sub-group strengths, standby spare bus reserves and the limited number of routes to which they can be scheduled. If further sub-grouped by a distinct livery for other than all day, high priority, high frequency services, high capacity buses may be found sidelined in depots for long off-peak periods each day.

3.19.3 Meeting Minimum Depot Fuel Quotas

Many operators have diesel (or natural gas) supply contracts in place with bulk fuel delivery vendors which specify minimum fuel storage top up thresholds for tanker deliveries and/or minimum weekly, fortnightly or monthly accounting period consumption thresholds which will attract bulk fuel discounts. These fuel supply arrangements, while intended to achieve economies of scale for best fuel price, indirectly result in buses with high kilometre routes being deliberately stationed at particular depots so minimum depot fuel order thresholds are reached, albeit that the selection of the vehicles' home depot may be considered suboptimal from both a scheduling and dead running perspective than other available depots. High capacity buses operating high frequency limited stop and express routes for long periods of the day consume fuel at considerably higher rates per day than smaller capacity 12.5m buses and are tempting targets for operators to selectively place at depots where attainment of minimum fuel quotas is a priority consideration.

3.19.4 Assessing Load Profile and Turnover for HCV Deployment

If selection of high capacity bus routes is based solely on driver reported or netBi measured load profiles, such may result in high capacity vehicles being inefficiently deployed to infrequent, low passenger turnover routes with resulting network de-optimisation if such routes don't share common termini with other routes, limiting interlining opportunities to reduce layover time and dead running needed to reposition trip origins. The challenge when selecting target routes for high capacity vehicles will be to contrast the cost per passenger-kilometre of augmenting low frequency crowded routes with low passenger turnover against the cost of augmenting high frequency routes with high passenger turnover along the route.

The latter routes are generally considered better candidates for cost-effective deployment of a dedicated high capacity vehicle fleet, however due to their high frequency, turn back contra-peak operation and servicing of multiple destinations, these routes may have the desired high patronage turnover but demand may not necessarily justify use of high capacity vehicles throughout the day.

3.19.5 Service Improvement Program Business Case – High Capacity Vehicle Deployment (Gateway 2)

This section describes a recent *TransLink* business case to reallocate high capacity vehicles to specific bus routes that consistently delivered full standing loads. The business case highlights the issues that were considered and constraints encountered when allocating high capacity vehicles to other bus routes.

As part of its 20 February 2012 *Service Improvement Program*, *TransLink* reallocated high capacity vehicles to operate on specific Brisbane bus routes for the first time. The objective of this project was to achieve a more functional and efficient utilisation of the Brisbane Transport high capacity bus fleet. By reallocating 14.5m rigid and 18m articulated high capacity vehicles to known congested routes, *TransLink* sought to proactively manage increased passenger demand without increasing peak bus service numbers.

Specific routes were selected largely on the basis of driver full bus reports and the project proposed an increase in weekly capacity on the network of 2,640 seats to address the growth in passenger demand. The Brisbane bus routes selected by the project team have been summarised below in Table 21.

Table 21: Proposed Deployment of High Capacity Vehicles on Brisbane Bus Routes

Route	To/From	Operations Proposal
66	Woolloongabba to Royal Brisbane Womens Hospital via Busway	Operate using articulated (18 metre) buses, 5 days a week (inbound and outbound)
109	UQ Lakes to CBD via Inner Busway	Operate using 18 metre articulated buses, 5 days a week (inbound and outbound), and 14.5 metre vehicles on Saturday and Sunday.
111	Eight Miles Plains to CBD via South East Busway	Operate using 18 metre articulated buses, 7 days a week (inbound and outbound)
130	Calamvale to CBD via Mains Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
139	Sunnybank to University of Queensland via South East Busway	Operate using 14.5 metre vehicles, 5 days a week (inbound and outbound)
140	Brown Plains to CBD via Mains Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
150	Browns Plains to CBD via Warrigal Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
P137 and P142	Sunnybank and Browns Plains to CBD	Additionally routes 137 and 142 to be allocated exclusively to 14.5 metre vehicles
160	Garden City to Queen Street Bus Station	Operate using 18 metre articulated buses, 5 days a week (inbound and outbound)
169	Eight Mile Plains to University of Queensland via Busway	Operate using 14.5 metre vehicles 7 days a week (inbound and outbound)

Most the routes listed in Table 21 are considered to be all hour high frequency priority weekday routes, with the exception of Routes P137 and P142 which are limited stop, peak only routes. Some of the above listed routes incurred additional running time allocations, but it is unclear from the business case if this was justified by increased traffic congestion or in anticipation of future higher passenger loads and longer dwell times at bus stops. Full implementation required some operational platform adjustments at Queen Street and Browns Plains Bus Stations to accommodate the longer high capacity vehicle reallocations.

The business case supported withdrawal of high capacity vehicles from selected routes and their reallocation to specific HFP routes with known consistently high or full standing loads. This resulted in the need to augment some of the services on the routes from which the high capacity vehicles were drawn to ensure their commuters received a level of service commensurate with that which existed before the higher capacity vehicles were redeployed. The following routes were identified by the project for supplementary augmentation:

- Route 135: Two additional trips at 7:30 and 8:00 am to compensate passengers who previously had access to articulated vehicles on Route 135 trips commencing at 7:17am and 7:46am,
- Route 136: One additional trip at 7:13am to compensate passengers who previously had access to articulated vehicles on the 6:58am trip, and
- Route 155: One additional trip at 7:25am to compensate passengers who previously had access to articulated vehicles on the 7:35am trip.

It is understood at present that there is no documented *TransLink* policy which explicitly states that redeployment of higher capacity vehicles to better match supply with passenger demand should result in maintenance of the current level of capacity, and the HFP routes listed in

Table 22 were excluded from the reallocation of higher capacity vehicles for the reasons indicated.

Table 22: Routes Excluded from Redeployment of High Capacity Vehicles

Route	Reason for being Excluded from HCV Project
412	Route 412 cannot be allocated as a Higher Capacity Route as it originates from the Toowong Bus Depot which currently does not accommodate high capacity vehicles. Additionally Brisbane Transport has advised that Stop 16 Adelaide Street cannot accommodate 14.5 metre vehicles (a shared stop with Route 109)
385	Route 385 is unsuitable as a Higher Capacity Route as the alignment it operates on cannot facilitate 14.5 metre vehicles, in particular along Coopers Camp Road. Additionally the bus stops at Bardon and Paddington are not set up to handle 14.5 metre vehicles
333 345	Both these bus services operate from the Virginia Bus Depot which currently does not accommodate higher capacity vehicles. KGS stop cannot accommodate 14.5 metre or articulated vehicles. Would result in excessive dead running associated with repositioning vehicles
196	Considering the current level of service and the alternative bus routes in the corridor (199 and CityGlider), Rroute 196 is not being considered as a Higher Capacity Route at this time
120	Route 120 was transitioned to a HFP route in June 2011. Currently there is insufficient demand for higher capacity vehicles on this route
200 and 222	Route 222 was upgraded to a full HFP route in June 2011. It has provided additional capacity throughout the Old Cleveland Road corridor resulting in a reduction in overcrowding on route 200. Currently there is no need to introduce Higher Capacity Vehicles on Routes 200 or 222 as both are not at capacity
180 and 100	These routes will be transitioned to HFP status on 31st October. TTA will monitor their performance and consider allocating higher capacity vehicles if demand warrants

3.20 Passenger Vehicle Transportation Award 2010

Fair Work Australia introduced the Commonwealth *Passenger Vehicle Transportation Award* on 1 January 2010. Subsequent amendments to the *Award* took effect on 21 June 2011. This modern national award replaced previous State specific awards (referred to as *Division 2B State Awards*) and has transitional arrangements in place effective up till 1 July 2014. The Commonwealth award applies throughout Australia to employees in the passenger transportation industry, defined by the *Award* as the transport of passengers by motor vehicle, limousine, hire car, bus, coach, electric tram, monorail or light rail vehicle. The *Award* does not apply to employees who are already covered by a modern enterprise award or an enterprise instrument commonly known as an *Enterprise Bargaining Agreement*.

Neither the making of this award nor the operation of its transitional arrangements was intended to result in a reduction in the net take-home pay of employees. The *Award* contains the minimum conditions of employment for employees and the monetary obligations imposed on their employers, but discharge of monetary obligations does not preclude any voluntary or employee negotiated over-award payments. Bus operators, for instance, may freely choose to provide monetary benefits above the minimum employee entitlements specified by the *Award*.

An employer and individual employee may agree to vary the application of certain provisions of the *Award* to meet the genuine needs of the employer and individual employee. The terms the employer and the individual employee may agree to vary are confined to:

- Arrangements for when work is to be performed,
- Overtime rates,
- Penalty rates,
- Allowances, and
- Leave loading.

It is understood that several *TransLink* bus operators have chosen to adopt the modern federal award, while most others have chosen to retain *Enterprise Bargaining Agreements* with their employees that were already in operation before the new federal award replaced existing State awards.

3.20.1 High Capacity Vehicle Allowance

Clause 15.1(b) of the *Passenger Vehicle Transportation Award 2010* stipulates that an employee required to drive an articulated bus during a shift will be paid an additional $10.00 allowance for that shift. This amounts to a 1.56% loading on the standard weekly rate defined in the *Award* for a Grade 3 employee earning $640/week. The award does not provide a precise definition of an articulated bus, but is reasonably assumed to exclude 14.5m rigid and double deck buses. It is understood that Brisbane Transport currently pays its bus drivers a 15% loading on shifts that include the driving of articulated buses, but it is unknown if this loading also currently applies to 14.5m rigid buses.

It is also uncertain whether bus drivers on the federal *Award* are paid the additional 1.56% for all shifts, regardless of whether an articulated or other high capacity vehicle was actually deployed on their respective shifts. Given allowances may be varied above the minimum set by the federal *Award*, some operators may choose for instance to pay all drivers who hold a HR class licence (refer Section 3.6.4.1) a high capacity bus shift allowance, as this would be an easier method of calculating the allowance payment when vehicle allocations are regularly changed on the day of operation.
We are also uncertain if other *TransLink* operators such as Thompson Bus Services, Surfside Bus Lines and Logan City Bus Service pay their high capacity vehicle drivers a HCV allowance or a pay loading, and forthcoming stakeholder interviews will attempt to ascertain this information.

3.20.2 Minimum Wage Rates for Drivers

The minimum wage rates for full-time adult drivers and other employees are prescribed in the federal *Award* for Grade 2 to Grade 6 employees inclusive. The *Award* also covers pay and conditions for part-time and casual employees and both are assumed to work less than 38 hours per week. Casual drivers attract an additional 25% loading over rates prescribed for full-time drivers of a similar grade.

The federal *Award* provides definitions for each grade of employee as summarised in Table 23 below. Grade 3 and higher drivers may operate heavy omnibuses and there is no distinction in these 4 *Award* classifications specifically given to drivers of high capacity buses.

Table 23: Driver Grades Defined in Passenger Vehicle Transportation Award

Grade	Description
Grade 2	A driver of a passenger vehicle with a carrying capacity of less than 25 school children to and/or from a school
Grade 3	An employee engaged in driving a passenger vehicle with a carrying capacity of 25 or more school children to and/or from school, or employee engaged in driving a passenger vehicle with a carrying capacity of less than 25 passengers on a specified route service which operates regularly between fixed terminals
Grade 4	Employees who efficiently operate passenger vehicles and issue tickets, balance and account for tickets and revenue, practice basic customer relations when providing information to passengers and the general public, inspect and monitor general conditions of the passenger vehicle, perform basic mechanical support duties and report and record information
Grade 5	An employee who - performs the duties of a driver with a sound understanding of operational work practices and procedures, performs activities of increasing complexity with some scope to exercise initiative in the application of established work procedures, may instruct other employees including on-the-job training, operates special services with a sound knowledge of the routes of other depots, instructs new drivers in route and passenger vehicle operations, inducts new drivers to aspects of depot operations and information, communicates with all types of customers with an advanced degree of courtesy and accuracy of information, and carries out duties associated with passenger surveys and service monitoring

Grade 6	Employees who are classified as supervisors and/or trainers and who perform more complex activities, which may require the exercise of knowledge and initiative in the application and establishment of work procedures. An employee at this level performs the duties of driver, plus as required, provides training, supervision, inducting and monitoring of trainee drivers, drives routes in other depots to cover vehicle schedules and assists in preparing rosters and amendments. This employee is required to have a customer service focus and is also required to provide support to operations officers at special events including supervision and coordination of transport movements, and is responsible for routine probationary service monitoring and assessment of new drivers

Most bus drivers operating *TransLink* urban routes would fall within the definition of Grade 4 employees or higher, given they already collect fares and issue tickets. Additional allowances are paid to drivers who supervise trainee drivers, but it is not known at this stage if this includes trainees on high capacity vehicles.

It would appear that minimum wage rates for junior bus drivers (aged 20 and under) are not applicable to bus drivers in Queensland, as the new Queensland driver licensing regime requires persons under 23 years of age to hold a learner's permit for 1 year, then a P1 licence for 1 year, a P2 licence for 2 years, and an open C or similar class license for another year before becoming eligible for a heavy vehicle licence.

3.20.3 Vehicle Allowance

The federal *Award* provides for employers to pay a vehicle allowance of $0.74/km however it does not provide a definition for the vehicle allowance and it is not clear if this applies to urban bus drivers or long distance coach drivers. This matter will also be clarified during stakeholder interviews.

3.20.4 Medical Examination Allowance

Bus drivers are expected to cover their own costs of obtaining a heavy vehicle licence and this expense is not normally covered by the operator but the federal *Award* provides for drivers to claim a *Medical Examination Allowance*. A medical examination is required by any employee applying for or renewing a heavy omnibus *Driver Authorisation* in Queensland and it is likely the *Medical Examination Allowance* would only apply to existing licence holders who need to apply for or renew their authorisations during work hours.

3.20.5 Fatigue Management

The *Award* sets out various rules on maximum hours of work which have presumably been aligned with those in the national heavy vehicle fatigue management regulations which will take precedence under future law. While there are no known fatigue management rules that would apply specifically to high capacity route bus drivers, HCV deployment in lieu of standard buses could reduce maximum HCV driver hours if considered necessary to contribute to improved driver fatigue management by bus operators.

Appendix A

Current DDA Exemptions for School Buses

Transport Standards Part	Comments
3.2 Access for passengers in wheelchairs	Requires that passengers with mobility aids must be able to enter and exit a conveyance (vehicle) and position their aids in allocated spaces, with or without the requested assistance of the bus driver
6.2 Boarding ramps	Specifies that a boarding ramp must comply with the relevant Australian Standard
6.3 Minimum allowable width (ramps)	-
6.4 Slope of external boarding ramps	Specifies the slope of boarding ramps, for both assisted and unassisted wheelchair access
8.2 When boarding devices must be provided	-
8.3 Use of boarding devices	Specifies that a boarding device must be provided at all designated bus stops
8.4 Hail-and-ride services	Specifies the use of boarding devices for Hail-and-ride services
8.5 Width and surface of boarding devices	-
8.6 Maximum load to be supported by boarding device	-
8.7 Signals requesting use of boarding device	-
8.8 Notification by passenger of need for boarding device	-
9.1 Minimum size for allocated space	-
9.4 Number of allocated spaces to be provided in buses	-
9.7 Consolidation of allocated parking spaces on vehicles	Suggests that allocated spaces should be consolidated
9.9 Use of allocated space for other purposes	Specifies that allocated spaces can be used for other purposes when not occupied
9.11 Movement of mobility aid in allocated space	Specifies that an allocated space must constrain movement of a mobility aid towards the front and sides of a conveyance (vehicle)
10.1 Compliance with Australian Standard (surfaces)	Specifies the ground and floor surface properties on conveyances (vehicles)
11.3 Handrails on steps	-
11.4 Handrails above access paths	-
11.5 Compliance with Australian Standards (grab rails)	Specifies that grab rails must comply with the relevant Australian Standard
11.6 Grab rails to be provided where fares are to be paid	-
11.7 Grab rails to be provided in allocated spaces	-
12.1 Doors on access paths	Requires that any doors along an access path not present a barrier to independent travel
12.4 Clear opening of doorways	-

12.6 Automatic or power-assisted doors	-
14.1 Stairs not to be sole means of access	-

Appendix B

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22 *Road Planning and Design Manual 2004, Queensland Department of Transport and Main Roads*

23 *South East Queensland Infrastructure Plan and Program 2010-2031*

24 *South East Queensland Regional Plan 2009-2031*

25 *TransLink Annual Report 2010/11*

26 *TransLink Network Plan 2011*

27 *TransLink Network Plan 2009 (Unpublished)*

28 *TransLink Public Transport Infrastructure Manual (Version 1) 2007*

29 *TransLink School Policy*

30 *TransLink Service Improvement Program Business Case - High Capacity Vehicle Deployment (Gateway 2)*

31 *TransLink Strategic Plan*

32 *Transport Infrastructure (Busway) Regulation 2002 (Reprint No. 1A, 2006)*

33 *Transport Infrastructure Act 1994 (Reprint No. 13E, 2012)*

34 *Transport Operations (Passenger Transport) Act 1994 (Reprint No. 8A, 2012)*

35 *Transport Operations (Passenger Transport) Regulation 2005 (Reprint No. 5C, 2011)*

36 *Transport Operations (Passenger Transport) Standard 2010 (Reprint No. 1A, 2011)*

37 *Transport Operations (Road Use Management - Mass, Dimensions and Loading) Regulation 2005 (Reprint No. 5, 2011)*

38 *Transport Operations (Road Use Management - Road Rules) Regulation 2009 (Reprint No. 2B, 2011)*

39 *Transport Operations (Road Use Management - Vehicle Standards and Safety) Regulation 2010 (Reprint No. 1C, 2011)*

40 *Transport Operations (Road Use Management) Act 1995 (Reprint No. 12B, 2012)*

41 *Transport Operations (TransLink Transit Authority) Act 2008 (Reprint No. 1D, 2010)*

42 *Transport Operations (TransLink Transit Authority) Regulation 2008 (Reprint No. 1B, 2008)*

43 *Transport Planning and Coordination Regulation 2005 (Reprint No. 2, 2010)*

44 *TTA Public Transport Infrastructure Planning Policy*

45 *TTA Public Transport Services Planning Policy*

46 *Vehicle Standard (Australian Design Rule 42/04 - General Safety Requirements) 2005*

47 *Vehicle Standard (Australian Design Rule 43/04 - Vehicle Configuration and Dimensions) 2006*

48 *Vehicle Standard (Australian Design Rule 44/02 - Specific Purpose Vehicle Requirements) 2006*

49 *Vehicle Standard (Australian Design Rule 58/00 - Requirements for Omnibuses Designed for Hire and Reward) 2006*

50 *Vehicle Standard (Australian Design Rule 59/00 - Standards for Omnibus Rollover Strength) 2007*

51 *Vehicle Standard (Australian Design Rule 65/00 - Maximum Road Speed Limiting for Heavy Goods Vehicles and Heavy Omnibuses) 2006*

52 *Vehicle Standard (Australian Design Rule 68/00 - Occupant Protection in Buses) 2006*

53 *Vehicle Standard (Australian Design Rule 80/03 - Emission Control for Heavy Vehicles) 2006*

54 *Vehicle Standard (Australian Design Rule 83/00 - External Noise) 2005*

Appendix C

Depot Evaluation Report

Document Information

Client	TransLink Transit Authority
Job Number	4746
Title	Research and Analysis of High Capacity Vehicle Use - Depot Evaluation for High Capacity Vehicles
Prepared by	MRCagney Pty Ltd Brisbane, Queensland
Date	24 September 2012

Quality Assurance Register

Issue	Description	Prepared by	Reviewed by	Authorised by	Date
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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis of high capacity vehicle *(HCV)* use within its South East Queensland network. The subject high capacity vehicle types nominated by *TransLink* for the study are already in service on its network and include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

This technical study assesses the suitability and readiness of 16 existing bus depots in South East Queensland for future deployment of the 4 alternative high capacity vehicle types. The bus operators and depots selected for evaluation in consultation with *TransLink* were:

- Clarks Logan City Bus Service
  - Loganlea Bus Depot, 42 Jutland Street, Loganlea
- Hornibrook Bus Lines
  - Clontarf Bus Depot, 19 Grice Street, Clontarf
  - North Lakes (Satellite) Bus Depot, Wills Street, North Lakes
- Park Ridge Transit
  - Park Ridge Bus Depot, 3830 Mount Lindsay Highway, Park Ridge
- Surfside Buslines
  - Coomera Bus Depot, Old Coach Road, Upper Coomera
  - Molendinar Bus Depot, 10 Mercantile Court, Molendinar
  - Tweed Heads Bus Depot, Ourimbah Road, Tweed Heads
- Veolia Transdev Queensland
  - Capalaba Bus Depot, 10 Smith Street, Capalaba
- Brisbane Transport
  - Bowen Hills Bus Depot, Abbotsford Road, Bowen Hills
  - Carina Bus Depot, Creek Road, Carina
  - Garden City Bus Depot, MacGregor Street, Upper Mount Gravatt
  - Richlands (Satellite) Bus Depot, Government Road, Richlands
  - Sherwood Bus Depot, Sherwood Road, Sherwood
  - Toowong Bus Depot, Dean Street, Toowong
  - Virginia Bus Depot, Ferric Street, Virginia
  - Willawong Bus Depot, Sherbrooke Road, Willawong
  - Trade Coast Bus Depot, Schneider Road, Eagle Farm (currently under construction).

1.2 Depot High Capacity Vehicle Suitability Evaluation Criteria

In this study, each depot has been evaluated for its suitability and readiness to maintain, service and accommodate the 4 high capacity vehicle types. Depots were inspected and assessed for:

- Existence and suitability of existing facilities, plant and equipment necessary to maintain and service each high capacity vehicle type,
- Adequate height, width and clearance of garage work bay roller access doors for manoeuvring and entry of each high capacity vehicle into existing covered mechanical, electrical and body maintenance work bays,
- Sufficient garage roof truss, pendant fixture and suspended service heights for worker safe hoisted undercarriage and bus roof-top maintenance of each high capacity vehicle,
- Adequate covered garage pit and/or work bay depth, inclusive of internal circulation passageways, or adequate garage building width between opposing drive-through access doors for floor level and hoisted chassis maintenance on the longer 14.5m rigid and 18m articulated buses, either under full cover, or partial cover to a level exterior concrete hardstand apron,
- Minimum clear approach length and width of existing garage hardstand aprons to safely manoeuvre, turn in and reverse out each high capacity bus type from existing garage maintenance work bays,
- Sufficient height and width of existing bus washing, refuelling, high pressure cleaning, tyre repair, and other bus servicing sheds and annexes for manoeuvring and entry of each high capacity vehicle type,
- Minimum clear approach and departure length and turning path width to drive each high capacity bus type into or through servicing sheds and annexes,
- Existing refuelling capability for each high capacity bus type, including where applicable, CNG and/or diesel refuelling bowsers and Adblue urea dispensers for new high capacity diesel buses fitted with Euro 5 (or later) environmentally rated SCA engines,
- Swept path template overlaying on all depot circulation and parking yard access corridors to ensure each high capacity bus type could be safely driven around and manoeuvred within all existing depot confines without accidental collisions or side swipes,
- Determination of maximum depot parking capacities for each high capacity bus type, based on existing depot yard layouts with appropriate modifications where necessary, for future high capacity vehicle parking and depot circulation. This has included development of concept designs for new yard parking schemes to accommodate high capacity vehicles in depots currently configured only to accommodate standard length 12.5m rigid buses,
- Impacts of each high capacity bus type on the depot standard bus parking capacity and depot fleet passenger carrying capacity, and
- Identification of the high capacity bus type(s) best suited for deployment at each depot.

1.3 Summary of Findings

Depot High Capacity Vehicle Maintenance, Servicing and Accommodation Assessments

In the context of this study, *Bus Maintenance* encapsulates all scheduled, preventative and reactive mechanical, electrical and body repair activities undertaken in each depot to maintain the roadworthiness, amenity and safety of its resident bus fleet. Maintenance activities were characterised by fault diagnostics, dismantling, repair or replacement of vehicle components and performed by qualified tradespersons or contractors with specialised knowledge and skills.

Bus maintenance tasks were typically performed under cover over garage pits or in work bays fitted out with external roller or folding doors, work benches, parts storage shelving, parts cleaning troughs, overhead lighting, single and 3 phase appliance power sockets, reticulated water and compressed air outlets. Specialised hand and power tools, inspection lights, test instruments, drum trolleys, mobile pump out and welding equipment, cleaning consumables, spare component assemblies and parts were invariably required at hand in garage work bays for tradespersons or contractors to undertake their maintenance tasks.

Where vehicles had to be raised for undercarriage maintenance in mechanical work bays; 6 mobile multi-post wheel hoists or adjustable height axle stands were additionally required. Where maintenance work had to be undertaken above the vehicle's roofline; mobile trestles, elevated work platforms or catwalks and roof truss tethered anti-fall safety harnesses were additionally required. Dedicated pits or work bays fitted with in-ground suspension shakers, brake testers and wheel aligners were needed for heavy vehicle safety testing, and a general workshop equipped with a spare parts and materials store, welding bay, essential machine tools such as a lathe, band saw, pedestal grinding wheel and press drill, an overhead radial or monorail chain hoist and fixed work stands were also needed for major vehicle assembly repairs such as engine and differential overhauls.

With the exception of spare components and parts unique to each vehicle type, the necessary human resources and maintenance facilities for future high capacity vehicle maintenance already existed at most depots assessed during the study and were already used to maintain existing buses. Where such didn't exist, maintenance was either being transferred offsite to a mother depot in the case of satellite bus depots, or outsourced to specialist contractors. Major accident repairs, full body repaints, structural rebuilds, transmission overhauls and electronic equipment repairs were commonly outsourced to specialist contractors by most bus operators.

Minor new maintenance equipment purchases such as additional pairs of multi-post hoists for high capacity vehicles, energy guidance system cylinder pressurisation and bellows removal tools for articulated buses, and higher work trestles and tethered harness cables for double deck buses were not considered in the study to be significant impediments to future high capacity vehicle deployment. Significant garage rebuilds, upgrades or modifications needed for future high capacity vehicle maintenance were however considered to be major impediments to future high capacity vehicle deployment and have included:

- Garage work bay roller doors incapable of being easily raised under existing wall or roof structures found too low to permit double deck bus entry,
- Garage roof trusses, overhead pendant fixtures and reticulated service pipes found too low for double deck bus hoisting and/or roof top repairs,
- Garage work bays too short for covered floor level or partially covered hoisted 14.5m rigid and articulated bus undercarriage maintenance, and

- Existing garage concrete aprons too narrow or short to turn and/or manoeuvre high capacity vehicles into maintenance work bays between existing door slides and wall or roof structural members.

In the context of this study, *Bus Servicing* encompassed routine vehicle upkeep tasks which did not involve dismantling or replacement of vehicle components. Bus servicing was performed by unskilled personnel such as drivers, cleaners and labourers, and completed either on an exterior hardstand, in an ancillary garage bay, or under a covered building lean-to, annexe or shed separated from and not requiring vehicle entry into the primary bus maintenance garage. Routine bus servicing tasks included:

- Bus exterior washing, interior cleaning, Adblue urea tank top-up and refuelling,
- High pressure chassis, engine compartment, wheel and undercarriage cleaning,
- Tyre storage, wear inspection, replacement, rotation and rim balancing,
- Alternator, water pump, air conditioner and radiator fan belt tightening or replacement,
- Chassis, suspension, axle, drive train, wheelchair loader and door mechanism greasing,
- Engine, transmission, differential and steering box oil replacement or top-up, and
- Water, water additive, pneumatic and hydraulic oil replacement or top-up.

At large bus depots, bus exterior washing, interior cleaning, Adblue top-up and refuelling were semi-automated on a two stop process line, and performed daily or bi-daily by bus drivers returning to depot, some with and others without the assistance of a rostered duty cleaner (or refueller in the case of compressed natural gas buses). All other abovementioned bus servicing tasks, including bus exterior washing in the case of small depot operators, were performed by full-time semi-skilled staff such as cleaners and labourers, or by contractors in the case of high pressure chassis cleaning.

Major facility rebuilds, upgrades or modifications needed for routine high capacity bus servicing considered to be significant impediments to future high capacity vehicle deployment included:

- Non-existent compressed natural gas (CNG) refuelling capability at Brisbane Transport depots for existing articulated buses. It has been noted from interviews with Brisbane Transport that it was no longer intended to procure more CNG articulated buses, and depot assessments assumed that any future new Brisbane Transport articulated buses, if procured, would be powered by diesel,
- Service building, annexe and shed roof trusses, overhead pendant fixtures and/or reticulated service pipes too low to permit double deck bus entry,
- Existing bus washing machine flail/brush spindles, water harvesting pipes and crossover frame heights too low for double deck buses, and
- Existing concrete aprons too narrow or short to manoeuvre high capacity vehicles into tyre repair bays between existing roller door frames and wall or roof structural members.

High capacity vehicle *Depot Accommodation and Circulation* constraints have been identified at 12 of the 16 assessed depots, but in every case, appropriate low cost modifications to existing depot yard circulation and parking schemes (described in Section 3.6) have enabled all high capacity vehicle types to be accommodated in all depots. None of the existing circulation constraints or yard modifications proposed was considered to be a significant impediment to potential future deployment of high capacity buses.

Tables appearing overleaf on the following 2 pages summarise the high capacity vehicle suitability assessments for the 8 Brisbane Transport and 8 private operator bus depots surveyed during the study.

Bus Depot	Mechanical Maintenance			Body/Electrical Maintenance			Bus Refuelling			Bus Exterior Washing			Bus Chassis Cleaning			Accommodation & Circulation		
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses
Brisbane Transport																		
Bowen Hills	No. Shed Roof Too Low	Yes	Yes. But Only Future Diesel Artics	No. Shed Roof Too Low	Yes	Yes	Yes	Yes	Yes. But Only Future Diesel Artics	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	No. Shed Roof Too Low	Yes	Yes	No. Will Need Resumption of Car Parking Spaces and Added High Capacity Bus Circulation and Exit on Gebbie Street		
Garden City	Yes	Yes	Yes	Yes. Will Need Elevated Catwalks	Yes	Yes	Yes	Yes	Yes	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	Yes	Yes	Yes	Yes. But Raise Water Harvest Pipe on Logan Rd Boundary	Yes	Yes
Carina	No. Won't Fit Under Roller Doors But Bus Can be Hoisted in North Building	Yes	Yes. Has Existing CNG Articulated Bus Maintenance Facilities	No. South Building Roof Too Low	Yes	Yes	No. South Building Roof Too Low	Yes	Yes. But Only 10 Max CNG Artic Buses or Future Diesel Artic Buses	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	Yes	Yes	Yes	Yes. But Would Need Bus Parking Lanes Along Eastern Boundary Kept Clear for Late Night High Capacity Bus Entry to Rear of Yard Lanes		
Virginia	No. Door Heights OK But Only Body Shed Roof High Enough	Yes	No. Shed Widths Too Short and Doors too Low to Hoist	Yes. Door Heights OK But Only Body Shed Roof High Enough	Yes	Yes. With Partial Cover	Yes	Yes	Yes	Yes. But Wash Roller Frame and Down Pipe Need To be Raised	Yes	Yes	Yes	Yes	Yes	Yes. But Existing Yard Lanes Would Need to be Shortened One 12.5m Rigid Bus Length to Enable High Capacity Bus Depot Circulation		
Willawong	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. Shed OK. Wash Roller Frame too Short	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Richlands	No. All Maintenance Required at Toowong Bus Depot	Yes. Partial Cover But All Hoisted Major Repair & Maintenance Required at Toowong Bus Depot		No. All Maintenance Required at Toowong Bus Depot	Yes	Yes	No. Roof Trusses & Braces Too Low	Yes	Yes. But Only Future Diesel Artics	No. Roof Too Low. Could Wash on Hard Stand	Yes	Yes	No. All Chassis Cleaning Woukd Need to be Completed at Toowong Bus Depot			Yes	Yes	Yes
Toowong	Yes	Yes	Yes	Yes	Yes	Yes	No. Service Shed Roof Trusses Too Low	Yes	Yes	No. Service Shed Roof Trusses Too Low	Yes	Yes	Yes	Yes	Yes	Yes. But Existing Yard Lanes Would Need to be Shortened One to Three 12.5m Rigid Bus Lengths in Sections to Enable High Capacity Bus Circulation		
Sherwood	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But Only Future Diesel Artics	Yes. Shed OK. Wash Roller Frame Too Short	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Bus Depot	Mech & Elect Maintenance			Body Maintenance			Bus Refuelling			Bus Exterior Washing			Bus Chassis Cleaning			Accommodation & Circulation		
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses
Clarks Logan City Bus Service																		
Loganlea	Yes	Yes	Yes	Yes. But With Minimal Height Clearance	Yes. With Partial Cover	Yes. With Partial Cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. Existing Yard Layout Could be Easily Modified Using Lanes for Improved High Capacity Bus Circulation		
Hornibrook Bus Lines																		
Clontarf	Yes	Yes	Yes. But Only In 3 Drive-Through Bays. Partial Cover Only in 16m Short Bays	Yes. Some Lights Would Need to be Raised in Drive-Through Bay	Yes	Yes. Partial Cover in Short Bays	Yes	Yes	Yes	Yes	Yes	Yes	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes	Yes	Yes
North Lakes	Yes. Basic Maintenance Only with All Hoisted Major Repairs and Maintenance Required at Clontarf Bus Depot			Yes. Basic Maintenance Only with All Major Maintenance and Repairs Required at Clontarf Bus Depot			Yes	Yes	Yes	Yes	Yes	Yes	Yes. With Chassis Cleaning at Clontarf Bus Depot			Yes. 6 Bus Bays at Rear and 1 Lane Bay on Eastern Side of Yard Would Need to be Kept Clear at All Times for High Capacity Bus Circulation		
Park Ridge Transit																		
Park Ridge	Yes. But 12 Bus Parking Bays in Front of Shed to be Kept Clear for Manoeuvring. Downpipe on Front of Shed to be Lifted			Yes	Yes	Yes	Yes. Would Need Adblue Dispenser for New High Capacity Buses			Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. But 12 Bus Parking Bays in Front of Maintenance Shed to be Kept Clear for High Capacity Bus Manoeuvring		
Surfside Buslines																		
Molendinar	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tweed Heads	No. All Repairs and Maintenance Only on Hard Stand Area	No. Covered or Partially Covered. But Can Only be Hoisted for Major Repairs and Maintenance on Garage Hard Stand		No. All Repairs and Maintenance Only on Hard Stand Area	Yes. Covered	Yes. Partially Covered	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But 31 (Currently Unused) Standard Bus Parking Bays Would Need to be Given Up for High Capacity Bus Circulation in Parking Yard		
Coomera	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Veolia Transdev Queensland																		
Capalaba	No. Door Height Too Low. All Maintenance & Repairs Only on Hard Stand	Yes	Yes	No. Door Height Too Low. All Maintenance & Repairs Only on Hard Stand	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But This Depot Uses Highly Packed First In-Last Out Yard Parking. High Capacity Bus Parking Would Require 7 Bus Parking Spaces in Access Corridor be Kept Clear Till Late Evening		

Depots Found Suitable for All High Capacity Vehicle Types

6 of the 16 assessed bus depots have been identified as universally suitable, with minimal or no major upgrades for maintenance, servicing and accommodation, of a large high capacity bus fleet comprising of

any high capacity bus type or combination of high capacity bus types. The universal high capacity bus depots identified were:

- Loganlea Bus Depot,
- Molendinar Bus Depot,
- Coomera Bus Depot,
- Garden City Bus Depot,
- Willawong Bus Depot, and
- Sherwood Bus Depot.

Double Deck Buses Not Recommended for any Brisbane Transport Bus Depot

5 old generation Brisbane Transport bus depots originally designed for maintenance of single deck buses have existing garage roller doors, building roof trusses, or service critical building heights too low for double deck bus entry. Old Brisbane Transport depots found unsuitable for double deck bus maintenance and/or servicing were the:

- Bowen Hills Bus Depot,
- Carina Bus Depot,
- Virginia Bus Depot,
- Toowong Bus Depot, and
- Richlands Satellite Bus Depot.

Earlier high capacity bus studies further identified a large number of existing low clearance railway bridges on the Ipswich Railway Line which present a formidable physical barrier to double deck bus operations at numerous locations from Darra inbound to the city, and with two other flood prone low railway bridges over Oxley Road at Corinda and Muriel Avenue at Rocklea, effectively block double deck bus road movements along the western, southern and eastern public road approaches to the Sherwood Bus Depot. Double deck buses could only be operated currently without low bridge avoiding route diversions on Brisbane Transport suburban bus services out of the Garden City and Willawong Bus Depots.

The inability to freely accommodate, maintain, service or operate double deck buses from 6 out of 8 existing bus depots makes this high capacity bus type a less flexible and viable option than single deck high capacity buses for future Brisbane Transport suburban bus operations. Deployment of double deck vehicles has therefore not been recommended for any Brisbane Transport bus depot.

Maximum Depot High Capacity Vehicle Parking Capacity Assessments

The majority of depots currently accommodated only standard 12.5m length rigid buses and utilised either nose-to-tail yard parking lanes or yard perimeter parking bays with narrow turning and circulation corridors designed to maximise standard bus parking densities. Whilst 12 of the 16 depots assessed required yard parking scheme modifications to enable high capacity bus entry and accommodation, major yard parking scheme changes were essentially confined to providing new forward in-out parking lanes for articulated buses in yards with perimeter parking bays only.

To determine which high capacity vehicle type made best use of the existing depot property within its boundary length, width and circulation constraints, maximum parking capacities were evaluated for every high capacity vehicle type and compared to the depot's standard bus parking capacity. These evaluations were performed for all high capacity vehicle types irrespective of whether their operators had adverse opinions about, or existing maintenance and servicing facilities were considered unsuitable for particular high capacity vehicle types, and the results of the evaluation appear in the table overleaf.

Bus Depot	Suitable (with Minor Upgrades)			Depot Refuelling Capability	TransLink Advised Depot Safe Working Capacity	Total TransLink Buses Currently Garaged	Assessed Maximum Depot Parking Capacity			
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses				12.5m Standard Rigid Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses
Brisbane Transport										
Bowen Hills	No	Yes	Yes (Note 9)	Diesel	112	111	112	54 (Note 6)	44	28
Garden City	Yes	Yes	Yes	CNG + Diesel	200	183	184	184	153	118
Carina	No	Yes	Yes (Note 10)	Diesel	160	174	185	183 (Note 6)	156	119
Virginia	No	Yes	Yes	CNG + Diesel	160	179	179	108 (Note 6)	80	58
Willawong	Yes	Yes	Yes	CNG + Diesel	200	193	222	222	185	148
Richlands	No	Yes	Yes (Note 9)	Diesel	45	32	56	49 (Note 6)	44	75
Toowong	No	Yes	Yes	CNG + Diesel	165	182	183	155 (Note 6)	132	108
Sherwood	Yes	Yes	Yes (Note 9)	Diesel	200	142	215 (Note 3)	215 (Note 6)	172	129
Trade Coast (Note 1)	Likely	Yes	Yes	Diesel (Note 2)	200	0	200 (Note 4)	200 (Note 4)	160 (Note 4)	120 (Note 4)
Clarks Logan City Bus Service										
Loganlea	Yes	Yes	Yes	Diesel	135	125	138 (Note 7)	136 (Note 7)	124 (Note 7)	51 (Note 7)
Hornibrook Bus Lines										
Clontarf	Yes	Yes	No	Diesel	60	48	52	25	21	9
North Lakes	Yes	Yes	Yes	Diesel	60	13	57	28	28	28
Park Ridge Transit										
Park Ridge	Yes	Yes	Yes	Diesel	120	80	121	119	74	19
Surfside Buslines										
Molendinar	Yes	Yes	Yes	Diesel	160	247	170	142	110	46
Tweed Heads	No	Yes	Yes	Diesel	150	61	150	113 (Note 6)	113	79 (Note 7)
Coomera	Yes	Yes	Yes	Diesel	125	0	190	186	144	126
Veolia Transdev Queensland										
Capalaba	No	Yes	Yes	Diesel	95	119	105 (Note 5)	50 (Note 8)	45 (Note 8)	12 (Note 8)

Note 1: As at 31 August 2012, the new Trade Coast (Eagle Farm) Bus Depot was still under development.
Note 2: Trade Coast is located close to a high pressure gas pipeline and could be developed as a new CNG + Diesel bus depot.
Note 3: Sherwood Bus Depot has sufficient reserve yard parking space to accommodate up to 258 standard 12.5m rigid buses.
Note 4: Based on TransLink advised depot parking capacity and similar yard lane layout to Willawong and Sherwood Bus Depots.
Note 5: Based on 105 first in-last out high density bus yard parking plus 26 standard 12.5m buses parked in on-site building.
Note 6: These depots are considered unsuitable for double deck buses because of building height or road access restrictions.
Note 7: Parking layout and access/circulation corridors to be modified at this depot for high capacity buses and numbers listed.
Note 8: Additional parking of high capacity vehicles in two on-site building through-running lanes would increase these capacities.
Note 9: BT articulated buses are currently CNG only. These depots would only be suitable for future diesel articulated buses.
Note 10: Carina Depot has an existing low pressure natural gas pipeline suitable for refuelling 10 CNG articulated buses/day.

Recommended High Capacity Vehicle Types Based on Depot Equivalent Standard Bus Capacity Reduction Impacts

The relative impacts of accommodating each high capacity vehicle type in each depot have been quantified in terms of the net decrease caused to the depot's existing standard bus parking capacity and the change in its standard bus fleet passenger carrying capacity with high capacity buses deployed to the maximum parking capacities indicated in the table above. Whilst accommodation of any particular high capacity bus type to its maximum depot parking capacity was considered unlikely in the near future, relative changes to equivalent standard bus capacities provided a useful comparison for recommending and ranking those high capacity bus types best suited to each depot site.

All depots have been determined to be suitable for maintenance and servicing of at least two alternative high capacity vehicle types, but the introduction of high capacity buses onto standard bus depot sites has generally incurred a high reduction in the depot's equivalent standard bus parking capacity. Loss of equivalent standard bus parking capacity was typically highest for 14.5m and 18m articulated buses and lowest for 12.5m double deck buses, the latter of which could be readily accommodated in the greatest number of existing standard bus parking spaces at all depots other than Tweed Heads. Further, no material loss of equivalent standard bus parking capacity was attributable to double deck buses accommodated at the Clontarf, Molendinar and Capalaba Bus Depots, and although not recommended for Brisbane Transport, incurred no loss of standard bus parking space at its 4 largest depots.

Across all depots, 14.5m rigid and articulated buses incurred an average 9% net reduction in standard bus parking capacity, where 12.5m double deck buses incurred only an average 4% net reduction.

Bus Depot	Suitable for This Depot (with Minor Upgrades)			Recommended for This Depot (as Ranked by Capacity)				Std Bus Capacity	Equiv Std Bus Parking Capacity Decrease			Equivalent Std Bus Passenger Capacity Increase/Decrease			
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses	12.5m Double Deck Buses	14.5m Rigid Buses	2 Door 18m Artic Buses	3 Door 18m Artic Buses	12.5m Standard Rigid Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	2 Door 18m Artic Buses	3 Door 18m Artic Buses
Brisbane Transport															
Bowen Hills	No	Yes	Yes (Note 1)	No	1	3	2	112	-6	-11	-9	31	-5	-24	-19
Garden City	Yes	Yes	Yes	No	1	3	2	184	0	-12	-18	127	6	-37	-15
Carina	No	Yes	Yes (Note 1)	No	1	3	2	185	0	-7	-3	126	8	-18	3
Virginia	No	Yes	Yes	No	1	3	2	179	-13	-24	-25	62	-9	-35	-25
Willawong	Yes	Yes	Yes	No	1	3	2	222	0	-10	-14	153	7	-38	-12
Richlands	No	Yes	Yes (Note 1)	No	1	3	2	56	-7	-11	-10	27	-1	-15	-13
Toowong	No	Yes	Yes	No	1	3	2	183	-21	-25	-22	86	-12	-40	-21
Sherwood	Yes	Yes	Yes (Note 1)	No	1	3	2	215	0	-18	-35	148	-2	-55	-32
Clarks Logan City Bus Service															
Loganlea	Yes	Yes	Yes	1	4	3	2	138	-2	-15	-6	92	16	-11	-2
Hornibrook Bus Lines															
Clontarf	Yes	Yes	No	1	2	No	No	52	0	-1	-4	17	4	-6	-4
North Lakes	Yes	Yes	Yes	1	2	No	No	57	-17	-17	-17	5	-7	-7	-2
Park Ridge Transit															
Park Ridge	Yes	Yes	Yes	1	2	3	3	121	-2	-12	-9	80	9	-5	-2
Surfside Buslines															
Molendinar	Yes	Yes	Yes	1	4	3	2	170	0	-15	-2	98	-5	-14	-6
Tweed Heads	No	Yes	Yes	No	1	3	2	150	-31	-16	-16	59	8	-39	-25
Coomera	Yes	Yes	Yes	1	2	4	3	190	-4	-11	-22	124	-11	-34	-11
Veolia Transdev Queensland															
Capalaba	No	Yes	Yes	No	1	2	2	105	0	0	0	35	14	-3	-1
					Equiv Std Bus Totals			2319	-103	-205	-212	1271	19	-383	-186
					Percent of Std Bus Capacity				**-4%**	**-9%**	**-9%**	**55%**	**1%**	**-17%**	**-8%**

High capacity vehicle impacts on the depot's standard bus fleet passenger carrying capacities were also compared and quite significant differences emerged between the alternative vehicles.

When compared at fully seated plus 50% standing loads, double deck buses increased fleet carrying capacity at every depot, averaging a substantial 55% net increase across all depots. 14.5m rigid buses increased the fleet passenger carrying capacity in half the depots assessed, but decreased it in half the other depots, averaging a 1% net increase across all depots. Articulated buses substantially decreased fleet passenger carrying capacity in every depot, averaging a 17% reduction across all depots for the 2 door articulated buses, and 8% reduction for the 3 door articulated superbuses.

The sensitivity of equivalent standard bus passenger carrying capacity assessments to standing loads was tested over the range of 25% to 100% standing, and while a 3% improvement was observed for the 3 door articulated bus, relative assessments remained virtually unchanged between the 4 high capacity vehicle types.

Recommendations and rankings for the 4 high capacity types have been listed in the assessment table above and summarised as follows:

- Double Deck Buses have been recommended as the best high capacity vehicle choice for private operator depots where they can be accommodated, maintained and operated,
- 14.5m Rigid Buses have been recommended as the best high capacity bus choice for all Brisbane Transport depots and for private operator depots where double deck buses cannot be accommodated, maintained or operated, but excluding Loganlea and Molendinar where a high parking capacity loss would be incurred for the 14.5m rigid bus,
- 3 Door Articulated Buses have been only been recommended at Loganlea and Molendinar Bus Depots, based on loss of parking capacity with 14.5m buses, and
- 2 Door Articulated Buses have not been recommended for deployment to any depot.

Alternately Extended Depot Bus Parking Lanes

Review of all the assessed depot layouts has indicated that bus yards with nose-to-tail parking lanes achieve 5 to 15% higher equivalent standard bus parking densities (i.e. buses per unit area of yard parking space) than yards configured with perimeter parking bays. All existing Brisbane Transport and 3 new private operator depots had implemented nose-to-tail bus parking lanes, but when the lanes were converted, and their circulation accesses widened for parking high capacity vehicles, equivalent standard bus parking space was reduced generally in accordance with the colour coded table and legend below.

12.5m Standard Rigid Bus	12.5m Double Deck Bus	14.5m Rigid Bus	18m Articulated Bus
2	2	1	1
3	3	2	2
4	4	3	2
5	5	4	3
6	6	5	4
7	7	6	5
8	8	7	5
9	9	7	6
10	10	8	7

(green)	<6% Equivalent Standard Bus Parking Capacity Loss
(yellow)	6% - 15% Equivalent Standard Bus Parking Capacity Loss
(red)	>15% Equivalent Standard Bus Parking Capacity Loss

It has been however been demonstrated by the Sherwood Bus Depot example appearing in Section 3.7.2 of the report that lost high capacity vehicle parking capacity could potentially be recovered in most depots by alternately extending lanes into yard circulation corridors widened for high capacity bus turning.

2. High Capacity Bus Depot Facilities

2.1 Study Background

This technical study investigates the suitability of 16 existing bus depots in South East Queensland for future deployment of 4 alternative high capacity vehicle (*HCV*) types, namely the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

Criteria used to evaluate the suitability and compatibility of each depot for future high capacity vehicle deployment have included detailed assessments and checks for:

- Adequate height, width and clearance of garage work bay roller access doors for manoeuvring and entry of each high capacity bus type into existing covered mechanical, electrical and body maintenance work bays,
- Existence of sufficient garage roof truss, pendant fixture and suspended service heights for worker safe hoisted undercarriage and standing bus roof-top maintenance on each high capacity vehicle type,
- Adequate work bay depth, inclusive of internal circulation passageways, or garage building width between opposing drive-through garage access doors for both floor level and hoisted chassis maintenance on 14.5m rigid and 18m articulated buses, under full or partial cover to levelled concrete hardstands,
- Minimum approach length and width of existing garage hardstand aprons to manoeuvre, turn in and reverse out each high capacity bus type from existing garage maintenance work bays,
- Sufficient height and width of existing bus washing, refuelling, high pressure cleaning, tyre repair, and other onsite servicing sheds or annexes for entry of each high capacity vehicle type,
- Existence of sufficient approach and departure length and swept turning path width to drive each high capacity bus type into or through onsite servicing sheds and annexes,
- Existing depot refuelling capability for each high capacity bus type, including where applicable, CNG or diesel refuelling bowsers and Adblue urea dispensers for new high capacity diesel buses likely to be fitted with Euro 5 or higher environmentally rated SCA engines,
- Swept path template overlaying on all existing depot bus circulation and parking yard access corridors to ensure each high capacity bus type can be safely driven around and manoeuvred within all existing depot confines,
- Development of concept designs for new yard parking layouts and circulation accesses to accommodate high capacity vehicles in depots currently configured only to accommodate standard 12.5m length rigid buses,
- Determination of maximum depot parking capacities for each high capacity bus type, based on existing depot layouts with appropriate modifications for future high capacity vehicle parking and circulation,
- Quantification of the impacts of each high capacity bus type on the depot equivalent standard bus parking capacity and its equivalent standard bus fleet passenger carrying capacity, and
- Identification of the high capacity bus type(s) best suited for deployment at each depot.

2.2 High Capacity Vehicle Maintenance and Servicing Facilities

2.2.1 Portable Hand Tools and Test Equipment

Portable hand tools and test equipment needed to maintain high capacity buses in existing bus garages will, in the main, be identical to those already procured and in use for maintenance of standard 12.5m rigid buses. Different facilities, mobile and fixed plant will however be required to maintain the longer chassis and bodies of single deck high capacity buses, and the higher body of the double deck bus.

2.2.2 Exterior Hardstand Bus Maintenance Work Areas

Uncovered exterior concrete hardstands similar to that shown below in Figure 1 can be used to maintain a small fleet of buses on most days of the year in South East Queensland sunny climatic conditions, and can accommodate both standard 12.5m rigid buses and all high capacity vehicle types. However exterior hardstand work areas cannot generally be used for underfloor chassis maintenance at night or during wet weather and when protracted periods of rainy weather set in, reliance on exterior hardstand work areas may lead to a number of stopped buses with little or no prior warning.

Figure 1: Uncovered Exterior Hardstand Work Area (*Photo: Surfside Buslines and Endurequip*)

Undercarriage mechanical and electrical bus maintenance is typically expedited on exterior hardstand areas using 4 or 6 mobile multi-post hoists similar to those depicted above in Figure 1, but there are recognised health and safety risks to tradespersons working on exterior hardstands continuously exposed to solar radiation, extremes of hot and cold weather, unpredictable wind gusts and sudden rain showers. Wet electrical power appliances, mobile hoist plugs and leads laid across an exterior hardstand work area may become live or randomly drop out electrical safety protection devices, create trip, slip and fall hazards to maintenance personnel, can be accidentally driven over when trying to relocate buses off the hardstand in a hurry, and hoisted buses can become trapped aloft on wet hoists.

Latest generation battery powered mobile multi-post hoists manufactured by companies such as MAHA and illustrated overleaf in Figure 2 are cable free and eliminate many of these recognised electrical safety hazards, but only one bus depot (viz. the Brisbane Transport Sherwood Bus Depot) visited during this study owned and operated cable free battery powered multi-post hoists and deployed them only within their covered garage work spaces.

Figure 2: Cable Free Battery Powered Mobile Multi-Post Hoist (*Photo: MAHA GmbH & Co*)

Portable undercarriage inspection lamps and power tools, test instruments and toolboxes, mobile welding and pumping equipment, parts storage shelving, work stands and benches needed to be readily at hand to tradespersons completing underfloor maintenance work on buses cannot be left unsecured and exposed to the weather on exterior hardstands, and when used for such, suffer faster deterioration. Further, mechanical and body maintenance requiring tradespersons or contractors to climb on top of bus roofs cannot generally be undertaken with safely on uncovered exterior hardstand work areas.

2.2.3 Covered Garage Maintenance Pits and Work Bays

Weather protected, roller or folding door accessible, well lit, well ventilated and naturally exhausted interior pit or floor level work bays fitted with reticulated town water, single and 3 phase power and compressed air tool outlets, parts storage shelving and work benches are considered to be healthier, safer, faster, more reliable and more efficient for high turnaround bus maintenance than exterior hardstand areas. Fully covered bus maintenance work bays enable implementation of 24 hour x 7 day and night work shifts, and when also fitted with roller or folding doors, can be closed at any time to secure and protect personnel, equipment and vehicles from the elements.

Figure 3: Bus Underfloor Maintenance Pit (*Photo: Clarks Logan City Bus Service*)

Bus chassis mechanical and electrical maintenance frequently requires work to be completed underfloor. Some (generally older) garages incorporate maintenance bays with longitudinal drive-on pits for underfloor maintenance similar to that shown above in Figure 3, but because pits need to be accessed by steep internal ladders covered over by a parked vehicle, are narrow, difficult to keep clean and drained, and are themselves recognised as potential fall and back strain hazards, modern garages now tend to only utilise mobile multi-post hoists augmented with adjustable height wheel stands to hoist vehicles above head height, where personnel can safely work on level floors. Buses need to be hoisted on both exterior hardstand and interior work bays to a height of approximately 1750mm above floor level (*AFL*) for tall tradespersons to continuously work below without excessive crouching or risk of back strain.

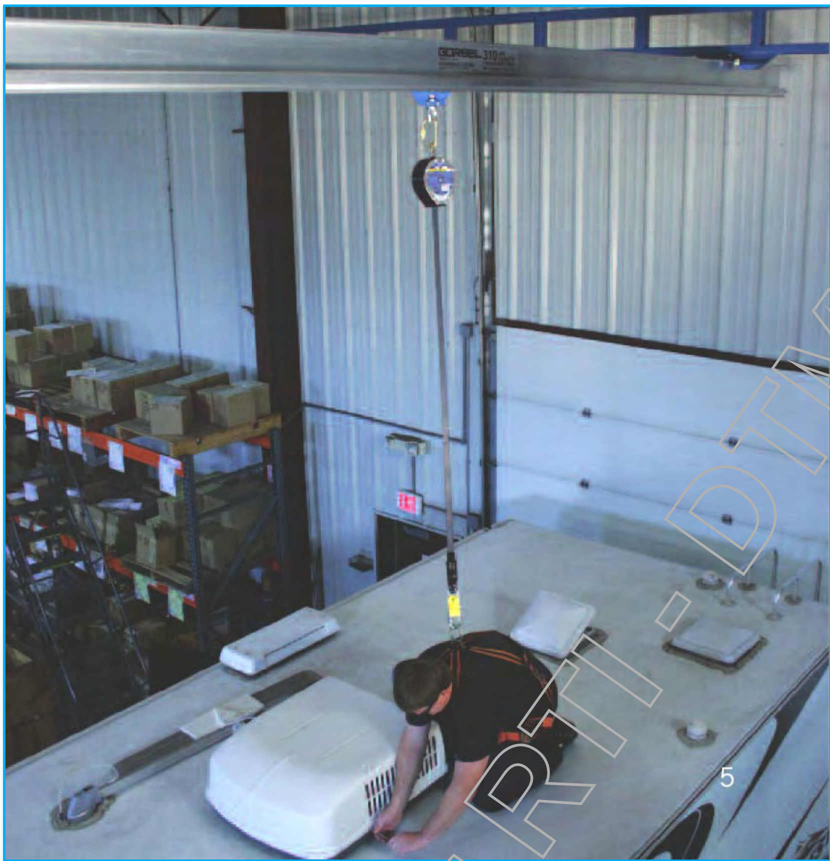
Modern garage work bays also address personnel safety, adopting high bay pendant luminaires for shadow-free high luminance artificial lighting, suspended multi-post hoist cables, power outlets, compressed air and water hoses to deliver services both above and off-floor as illustrated below in Figure 4.

Figure 4: Modern Garage Maintenance Work Bays (*Photo: Brisbane Transport and Endurequip*)

The clear height and bus turn-in manoeuvring width of covered maintenance work bay roller or folding door openings, work bay length, and below roof truss or suspended service fitting height clearance ultimately determine which high capacity vehicle types can be maintained within existing covered garage buildings. For existing garage covered work bays with adequate door height and width clearances, it is possible to reverse a longer length high capacity vehicle into a standard 12.5m rigid bus bay, work on the rear sections of the vehicle under cover, turn around and forward drive the vehicle back into the bay and complete work on its forward sections under cover. If garage work bays or pits have opposing high roller door openings suitable for drive-through, or a single high roller door opening onto a level exterior concrete hardstand apron as found at many existing old garages, longer 14.5m rigid and 18m articulated buses can alternatively be hoisted partly over the work bay and partly on the hardstand, thereby providing partial, but acceptable, weather protected work cover.

A maintenance need also exists in garages for tradespersons or contractors to occasionally stand on bus roofs to repair/replace leaking or damaged roof moulds, engine air intakes, air conditioners, ventilation or emergency escape hatches and radio or GPS equipment antennas. Increased demand for roof top work applies particularly to compressed natural gas (CNG) buses where high pressure shut-off valves need to be regularly closed for welding, gas cylinder replacements or engine fuel component repairs, and CNG cylinders installed in lift off carry frames need to be hoisted off and onto buses for compulsory annual and 5 yearly inspection and static pressure testing.

Figure 5: Tethered Anti-fall Safety Harness for Bus Roof Top Work



To carry out bus maintenance above the vehicle roofline, tradespersons or contractors must access the vehicle roof off a mobile trestle or scissor lift elevated platform brought alongside the vehicle, or from a drive-in fixed height catwalk erected level with the vehicle rooftop. While working on the vehicle roof, repairers must be safely tethered to a recoiling anti-fall safety harness underslung by rollers off an overhead beam or taut wire cable running the length of the vehicle similar to that depicted above in Figure 5. When tethered by harness, the repairer must be able to stand fully erect on the bus roof below roof trusses, luminaires, air ducts, hoists and other suspended objects likely to cause an accidental head injury or fall.

Where pits are not incorporated in covered work bays for routine bus maintenance, the need to either hoist the bus and stand under its chassis, or to stand on the vehicle's roof adds an extra above floor level *(AFL)* clearance imposition to the underside of roof trusses and roof suspended fixtures or services of approximately 2.4m to 2.8m to the overall vehicle height.

The additional 1.1 - 1.2m height of a double deck bus over that of single deck high capacity buses has been identified as a significant barrier to its maintenance in many existing SEQ covered garage buildings originally designed for single deck 3.1m to 3.4m high buses. By way of example, the new Brisbane Transport Willawong garage work bays shown above in Figure 4 have a raised folding door height of around 4.4m, close to the height of the Bustech double deck bus, and their interior service pipe and roof truss tie clearances were found to be precariously close to the raised AFL height needed to stand fully erect under, and taut harness wire height needed to stand fully erect on the double deck bus.

Only 3 SEQ bus operators and 6 of their new depots have industrial height garage maintenance buildings similar to the Clarks Logan City Bus Service garage illustrated below in Figure 6 with the necessary minimum door height and width clearances for turn-in bus manoeuvring, 19m or longer covered work bays, adequate side, front and rear clear working spaces, and rear of work bay walking and mobile plant accesses to readily accommodate the entire range of high capacity bus dimensions.

Figure 6: Industrial Standard High Bay Garage Building (*Photo: Clarkes Logan City Bus Service*)

2.2.4 Covered Bus Servicing Annexes and Sheds

Bus servicing covers a range of routine bus maintenance activities which do not involve substantial fault diagnosis, dismantling or replacement of vehicle components by qualified tradespersons or contractors. Servicing tasks are typically undertaken by unqualified personnel such as bus drivers, cleaners and labourers and completed on an exterior hardstand, in an ancillary garage bay, or under a covered building lean-to annexe or shed separated from the primary maintenance garage.

Common routine bus servicing activities include:

- Bus washing, bus interior cleaning, tyre pressure checking, Adblue top-up and refuelling,
- High pressure chassis, engine compartment, wheel and undercarriage cleaning,
- Tyre storage, wear inspection, replacement, rotation and balancing,
- Alternator, water pump, air conditioner and radiator fan belt tightening or replacement,
- Chassis, suspension, axle, drive train, wheelchair loader and door mechanism greasing,
- Engine, transmission, differential and steering box oil replacement or top-up, and
- Water, water additive and hydraulic oil replacement or top-up.

Most South East Queensland bus operators have covered drive-through bus servicing annexes or sheds for daily refuelling, Adblue dispensing, interior cleaning, tyre pressure checking and periodic wash down of their vehicles.

Large bus operators utilise automatic drive-through flail or stiff roller brush washing machines similar to that illustrated below in Figure 7 to wash their bus exteriors on a daily, bi-daily or twice-weekly exterior wash down cycle, while small bus operators prefer to manually wash their bus exteriors less frequently using low pressure water and detergent wash down brooms. Automatic drive-through washing machines can wash large fleet bus exteriors at a typical maximum rate of 30 - 40 vehicles per hour, where manual hand broom washing is typically limited to 4 – 5 standard 12.5m standard size buses per hour down to 3 - 4 high capacity single or double deck buses per hour.

Figure 7: Automatic Drive-Through Roller Brush Bus Washing Machine

Daily bus refuelling is typically undertaken by drivers on their return to depot, either after the first morning or last evening work shift, and refuelling operations typically include other ancillary tasks such as cabin debris removal and sweep out (or vacuuming), tyre pressure checking and re-pressurisation, engine and windscreen washer water level checking and top-up; and on new model Euro 5 diesel buses, Adblue urea tank top-up. These ancillary refuelling tasks are, more often than not, split between drivers and a rostered duty cleaner or full time bus refueller in the case of CNG buses.

Depot bus refuelling and washing annexes or sheds are invariably open-sided structures similar to those shown below in Figure 8. In practice, daily bus refuelling operations need to be physically separated from bus washing machine or manual broom wash down operations to prevent refuelling bays becoming contaminated with wash-down water or wind carried overspray, and to prevent chemically treated recycled wash down water being contaminated with diesel, oil, Adblue and engine anti-freeze spills.

Figure 8: Covered Drive-Through Bus Refuelling Sheds (*Photos: Hornibrook Buslines*)

Where automatic bus washing machines have been installed by large depot bus operators in older service sheds but only designed to wash up to a nominal single deck bus height of around 3m, these older machines will not wash the upper deck windows, body panels and exterior roof covings above the lower level of a double deck bus and such would have to be cleaned manually by broom or by a mobile drive around high capacity bus washing machine such as the unit shown below in Figure 9. These mobile bus washing units can fully wash the exteriors of 4 to 8 single or double deck high capacity buses per hour.

Figure 9: Mobile Drive Around High Capacity Bus Washing Machine

2.2.5 High Pressure Chassis Cleaning Aprons, Annexes and Sheds

Bus chassis and floor frames, wheels, engine compartments and undercarriages gradually build up dry hard thick crusts of wheel thrown small stones and gravel, and moist layers of diesel, exhaust and oil soaked dust, the latter of which poses a potential underfloor fire hazard if left untreated. Depending on the condition and sealing of road surfaces in the vehicle's service areas, these residues must be periodically scoured off at around 3 to 6 monthly intervals using either automatic or manually operated steam or detergent-boiled water high pressure jet nozzles.

Figure 10: Embedded Drive-Over High Pressure Jet Nozzle Chassis Cleaner

The water and thick road grime sludge removed during steam or high pressure jet chassis cleaning must be captured within a bunded or funnel-sectioned concrete apron, its water and condensate filtered and separated out to sewer, and the sludge piped to an underground holding tank for periodic removal by an industrial waste mini-tanker. High pressure chassis cleaning is normally carried out as both a separate operation to, and in a separate location from, bus exterior washing.

Covered pits or grates with embedded drive-over automatic chassis high pressure cleaning nozzles similar to those shown above in Figure 10 have been installed in some large operator bus garages, but most SEQ bus operators, including Brisbane Transport, use an exterior covered shed or open concrete apron equipped with an in-ground hydraulic bus hoist or drive-on ramp to clean their bus chassis using manual high pressure steam or high pressure detergent-boiled water lances. Manual chassis cleaning does a superior job to automatic pressure nozzle cleaning, but must be performed by cleaners suited up from head to toe in personal protective apparel including full cover industrial rain coats and hats, rubber boots and gloves, goggles and face masks. Manual chassis cleaning is an extremely hot, dirty and labour intensive task, and cleaners required to perform this type of work need regular breathers and can only reasonably be expected to clean from 10 - 13 standard size bus chassis per week. This throughput drops to around 8 – 9 larger size articulated or 14.5m rigid buses per week.

Queensland Department of Transport and Main Roads machinery inspectors will either refuse to inspect or stop buses found with excessive build-ups of undercarriage road grime and oil or diesel soaked residues, and chassis cleaning cycles are usually intensified in the lead-up to compulsory TMR 6 monthly bus machinery inspections. Because of the continuously wet, hot and greasy conditions which permeate bus chassis cleaning areas, underfloor pits and powered multi-post hoists cannot generally be used for manual chassis cleaning, but multi-post hoists can be used to place buses onto fixed height stands. This adds additional labour to the overall task, because high pressure cleaning aprons also have to be steam or high-pressure cleaned after each chassis clean to continually eliminate slippery work surfaces.

Similar problems arise to those described for exterior refuelling and bus washing sheds where over height or over length high capacity vehicles can't be easily hoisted, driven into or physically accommodated within existing covered chassis annexes and cleaning sheds originally designed for standard length 12.5m rigid buses.

2.3 High Capacity Vehicle Depot Circulation and Yard Parking

2.3.1 Garage Maintenance Bay and Service Shed Bus Manoeuvring

Australian Design Rule ADR43/04, Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* and the proposed new national *Heavy Vehicle Regulation 2012* stipulate the dimensional limits appearing overleaf in Table 1 for standard and high capacity heavy omnibuses registered for use on Queensland roads. The inner and outer turning circles listed in Table 1 are not specified at any particular travel speed in the design rule or either regulation, and are assumed to apply at a maximum bus turning speed of 5km/h.

In addition to legislated dimensional limits, *Austroads* has published a set of inner/outer wheel track turning circle and body wall-to-wall swept path templates for each high capacity vehicle type which it recommends for design of public road lanes, kerbs and roundabouts and for off-road building access manoeuvres, circulation paths and vehicle parking yards. Modified *Austroads* swept path templates have been regenerated in Figure 11 through Figure 15 using *AutoTurn Version 8.1* for the specific axle groups, wheelbases, front and rear overhangs and steering lock angles applicable to the high capacity bus types currently operating in South East Queensland.

Table 1: ADR43/04 and Heavy Vehicle Regulation Omnibus Permitted Dimensional Limits

Configuration or Dimension	2 Door 12.5m Rigid Bus (Reference)	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Maximum Length	12.5m	12.5m	14.5m	18m	18m
Maximum Height	4.3m	4.4m	4.3m	4.3m	4.3m
Maximum Width	2.5m	2.5m	2.5m	2.5m	2.5m
Outer Turning Circle	25m	25m	25m	24m	24m
Inner Turning Circle	Not Applicable	Not Applicable	Not Applicable	5.3m	5.3m
Rear Overhang	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	3.7m	3.7m

5km/h swept path templates illustrated in Figure 11 through Figure 15 have been used to assess slow vehicle manoeuvring and turns into garage exterior hard stand bays, covered work bays and pits, refuelling sheds, body wash down sheds and chassis cleaning sheds. Coloured 5km/h swept path templates appearing in Figure 11 through Figure 15 have been used to identify high capacity bus turns on all depot aerial views appearing in Section 3.6.

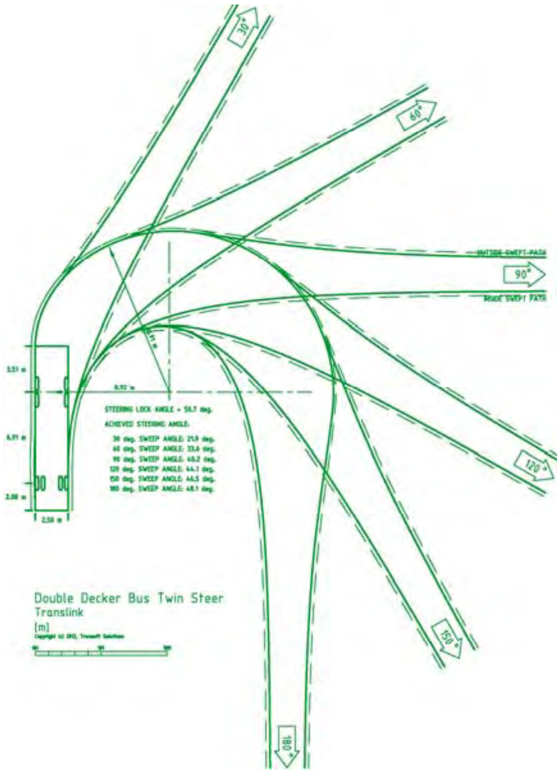
Austroads recommends a minimum 600mm side clearance be allowed to curbs, walls, door openings, poles and other solid vertical objects either side of its published vehicle paths when driven at 5km/h. These clearance envelopes have been illustrated in broken outline on the 5km/h swept path templates and used in all high capacity vehicle slow speed manoeuvring evaluations.

2.3.2 Depot and Parking Yard Bus Circulation

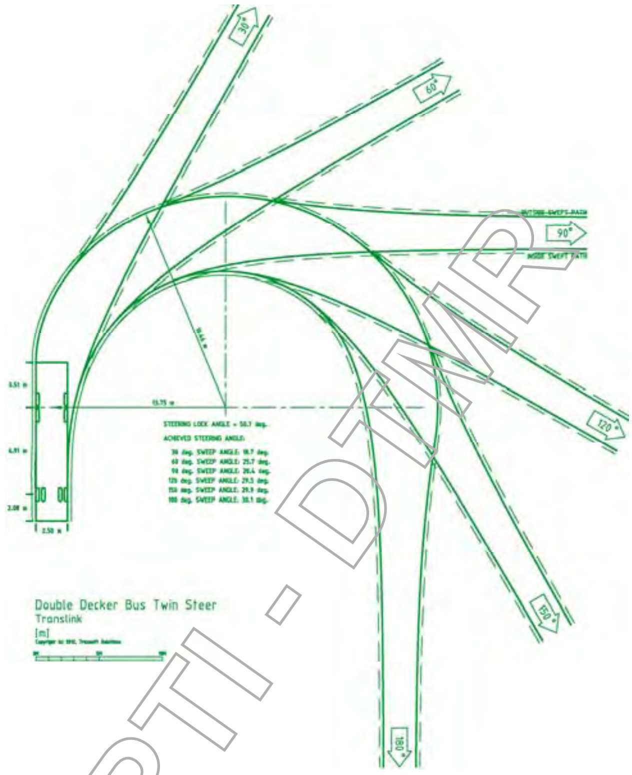
The 15km/h swept path templates shown in Figure 11 through Figure 15 have been adopted to assess most depot and parking yard circulation and access corridors between buildings to garage work bays and service sheds. Coloured 5km/h swept path templates appearing in Figure 11 through Figure 15 have been used to identify high capacity bus turns on all depot aerial views appearing in Section 3.6.

Austroads recommends a minimum 600mm side clearance to curbs, walls, poles and other solid objects either side of vehicle paths when driven at speeds of 5 to 15km/h. These clearance envelopes are shown in broken outline on the 15km/h swept path templates and have been used in most high capacity bus depot circulation evaluations. Circulation assessments have also included identification of existing low aerial cable crossings, building awning and soffit overhangs and tree branches likely to impact double deck bus circulation between existing depot and garage buildings.

Figure 11: 12.5m Twin Steer Double Deck Bus Swept Path Templates at 5km/h and 15km/h

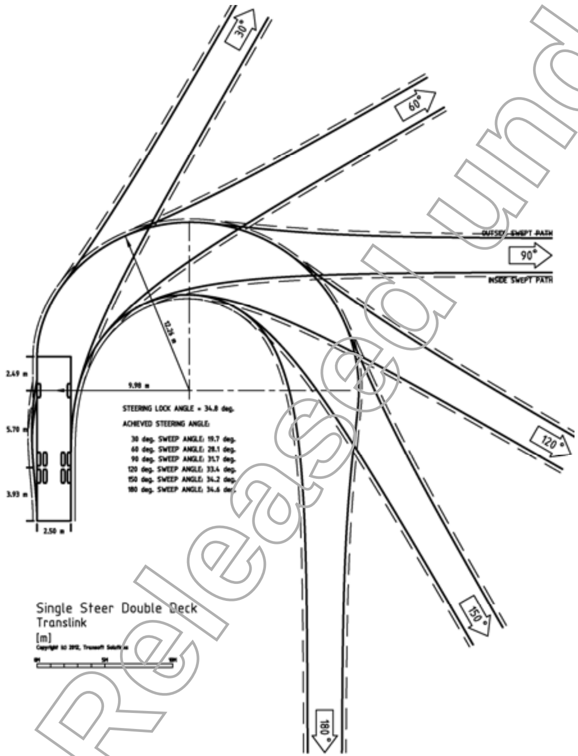


12.5m Twin Steer Double Deck Bus at 5km/h

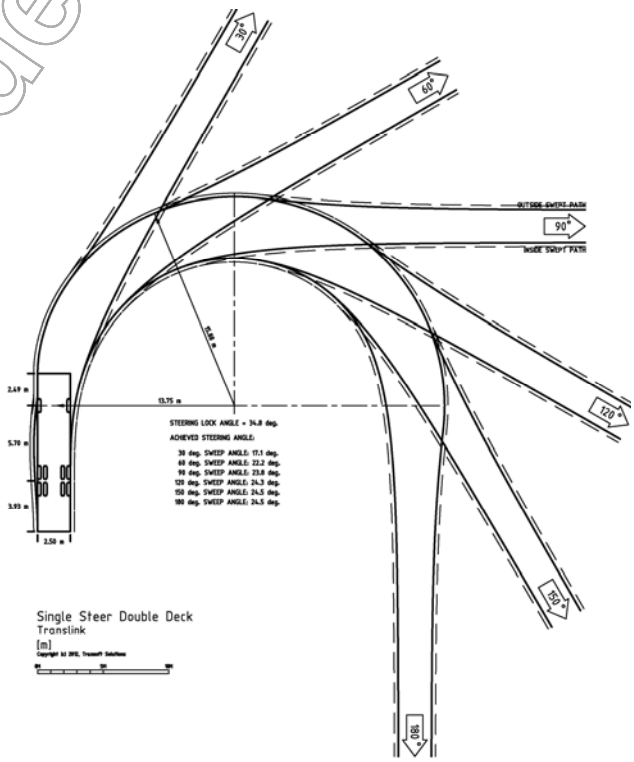


12.5m Twin Steer Double Deck Bus at 15km/h

Figure 12: 12.5m Single Steer Double Deck Bus Swept Path Templates at 5km/h and 15km/h

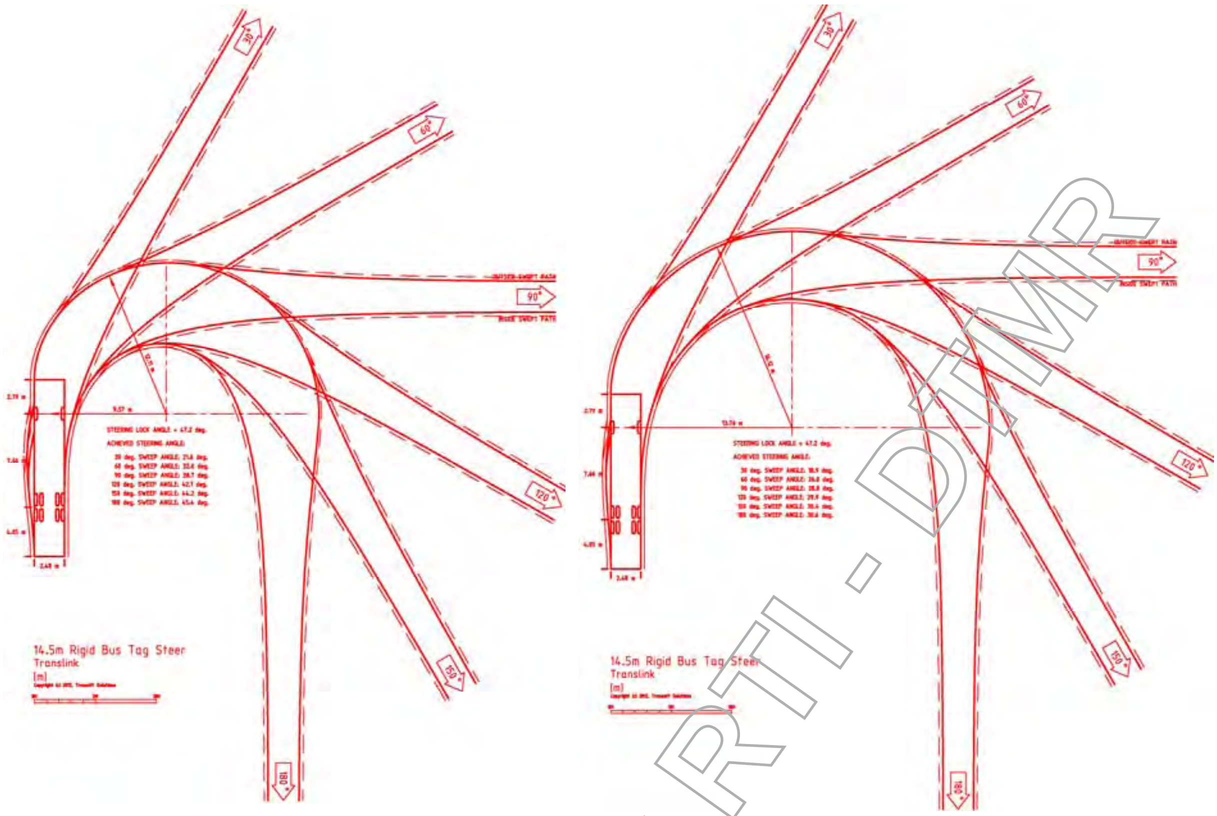


12.5m Single Steer Double Deck Bus at 5km/h



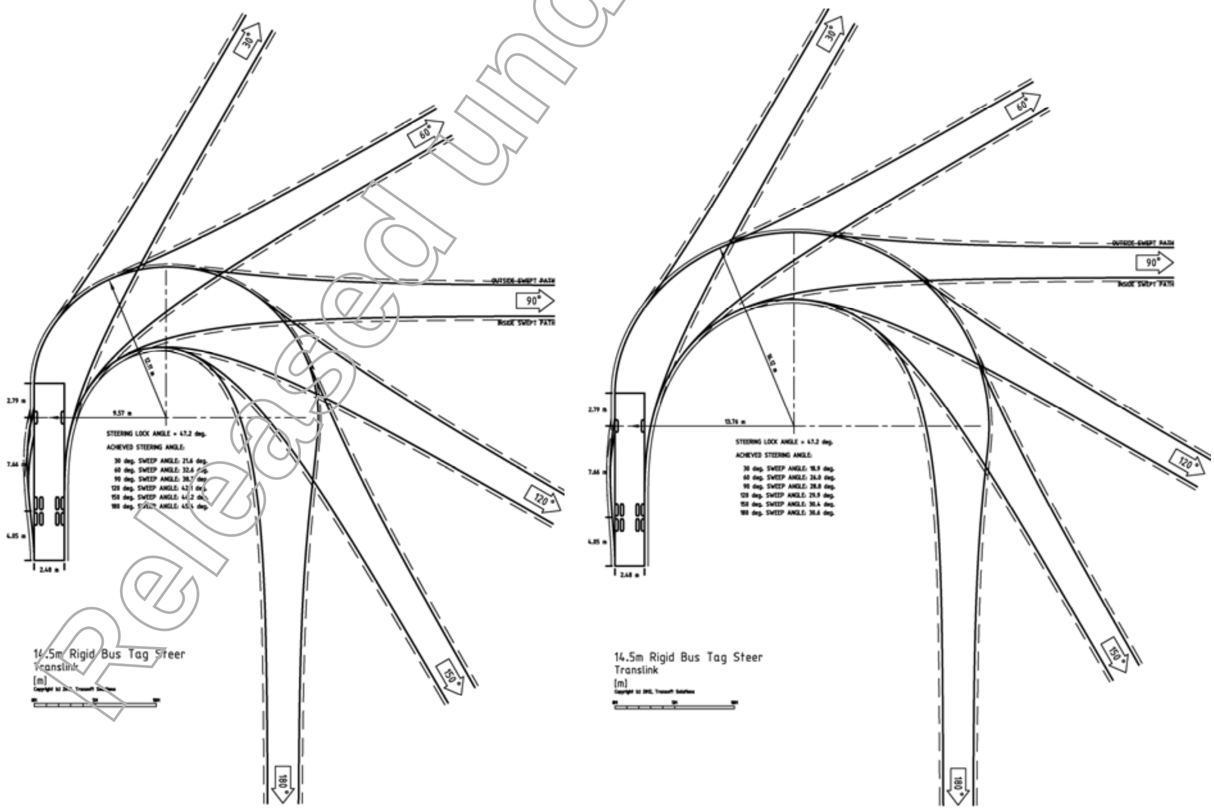
12.5m Single Steer Double Deck Bus at 15km/h

Figure 13: 14.5m Steered Tag Axle Rigid Bus Swept Path Templates at 5km/h and 15km/h



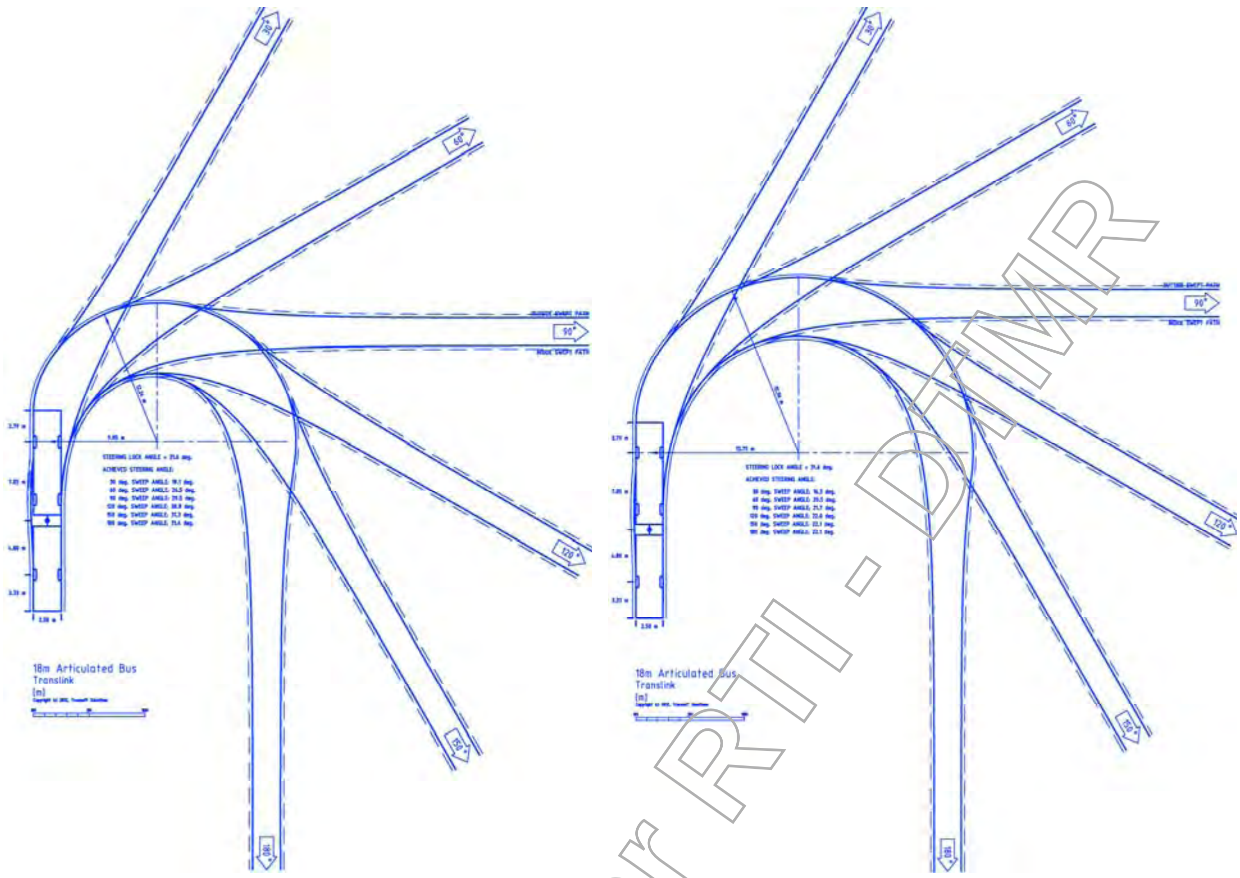
14.5m Steered Tag Axle Rigid Bus at 5km/h 14.5m Steered Tag Axle Rigid Bus at 15km/h

Figure 14: 14.5m Fixed Tag Axle Rigid Bus Swept Path Templates at 5km/h and 15km/h



14.5m Fixed Tag Axle Rigid Bus at 5km/h 14.5m Fixed Tag Axle Rigid Bus at 15km/h

Figure 15: 18m Fixed Rear Axle Articulated Bus Swept Path Templates at 5km/h and 15km/h



18m Fixed Rear Axle Pusher Articulated Bus at 5km/h 18m Fixed Rear Axle Pusher Articulated Bus at 15km/h

2.3.3 Maximum Depot High Capacity Bus Parking Capacity

Maximum depot yard parking capacities have been evaluated for every high capacity vehicle type at the 16 bus depots nominated in Section 3.1 and have been estimated only for existing yard lanes and perimeter bus parking spaces located in depots adjacent to existing buildings and fences. Maximum parking capacities exclude buses parked in high usage garage exterior hard stand work areas and work bays, on service aprons and in service sheds, unless otherwise already accommodated in such at densely packed bus depots described later in the layout assessments appearing at Section 3.6.

The bus depot parking capacity study has identified 3 different bus parking schemes common use at the 16 assessed bus depots:

- **Nose-to-Tail Bus Parking Lanes:** This parking scheme was employed at all Brisbane Transport bus depots and at 3 new private operator bus depots. (Refer to Figure 16),
- **Perimeter Parking Bays:** This parking scheme was identified at most private operator bus depots. Under this arrangement, buses are parked around yard perimeters and alongside depot and garage buildings. Most private operators used line marked angled rows of perimeter bus parking bays, but one operator, Surfside Buslines, used unmarked 90º perimeter parking bays with buses parked in rows one or two deep. (Refer to Figure 17), and
- **Densely Packed (First In-Last Out) Parking:** This parking scheme was adopted at 2 highly congested private operator bus depots. Under this parking scheme, all perimeter bus parking bays were initially occupied by buses returning to depot following the afternoon peak, then the yard access and depot circulation corridors were back filled from the rear of the yard by buses returning in the early evening, and finally garage maintenance parking bays and service sheds

occupied by buses returning in the late evening. With this parking arrangement, buses can only be dispatched on the following day from the road frontage to the rear of the depot yard in the reverse order (i.e. first in-last out) to the previous day's bus returns.

Depot yards employing nose-to-tail bus parking lanes with perimeter access and circulation corridors as depicted in Figure 16 achieved considerably higher parking densities than depot yards which only utilised perimeter bus parking bays and inter-bay access corridors illustrated by Figure 17. Nose-to-tail parking lanes must generally be dedicated to each particular bus type stationed onsite or as reserved non-dispatchable mixed bus maintenance lanes. They have the advantage of one-way forward in-out bus parking but can cause bus entrapment and mis-dispatch if buses scheduled for maintenance are accidentally placed amongst other buses on dispatchable lanes. In large depots, nose-to-tail lane parking necessitates employment of a full-time dispatcher to continually manage the yard, and rigorous adherence by all bus drivers and garage personnel to parking buses on their prescribed "bus type" and "maintenance" lanes when returned to the yard.

Figure 16: Depot Yard with Nose-to-Tail Bus Parking Lanes (*Photo: Brisbane Transport*)

Perimeter bus parking bays afford considerably greater AM dispatch flexibility and easier management of bus yards than do nose-to-tail bus parking lanes, primarily because perimeter parking bays enable particular buses to be assigned by fleet number either to live service or scheduled maintenance the following day without concern as to where buses might be parked on their return to the depot yard.

In yards already configured for perimeter bay parking, mixed vehicle size capacity assessments have been generally based on one-for-one substitution of high capacity buses for standard 12.5m rigid buses in bays long enough to park such, and for which the vehicle's 5km/h turning template overlay proved the high capacity bus could be easily and safely manoeuvred into the parking bay without accidental collisions or restricting the circulation of other buses. Articulated bus 5km/h templates were used to test forward in-out parking on nose-to-tail parking lanes only. Double deck and 14.5m rigid bus 5km/h templates were used to test reverse or forward parking in perimeter bays and forward in-out parking on nose-to-tail lanes.

Figure 17: Depot Yard with Perimeter Bus Parking Bays (*Photo: Park Ridge Transit*)

2.3.4 High Capacity Vehicle Impact on Depot Equivalent Standard Bus Parking Capacity

During assessments, it was observed at depot sites with parking layouts configured to maximise 12.5m rigid bus storage, that collocating a just a few high capacity buses with 12.5m rigid buses in shared bus parking yards resulted in an immediate and sometimes quite substantial reduction in the depot's equivalent standard bus capacity. Changes to an existing depot's equivalent standard bus capacity have been considered in the assessments from two perspectives; by the net reduction in the depot's available maximum standard bus parking spaces, and by the net reduction or increase in the passenger carrying capacity of the depot's total fleet.

Table 2: High Capacity to Standard Bus Substitution Ratios Used for Nose-to-Tail Parking Lanes

12.5m Standard Rigid Bus	12.5m Double Deck Bus	14.5m Rigid Bus	18m Articulated Bus
2	2	1	1
3	3	2	2
4	4	3	2
5	5	4	3
6	6	5	4
7	7	6	5
8	8	7	5
9	9	7	6
10	10	8	7

<6% Equivalent Standard Bus Parking Capacity Loss

6% - 15% Equivalent Standard Bus Parking Capacity Loss

>15% Equivalent Standard Bus Parking Capacity Loss

In depot yards which were already configured or needed to be reconfigured for nose-to-tail lane parking of high capacity vehicles, maximum parking capacity assessments were based on resuming entire standard bus lane(s) and substituting the alternative bus type in the ratios summarised above in Table 2. Less than a 6% loss of equivalent standard bus parking capacity was readily achieved for all high capacity bus types in existing depots yards with 6 or 7 nose-to-tail standard bus parking lanes, but very significant losses occurred on short nose-to-tail parking lanes with 4 or less standard bus parking spaces when repopulated with 14.5m rigid and 18m articulated buses, generally in accordance with the shading legend specified under Table 2.

Significantly wider access corridor and circulation swept turning paths were needed to manoeuvre newly introduced high capacity vehicles in depot yards and/or into garage work bays than were needed for existing standard 12.5m rigid buses. Each high capacity vehicle's 5km/h turning template was therefore overlaid at the lead in(s) to and exit(s) from resumed high capacity bus lane(s), and their parking manoeuvres separately assessed for reverse or forward parking in yard perimeter bays. Only existing parking lanes and bays with a minimum clear width of 3.45m were assessed for high capacity vehicle parking in adjacent lanes and bays, and a minimum nose-to-tail spacing of 800mm was adopted between buses parked on lanes. At some depots, high capacity bus manoeuvring into and out of lanes and work bays resulted in a further loss of equivalent standard bus parking spaces.

2.3.5 High Capacity Vehicle Impact on Depot Equivalent Standard Bus Passenger Carrying Capacity

The maximum passenger carrying capacities of each bus type reviewed in the study were:

- 2 Door 12.5m Rigid Bus: 44 seated + 31 standing = 75 passengers,
- 2 Door 12.5m Double Deck Bus: 96 seated + 20 standing = 116 passengers,
- 2 Door 14.5m Rigid Bus: 56 seated + 36 standing = 92 passengers,
- 2 Door 18m Articulated Bus: 64 seated + 24 standing = 88 passengers, and
- 3 Door 18m Articulated Superbus: 52 seated + 60 standing = 112 passengers.

As illustrated below in Table 3, the equivalent standard bus carrying capacity of each high capacity bus type varies considerably, depending on the average standing passenger load typically carried during service peak periods.

Table 3: High Capacity Vehicle Equivalent Standard Bus Passenger Carrying Capacities

Bus Type	Maximum Passenger Capacity		Equivalent Standard Bus Passenger Capacity (At Percent Standing Capacity)						
	Seated	Standing	100%	75%	67%	50%	33%	25%	0%
2 Door 12.5m Standard Rigid Bus	44	31	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2 Door 12.5m Double Deck Bus	96	20	1.55	1.65	1.69	1.78	1.89	1.95	2.18
2 Door 14.5m Rigid Bus	56	36	1.23	1.23	1.24	1.24	1.25	1.26	1.27
2 Door 18m Articulated Bus	64	24	1.17	1.22	1.24	1.28	1.33	1.35	1.45
3 Door 18m Articulated Bus	52	60	1.49	1.44	1.42	1.38	1.33	1.29	1.18

An assumed mid-range loading of 100% seated + 50% standing passengers has been adopted to assess the impact of each high capacity bus type on the depot equivalent standard bus fleet passenger carrying capacity using:

- 2 Door 12.5m Double Deck Bus = 1.78 equivalent standard buses,
- 2 Door 14.5m Rigid Bus = 1.24 equivalent standard buses,
- 2 Door 18m Articulated Bus = 1.28 equivalent standard buses, and
- 3 Door 18m Articulated Bus = 1.38 equivalent standard buses.

2.4 Outlook for Natural Gas Powered High Capacity Buses

The cost of fuel represents a major bus operating expense for high capacity vehicles, second only to the driver wages. Between 2000 and 2008, Brisbane City Council placed 539 standard 12.5m rigid compressed natural gas (*CNG*) buses and 30 articulated CNG buses into service with the two key objectives of cutting its continually rising and volatile diesel fuel costs and cleaning up its city bus fleet tailpipe exhaust emissions.

Large scale deployment of CNG buses also occurred in most other Australian mainland capital cities from 2000 to 2005 at bus depots with ready access to utility high pressure natural gas pipelines, but began tailing off nationally from FY2004/05 when Australia's largest public transport operator, the NSW State Transit Authority reverted to procuring clean diesel buses in advance of then announced Commonwealth Government changes to the alternative fuel excise and diesel rebate scheme for public transport buses taking effect from 2012. Only 4[##] Brisbane Transport bus depots currently have a reticulated high pressure natural gas pipeline supply, gas compressor and bulk storage station suitable for daily refuelling of a large fleet of CNG buses in South East Queensland, namely the:

- Willawong Bus Depot,
- Garden City Bus Depot,
- Toowong Bus Depot, and
- Virginia Bus Depot.

[##]Note: Brisbane City Council's Carina Bus Depot has a medium pressure natural gas pipeline and small CNG compressor station suitable for daily refuelling of 15 standard size CNG buses, but the depot no longer operates CNG buses.

All four of these Brisbane Transport CNG bus depots have dual (CNG and diesel) refuelling bowsers and Adblue urea dispensers collocated within their refuelling sheds, and Council's diesel fleet strength is again growing as a result of the Federal Government's alternative fuel excise and diesel rebate policies which have overseen the decline in new CNG bus builds nationwide. Notwithstanding that imported new Euro 5 diesel engine exhaust emissions are as clean as their predecessor CNG engine emissions, a natural gas engine will always maintain a 6 to 12% lower greenhouse gas emission lead on the most efficient diesel engine available. Australian State and Territory Governments responsible for funding public transport are no longer able to recoup royalties on their indigenous natural gas reserves previously supplied to bus depots at State regulated prices to refuel CNG buses, and operators and State transit authorities remain vulnerable to highly volatile international market prices for imported crude oil and bulk distillate.

Confronted by an urgent need to replace its then aging fleet of high floor diesel buses stationed at older bus depots with diesel only refuelling, Brisbane City Council ceased construction of new CNG buses later than most other States in 2009 and reverted back to procurement of Euro 5 clean diesel buses only. Brisbane Transport has advised that Council has no immediate plans to resume construction of new CNG buses in the near future but has certainly not abandoned the option to resume constructing and deploying more natural gas fuelled buses over the long term, should the economics of fuelling its fleet again favour natural gas over diesel.

Council has experienced two high pressure CNG cylinder explosions over the past 6 years and the political appetite for more CNG buses has somewhat waned particularly with the shift in subsidised operating economics between diesel and CNG brought about by the 2012 changes to the federal alternative fuel excise and diesel rebate. It is however foreseen that depleting global crude oil reserves and increasing international demand for fossil fuels are more likely than not to shift the economic advantage back in favour of natural gas within the coming decade.

Brisbane Transport has stated in interviews that its CNG articulated buses suffer from a high CNG storage cylinder axle weight penalty of around 1.5t, very sluggish acceleration and limited daily operating range of less than 450km, and articulated buses are therefore no longer considered suitable future candidates for powering by compressed natural gas. It has been suggested that 14.5m rigid buses would however be suitable future candidates for CNG, but none has ever been built or trialled in service. As for articulated buses, the roof height and axle weight of double deck buses would also preclude them as suitable candidates for powering by compressed natural gas.

Emerging new technology natural gas to hydrogen fuel cell, liquid natural gas (LNG) and small gas engine LNG/L-Ion hybrid powered city buses already being trialled overseas are likely to entice Council and other Australian capital city bus operators to again consider natural gas as a viable alternative fuel to clean diesel. In South East Queensland, bulk LNG can now be trucked to Brisbane bus depots at prices per gigajoule lower than that of clean diesel and Adblue urea, but would require roll out of more new natural gas buses, on-site cryogenic storage tanks, and cryogenic liquid natural gas refuelling bowsers if these emerging alternative technologies proved more viable than diesel.

In countries with proven high indigenous reserves of natural gas such as Russia, Canada, Norway, USA, Indonesia and Malaysia which are also large natural gas exporters like Australia, the pressure to change energy security and balance of trade policies and to recover more State royalty revenues earned from increased local gas consumption could well reverse the Australian capital city bus operator trend back to natural gas fuelled buses. For those capital city bus operators such as Brisbane Transport with an existing large fleet of CNG buses, bulk LNG can now be tanker delivered, stored on-site in cryogenic tanks, warmed and flashed back to gas at ambient temperatures and compressed to CNG at large bus depots with no existing or future likely prospect of access to a gas utility installed high pressure pipeline.

3. Depot Assessments for High Capacity Bus Deployment

3.1 Bus Depots Assessed for Study

The following SEQ bus operators and depots were identified in consultation with *TransLink* as those most likely to deploy high capacity vehicles on high frequency priority (*HFP*) services, long haul *Rocket* and *Express* limited stop services, and proposed future new *UrbanLink* and *ExpressLink* trunk services over the coming decade.

- Clarks Logan City Bus Service
  - Loganlea Bus Depot, 42 Jutland Street, Loganlea
- Hornibrook Bus Lines
  - Clontarf Bus Depot, 19 Grice Street, Clontarf
  - North Lakes (Satellite) Bus Depot, Wills Street, North Lakes
- Park Ridge Transit
  - Park Ridge Bus Depot, 3830 Mount Lindsay Highway, Park Ridge
- Surfside Buslines
  - Coomera Bus Depot, Old Coach Road, Upper Coomera
  - Molendinar Bus Depot, 10 Mercantile Court, Molendinar
  - Tweed Heads Bus Depot, Ourimbah Road, Tweed Heads
- Veolia Transdev Queensland
  - Capalaba Bus Depot, 10 Smith Street, Capalaba
- Brisbane Transport
  - Bowen Hills Bus Depot, Abbotsford Road, Bowen Hills
  - Carina Bus Depot, Creek Road, Carina
  - Garden City Bus Depot, MacGregor Street, Upper Mount Gravatt
  - Richlands (Satellite) Bus Depot, Government Road, Richlands
  - Sherwood Bus Depot, Sherwood Road, Sherwood
  - Toowong Bus Depot, Dean Street, Toowong
  - Virginia Bus Depot, Ferric Street, Virginia
  - Willawong Bus Depot, Sherbrooke Road, Willawong
  - Trade Coast Bus Depot, Schneider Road, Eagle Farm (currently under construction).

3.2 Maximum Bus Depot High Capacity Bus Parking Capacity

Maximum bus depot parking capacities have been summarised overleaf in Table 4 for the 3 high capacity vehicle body sizes and compared with existing maximum standard 12.5m rigid bus parking capacities. Depot bus parking capacities have been calculated for existing yard layouts, depot circulations, turning directions, access corridor widths and perimeter bay and/or nose-to-tail parking lane schemes. Table 4 further nominates those depots with existing bus maintenance and servicing facilities considered to be already suitable for each high capacity vehicle type, or capable of being made ready for high capacity bus types at low cost with minor new plant procurements, yard modifications and garage building upgrades.

Maximum high capacity bus parking capacities listed in Table 4:

- Are for <u>one</u> high capacity vehicle type per depot only. For example, up to 54 x 12.5m double deck <u>or</u> 44 x 14.5m rigid <u>or</u> 28 x 18m articulated buses could be parked in Bowen Hills Bus Depot and supplemented with standard 12.5m rigid buses in unoccupied parking spaces; but 54 x double deck <u>and</u> 44 x 14.5m rigid buses could not be simultaneously parked in the depot,
- Assume selected bus and/or car parking spaces can be resumed as needed to widen circulation and access paths for high capacity vehicle turns into and out of existing bus parking bays and lanes. Specific depot bus and car parking space resumptions for high capacity vehicle yard circulations and garage work bay or parking manoeuvres are described later in Section 3.6, and
- Assume both forward in-out parking in nose-to-tail lanes <u>and</u> forward or reverse parking of 12.5m double deck and 14.5m rigid buses in perimeter bays, but only forward in-out parking of 18m articulated buses in aligned multiple perimeter parking bays and nose-to-tail parking lanes.

Attention is drawn to the notes appearing below Table 4. Whilst all depot yards have been identified as suitable for parking high capacity vehicles with appropriate modifications, not all depots have the maintenance, servicing and/or refuelling facilities necessary for particular high capacity bus types. It should be particularly noted that existing Brisbane Transport 18m articulated buses are natural gas vehicles and can only be stationed at depots with an existing reticulated natural gas supply, CNG bulk storage cylinders and refuelling bowsers.

Table 4: Assessed Maximum Depot Parking Capacities for All Vehicle Types

Bus Depot	Suitable (with Minor Upgrades)			Depot Refuelling Capability	TransLink Advised Depot Safe Working Capacity	Total TransLink Buses Currently Garaged	Assessed Maximum Depot Parking Capacity			
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses				12.5m Standard Rigid Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses
Brisbane Transport										
Bowen Hills	No	Yes	Yes (Note 9)	Diesel	112	111	112	54 (Note 6)	44	28
Garden City	Yes	Yes	Yes	CNG + Diesel	200	183	184	184	153	118
Carina	No	Yes	Yes (Note 10)	Diesel	160	174	185	183 (Note 6)	156	119
Virginia	No	Yes	Yes	CNG + Diesel	160	179	179	108 (Note 6)	80	58
Willawong	Yes	Yes	Yes	CNG + Diesel	200	193	222	222	185	148
Richlands	No	Yes	Yes (Note 9)	Diesel	45	32	56	49 (Note 6)	44	15
Toowong	No	Yes	Yes	CNG + Diesel	165	182	183	155 (Note 6)	132	108
Sherwood	Yes	Yes	Yes (Note 9)	Diesel	200	142	215 (Note 3)	215 (Note 6)	172	129
Trade Coast (Note 1)	Likely	Yes	Yes	Diesel (Note 2)	200	0	200 (Note 4)	200 (Note 4)	160 (Note 4)	120 (Note 4)
Clarks Logan City Bus Service										
Loganlea	Yes	Yes	Yes	Diesel	135	125	138 (Note 7)	136 (Note 7)	124 (Note 7)	51 (Note 7)
Hornibrook Bus Lines										
Clontarf	Yes	Yes	No	Diesel	60	48	52	25	21	9
North Lakes	Yes	Yes	Yes	Diesel	60	13	57	28	28	28
Park Ridge Transit										
Park Ridge	Yes	Yes	Yes	Diesel	120	80	121	119	74	19
Surfside Buslines										
Molendinar	Yes	Yes	Yes	Diesel	160	247	170	142	110	46
Tweed Heads	No	Yes	Yes	Diesel	150	61	150	113 (Note 6)	113	79 (Note 7)
Coomera	Yes	Yes	Yes	Diesel	125	0	190	186	144	126
Veolia Transdev Queensland										
Capalaba	No	Yes	Yes	Diesel	95	119	105 (Note 5)	50 (Note 8)	45 (Note 8)	12 (Note 8)

Note 1: As at 31 August 2012, the new Trade Coast (Eagle Farm) Bus Depot was still under development.
Note 2: Trade Coast is located close to a high pressure gas pipeline and could be developed as a new CNG + Diesel bus depot.
Note 3: Sherwood Bus Depot has sufficient reserve yard parking space to accommodate up to 258 standard 12.5m rigid buses.
Note 4: Based on TransLink advised depot parking capacity and similar yard lane layout to Willawong and Sherwood Bus Depots.
Note 5: Based on 105 first in-last out high density bus yard parking plus 26 standard 12.5m buses parked in on-site building.
Note 6: These depots are considered unsuitable for double deck buses because of building height or road access restrictions.
Note 7: Parking layout and access/circulation corridors to be modified at this depot for high capacity buses and numbers listed.
Note 8: Additional parking of high capacity vehicles in two on-site building through-running lanes would increase these capacities.
Note 9: BT articulated buses are currently CNG only. These depots would only be suitable for future diesel articulated buses.
Note 10: Carina Depot has an existing low pressure natural gas pipeline suitable for refuelling 10 CNG articulated buses/day.

3.3 Bus Depot High Capacity Vehicle Maintenance Capability

Table 5 below and Table 6 overleaf summarise the high capacity vehicle maintenance and servicing capability assessments for all Private Operator and Brisbane Transport Bus Depots respectively.

Table 5: Private Operator Bus Depot High Capacity Vehicle Maintenance & Servicing Capability

Bus Depot	Mech & Elect Maintenance			Body Maintenance			Bus Refuelling			Bus Exterior Washing			Bus Chassis Cleaning			Accommodation & Circulation		
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses
Clarks Logan City Bus Service																		
Loganlea	Yes	Yes	Yes	Yes. But With Minimal Height Clearance	Yes. With Partial Cover	Yes. With Partial Cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. Existing Yard Layout Could be Easily Modified Using Lanes for Improved High Capacity Bus Circulation		
Hornibrook Bus Lines																		
Clontarf	Yes	Yes	Yes. But Only In 3 Drive-Through Bays. Partial Cover Only in 16m Short Bays	Yes. Some Lights Would Need to be Raised in Drive-Through Bay	Yes	Yes. Partial Cover in Short Bays	Yes	Yes	Yes	Yes	Yes	Yes	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes	Yes	Yes
North Lakes	Yes. Basic Maintenance Only with All Hoisted Major Repairs and Maintenance Required at Clontarf Bus Depot			Yes. Basic Maintenance Only with All Major Maintenance and Repairs Required at Clontarf Bus Depot			Yes	Yes	Yes	Yes	Yes	Yes	Yes. With Chassis Cleaning at Clontarf Bus Depot			Yes. 6 Bus Bays at Rear and 1 Lane Bay on Eastern Side of Yard Would Need to be Kept Clear at All Times for High Capacity Bus Circulation		
Park Ridge Transit																		
Park Ridge	Yes. But 12 Bus Parking Bays in Front of Shed to be Kept Clear for Manoeuvring. Downpipe on Front of Shed to be Lifted			Yes	Yes	Yes	Yes. Would Need Adblue Dispenser for New High Capacity Buses			Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. But 12 Bus Parking Bays in Front of Maintenance Shed to be Kept Clear for High Capacity Bus Manoeuvring		
Surfside Buslines																		
Molendinar	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tweed Heads	No. All Repairs and Maintenance Only on Hard Stand Area	No. Covered or Partially Covered. But Can Only be Hoisted for Major Repairs and Maintenance on Garage Hard Stand		No. All Repairs and Maintenance Only on Hard Stand Area	Yes. Covered	Yes. Partially Covered	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But 31 (Currently Unused) Standard Bus Parking Bays Would Need to be Given Up for High Capacity Bus Circulation in Parking Yard		
Coomera	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Veolia Transdev Queensland																		
Capalaba	No. Door Height Too Low. All Maintenance & Repairs Only on Hard Stand	Yes	Yes	No. Door Height Too Low. All Maintenance & Repairs Only on Hard Stand	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But This Depot Uses Highly Packed First In-Last Out Yard Parking. High Capacity Bus Parking Would Require 7 Bus Parking Spaces in Access Corridor be Kept Clear Till Late Evening		

Table 6: Brisbane Transport Bus Depot High Capacity Vehicle Maintenance & Servicing Capability

Bus Depot	Mechanical Maintenance			Body/Electrical Maintenance			Bus Refuelling			Bus Exterior Washing			Bus Chassis Cleaning			Accommodation & Circulation		
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses
Brisbane Transport																		
Bowen Hills	No. Shed Roof Too Low	Yes	Yes. But Only Future Diesel Artics	No. Shed Roof Too Low	Yes	Yes	Yes	Yes	Yes. But Only Future Diesel Artics	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	No. Shed Roof Too Low	Yes	Yes	No. Will Need Resumption of Car Parking Spaces and Added High Capacity Bus Circulation and Exit on Gebbie Street		
Garden City	Yes	Yes	Yes	Yes. Will Need Elevated Catwalks	Yes	Yes	Yes	Yes	Yes	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	Yes	Yes	Yes	Yes. But Raise Water Harvest Pipe on Logan Rd Boundary	Yes	Yes
Carina	No. Won't Fit Under Roller Doors But Bus Can be Hoisted in North Building	Yes	Yes. Has Existing CNG Articulated Bus Maintenance Facilities	No. South Building Roof Too Low	Yes	Yes	No. South Building Roof Too Low	Yes	Yes. But Only 10 Max CNG Artic Buses or Future Diesel Artic Buses	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	Yes	Yes	Yes	Yes. But Would Need Bus Parking Lanes Along Eastern Boundary Kept Clear for Late Night High Capacity Bus Entry to Rear of Yard Lanes		
Virginia	No. Door Heights OK But Only Body Shed Roof High Enough	Yes	No. Shed Widths Too Short and Doors too Low to Hoist	Yes. Door Heights OK But Only Body Shed Roof High Enough	Yes	Yes. With Partial Cover	Yes	Yes	Yes	Yes. But Wash Roller Frame and Down Pipe Need To be Raised	Yes	Yes	Yes	Yes	Yes	Yes. But Existing Yard Lanes Would Need to be Shortened One 12.5m Rigid Bus Length to Enable High Capacity Bus Depot Circulation		
Willawong	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. Shed OK. Wash Roller Frame too Short	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Richlands	No. All Maintenance Required at Toowong Bus Depot	Yes. Partial Cover But All Hoisted Major Repair & Maintenance Required at Toowong Bus Depot		No. All Maintenance Required at Toowong Bus Depot	Yes	Yes	No. Roof Trusses & Braces Too Low	Yes	Yes. But Only Future Diesel Artics	No. Roof Too Low. Could Wash on Hard Stand	Yes	Yes	No. All Chassis Cleaning Would Need to be Completed at Toowong Bus Depot			Yes	Yes	Yes
Toowong	Yes	Yes	Yes	Yes	Yes	Yes	No. Service Shed Roof Trusses Too Low	Yes	Yes	No. Service Shed Roof Trusses Too Low	Yes	Yes	Yes	Yes	Yes	Yes. But Existing Yard Lanes Would Need to be Shortened One to Three 12.5m Rigid Bus Lengths in Sections to Enable High Capacity Bus Circulation		
Sherwood	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But Only Future Diesel Artics	Yes. Shed OK. Wash Roller Frame Too Short	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

3.4 Universal High Capacity Vehicle Compatible Bus Depots

6 new generation bus depots have been identified as universally suitable for parking, maintenance and servicing of a large fleet of any high capacity bus type or combination of high capacity bus types with minimal or no facility upgrades, yard parking or building modifications:

- Loganlea Bus Depot,
- Molendinar Bus Depot,
- Coomera Bus Depot,
- Garden City Bus Depot,
- Willawong Bus Depot, and
- Sherwood Bus Depot.

3.5 Barriers to Future Brisbane Transport Double Deck Bus Deployment

Low existing garage building and/or service shed roof heights present a major challenge to potential future deployment of double deck buses in old generation Brisbane Transport bus depots originally designed and constructed for maintenance of single deck buses. Whilst it has been established that high twin deck vehicles could be maintained in the less than 4 year old new Willawong and Sherwood Bus Depots, 4.3 to 4.4m high double deck buses will only just pass under fully raised garage doors with minimum acceptable clearance and double deck bus roofs would come precariously close to overhead fittings and building services within their new garage buildings when hoisted to 1750mm nominal AFL. (Refer to photograph of Willawong Bus Depot garage maintenance bay appearing at Figure 4).

Earlier high capacity bus studies have identified a large number of existing low clearance railway bridges on the Ipswich Railway Line. This railway line acts as a physical barrier to double deck bus operations in numerous locations from Darra inbound to the city, and in combination with other flood prone low railway bridge clearances over Oxley Road at Corinda and Muriel Avenue at Rocklea, effectively block off double deck bus road movements along the western, southern and eastern public road approaches to the Sherwood Bus Depot.

The inability to freely station double deck buses at so many existing old bus depots and operate them without excessive route diversions from the new Sherwood Bus Depot render double deck buses a less flexible and attractive high capacity vehicle option than single deck high capacity vehicles for Brisbane Transport suburban bus operations.

3.6 High Capacity Bus Depot Parking, Manoeuvring and Circulation Assessments

3.6.1 Swept Path Turning Template Overlay Colour Codes

Section 3.6 presents details of modifications required at specific bus depots to enable high capacity bus manoeuvres into and out of existing garage maintenance bays and service sheds, and for depot yard and inter-building circulation. Where turning templates have been included on depot aerial views appearing in the figures, they have been appropriately scaled to the aerial view and colour coded as follows:

- Green for 12.5m twin steer double deck bus swept paths (per Figure 11),
- Red for 14.5m steered tag axle rigid bus swept paths (per Figure 13), and
- Blue for 18m fixed rear axle pusher type articulated bus swept paths (per Figure 15).

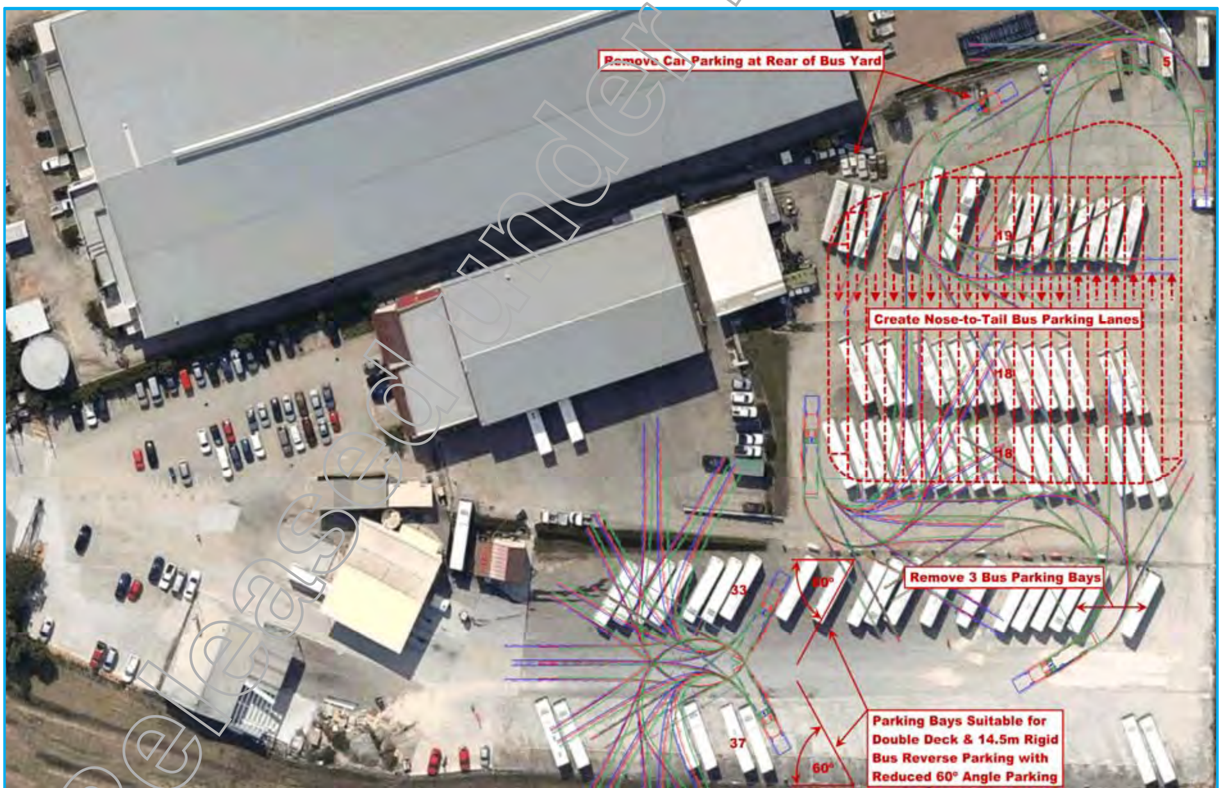
3.6.2 Loganlea Bus Depot

Loganlea Bus Depot has an existing large hardstand apron in front of its primary garage building and swept path turning template overlays identified no issues with manoeuvring any high capacity bus types into existing garage mechanical and electrical work bays, the body repair, tyre servicing, refuelling and wash sheds, or between any buildings on the depot site.

Perimeter bus parking bays in the southern section of the Loganlea yard shown in Figure 18 are currently used for reverse angle parking of standard 12.5m rigid buses and would also be suitable for reverse parking double deck or 14.5m rigid buses if permanently line marked as 60° angled parking bays on both sides of the southern yard central access corridor.

Clarks presently own and operate 4 articulated buses and park them in the rearmost northern yard row of perimeter parking bays, however turning template overlays have indicated the current northern yard parking arrangement would be unsuitable for more than a maximum of around 10 articulated buses, 25 double deck or 14.5m rigid buses due to existing narrow yard circulation and access corridors. The northern section of the yard has however been found deep enough to create 19 x 3.5m wide nose-to-tail bus parking lanes suitable for parking a large number of high capacity buses. This alternative parking scheme would necessitate elimination of all car parking along the northern yard perimeter and resumption of 3 bus bays at the entrance into the northern yard from the southern yard as shown below on Figure 18 to provide adequate turn-in and manoeuvring space to optimise the yard's combined high and low capacity bus parking density.

Figure 18: Loganlea Bus Depot Layout



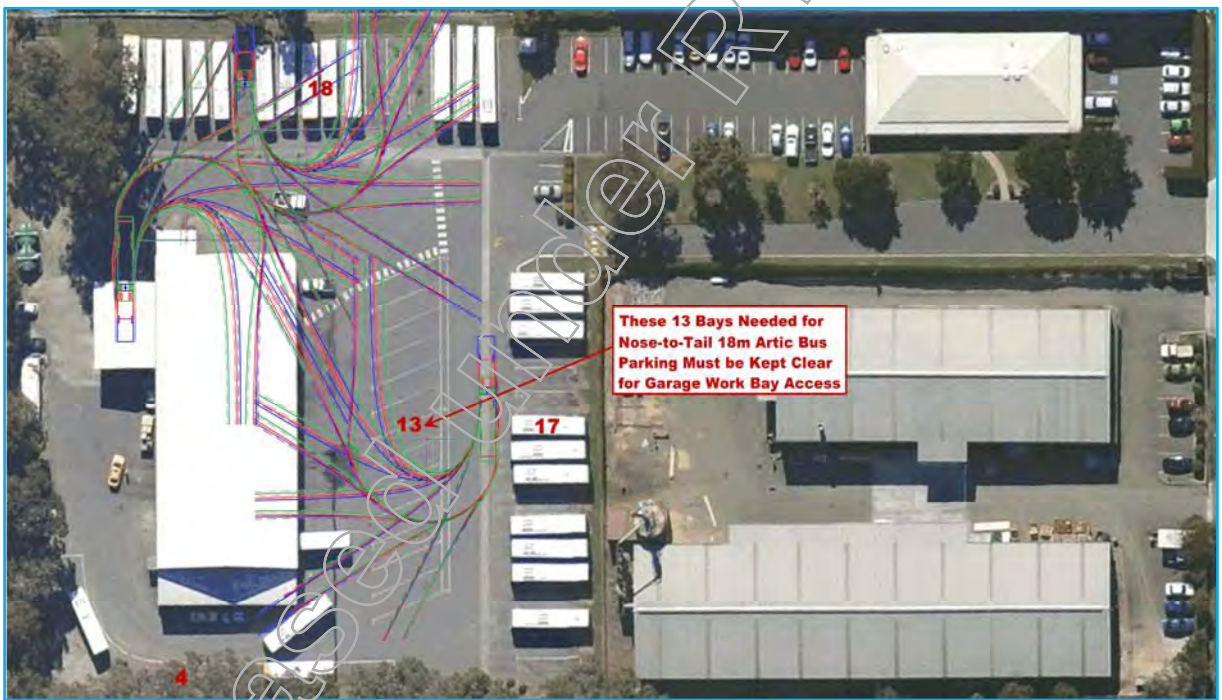
3.6.3 Clontarf Bus Depot

Clontarf Bus Depot currently has a total yard parking capacity of 52 standard 12.5m rigid bus spaces in the marked perimeter and island parking bays illustrated overleaf in Figure 19. Turning template overlays have confirmed that all high capacity bus types can manoeuvre into and out of existing garage maintenance and service bays and be driven around the garage building at a slow speed of 5km/h, but this depot only has 3 existing drive-through bays in the garage wide enough to hoist 18m articulated buses for chassis mechanical and electrical maintenance.

Double deck and 14.5m rigid buses already stationed at Clontarf Bus Depot are currently reverse parked on the eastern side of the 90° parking bays along the northern boundary of the depot yard, and turning template overlays have indicated that up to 9 articulated buses could potentially be reverse parked in these same bays. Reverse parking of 18m articulated buses in these 3.5m wide perimeter parking bays is considered to be a high collision accident risk and reverse parking of articulated buses would not therefore be recommended along the northern yard boundary.

Turning template overlays alternatively indicated that if the existing 13 island bays in front of the garage building were converted to south facing nose-to-tail parking lanes used exclusively for articulated bus parking, up to 6 articulated buses could be parked in the island parking area and a further 3 articulated buses in the existing southern perimeter standard 12.5m rigid bus bays. Some of the island parking bays would however need to be kept clear throughout the day for buses to access the 7 garage maintenance bays. This workaround option is considered practicable for standard size buses returning to depot in the late evening, but is not considered practicable for a small fleet of articulated buses returning to depot continuously throughout the day. Articulated buses have therefore not been recommended for Clontarf Bus Depot.

Figure 19: Clontarf Bus Depot Layout



3.6.4 North Lakes Satellite Bus Depot

North Lakes Bus Depot, shown overleaf in Figure 20, is a satellite of Clontarf and buses stationed at the former must periodically be swapped with similar size buses from Clontarf for hoisted major mechanical maintenance, chassis cleaning, electrical and body repairs.

North Lakes is a new Hornibrook facility and utilises nose-to-tail bus lanes suitable for parking of all high capacity vehicle types with yard circulation at a slow speed of 5km/h, but 6 rigid bus bays at the rear of the yard shown arrowed on Figure 20 would need to be kept clear throughout the day for returning high capacity bus lane turn-ins and rear of yard bus circulation. The 6 bays at the rear could be occupied by returning late night standard size buses, but only after high capacity buses stationed at the site had already occupied their allocated (bus type) lanes.

Albeit turning template overlays have indicated this depot would be suitable for accommodation of 18m articulated buses, this high capacity bus type could not be swapped with like-for-like buses from Clontarf Bus Depot and 18m articulated buses have therefore also not been recommended for North Lakes.

Figure 20: North Lakes Bus Depot Layout

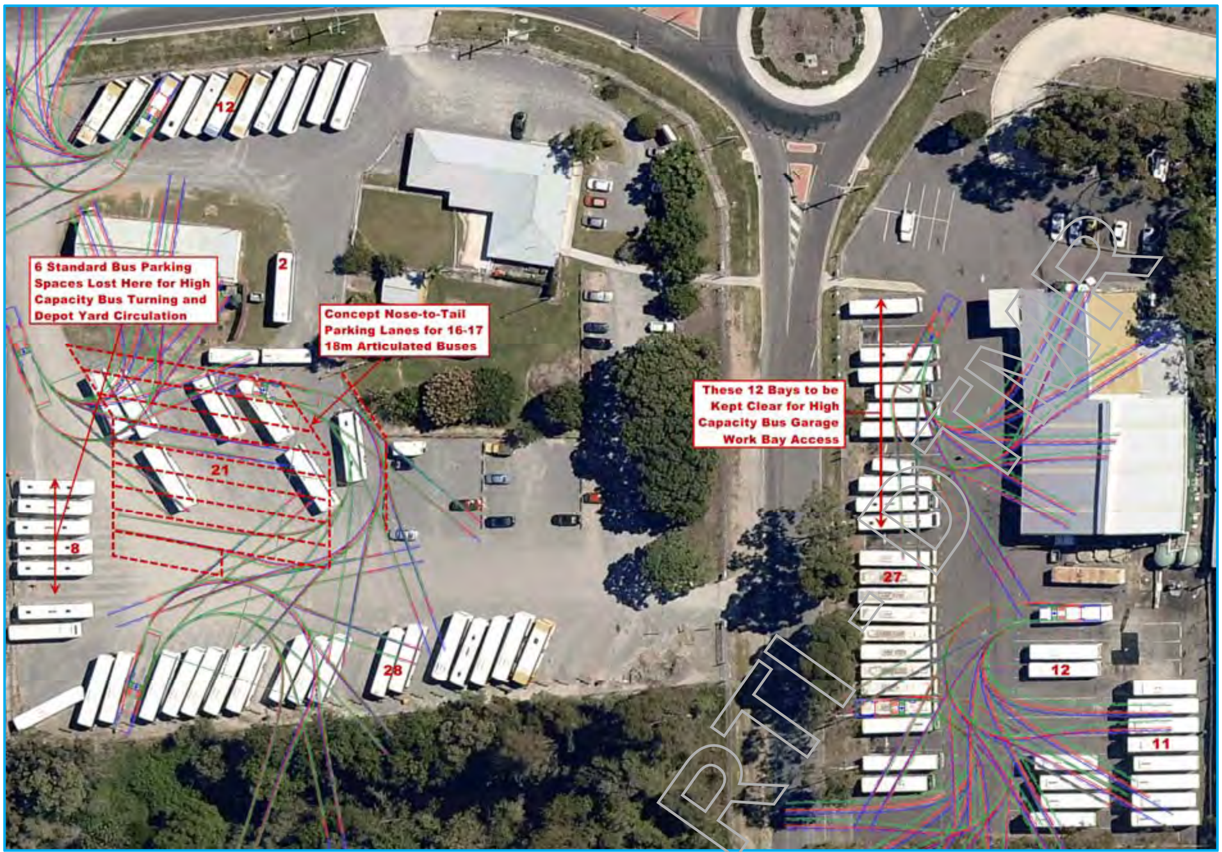
3.6.5 Park Ridge Bus Depot

Park Ridge Bus Depot is a medium size depot split across 2 properties either side of Talinga Drive in Park Ridge and has a combined total yard parking capacity of approximately 121 standard 12.5m rigid buses distributed where indicated overleaf in Figure 21. Turning template overlays have confirmed that all high capacity bus types could potentially operate from this depot, but up to 12 bus parking bays located in front of the primary garage building would need to be kept clear throughout the day for high capacity bus manoeuvring in and out of the existing garage maintenance work bays.

Every 12.5m rigid bus parking bay on both of the depot properties could potentially be used for reverse parking of 12.5m double deck buses, and up to 74 bays, mostly located on the southern depot property site (shown to the left hand side of Figure 21), were suitable for parking 14.5m rigid buses.

Only 2 informal parking locations on the southern depot property could be found where 18m articulated buses could be driven forward in-out using the current yard layout and circulation travel direction. A concept nose-to-tail parking lane design has therefore been presented in Figure 21 for parking of up to an additional 16 or 17 articulated buses on the southern depot property with a small loss of 6 standard 12.5m parking bays on the turn-in (left hand) side of the proposed articulated bus lanes.

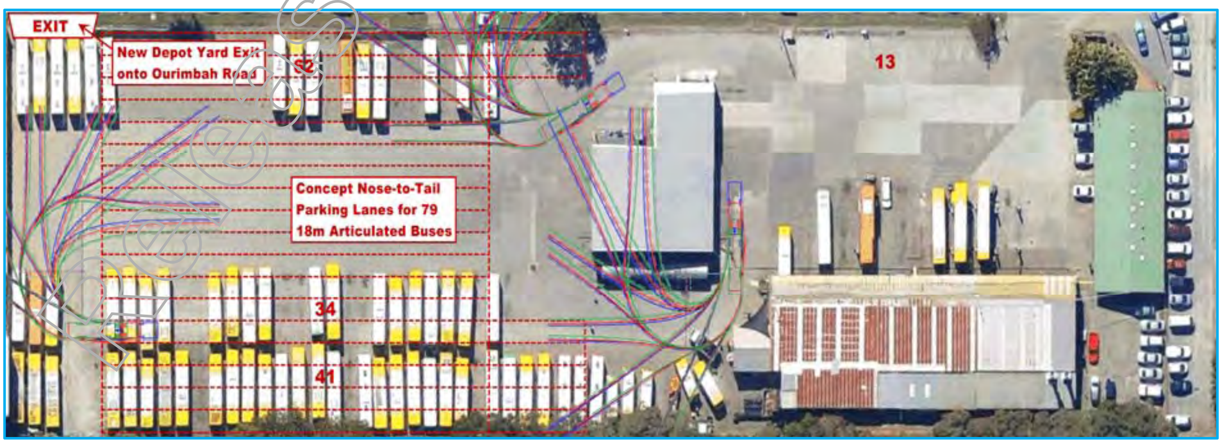
Figure 21: Park Ridge Bus Depot Layout



3.6.6 Tweed Heads Bus Depot

Tweed Heads Bus Depot has a long narrow yard capable of accommodating up to 150 standard 12.5m rigid buses reverse parked in first in-last out formation and distributed around the site where indicated in Figure 22. Because of its low access door heights, double deck buses cannot enter any of the existing covered garage maintenance work bays and would not therefore been recommended in substantial numbers at this depot. The existing low garage roof height prevents even single deck buses from being hoisted for underfloor mechanical and electrical repairs in the covered garage work bays, and all hoisted bus maintenance at this site is presently performed on the weather exposed exterior hardstand area in front of the main garage building. (Refer to Figure 1 for a photograph of the Tweed Heads Bus Depot garage hardstand area).

Figure 22: Tweed Heads Bus Depot Layout



The resident bus fleet at Tweed Heads Bus Depot is comprised almost entirely of standard single deck 12.5m route buses, supplemented with a few 6 to 8m long minibuses. The property alignment is long and narrow and maximum standard bus parking density has been attained on this site by reverse parking buses around the perimeter in rows of up to two deep, each served by a shared central access corridor. Because nearly all the resident buses are similar, they can be dispatched in first in-last out order generally irrespective of the previous day's return to depot bus arrival order, a strategy which works well for a depot with a large uniform fleet of similar sized buses.

The present yard layout would be suitable for mixed reverse parking of 12.5m double deck and 14.5m rigid buses, but turning template overlays have demonstrated that wherever either of these high capacity buses was reversed parked in the yard, the site depth would diminish the reverse in-forward out yard capacity from 4 to 3 opposing rows with a substantial loss of equivalent standard bus parking capacity. Further, the current yard parking configuration and layout is unconducive to mixed parking of standard 12.5m rigid and 18m articulated buses; the latter of which cannot be safely reverse parked in standard width bays without high ongoing risk of repeated in-yard reversing collisions.

A concept nose-to-tail forward in-forward out parking lane configuration has been presented in Figure 22 which would enable mixed parking of standard 12.5m rigid, 12.5m double deck, extended 14.5m rigid and 18m articulated buses on split "bus type" lanes suitable for first in-first out dispatching. The concept design shown retains near equivalent total standard 12.5m rigid bus parking capacity but utilises a new exit to, and Ourimbah Road for depot circulation. If this was unacceptable, an internal circulation access corridor could be included in the concept design at the rear of the yard but would result in a total yard parking capacity loss of approximately 18 standard 12.5m rigid bus parking spaces.

3.6.7 Capalaba Bus Depot

Capalaba Bus Depot adopts a very high density first in-last out bus parking scheme. The yard can accommodate up to 105 standard 12.5m rigid buses, but the depot boasts a spare building with access to Smith Street capable of stabling up to an additional 26 standard size buses under cover where indicated on Figure 23 overleaf. The spare building houses Veolia's front counter, depot office and store, and is not normally used for bus parking until the depot yard has been completely packed out with vehicles, including parking of last evening returning buses in the garage maintenance hardstand bays and in all the yard circulation accesses other than the primary accesses off Smith Street in front of the refuelling shed and garage hardstand apron.

Because of low access door heights, double deck buses cannot enter any of the existing covered garage maintenance work bays, but could enter all other onsite bus service sheds and the spare building. Double deck buses have not been recommended in substantial numbers at this depot, but Veolia has advised it could accommodate a small fleet of double deck buses on its site and presumably maintain them on the exterior garage hardstand apron.

Maximum high capacity bus parking estimates listed in Table 4 for Capalaba Bus Depot have assumed availability of and ready access to 3 through-running (forward in-out) parking lanes, and resumption of 6 existing car parking spaces where marked on the western side of the spare building in Figure 23. Circulation access to these 3 high capacity bus lanes is normally only blocked off by the last 7 buses returning to the depot in the late evening.

An additional 2 optional through-running lanes are available at the depot within the spare building itself, but access to them is blocked by the last 18 buses returning to depot at night. If used, these 2 covered through-running lanes would effectively prevent standard size buses being parked within the spare building if need to be dispatched prior to the high capacity buses and would only therefore be feasible high capacity bus parking lanes if all standard 12.5m rigid buses could be readily accommodated in the open yard. For these reasons, maximum high capacity bus counts presented for Capalaba in Table 4 exclude high capacity bus parking in the 2 optional covered through-running lanes shown on Figure 23.

Figure 23: Capalaba Bus Depot Layout

3.6.8 Bowen Hills Bus Depot

Most old Brisbane Transport depots such as Bowen Hills Bus Depot have existing shed roof heights too low for covered maintenance and servicing of double deck buses. Bowen Hills can however accommodate both 14.5m rigid and future diesel articulated buses under full cover, but does not have an on-site refuelling capability for current generation Brisbane Transport CNG articulated buses.

Buses parked in the unhatched lanes shown in the aerial view on Figure 24 overleaf face northward and exit directly to Geebie Street (i.e. to the right hand side on the layout view). Buses parked in the lanes shown hatched face towards, and exit oppositely to the southern end of the yard, and these are the only forward in-out lanes which could be used to park 18m long articulated buses and around 95% of 14.5m rigid buses. Turning template overlays have indicated that both these high capacity bus types can be turned into all maintenance and servicing sheds and back to Geebie Street at the southern end of the bus yard if the existing bus bay identified on the figure was kept permanently clear, but neither high capacity vehicle could exit to Gebbie Street at the northern end of the existing yard or circulate the yard unless driven inbound up Abbotsford Road and back into the depot at its southern entry gate. A new depot exit would therefore need to be created onto Gebbie Street in the approximate location shown on Figure 24 to enable both depot exiting to, and turn back circulation off Geebie Street. Creation of this new exit would necessitate resumption of 6 existing car parking spaces, 2 of which could be relocated to the opposite side of the proposed exit shown on Figure 24.

Figure 24: Bowen Hills Bus Depot Layout

3.6.9 Carina Bus Depot

There are two large garage buildings at Carina Bus Depot; the north garage building used primarily for hoisted and floor level bus mechanical maintenance, and the south garage building used for floor level electrical and body maintenance, bus servicing and refuelling. The north building roller door and south building roller door and roof truss clearance heights are too low for double deck bus entry.

Figure 25: Carina Bus Depot Layout

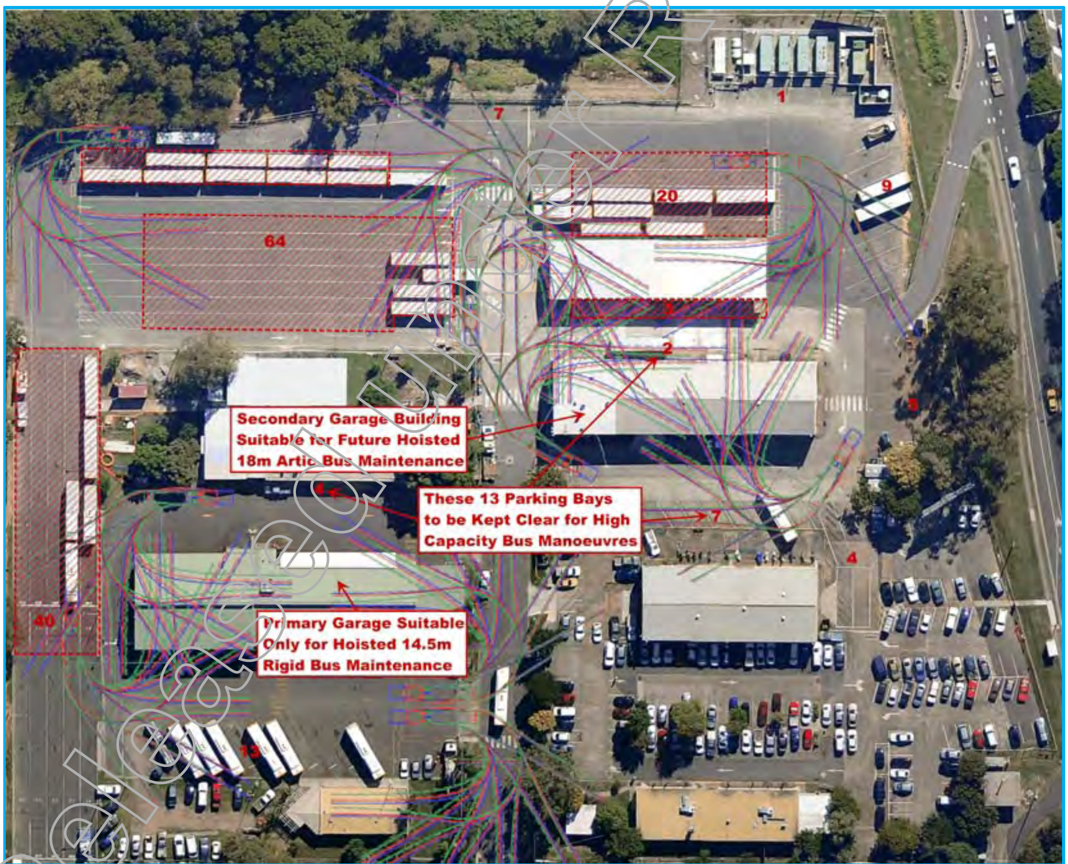
Both garage buildings, the bus washing and chassis cleaning sheds, and yard circulation corridors would be suitable for up to 156 14.5m rigid buses or 119 future 18m diesel articulated buses, and it is understood from Brisbane Transport that both these high capacity diesel vehicle types have previously operated from Carina Bus Depot. This depot houses an existing covered CNG refuelling station on site capable of refuelling up to 10 CNG articulated buses per night, but no CNG buses are currently being operated from the depot.

To maximise high capacity bus parking, the 16 bus parking bays (also occasionally used for driver car parking) along the eastern yard perimeter would need to be kept clear throughout the day, but could be filled in the late evening by late returning or late night refuelled and washed buses after all the high capacity bus lanes had been populated.

3.6.10 Virginia Bus Depot

Virginia Bus Depot is a dual fuel (CNG + diesel) bus depot but presently only CNG 12.5m rigid buses are being operated from the site. Significantly, Virginia is the only bus depot located in the Brisbane northern region which can currently refuel Brisbane Transport's existing CNG articulated buses. While the new Trade Coast Bus Depot still in development could potentially become a second dual fuel bus depot for both the Brisbane northern and eastern regions, Virginia is more centrally placed to deliver bus services in the northern suburbs and would incur considerably less dead running to and from the depot.

Figure 26: Virginia Bus Depot Layout



Existing primary (mechanical maintenance) garage building access doors are high enough to permit entry of double deck buses but the building's roof height is too low for hoisted undercarriage maintenance on a 4.3 – 4.4m high vehicle. Double deck buses could also potentially enter through the work bay access doors to other body and electrical, servicing and refuelling sheds on the Virginia site, but existing bus roof maintenance catwalks, washing machine roller frames and a stormwater harvesting downpipe would have to be raised for their maintenance, repairs and servicing.

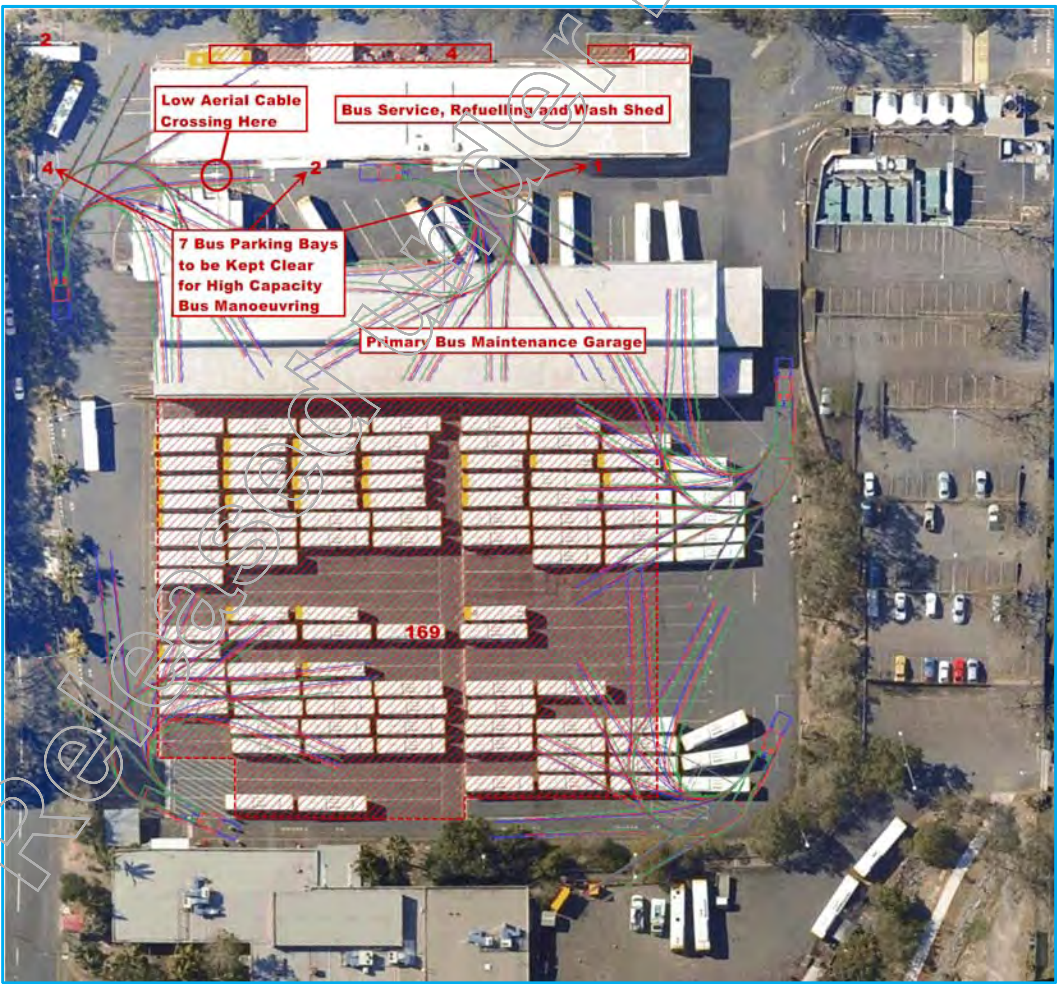
The primary garage is neither wide enough, nor its doors high enough, to enable hoisting of 18m articulated buses under partial cover, but the building is suitable for hoisting 14.5m rigid buses completely under cover. There are two other high bay maintenance buildings at Virginia Bus Depot currently being used for body and electrical maintenance but previously also utilised for hoisted bus mechanical maintenance; and although neither building is wide enough to fully cover an 18m articulated bus, one building has opposing drive-through access doors high enough for hoisting articulated buses under partial cover to an existing level concrete hardstand apron. This building could again be adopted as a secondary garage for future hoisted articulated bus undercarriage maintenance.

The hatched zones appearing on the existing yard nose-to-tail lanes in Figure 26 above identify where 18m articulated buses could potentially be parked on the Virginia site. Existing yard access and circulation corridors at Virginia Bus Depot have been designed exclusively for 12.5m standard bus turning and manoeuvring, and lanes would need to be shortened as illustrated in the aerial view for 14.5m rigid and/or 18m articulated bus turns. Because 14.5m rigid buses can be forward or reverse parked, additional perimeter parking bays have been identified at Virginia which are inaccessible to articulated buses, but both bus types exact a similar and very substantial reduction in the depot's parking capacity equivalent to approximately 25 standard bus spaces.

3.6.11 Toowong Bus Depot

Toowong Bus Depot is a dual fuel (CNG + diesel) bus depot and presently both CNG and diesel standard 12.5m rigid buses are operated to the Brisbane western region from this site.

Figure 27: Toowong Bus Depot Layout



Two large maintenance buildings exist at Toowong; a bus servicing, refuelling and washing shed, and a primary maintenance garage building in which all bus mechanical, electrical, body and tyre maintenance are undertaken. An existing low aerial cable crossing (refer to Figure 27 above) connects the two buildings and would have to be raised or buried to permit double deck bus entry into the primary garage work bays. The primary maintenance garage door and roof heights, and the building's adjoined chassis cleaning shed are high enough for pit, floor level and hoisted double deck bus undercarriage maintenance, but the roof truss height within the bus service, refuelling and wash shed is too low for double deck bus entry.

Toowong has a very densely packed bus parking scheme and is currently home to some 183 standard 12.5m rigid buses parked nightly to overflowing on every nose-to-tail parking lane and in every available yard and building perimeter parking bay. This depot also functions as the major maintenance and chassis cleaning centre for a further 32 standard size buses stationed offsite at the Richlands Satellite Bus Depot and all of the latter buses must periodically return to, exchange with and be stored at the Toowong mother depot.

Deployment of just a few 14.5m rigid and/or articulated buses at Towong Bus Depot would have a significant impact on its equivalent standard parking capacity as can be readily visualised from a cursory inspection of the aerial view appearing in Figure 27. All the high capacity bus turning template overlays shown on the aerial view identify locations where standard bus parking capacity would need to be crimped back for high capacity bus manoeuvring. Some 10 perimeter bus parking bays would immediately disappear from Toowong when the first high capacity buses were brought onto site, and from one to two standard bus parking spaces would further disappear off the end of each yard lane given over to parking either high capacity bus type. The hatched areas in Figure 27 show all the available parking spaces where 18m articulated buses could be parked, and aptly illustrate the parking capacity shrinkage caused by both high capacity bus types which have similar swept turning paths.

3.6.12 Richlands Satellite Bus Depot

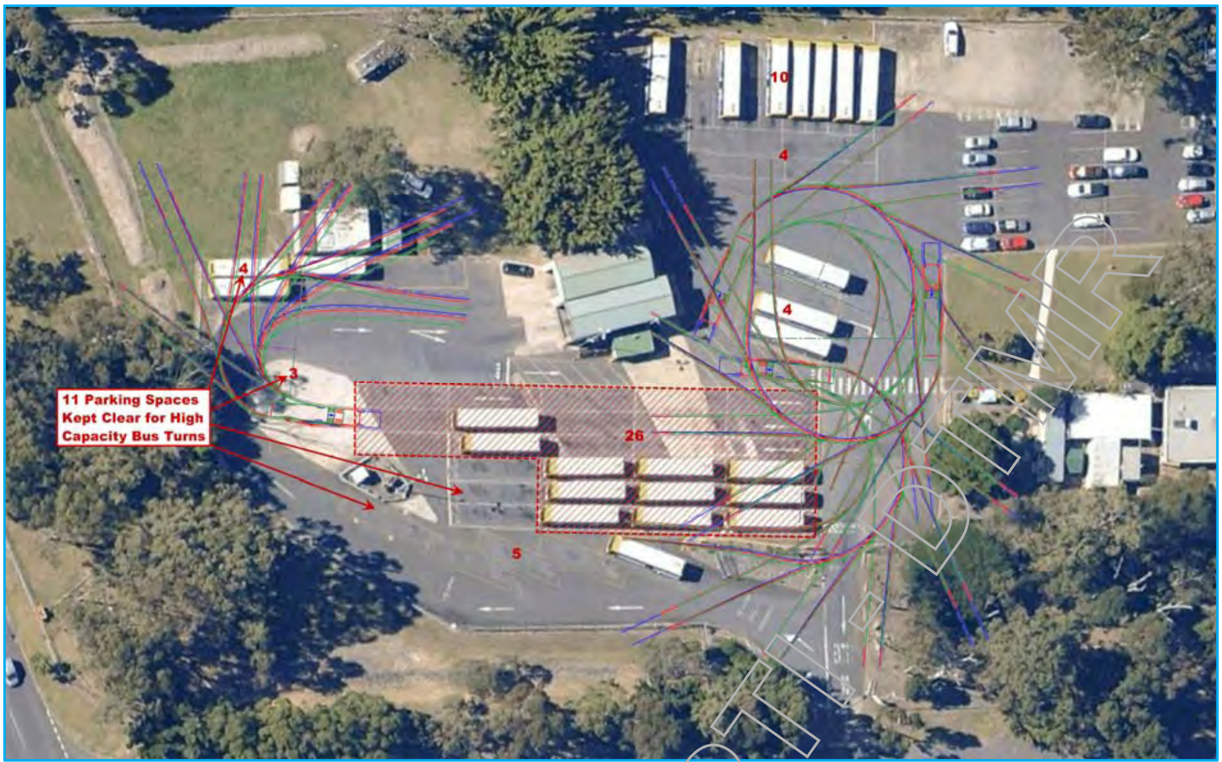
Richlands Bus Depot is currently a satellite of Toowong Bus Depot but major maintenance and chassis cleaning on the standard rigid 12.5m buses stationed at Richards could readily be transferred to Brisbane Transport's new Willawong Bus Depot.

Willawong has been identified elsewhere in this report as a double deck compatible bus depot and has no close low clearance bridges which would obstruct double deck bus movements on its surrounding public road network. Richlands could therefore conceivably become a double deck bus maintenance satellite of Willawong, but as for Sherwood Bus Depot, the suburban double deck bus services operating out of Richlands would effectively be hemmed in by existing low railway bridges to the near north, west and CBD inbound of Richlands, and the depot has not therefore been recommended as a potential home for double deck buses.

As for other bus depots presently only accommodating standard size buses, Richlands has a parking yard layout with very tight swept turning paths specifically tailored to maximise onsite storage of 12.5m rigid buses. A maximum of 15 future diesel articulated buses could potentially be stationed at Richlands Bus Depot in the hatched nose-to-tail parking area illustrated on the aerial view overleaf in Figure 28, but at a substantial depot holding capacity loss of equivalent to 10 standard bus parking spaces. The absolute minimum capacity loss to park as few as nine 14.5m rigid buses or six articulated buses on the existing Richlands bus lanes would be 3 standard bus parking spaces.

Richlands is a diesel only bus depot and none of Brisbane Transport's existing CNG articulated buses could currently be stationed at the site. This site is best suited to 14.5m rigid buses.

Figure 28: Richlands Bus Depot Layout



3.7 Impacts of High Capacity Vehicles on Depot Standard Bus Capacity

3.7.1 Depot Parking and Passenger Carrying Capacity Impacts

Table 7 below quantifies the impacts on each bus depot if it were to be populated to its maximum parking capacity with each high capacity bus type in the numbers earlier shown in Table 4. Whilst it would be unlikely that any bus depot would be populated to its maximum high capacity vehicle parking capacity in the near future, Table 7 provides a useful insight into the relative impacts on each depot of deploying the 4 alternative high capacity bus types.

Table 7: Recommendations Based on Depot Equivalent Standard Bus Capacity

Bus Depot	Suitable for This Depot (with Minor Upgrades)			Recommended for This Depot (as Ranked by Capacity)				Std Bus Capacity	Equiv Std Bus Parking Capacity Decrease				Equivalent Std Bus Passenger Capacity Increase/Decrease			
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses	12.5m Double Deck Buses	14.5m Rigid Buses	2 Door 18m Artic Buses	3 Door 18m Artic Buses	12.5m Standard Rigid Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	2 Door 18m Artic Buses	3 Door 18m Artic Buses
Brisbane Transport																
Bowen Hills	No	Yes	Yes (Note 1)	No	1	3	2	112	-6	-11	-9	31	-5	-24	-19
Garden City	Yes	Yes	Yes	No	1	3	2	184	0	-12	-18	127	6	-37	-15
Carina	No	Yes	Yes (Note 1)	No	1	3	2	185	0	-7	-3	126	8	-18	3
Virginia	No	Yes	Yes	No	1	3	2	179	-13	-24	-25	62	-9	-35	-25
Willawong	Yes	Yes	Yes	No	1	3	2	222	0	-10	-14	153	7	-38	-12
Richlands	No	Yes	Yes (Note 1)	No	1	3	2	56	-7	-11	-10	27	-1	-15	-13
Toowong	No	Yes	Yes	No	1	3	2	183	-21	-25	-22	86	-12	-40	-21
Sherwood	Yes	Yes	Yes (Note 1)	No	1	3	2	215	0	-18	-35	148	-2	-55	-32
Clarks Logan City Bus Service																
Loganlea	Yes	Yes	Yes	1	4	3	2	138	-2	-15	-6	92	16	-11	-2
Hornibrook Bus Lines																
Clontarf	Yes	Yes	No	1	2	No	No	52	0	-1	-4	17	4	-6	-4
North Lakes	Yes	Yes	Yes	1	2	No	No	57	-17	-17	-17	5	-7	-7	-2
Park Ridge Transit																
Park Ridge	Yes	Yes	Yes	1	2	3	3	121	-2	-12	-9	80	9	-5	-2
Surfside Buslines																
Molendinar	Yes	Yes	Yes	1	4	3	2	170	0	-15	-2	98	-5	-14	-6
Tweed Heads	No	Yes	Yes	No	1	3	2	150	-31	-16	-16	59	8	-39	-25
Coomera	Yes	Yes	Yes	1	2	4	3	190	-4	-11	-22	124	-11	-34	-11
Veolia Transdev Queensland																
Capalaba	No	Yes	Yes	No	1	2	2	105	0	0	0	35	14	-3	-1
					Equivalent Std Bus			2319	-103	-205	-212	1271	19	-383	-186
					Percent of Std Bus Capacity				**-4%**	**-9%**	**-9%**	**55%**	**1%**	**-17%**	**-8%**

Note 1: BT articulated buses are currently CNG only. These depots would only be suitable for future diesel articulated buses.

Decreases in depot equivalent standard bus parking capacity listed in Table 7 have been determined from the total reduction in perimeter parking bays and summation of whole and partial standard bus parking spaces given over at the head and tail ends of lanes for high capacity bus manoeuvring and turning. Increases and decreases in depot equivalent standard bus passenger capacity have been determined for all bus types on the assumption that each would typically be loaded in peak service to its fully seated plus 50% standing passenger carrying capacity.

Findings and recommendations drawn from the comparison of equivalent standard bus capacity changes shown in Table 7 are:

- **Double Deck Buses:** In depots where they could be reasonably accommodated, maintained and operated, double deck buses caused the least reduction (averaging around 4%) in depot equivalent standard bus parking capacity, and were the only high capacity bus type which consistently generated a net increase in equivalent standard bus passenger carrying capacity. Across all depots assessed, double deck buses increased average passenger carrying capacity per standard bus parking space given over to their parking by 55%. Double deck buses have therefore been recommended and ranked highest for all bus depots where they could be accommodated, maintained and operated.

- **14.5m Rigid Buses:** All 8 existing Brisbane Transport bus depots can accommodate double deck buses in their parking yards, but only 2 Brisbane Transport depots (Garden City and Willawong) could currently maintain and operate them. Single deck 14.5m rigid and 18m articulated buses are better suited to greater Brisbane suburban roads characterised by numerous obstacles to high profile vehicles such as low clearance bridges and tree branches, and poles, posts and shop awnings built out to the kerb against narrow left side lanes with high cross falls.

  When averaged across all depots, equivalent standard bus parking reductions caused by 14.5m rigid and 18m articulated buses were identical at around 9%, but actually varied quite significantly from depot to depot. Minimum equivalent standard bus parking capacity loss occurred with 14.5m rigid buses in large depot yards configured for perimeter parking and existing wide access corridors that could absorb their extra 2m length and wide swept path turning radii. For the majority of depots which utilised nose-to-tail parking lanes, the equivalent standard bus parking capacity loss was minimal only for existing lanes with 6 to 8 standard bus parking spaces.

  When the 2 single deck high capacity bus types were compared by relative price, maintainability, ease of deployment to existing depots and equivalent standard bus passenger carrying capacity, the 14.5m rigid bus easily outperformed both the 2 and 3 door articulated buses. For these reasons, the 14.5m rigid bus has been assessed as the best high capacity bus type for general deployment to all Brisbane Transport and most private operator bus depots where double deck buses were not considered a practical option.

- **18m Articulated Buses:** Generally, articulated buses have proven to be the most expensive, space hungry and least attractive high capacity vehicle option to deploy at the majority of existing Brisbane Transport and private operator bus depots. These 18m long vehicles require both forward in-out yard parking lanes and generously wide yard turning accesses, making them particularly difficult to integrate at depots with yards configured for standard bus perimeter bay parking where space has needed to be found to create articulated bus parking lanes. These buses were highly wasteful of depot lane parking spaces other than in depots which already parked 3, 6 or 7 standard size buses per lane, and at some of these depots, were too long to maintain under cover within existing garage buildings.

  At approximately 50% of the bus depots assessed, deployment of articulated buses resulted in a lower net reduction of equivalent standard bus parking capacity than did 14.5m rigid buses, but for all depots assessed, including those with better parking space utilisation, the import of articulated buses onto site resulted in a very considerable reduction in equivalent standard bus passenger carrying capacity. An average 17% decrease in depot equivalent standard bus carrying capacity was calculated for 2 door articulated buses and an 8% decrease for 3 door articulated buses, where 14.5m rigid buses achieved slightly better than break even passenger carrying capacity with the standard buses they displaced.

  Articulated buses have therefore not been recommended for most depots and relegated to the lowest ranking for general deployment of all the high capacity bus types. In the two depots (Loganlea and Molendinar) where articulated buses were recommended ahead of 14.5m buses, the 3 door articulated bus was ranked higher than the 2 door articulated bus.

3.7.2 Alternately Extended High Capacity Bus Parking Lanes

In this section, we have described an alternately extended yard parking lane configuration which would significantly improve mixed standard and high capacity bus parking densities in most the existing bus depot yards assessed during the study, and describe how alternately extended lanes would operate in practice at the Sherwood Bus Depot. Sherwood is Brisbane Transport's second largest and newest bus depot, and is currently home to 102 standard 12.5m rigid diesel buses and 40 high capacity 14.5m rigid diesel buses. An aerial view of the Sherwood Bus Depot layout plan appears below in Figure 29.

Figure 29: Sherwood Bus Depot Layout

Albeit very similar in its yard parking scheme and site building layout to the new Willawong Bus Depot, Sherwood utilises 43 x 5 standard bus length parking lanes, where Willawong utilises 37 x 6 standard bus length parking lanes. Reference to Table 2 indicates that 6 and 7 standard bus length parking lanes minimise wasted parking lane space for all high capacity vehicle sizes, where 4 and 5 standard bus length parking lanes are highly wasteful of equivalent standard bus parking space for 18m articulated buses. With 43 lanes, Sherwood tops the wasted space list for all the assessed depots in this regard with a net reduction of around 17% storage capacity on every standard bus lane given over to articulated bus parking.

Figure 30 overleaf presents a section of the Sherwood depot bus yard and illustrates the concept for alternately extended high capacity bus parking lanes. While double deck buses have neither been recommended for Sherwood Bus Depot nor shown on
Figure 30, the alternately extended parking lane scheme works equally well for all high capacity bus types, and for mixed parking of high capacity and standard size buses.

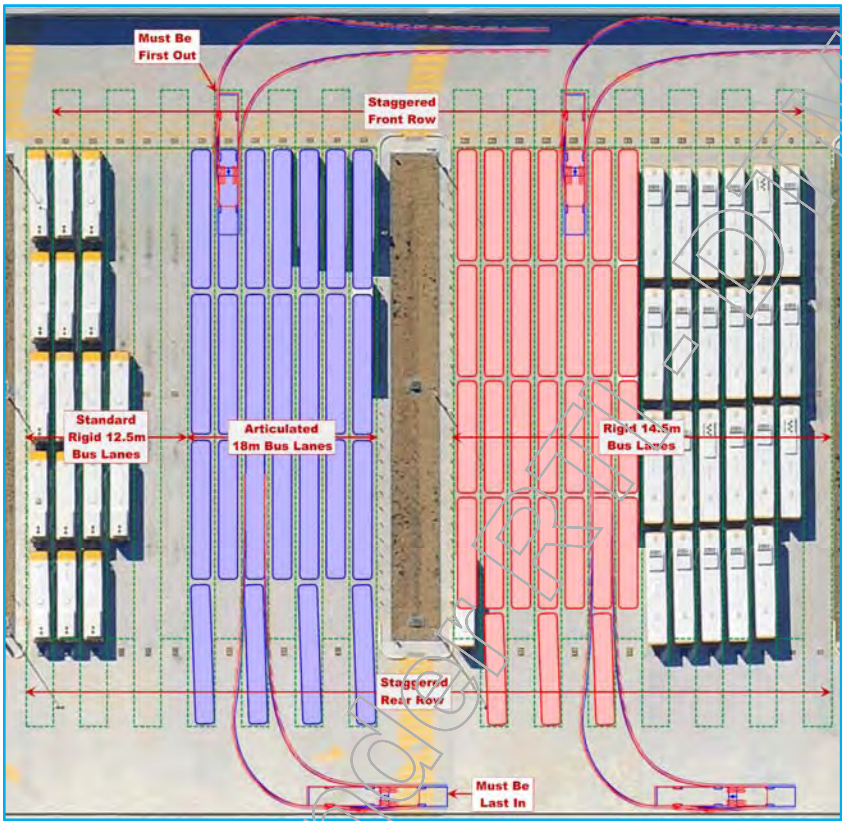
Alternate lane extensions can be utilised either at the rear or front, or at the rear and front of each nose-to-tail parking lane to recover lost parking space traded off for high capacity bus turn-ins from and turn-outs to perimeter circulation corridors respectively. Blue (articulated) and red (14.5m rigid) shaded bus outlines shown on
Figure 30 only use the rear of each alternately extended lane, increasing each by an additional high capacity bus space. Closer inspection of
Figure 30 will further reveal that an extra 14.5m rigid bus could be parked on every alternately extended lane using both their front and rear extensions.

Operating the concept alternately extended lane scheme at Sherwood would require driver, maintenance and servicing personnel adherence to 2 simple parking rules, namely:

1 All indented rear lanes to be filled before parking buses in the rear extended lanes, and

2 All front extended lanes to be cleared before taking buses from front indented lanes.

Figure 30: Alternately Extended High Capacity Bus Lane Concept Design



In the example illustrated, alternate rear lane extensions would improve the Sherwood Bus Depot 3 door articulated bus parking capacity by the equivalent of 42 standard buses and its passenger carrying capacity by the equivalent of 33 standard buses. The improvement gained for 14.5m rigid buses would be an increased parking capacity equivalent to 22 standard buses and passenger carrying capacity equivalent to 29 standard buses.

Appendix D

Performance Evaluation Report

Document Information

Client	TransLink Transit Authority
Job Number	4746
Title	Research and Analysis of High Capacity Vehicle Use - Operational Performance Evaluation of High Capacity Vehicles
Prepared by	MRCagney Pty Ltd Brisbane, Queensland
Date	6 August 2012

Quality Assurance Register

Issue	Description	Prepared by	Reviewed by	Authorised by	Date
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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis of high capacity vehicle *(HCV)* use within its South East Queensland network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in service on its network and include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

In this report, the operational performances of the 4 nominated high capacity vehicles are compared to that of the reference standard vehicle operated by all *TransLink* bus service providers in South East Queensland, namely the:

- Two Door 12.5m Rigid Bus.

1.2 Study Objectives

The objectives of this study were to:

1. Define bus stop dwell time, describe how excessive stop dwell time adversely impacts high capacity bus service timetables, scheduling, frequency and reliability, renders high capacity bus services non-competitive with private motor vehicles on long routes, and consumes valuable inner city station and kerbside stop capacity during peak service periods,
2. Explain why dwell time minimisation is crucial to high capacity vehicle operational performance, present international research into the key factors which increase stop dwell time, and outline world best practice bus configurations, station and stop geometrics, fare collection and bus operating strategies exploited by overseas mass transit agencies similar to *TransLink* to minimise stop dwell time,
3. Identify the significant differences between world best practice dwell time mitigation practices and contemporary route bus operating practices in South East Queensland,
4. Explain why all door boarding is considered crucial to the efficiency and viability of SEQ high capacity bus services, and profile compelling overseas case studies detailing where, why and how all door boarding has been successfully implemented in concert with random proof of payment fare evasion monitoring,
5. Measure and compare the average boarding and alighting times per passenger on the 4 high capacity vehicles with those of the reference standard vehicle, and determine the relative contributions of average passenger boarding and alighting times to average stop dwell time,
6. Measure and compare passenger alighting preferences on the 4 high capacity vehicles with those of the reference vehicle using front door only boarding, and determine the relative impacts of passenger alighting preferences on front door boarding conflicts that increase dwell time and rear door conflict-free concurrent alighting which reduces dwell time,
7. Measure and compare the average in-traffic service speeds, deceleration rates into, and acceleration rates out of bus stops on the 4 high capacity vehicles with those of the reference

vehicle, and determine the relative contributions of the number of stops per journey and dwell time per stop to the overall increase in total service delay and reduction in average service speed,

8 Measure and compare seated and standing passenger space utilisations during peak and off-peak services on the 4 high capacity vehicles with those of the reference vehicle, and determine the relationship between seating capacity, average standee counts and average standing times,

9 Develop a model based on and proofed against measured live service data to compare the relative operational performances of the 4 high capacity vehicles with that of the reference vehicle and a private motor vehicle over a broad range of typical SEQ operating parameters using front door only passenger boarding,

10 Modify the model to predict the operational performances of the 4 high capacity vehicles against the reference vehicle and private motor vehicle over an identical range of operating parameters using all door passenger boarding the determine its likely benefits,

11 Identify the service and route characteristics to which each high capacity bus type is best suited for front door and all door boarding, and

12 Define alternatives to optimise future mass transit high capacity vehicle operational performance on South East Queensland high capacity bus services.

1.3 Executive Summary

Rapid growth in high capacity vehicle fleet strengths has been identified over the past 3 years in all Australian State capital cities and the national capital. The rapid growth has been primarily driven by the progressive outstripping of standard 12.5m route bus capacity by rising patronage demand, and to a lesser extent, by the opportunity to fast track high floor low capacity route bus retirements before legislated 2012 and 2017 national transport disability target compliances fall due.

Only one capital city has the necessary bus rapid transit infrastructure already in place, or planned for future construction, to transition from the Australian traditional low speed, low capacity route service operating model to a world class high speed, high capacity mass transit operating model, and greater Brisbane stands well positioned in this regard to lead the nation in the exploitation of its young and still growing high capacity bus fleet.

Research undertaken during this study has uncovered very significant differences between overseas best practice mass transit high capacity bus operations and those in South East Queensland. To realise greater Brisbane's emerging opportunity, both *TransLink* and its high capacity bus operators will need to shift focus from what has in the past been best practice for traditional low speed, low capacity bus route operations to what is currently proven international best practice for mass transit high frequency, high capacity bus operations, and that has been clearly identified in our research as *Dwell Time Minimisation*.

The pivotal role of dwell time minimisation to high capacity bus service efficiency, performance and viability is such that international best practice mass transit agencies and their service operators go to extraordinary lengths to fine tune vehicle cabin layouts, station and kerbside stop geometrics, electronic signage systems, fare collection procedures and service operations to crimp just fractions of a second off their average passenger boarding and alighting times.

Overseas Mass Transit versus SEQ High Capacity Bus Operations

In stark contrast to contemporary South East Queensland high capacity bus operations which use bus cabin layouts designed for maximum seating capacity, front door only boarding, and drivers tasked with answering passenger travel enquiries, selling tickets, topping up *go cards* and monitoring fare evasion; world best practice mass transit bus service providers exploit:

1. All door passenger boarding and alighting at all bus stations and kerbside stops,
2. Cross platform interchanges for high loading capacity intermodal passenger transfers,
3. More and wider exterior bus plug doors carefully positioned and spaced to quickly distribute passengers to seated and standing areas with minimum platform and on-vehicle movements, and to equalise passenger boarding and alighting counts through all bus doors,
4. Optimisation (rather than maximisation) of bus seating capacity to afford wide aisle passenger circulation spaces throughout bus saloons, increased total passenger seated and standing capacity, improved standee comfort, and eliminate standee blockages and bottle necks to alighting and boarding passenger flows,
5. 100% step-free, ramp-free ultralow flat floor designs throughout bus saloons with minimum or no climb-on plinth mounted seats. This facilitates passenger movements aboard buses when decelerating and accelerating at stops by eliminating the potential hazards of passenger slips, trips and falls,
6. On-vehicle next stop visual and (public address) audible passenger cueing signs to advise passengers of the next stop in advance of arrival, and to request alighting passengers to begin to mobilise to doors. Similar passenger cueing signs and public address announcements are promulgated on bus station platforms to ready waiting passengers in advance for boarding at bus set downs,
7. Reserved passenger storage areas opposite and adjacent to bus doors to muster alighting passengers ready for disembarking prior to stop arrival, and to temporarily store boarding passengers during and after departing from stops,
8. Smartcard readers mounted at doors and in defined passenger door storage areas to enable alighting passengers to tag off both prior to stop arrival and while stopped, and boarding passengers to tag on both while stopped and after stop departure,
9. Dual berth inner suburban bus station designated stop bays and kerbside stops to obviate random high frequency bus arrival clashes,
10. Limited or no driver onboard ticket selling and interaction with passengers,
11. No onboard driver smartcard top up crediting, and
12. Roaming random "proof of payment" ticket inspections and hefty fines for non-valid smartcard and ticket holders applied uniformly across all travel modes (bus, train, light rail and ferry) to both monitor and manage modal and intermodal fare evasion.

In Part 2 of the study, the authors have measured average stop boarding, alighting and dwell times per passenger using *go card* ticketing data captured on several hundreds to thousands of bus services operated by the 4 high capacity vehicles, and both older high floor and new ultralow floor standard size buses between 1 March and 8 April 2012. The measured results have identified stop delays in the order of 2.5 to 4 times longer than best practice planning times adopted by overseas mass transit planners and station designers for similar length high capacity vehicles with 2 and 3 double width doors.

In a similar study undertaken by the Queensland University of Technology at the lead stop operated Mater Hill Busway Station just prior to smartcard implementation in 2004, very high peak period dwell times were cited ranging from 4.8s per passenger at the lead stop loading area up to 12.7s per passenger at the third rear of platform loading area, the latter proving to be almost an order of magnitude higher than best practice mass transit planning times for a comparable bus rapid transit (*BRT*) station.

The very high peak dwell time at lead stop busway stations is well known to be caused by passenger relocation delays along platforms to board buses, and modern GPS based real time passenger information systems installed on best practice mass transit bus stations cue passengers to relocate to predicted set down loading areas well in advance of bus arrivals and continuously monitor and sort service destinations displayed on signs into the sequential order of actual platform set downs. The authors have highlighted that similar functionality should be available on the new *TransLink INIT Customer First* real time passenger information system signs and is considered essential to efficient future peak period high capacity vehicle mass transit operations using busways.

Measured High Capacity Vehicle Operational Performance

Go card ticketing data measurements, on-vehicle trips and station passenger movement surveys have revealed the reasons why local SEQ high capacity bus services have underperformed their overseas mass transit counterparts. Key findings of the study have concluded that adoption of the earlier mentioned international best practice dwell time minimisation strategies will greatly improve future high capacity mass transit operations in South East Queensland. Relevant key findings from the study evidencing this conclusion were as follows:

1. The fastest average boarding, alighting and dwell times per passenger for the 4 high capacity vehicles were measured on the Brisbane Transport 2 door 18m articulated bus Route 111 services. On-vehicle observations clarified this occurred because alighting busway station passengers positioned themselves at bus doors in advance of station arrivals and double streamed off at rear doors and in single file at front doors with minimal conflict to boarding passengers. Route 111 high capacity services had a very high incidence of concurrent passenger rear door alighting and virtually no interaction took place between Brisbane Transport articulated bus drivers and boarding passengers.
2. In contrast to the Brisbane Transport Route 111 articulated bus services, Clarks Logan City Route 555 articulated bus drivers experienced a very high incidence of interaction with passengers primarily for requested paper ticket purchases and *go card* top ups. Driver-passenger interactions were observed to not only block off one channel of boarding passengers at the double width front doors, but to cause conflicts in the free flowing front door channel between boarding *go card* users and those passengers who chose to alight via the front door.

   Consequently, average boarding times per passenger measured on both Clarks Logan City articulated buses were 1 second (or 40%) longer than on the Brisbane Transport articulated buses, and monopolised total dwell time to the extent that no significant difference was found between the two Clarks Logan City bus variants. The total stop dwell time savings accrued from the very high middle door passenger alighting counts on the superbus were consequently fully negated out.
3. The longest average alighting time per passenger was measured on the double deck bus and passengers from its upper deck were frequently observed to continue alighting through the double width rear door in single file after all alighting passengers on the lower deck had fully disembarked. A near 50%:50% even split was measured during trips between the mostly young and able bodied passengers who elected to sit on the upper deck and generally older passengers who chose to sit on the lower deck.

   At the high AM peak offloading stops in Fortitude Valley and the CBD, passengers alighting from the upper deck continued to disembark for periods of up to 10 seconds after passengers on the lower deck had already exited. Boarding times on the double deck bus were found to be unaffected by upper deck use, but upper deck alighting times were randomly and frequently delayed by passengers fearful of descending the upper deck stairway until the double deck bus had completely come to rest.
4. Without exception, average boarding times per passenger greatly exceeded average alighting times on all bus types, including the double deck and standard 12.5m rigid buses, and dominated average dwell times. Average boarding times were increased on off-peak bus services

by passenger preferences to alight at the front door and block boarding passengers, were highest on the 2 door articulated buses, and lowest on the 14.5m rigid bus for which over 80% of passengers currently choose to alight via the rear door.

The impact of passenger front door alighting preferences proved to be much less significant however on peak period AM inbound and PM outbound services where boarding and alighting passenger flows were identified as predominantly non-conflicting and unidirectional, i.e. over 95% of passengers boarded or alighted in one direction only without door flow channel conflicts.

5 Examination of manufacturer floor layout plans for all 5 bus types examined identified a very high correlation between door alighting preferences and rear door proximity to passenger seating and standing areas. It has been consequently determined that passengers have no inherent preferences to alight at any particular door; they merely choose to exit via the nearest available door. This finding has proven to be very important to the future successful implementation of all door boarding because it enables high capacity bus passenger rear door alighting preferences to be tailored through careful design of high capacity bus seating and standing areas and selective positioning of their (middle and) rear door proximities.

6 Measured average passenger boarding, alighting and dwell times were unexpectedly found to be slightly higher on the all door boarding *CityGlider* ultralow floor 12.5m rigid buses than on similar front door only boarded Route 345 ultralow floor 12.5m *CityBuses*. Only around 1 in 4 passengers on the *CityGlider* service boarded at the narrow rear door and around 3 in 4 *CityGlider* passengers preferred to alight and conflict with rear door boarding passengers. This finding has discredited the mistaken notion that uncontrolled all door boarding reduces dwell time and has been explained by observing the imbalance between how passengers freely choose to board at the front door and alight at the rear door during off-peak services which comprise the vast majority of weekday high churn *CityGlider* bus services.

On several trips taken aboard the off-peak *CityGlider* service, it was observed that passengers who initially queued to board at the rear door deserted the queue to board at the front door while passengers were still alighting in single file through the narrow bus rear door. This often occurred after those who initially chose to board at the front door were already onboard and seated. When rear door queues occurred, they resulted in a longer stop dwell time because the bus had to hold over longer at the stop waiting for single file passenger boardings to finish at the rear door. Other notable contributors to poor dwell time performance sighted during the 10 – 15 minute driver variable off-peak services were the willingness of customer-friendly *CityGlider* drivers to hold over at stops for late arriving hailers and runners, and the laid back pace of alighting passenger movements to doors until after buses had stopped.

7 Measured in-service speeds and bus stop deceleration and acceleration rates were found to be lowest on the double deck and Brisbane Transport CNG 2 door articulated buses, and highest on the 14.5m rigid bus. In-service average stop acceleration and deceleration rates measured on every bus type were highly variable between drivers and found to be less related to vehicle brake/retarder performance and engine power than to personal driving habits. On identical buses for instance, some drivers were aggressive brake and accelerator users who pushed vehicle performance to the limit, whilst others were more passive and coasted into and slowly took off from bus stops. Irrespective of driving habits, average in-service stop deceleration and acceleration rates were found to be inversely proportional to incident average traffic speed for all bus types.

Average service speed was found to be proportional to average traffic speed and route length but inversely proportional to the number of stops per kilometre and average dwell time per stop. Ironically, aggressive acceleration and deceleration made little difference to average service speed, and aggressive drivers gained only fractions of a minute extra layover rest time at termini by pushing bus fuel consumption and brake lining wear to the limit. Buses on longer routes with few stops had the highest average speed, typically attaining greater than 50% average traffic speed, while buses on shorter routes with many stops attained speeds of around one third average traffic speed.

Very low average service speeds of around one fifth average traffic speed were recorded on sections of the Redcliffe 315 and Aspley 345 routes where stops were closely spaced and boarded or offloaded less than a few passengers.

8 Only 2% to 7% of high capacity vehicle weekday peak services carried standing loads, and for those that did, average standing times varied between 9 and 18 minutes, and maximum standing times between 19 and 37 minutes. No double deck peak period bus service carried standees other than those passengers who freely chose to stand when unoccupied seats were available.

Passengers on all bus types who observed to stand when seats were available and were predominantly young passengers who wanted to chat with friends or passengers who boarded for short trips and chose to stand near doors to be first off, avoid peak standing crushes or conflicts with other standees when alighting.

The majority of services operated by all bus types were in off-peak periods during which 56% to 73% of installed high capacity bus seats went unused and 57% to 61% of standard 12.5m rigid bus seats went unused.

9 Measured average and maximum standee counts and their standing periods were lowest on the high passenger turnover *CityGlider* and *Busway* 111 routes. Our analysis methodology has demonstrated that driver/operator overload reports and trip peak boarding counts do not provide reliable surrogates for determination of peak loading, overloading and overload duration periods, or for justifying replacement of standard 12.5m buses with larger high capacity buses.

We believe justification of high capacity bus deployment can only realistically be determined on high frequency, high passenger turnover services by measuring cumulative *go card* tag ons and tag offs incrementally along trips after each bus stop to calculate average and maximum standing loads and their durations. On high turnover, high frequency bus routes, average standing times were found to be very short and missed passenger pick-ups were collected within short headway periods by following services.

Impact of Maximised Seating on HCV Service Dwell Time and Lost Boarding Capacity

Interviews conducted by MRCagney consultants with 4 *TransLink* bus operators and 3 major Australian bus builders have established that SEQ route bus operators overwhelmingly advocate maximum seating capacity on their new ultralow floor buses. Only one bus operator interviewed declared its support for reduced seating on high capacity vehicles, but saw little merit in such on standard size route buses.

Common reasons given for maximising bus seat capacity were loss of seating capacity to wheelchairs and ultralow floor engine, transmission and wheel arch intrusions, increased peak period commuter comfort, and compliance with the *Queensland Transport Operations (Passenger Transport) Standard* which imposes strict time and distance limits for standing school children on Queensland bus services.

Most operators were unaware that the current *Standard* allowed for 3 children to be seated on a *Local Classification* route bus in each twin adult passenger seat, that the no standee rule only applied to *ADR58/00 Complying Buses* fitted with seat belts, the 90 minute school child maximum standing time limit only applied to school bus services operated on 40km and longer *Regional Classification* bus routes, and the *Standard* had been amended in December 2011 to remove the no standee rule for *Local Classification* school and route bus services operated over distances in excess of 20km.

It is evident that SEQ bus operator obsession with recovering lost seat capacity given over to wheelchair parking bays and to maximise seating capacity on new low ultralow floor buses has come at a very high cost to stop dwell time caused by:

- Abandonment of chassis manufacturer designed slip, trip and fall free 100% flat floors in favour of body manufacturer requested stepped up and ramped floors with climb-on passenger seats in cabin spaces to the aft of the rear door, (and in some cases even to the fore of the rear door),
- Abandonment of double width rear doors with adjacent passenger storage areas previously incorporated on all early vintage Brisbane high floor buses, in favour of narrow rear doors without passenger storage areas on new ultralow floor standard 12.5m buses. This has also been observed on some late model ultralow floor 14.5m rigid buses operating in greater Brisbane,
- Narrow aisle ways flanked either side by high plinth mounted seats, creating coach style seating layouts with no space for passengers to freely pass standees, and other constriction bottle necks to passenger movements both between doors and to the rear cabin spaces,
- Heighted standee discomfort caused by the need for standees to continually carry luggage to prevent trampling, to repeatedly lean over seated passengers or move toward doors to make way for alighting passengers, and highly crammed forward cabin areas because aisle ways rear of the aft door are too narrow, ramped and have low head clearances,
- Reduced total seated and standing capacity afforded by the extra tonne permitted axle weight (equal to 15 standing passengers) granted under new Australian design rules and heavy vehicle regulations exclusively to ultralow floor buses. SEQ bus operators prefer instead to convert their *COAG* granted concessional axle weight limits into underutilised seating capacity, and
- Higher bus procurement costs for extra seats, heavier plinth seat frames and floors; higher body frame, floor and seat maintenance and cleaning costs, and higher weight related fuel consumption and brake lining replacement costs for underutilised seating during off-peak services.

The longer total trip dwell time, resulting longer timetables and recurring operating expenses created by underutilised passenger seats are ultimately passed to *TransLink* through operating contracts, and the reduction in peak period boarding capacity translates to lost passenger revenue and higher subsidies throughout the 20 year average service life of every new ultralow floor bus currently entering service. The additional cost to *TransLink* of carrying underutilised seats increases in proportion to vehicle size and lost total passenger carrying capacity. This can be readily demonstrated by the 27.5% increase in total carrying capacity of the 3 door Logan City articulated superbus over the 2 door Brisbane Transport and Clarks Logan City articulated buses.

Modelling Analyses of High Capacity Vehicle Front Door Only Boarding

Operational performance modelling has been used in this study to evaluate the route characteristics best suited to each front door boarded high capacity vehicle type relative to both a standard 12.5m rigid bus and competing private motor vehicle during the AM inbound and PM outbound peak periods. The model developed has been used to test:

- Each bus type boarded to its respective maximum seated and standing capacity,
- On 5 different routes lengths between 5km and 25km,
- With between 2 and 32 bus stops per trip,
- Including average passenger walking or driving time to stops when comparing the competitiveness of each bus type to a private motor vehicle completing the same trip,
- Using measured average passenger door boarding and alighting times and passenger door alighting preferences for front door only boarding, and both calculated average passenger door

boarding and alighting times for balanced concurrent minimum dwell and unbalanced current passenger door alighting preferences for all door boarding,

- Operating at 3 peak period *RACQ* and *Translink* published Brisbane average traffic speeds of 30km/h for routes on CBD arterial, sub-arterial and local roads, 45km/h for routes on CBD multilane highways and motorways, and 75km/h for routes on busways, city ring roads and highways with dedicated bus only and T2/T3 transit lanes, and
- At measured average bus stop deceleration and acceleration rates applicable to each bus type.

For front door only boarding on all bus types during weekday peak periods, total trip dwell times were calculated as listed on the third line of the table below, and found to be independent of the total stops made. While total stop deceleration and acceleration times increased markedly with total stops made and average traffic speed, their combined total times shown shaded in green accounted for less than one third of total journey delay accrued by stopping, alighting and boarding passengers. Dwell time at stops to alight and board passengers dominated the operational performances of all bus types in proportion to their respective passenger capacities.

	Contribution of Bus Deceleration and Acceleration Time to Total Bus Stop Delay									
	Two Door 12.5m Standard Rigid Bus		Two Door 12.5m Double Deck Bus		Two Door 14.5m Extended Rigid Bus		Two Door 18m Articulated Bus		Three Door 18m Articulated Superbus	
Dwell	5.9 mins Total		11.0 mins Total		7.8 mins Total		6.3 mins Total		10.6 mins Total	
Bus Stops Per Trip	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay
30 Kilometre/Hour Average Traffic Speed										
2	0.2 min	1%	0.3 min	1%	0.2 min	1%	0.2 min	2%	0.2 min	1%
3	0.3 min	3%	0.6 min	3%	0.4 min	3%	0.5 min	4%	0.4 min	2%
4	0.5 min	4%	0.9 min	4%	0.6 min	4%	0.7 min	6%	0.7 min	3%
6	0.9 min	7%	1.5 min	6%	1.0 min	6%	1.2 min	9%	1.1 min	5%
8	1.2 min	9%	2.1 min	9%	1.4 min	8%	1.7 min	12%	1.6 min	7%
11	1.7 min	13%	3.0 min	12%	2.1 min	12%	2.5 min	16%	2.2 min	9%
16	2.6 min	18%	4.5 min	17%	3.1 min	17%	3.7 min	23%	3.3 min	14%
23	3.8 min	24%	6.6 min	23%	4.6 min	23%	5.5 min	30%	4.9 min	19%
32	5.3 min	31%	9.3 min	30%	6.4 min	29%	7.7 min	38%	6.9 min	24%
45 Kilometre/Hour Average Traffic Speed										
2	0.3 min	3%	0.5 min	2%	0.4 min	3%	0.4 min	3%	0.4 min	2%
3	0.6 min	5%	1.0 min	4%	0.8 min	5%	0.9 min	7%	0.8 min	4%
4	1.0 min	8%	1.4 min	6%	1.2 min	7%	1.3 min	10%	1.2 min	5%
6	1.6 min	12%	2.4 min	10%	2.0 min	12%	2.2 min	15%	2.0 min	9%
8	2.3 min	16%	3.3 min	13%	2.9 min	15%	3.1 min	20%	2.8 min	12%
11	3.2 min	22%	4.8 min	18%	4.1 min	21%	4.4 min	26%	4.1 min	16%
16	4.8 min	29%	7.2 min	25%	6.1 min	28%	6.7 min	35%	6.1 min	22%
23	7.1 min	38%	10.5 min	32%	9.0 min	37%	9.8 min	44%	8.9 min	30%
32	10.0 min	46%	14.8 min	40%	12.7 min	45%	13.8 min	52%	12.6 min	37%
75 Kilometre/Hour Average Traffic Speed										
2	0.9 min	7%	1.2 min	5%	1.1 min	7%	1.2 min	9%	1.0 min	5%
3	1.8 min	14%	2.3 min	10%	2.2 min	12%	2.5 min	16%	2.0 min	9%
4	2.8 min	19%	3.5 min	14%	3.3 min	17%	3.7 min	23%	3.0 min	12%
6	4.6 min	28%	5.9 min	21%	5.5 min	26%	6.2 min	33%	5.1 min	19%
8	6.5 min	35%	8.2 min	27%	7.7 min	33%	8.7 min	41%	7.1 min	25%
11	9.2 min	44%	11.7 min	35%	10.9 min	41%	12.4 min	50%	10.1 min	32%
16	13.8 min	54%	17.6 min	44%	16.4 min	51%	18.6 min	60%	15.2 min	42%
23	20.3 min	63%	25.8 min	54%	24.1 min	61%	27.2 min	68%	22.3 min	51%
32	28.6 min	71%	36.4 min	62%	33.9 min	68%	38.3 min	75%	31.4 min	60%

The impact of stop dwell time on high capacity bus service performance was found to diminish with increasing route lengths over 7.5km and falling average traffic speeds to the extent where high capacity buses began to alight and board their respectively higher passenger loads in total trip times only marginally higher than those achieved by standard rigid 12.5m buses. High capacity buses then jostled for highest overall operational performance ranking based on their respective passengers carried per unit total trip time as shown in the table below.

Further analyses of the modelling results showed that front door only boarding stop dwell times were highly unbalanced with current passenger alighting preferences, most particularly during off-peak periods and operational performance of all bus types could only be improved in both peak and off peak periods by reducing average boarding times per passenger and shifting passenger alighting preferences during off-peaks to 100% rear door alighting, other than at stops where no passengers were waiting to board.

Route Length	Routes Operated at 30km/h	Routes Operated at 45km/h	Routes Operated at 75km/h
	Mixed Traffic on Local, Arterial and Sub-Arterial Roads during Peak Period	Mixed Traffic on CBD Radial Highway or Motorway during Peak Period OR Off-Peak in Mixed Traffic on Local, Arterial and Sub-Arterial Roads	City Ring Road, Busway or Highway Bus Transit Lane during Peak Period OR Off-Peak in Mixed Traffic on a CBD Highway or Motorway
5km	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
10km	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
15km	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 2) 2 : 2 Door 14.5m Rigid (Note 2) 3 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
20km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic (Note 3) 1 : 2 Door Double Deck (Note 3) 2 : 2 Door 18m Artic 3 : 2 Door 14.5m Rigid 4 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
25km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 4) 2 : 2 Door 14.5m Rigid (Note 4) 3 : 2 Door 12.5m Rigid

Note 1: Up to a Limit of 22 Boarding/Alighting Stops
Note 2: Up to a Limit of 10 to 15 Boarding/Alighting Stops
Note 3: Up to a Limit of 10 Boarding/Alighting Stops
Note 4: Up to a Limit of 5 Boarding/Alighting Stops

The modelling analysis further verified that if it could be unshackled from the high average boarding time per passenger caused by driver ticket selling, *go card* top ups and passenger travel enquiries, the very high capacity 3 door articulated superbus with its very low 14% front door passenger alighting preference and very low average alighting time per passenger through the middle and rear doors would rise to number one ranking in all high capacity bus categories listed in the table above, other than those where 12.5m buses only have been nominated.

The ratio of average traffic speed to average service speed is a direct measure of the total time taken to complete a bus trip compared to the time taken to complete the same journey without stops using a private motor vehicle. An interesting phenomenon was identified in the modelling of high capacity front door loaded services at peak period bus service speeds, namely that their competitiveness with the private motor vehicle (including allowance for passenger walk or drive to stop times) improved with falling traffic speeds of 45km/h or lower. This occurred on city arterial, sub-arterial and local roads, highways and motorways at route lengths of 15km or longer and became increasingly independent of the actual number of stops made.

It has been found that with increasing congestion, for each percent drop in average traffic speed recorded over every successive RACQ Brisbane peak road speed survey, the percentage of service speed to traffic speed increased at a higher percentage rate, and favoured the higher 112 to 116 passenger 3 door articulated and double deck high capacity buses more so than it did the lower 88 – 92 passenger 14.5m rigid and 2 door articulated high capacity buses and the 75 passenger standard 12.5m rigid buses. Consequently, the outlook for high capacity buses looks set to continuously improve relative to the private motor vehicle.

Modelling Analyses of High Capacity Vehicle All Door Boarding

Modelling analyses have also been conducted to determine the likely improvement to operational performance of each high capacity vehicle type during peak periods using all door boarding.

All door boarding analyses have identified an infinite range of ratios exists between the percent of passengers who choose to alight through the (middle and) rear door(s) and the percent of passengers needed to board at the front door to equalise (or balance up) total boarding and alighting times through all doors in accordance with the average boarding and alighting times per passenger applicable to each bus type. If these percentages are not fully balanced, the stop dwell time increases above the ideal minimum to the longest time taken to alight and board the longest passenger queue(s) at any particular bus door, in much the same manner that was observed on the highly imbalanced all door boarded *CityGlider* 12.5m rigid buses.

It has been found that balanced concurrent alighting and boarding through all bus doors reduces dwell time to its ideal minimum by a factor very close to the ratio of total door channels divided by 2. For the 2 channel door double deck bus, 14.5m rigid bus and 2 door articulated bus, the minimum dwell time is half that currently obtained for front door only boarding. For the 3 door double deck bus, the minimum dwell time is a third of that currently obtained for front door only boarding, and for the standard bus with a single channel rear door, around 1.8 times lower.

Our analyses have also determined that a unique condition exists when alighting and boarding passenger percentages at every bus door are set proportional to their respective door loading channels. Under this special condition, minimum dwell time becomes totally independent of average boarding and alighting times per passenger for every given bus capacity. This unique condition occurs for each bus type when passengers are induced to alight and board in the following proportions:

- 2 Door 12.5m Rigid Bus: 2/3 Front Boarding, 1/3 Rear Boarding; 2/3 Front Alighting, 1/3 Rear Alighting
- 2 Door 12.5m Double Deck Bus: 50% Front Boarding, 50% Rear Boarding; 50% Front Alighting, 50% Rear Alighting
- 2 Door 14.5m Rigid Bus: 50% Front Boarding, 50% Rear Boarding; 50% Front Alighting, 50% Rear Alighting
- 2 Door 18m Articulated Bus: 50% Front Boarding, 50% Rear Boarding; 50% Front Alighting, 50% Rear Alighting
- 3 Door 18m Artic Superbus: 1/3 Front Boarding, 1/3 Middle and 1/3 Rear Boarding; 1/3 Front Alighting, 1/3 Middle and 1/3 Rear Alighting

An important property has been observed when passengers are induced to board and alight in proportion to all available bus door loading channels. The sensitivity of stop dwell time to the ratio of (middle and) rear door alighting percentage to front door boarding percentage mismatch is lower around the above listed unique conditions than at any other induced ratio. In practice, this would mean that if *TransLink* aimed to minimise dwell time on its high capacity bus services using all door boarding and chose to induce the unique ratio for each bus type listed above, actual dwell time achieved in service should remain close to its ideal minimum even if passengers didn't choose to exactly alight and board in ideal proportions at every door. Put simply, close enough would still prove to be good enough.

The authors have also further examined how well all door boarding would perform if current passenger (middle and) rear door alighting preferences were to stay unchanged. Based on current passenger rear door alighting preferences on each bus type, the percentage of passenger boardings needed to balance out their exits via the front and rear doors to achieve minimum stop dwell time would be:

- 2 Door 12.5m Rigid Bus: 81% Front, 19% Rear
- 2 Door 12.5m Double Deck Bus: 53% Front, 47% Rear
- 2 Door 14.5m Rigid Bus: 70% Front, 30% Rear
- 2 Door 18m Articulated Bus: 48% Front, 52% Rear
- 3 Door 18m Articulated Superbus: 44% Front, 28% Middle, 28% Rear.

These proportions indicate that only the double deck and 2 door articulated buses have close to ideal alighting preferences, but inducing the required ideal boarding percentages at both front and (middle and) rear bus doors for minimum dwell would prove far more difficult in practice than inducing passengers to simply equalise their boardings and alightings at all bus doors on all high capacity bus types.

It has been found that irrespective of the random choices of passengers to board and alight at particular doors, improved dwell times would still be achieved on all high capacity buses, but the dwell time reduction falls progressively with increasing shift from their ideal door alighting and boarding ratios. The changed relative rankings of high capacity bus operational performance with balanced all door boarding and alighting are presented in the table overleaf.

Approaches to Inducing Balanced All Door Passenger Boarding on High Capacity Buses

Based on overseas implementations that have already proven successful, the authors believe balanced all door boarding (but not alighting) can be induced by advertising the launch of, and repeated promotion of, a policy that passengers without tickets board at front doors and all other passengers with *go cards* form into equal length queues at all bus doors when boarding high capacity bus services. Human dislike of standing at the end of the longest queue should act to naturally balance boarding queues once the policy has been implemented and become common knowledge.

Learnings from both overseas research and the *CityGlider* experience are that passengers conditioned by decades of front door boarding need to be re-educated to board at all doors and signage at bus doors and on stop blades needs to reinforce the message to new passengers.

But there is a cause for caution. Equalised boarding through all doors on the narrow rear door ultralow floor rigid 12.5m standard bus does not minimise dwell time which requires that twice the number of passengers alight and board at the front door to the number who alight and board at the rear door. Rigid ultralow floor bus services are currently only suited to front door boarding and with so many now in service, it would be difficult to make these buses all door boarding compatible.

Route Length	Routes Operated at 30km/h	Routes Operated at 45km/h	Routes Operated at 75km/h
	Mixed Traffic on Local, Arterial and Sub-Arterial Roads during Peak Period	Mixed Traffic on CBD Radial Highway or Motorway during Peak Period OR Off-Peak in Mixed Traffic on Local, Arterial and Sub-Arterial Roads	City Ring Road, Busway or Highway Bus Transit Lane during Peak Period OR Off-Peak in Mixed Traffic on a CBD Highway or Motorway
5km	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
10km	1 : 2 Door 18m Artic 1 : 2 Door 14.5m Rigid 2 : 3 Door 18m Artic (Note 2) 2 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 3) 1 : 2 Door 14.5m Rigid (Note 3) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
15km	1 : 3 Door 18m Artic 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic 1 : 2 Door 14.5m Rigid 2 : 3 Door 18m Artic (Note 3) 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
20km	1 : 3 Door 18m Artic 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 4) 1 : 2 Door 14.5m Rigid (Note 4) 2 : 3 Door 18m Artic (Note 5) 3 : 2 Door 12.5m Rigid
25km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 3 Door 18m Artic (Note 5) 3 : 2 Door 12.5m Rigid

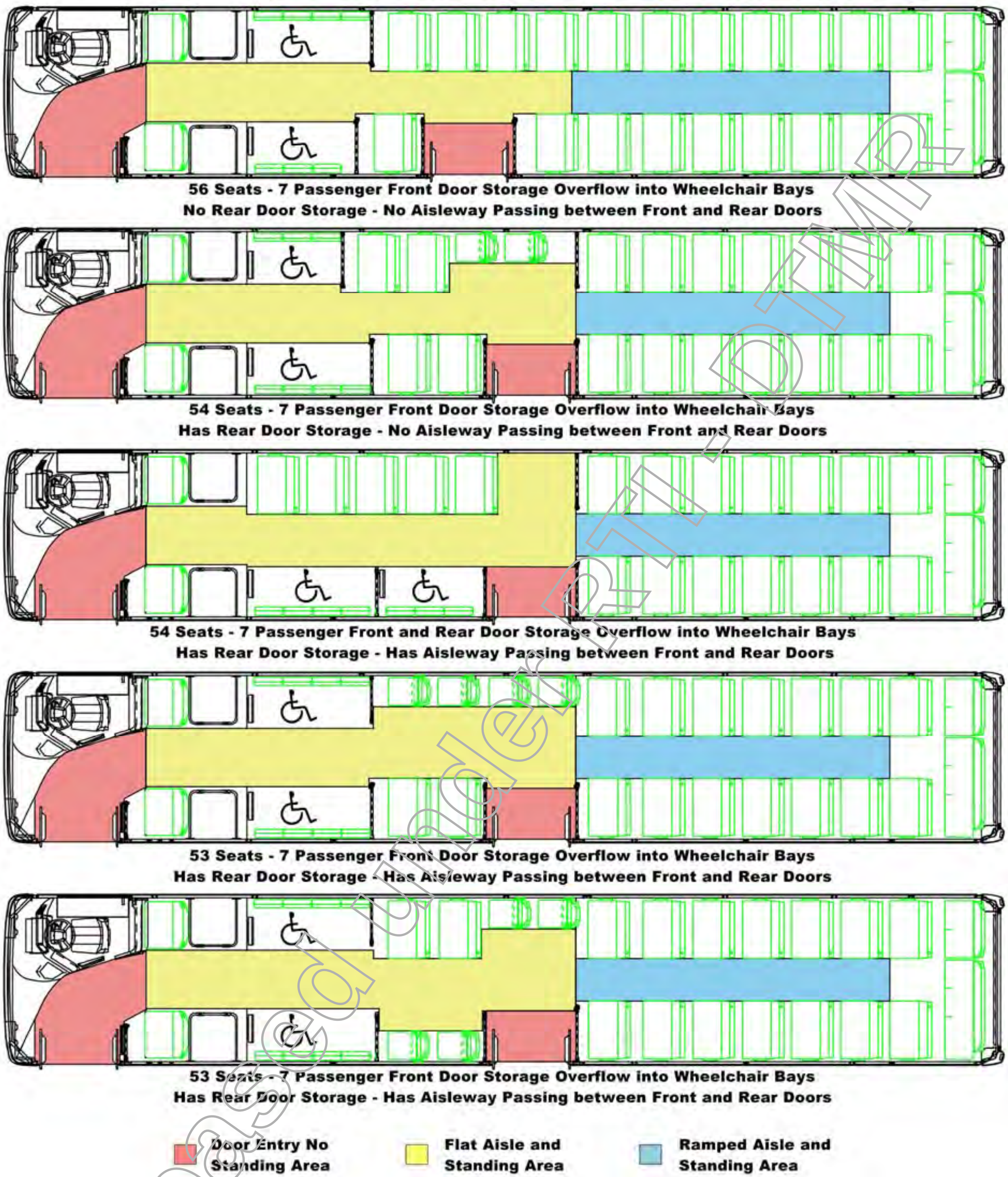
Note 1: Up to a Limit of 10 Boarding/Alighting Stops
Note 2: Up to a Limit of 20 Boarding/Alighting Stops
Note 3: Up to a Limit of 15 Boarding/Alighting Stops
Note 4: Up to a Limit of 8 Boarding/Alighting Stops
Note 5: Up to a Limit of 5 Boarding/Alighting Stops

Our analyses have shown that balanced alighting can only be induced through bus layout design. Measurements have clearly established that passenger alighting preferences can be manipulated by changing the proximity of (middle and) rear door positions to saloon seated and standing areas.

We have further determined that average boarding and alighting times per passenger could be almost halved again to further reduce peak period high capacity vehicle total trip dwell time by widening aisle ways for improved standee circulation and by creating dedicated passenger storage areas opposite and adjacent all doors. The highest reductions in average boarding and alighting times would occur if alighting cueing prompts to move passengers to these door storage areas prior to stopping were introduced, and if the on-vehicle *Cubic* card interface devices could be reprogrammed to enable *go card* tag offs before and during stops and *go card* tag ons during and after stops in the door passenger storage areas.

The most imbalanced passenger rear door alighting preference for future high capacity vehicle all door boarding was measured on the Brisbane Transport 14.5m rigid bus. Its layout is currently optimised for maximum seating capacity and front door only boarding, but is grossly unsuited to future all door boarding. We have demonstrated in the report (and reproduced overleaf) alternative layout modifications that would be needed to the 14.5m rigid bus rear door position, seating and standee areas, aisle way widths, and for creation of door storage areas to optimise the cabin layout for future minimum dwell balanced all door boarding and alighting. The layout modifications illustrated overleaf demonstrate how easily dwell time optimisation can be achieved on high capacity buses with as little as a 2 or 3 passenger seat reduction.

The authors have further recommended discontinuation of *go card top ups* and limited or preferably no ticket sales to induce balanced alighting and boarding through all high capacity vehicle front doors.



2. Mass Transit Dwell Time Research

2.1 Study Background

This technical report investigates 4 high capacity vehicle (*HCV*) types already operating TransLink route bus services in South East Queensland (*SEQ*) and contrasts the impacts of bus stop dwell time of their operating performance relative to that of a standard two door 12.5m rigid bus. The 4 high capacity vehicle types analysed herein include the:

- Two Door 12 - 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

Representative examples of the 4 high capacity vehicle types and the standard reference vehicle are depicted overleaf in **Figure 1** and

Figure 2 respectively.

In Part 2 of this report, we define bus stop dwell time and present a brief overview of how the longer average dwell time of high capacity buses impacts their timetable schedules, service frequencies, service reliabilities and stop occupancies during the peak periods. We then take a look at 6 key parameters known from international research to increase stop dwell time and the bus cabin layout configurations, station/stop geometrics, fare collection and operating strategies exploited by international transit authorities and operators to reduce bus station dwell times on high frequency mass transit bus operations. Next we contrast these overseas dwell time mitigation best practices with contemporary operating practices in SEQ on TransLink route bus services, and spotlight the fundamental differences.

We first explore the benefits of all door boarding, wider cabin front aisle ways, next stop cuing annunciation, exterior plug doors and rear door passenger storage areas to high capacity vehicle operating performance. We then challenge some parochial bus operator misconceptions regarding narrow rear bus doors, rear door locations, flat floors and maximisation of seating capacity, and show why striving to trim a second or two off passenger boarding and alighting times is not inconsequential. We also challenge some long standing TransLink policies to continue driver *go card* top ups for the (in)convenience of bus passengers, to maintain front door only boarding as a fare evasion deterrent, to deploy high capacity buses on services based solely on driver or operator reported recurrent 12.5m rigid bus overloading, and the notion that onboard driver ticket sales are cheaper than off vehicle ticket sales.

In Part 3, we analyse live service data captured from thousands of *go card* transactions and a dozen onboard ride surveys carried out on 4 high capacity vehicle and 2 standard 12.5m rigid bus services. We present a comparison of the live service operating statistics for each bus type and explain how bus stop dwell time is being monopolised by average passenger boarding time and why driver ticket sale and *go card* top-up delays have negated the benefit of the middle door on the 3 door articulated superbus. We also explain why narrow rear bus doors and lack of passenger information have thwarted realisation of expected stop dwell reductions from all door boarding on the *CityGlider* service and show how rear door location will similarly prevent realisation of all door boarding dwell time reduction on the 14.5m rigid bus.

The final sections of Part 3 use our measured data to model operating performance of the 4 high capacity bus types against that of both a standard 12.5m rigid bus and a private motor car. The model identifies route characteristics suited to each bus type and explores how performance could be dramatically improved through initiatives such as all door boarding, bus redesign and ticketing policy changes.

Figure 1: Representative Examples of the 4 High Capacity Vehicles

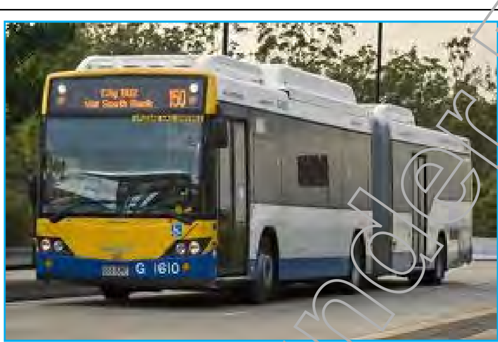
2 Door 12.5m Double Deck Bus		
2 Door 14.5m Rigid Bus		
2 Door 18m Articulated Bus		
3 Door 18m Articulated Superbus		

Figure 2: Representative Examples of the Standard Reference Vehicle

2 Door 12.5m Rigid Urban Route Bus		

2.2 Definition of Bus Stop Dwell Time

Dwell time is the time a bus remains stationary at a bus stop to enable passengers to board and alight, and includes the time required by the bus driver to open and close the bus doors. It is calculated as the difference between bus stop departure time and arrival time and includes the time taken at stops to mobilise passengers to bus doors.

Service planner scheduled dwell times may incorporate deliberate recovery time layovers at bus stops included in the driver's work block to resynchronise departure times from termini or selected mid-route timing point stops back to those appearing in published timetables, to sign off from a completed route, change destination signs and log back onto a new route assignment, to take an award stipulated comfort or meal break, or to give over the bus to another driver. This bus performance evaluation report excludes planner scheduled dwell times built into the driver's work block to enable a like-for-like comparison of high capacity and standard bus dwell times at bus stops used solely for the purpose of boarding and alighting passengers.

2.3 Dwell Time Impacts on High Capacity Bus Services

A serious concern with the large scale deployment of high capacity buses is the longer average dwell time accrued at bus stations and stops for increased passenger boardings and alightings than for standard capacity 12.5m rigid buses. The impacts of increased passenger boardings and alightings and resulting longer stop dwell times on high capacity bus services include:

- HCV Service Timetabling: Longer high capacity vehicle trip times create the need to publish different timetables for selected bus services according to the bus operator's preferred bus size allocation to the trip to meet its patronage demand. This causes drift in clock face scheduled start times from termini particularly on mixed runs scheduled for interleaving of different bus sizes. There is a strong temptation therefore by planners to shorten high capacity bus and extend low capacity bus layovers at termini to create a consistent clock face timetable. Once published timetables have been locked in for high capacity bus services, the operator must ensure it has similar size spare high capacity buses to cover HCV breakdowns, or suffer the added cost of substituting an extra driver and 2 standard capacity buses to cover the HCV service.
- Reduced Peak Period Service Frequency: In the twice daily service peak time windows, increased dwell time incurred by high capacity buses may limit their service frequency to say 3 services per hour, where previously 12.5m rigid buses carrying less passengers could provide a higher frequency of say 4 services per hour. Judged from a passenger perspective, operator substituted high capacity bus services would be viewed as less convenient and longer trips than the standard capacity bus services they replaced. Possible knock-on impacts of passenger disenchantment with substituted HCV services may be loss of patronage to the extent that it forces either reversion back to a high frequency low capacity bus service, or replacement of high with low capacity buses to match the bus size back to a permanently reduced passenger demand.
- Higher Bus Stop Occupancy Time: As multiple suburban route bus services converge on the major arterial, sub-arterial and busway corridors leading into the CBD, competition for available bus station and stop bays increases. High capacity buses not only take up a higher proportion of limited available station platform and bus stop kerbside space, but occupy the space for longer dwell periods. The impact of HCV stop occupancy is especially felt at bus stops located in the CBD where there is very limited available kerbside space and added competition from taxi ranks, car parking bays, loading zones, building accesses, pedestrian crossings, postal delivery zones and numerous other local government authority kerbside allocation demands. Where the option exists to lengthen station platform and bus stop bays in the CBD, such come at a high capital

cost to the transit or local government authority, and often at the expense of other important kerbside allocations which underpin the CBD business economy.

- Reduced Service Reliability: The cumulative effects of extended dwell time at bus stops can adversely impact on the reliability of sequentially blocked high capacity bus services. If one in a group of sequentially blocked high capacity bus services runs late due to excessive cumulative dwell time and insufficient terminus recovery time has been built into its scheduled layovers, late running cascades through all following services left in the driver's work block and may reach a point where the last service in the block may need to be cut or curtailed for the driver to comply with statutory *Fatigue Management Regulations*. TransLink's bus operators are presently penalised for late running and/or missed services not delivered in accordance with the performance management regime prescribed within operator *3G Contracts*.

2.4 Dwell Time Minimisation Research

According to the USA Transport Research Board's publication *Transit Capacity and Quality of Service Manual (2nd Edition)*, there are six key factors which influence bus stop dwell time, two of which relate to passenger demand (and therefore high capacity vehicles), and four which relate to average passenger service (alighting and boarding) times:

- Passenger Demand and Loading: The number of passengers passing through the highest volume bus door is considered a key factor in how long it will take for all passengers to be served (i.e. those alighted and boarded). The proportion of alighting to boarding passengers through the busiest bus door also affects how long it takes all passenger movements to complete as their respective movements are opposed.
- Bus Stop Spacing: The smaller the number of bus stops, the greater (in theory) the average number of passengers boarded and alighted per stop. A compromise is required between providing too few stops, each with relatively high dwell and passenger walking times, and too many stops which reduce the average number of passengers serviced per stop. Too many stops adversely impacts on average travel speed due to the lost time decelerating and accelerating the bus, and because of the increased probability of having to wait at traffic signals due to lower average speed, which is in turn further reduced by every stop needed to be made.
- Fare Payment Procedure: The time taken to pay fares has a significant influence over the total time required to serve boarding passengers. Some fare payment processes allow passengers to board through more than one door at busier stops, thus allowing multiple passengers to be served concurrently.
- Vehicle Type: Having to ascend and descend steps at or adjacent to doors while getting on and off a bus increases the average time required to serve each passenger.
- In-Vehicle Passenger Circulation: When standees are present on a bus, it takes more time for boarding passengers to clear the farebox area(s) and for alighting passengers to reach exiting doors. Standing passengers must move to the rear of the bus to make way for boarding passengers and clear aisle ways to enable free movement of alighting passengers to exit doors.
- Driver Passenger Assistance**: Dwell time can be randomly affected by the time taken to load and offload persons in wheelchairs, the elderly and other persons with mobility or visual disabilities, by drivers repeatedly answering ad-hoc passenger travel enquiries, selling tickets or crediting passenger smartcards, and from deliberately delaying stop departures for late arriving so-called 'bus hailers and runners'.

** Note: Driver passenger assistance is normally considered to be a random event rather than the norm, and is typically not included when measuring average stop dwell time, but as a measure of stop dwell time variability.

Optimising the abovementioned 6 factors can substantially reduce average bus stop dwell times. By way of example, the Denver (Colorado, USA) 16th Street Mall Shuttle operation has maintained an impressive short 75s peak headway with scheduled 12.5s average bus stop dwell times notwithstanding continuous high peak period passenger loadings on its 70 passenger capacity shuttle buses. This was accomplished through a deliberate combination of prepaid fares, fewer seats because typical passenger travel distances were known to be short, step free ultralow floor door entrances, and triple two-way full width streaming doors for concurrent all door boarding and alighting of passengers.

The following sections outline in greater detail various vehicle design, infrastructure design and ticketing policy initiatives known from international operator experience to significantly reduce average high capacity vehicle dwell times.

2.5 Vehicle Design Initiatives to Reduce Dwell Time

From acknowledged world best practice research paper - *Vehicle Selection for BRT: Issues and Options* which documents some 26 case studies of contemporary *Bus Rapid Transit (BRT)* systems operating successfully around the globe, important determinants of average stop dwell times were identified as bus seating, floor height, floor plan and door configuration, and important determinants of overall BRT system throughput capacity were identified as the physical vehicle size, aisle width, number of doors, door widths and positions, number of passenger seats and seating layout configuration.

2.5.1 Number and Width of Bus Doors

Irrespective of how fares are collected by a given transit agency, a large number of wide bus doors will markedly reduce average bus stop dwell time. Wide double flow channel doors generate less passenger movement conflicts than narrow single channel doors, and if wide enough, double doors can support either two-way streams (i.e. 2 opposing passenger flow channels) for boarding and alighting passengers through the same doors or two one-way flow streams through each door. Multiple doors have been found to promote linear and fast distribution of passengers throughout the vehicle cabin and take full advantage of the available seating and standing capacity with minimum passenger movements. A high capacity vehicle cannot maximise both its number of doors and number of available passenger seats, since both these passenger facilities compete for available wall space along the nearside of the vehicle.

A commonly employed design rule applied for determining the optimum number of boarding and alighting doors on high capacity route buses built for Canadian and USA prepaid city route services has been to fit at least one door every 3.05m of linear bus length. This rule is however not universal. For densely populated bus service corridors where simultaneous passenger boarding and alighting are continuously taking place, a larger number of passenger doors per vehicle length may be warranted, and on express services where most passengers alight en mass in the AM peaks and board en mass in the PM peaks at a limited number of bus stations and stops, fewer doors have been found more appropriate.

2.5.1.1 Single Door Channel Dwell Time Planning Estimates

Table 1 below presents estimated average bus stop dwell times per passenger used to plan services for single door route buses where only a one-way channel of passengers can pass through each bus door at a given time. The table also provides typical dwell time per passenger scheduling adjustments allowed for different fare collection situations, vehicles fitted with front only or front and rear single channel doors, when buses reach standing room only capacity, and for ultralow floor buses.

2.5.1.2 Multiple Door Channel Dwell Time Planning Estimates

Passengers can be boarded and alighted much more quickly through multiple bus door channels commonly utilised in North American cities on free shuttle high capacity bus services or prepaid route bus services exploiting prior proof-of-payment, pay-on-exit gates and prepaid smartcard fare collection systems. Multi-door multichannel bus services operated in this fashion adopt the tried and proven practices of heavy and light rail mass transit operators exploited to minimise train dwell times at busy inner city railway stations.

Table 1: Service Planning Dwell Times for Single Channel Bus Doors

PASSENGER DWELL TIME (seconds per passenger)		
SITUATION	OBSERVED RANGE	NOMINAL
BOARDING		
Prepaid Fares**	2.25 – 2.75	2.5
Single Ticket or Token	3.4 – 3.6	3.5
Exact Change	3.6 – 4.3	4.0
Swipe or Dip Card	4.2	4.2
Smart Card	3.0 – 3.7	3.5
ALIGHTING		
Front Door	2.6 – 3.7	3.3
Rear Door	1.4 – 2.7	2.1

Source: Transit Capacity and Quality of Service Manual, Ed 2, Transportation Research Board

** Includes no fare, bus pass, free transfer and pay-on-exit.

Add 0.5 seconds per passenger to boarding times when standees are present.

Subtract 0.5 seconds per passenger from boarding and alighting times for ultralow floor buses.

Table 2 below presents the planning average dwell times per passenger expected for multi-channel door boarding and alighting on high capacity bus services exploiting off-bus fare payment, and indicate up to a 4 fold reduction in the average bus stop dwell time per passenger is possible when compared with the dwell times shown above for single channel door buses in Table 1.

Table 2: Service Planning Dwell Times for Multi-Channel Bus Doors

NOMINAL PASSENGER DWELL TIMES (seconds per passenger)			
AVAILABLE DOOR CHANNELS	BOARDING	FRONT ALIGHTING	REAR ALIGHTING
1	2.5	3.3	2.1
2	1.5	1.8	1.2
3	1.1	1.5	0.9
4	0.9	1.1	0.7
6	0.6	0.7	0.5

Source: Transit Capacity and Quality of Service Manual, Ed 2, Transportation Research Board

Assumes no on-board fare payment required.

Increase boarding times by 20% when standees are present.

Reduce boarding times by 20%, front alighting times by 15% and rear alighting times by 25% for low-floor buses.

As another example, using Table 2 above for a busway station fitted with off-vehicle card interface devices similar to those deployed on QR railway stations, if all door boarding was permitted through both double (2 x 2 channel = 4 channel) doors on a typical Brisbane Transport low floor articulated bus, the average boarding time per passenger could be expected to reduce to around 0.7s (0.9s less 20%) per passenger. Similarly, with prepaid triple double door (3 x 2 channel = 6 channel) boarding at a busway station, the Clarks Logan City low floor articulated superbus could be expected to achieve a further reduction in dwell time to just 0.5s (0.6s less 20%) per passenger.

Similar dwell time reductions are theoretically possible for all door alighting from twin and triple dual channel bus doors, but the figures appearing in Table 2 assume both passenger movements to be mutually exclusive and therefore additive, where alighting passenger streams typically precede boarding passenger streams. It will be further noted from Table 2 that rear door passenger alighting is somewhat faster than front door alighting. This occurs primarily because a double rear door is centrally placed in the vehicle cabin and can therefore accommodate single file passenger streams off two opposing aisle sections forward and aft of the 2 channel door, where a double front door can only accommodate 2 single file passenger feeds from one aisle section aft of the front door which is constricted at the low floor vehicle's front wheel arches.

2.5.1.3 Effects of Multi-loading Channels on Mass Transit Bus Station Dwell Times

Table 3 below looks at the effects of concurrent multi-door, multi-channel passenger boarding and alighting during peak throughput periods at open platform mass transit bus and busway stations. This table calculates the complex interrelationships between platform loading areas, concurrent passenger boarding and alighting, vehicle capacity, number of doors and door widths. As would be anticipated, high capacity buses with multiple doors and wide 2 channel flow streams generate the fastest passenger throughputs.

Table 3: Bus Station Throughput for Multi-Door, Multi-Channel Passenger Loading

BUS LOADING CONDITION >>	A		B		C		D	
STATION THROUGHPUTS >>	Board	Alight	Board	Alight	Board	Alight	Board	Alight
PASSENGER BOARDINGS AND ALIGHTINGS AT BUS STATION PEAK LOADING CONDITION								
Passengers per Bus (No/bus)	20	20	20	20	20	20	30	30
Dwell Time per Passenger (s/pax)	2.0	2.0	1.2	1.2	0.7	0.7	0.5	0.5
Total Dwell Time (s)	40	40	24	24	14	14	15	15
VEHICLE LOADING CAPACITY								
Loading Area Capacity (buses/hr)	42	42	65	65	100	100	95	95
Effective Loading (m^2)	2.45	2.65	2.45	2.65	2.45	2.65	2.45	2.65
Station Capacity (buses/hr)	103	111	159	172	245	265	233	251
PASSENGER THROUGHPUT PER HOUR AT PEAK LOADING CONDITION								
Peak Flow Rate (4 x 15min/hr)	4120	4440	6360	6880	9800	10600	13980	15060
Average Pax Flow Rate (pax/hr)	2760	2970	4260	4600	6570	7100	9370	10090

Source: Highway Capacity Manual 2000, Transportation Research Board

Loading Condition A: Twin single door standard 12.5m route bus, simultaneous front door boarding and alighting.

Loading Condition B: Twin two door standard 12.5m bus, two door alighting then boarding, or dual stream simultaneous front door boarding and rear door alighting.

Loading Condition C: Twin two door extended 14.5m bus, double-stream boarding and alighting at both doors.

Loading Condition D: Triple two door 18m articulated bus, double-stream boarding and alighting at all 3 doors.

Note: Assumes 10s clearance time, 7.5% berthing failure rate, 60% coefficient of variation, 3 linear boarding areas, g/C = 1, random bus arrivals, PHF = 0.67, 50% of passengers board at busiest station, 40 seats per conventional bus, 60 seats per articulated bus and no standees.

2.5.1.4 Bus Door Placement

The objective with optimising door positioning is to ensure even passenger loading and unloading over the entire length of the vehicle cabin. Accordingly, doors should optimally be positioned to divide high capacity vehicle cabins into sections of approximately equal passenger capacity and aisle way circulation distance. A number of BRT applications, notably the Las Vegas and various European and South American BRT systems, employ an even distribution of doors and door channel entry/exit streams along the entire vehicle cabin length.

2.5.1.5 Exterior Opening Bus Door Mechanisms

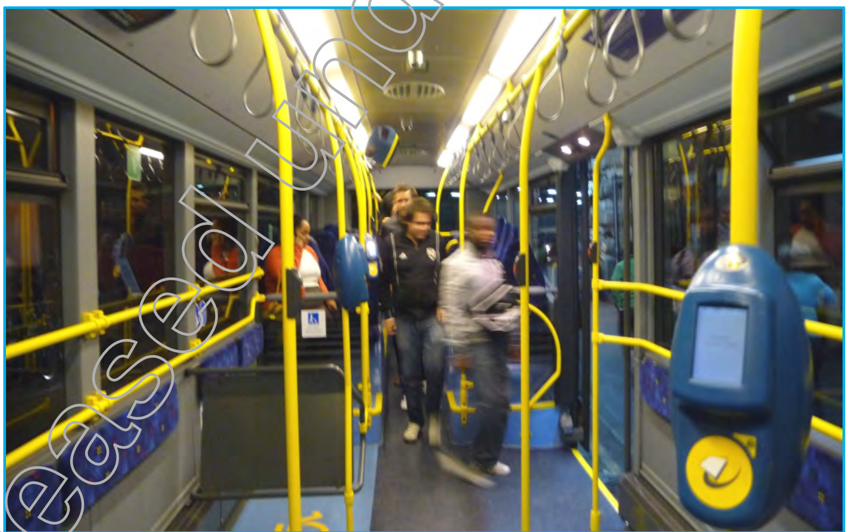
The time it takes for the bus driver to open and close the doors affects both the average stop dwell time and cabin passenger capacity. Most Australian manufactured buses employ either single leaf slide-glide or twin leaf bi-fold (also called 'Jack-knife') door mechanisms which open perpendicularly into the cabin, requiring passengers to stand clear of door swept paths to prevent accidental hand, arm, luggage and shoe entrapment. Such doors require constant driver vigilance to overview the front and rear door no standing access areas prior to and during the door opening and closing phases, and to delay door operations when requesting standees to stay clear of door access no standing areas.

Emerging new European bus door mechanisms use either single or twin leaf sliding plug doors similar to those used on modern aircraft, trams, light rail and heavy rail cars, which open outward and slide longitudinally over the exterior panelling of the vehicle. Such doors permit standing passengers to safely encroach further into preserved door access no standing spaces, thereby increasing total cabin standing capacity and mitigating the potential risk of passenger entrapment whilst opening.

2.5.1.6 Distributed Smartcard Reader Boarding Tag On and Alighting Tag Off

Another emerging trend on European and South American mass transit high capacity buses is to deploy one or two extra smartcard readers through the cabin space to reduce bus stop dwell time. Referred to as Cubic *OBCIDs* (*Onboard Card Interface Devices*) in South East Queensland, one or two such smartcard readers are typically only positioned at each door access on TransLink buses for boarding passengers to tag on and alighting passengers to tag off their *go cards*. Smartcard readers are located both at doors and on stanchions along the cabin in some European and South American bus designs so that passengers can tag on after bus departure from boarding stops and before bus arrival at alighting stops. Deactivation of these readers is typically timed out from door closures after bus stop departure and reactivated prior to the next stop arrival by stop centred GPS large radius geo-fence detections.

Figure 3: Distributed Smartcard Readers on a London Bus



An obvious downside to distributed Smartcard readers is the transit agency's reliance on passenger honesty. This fare collection strategy suffers to some extent from increased fare evasion as missed smartcard tagging cannot be visually or audibly monitored at bus doors by the driver.

2.5.2 Trading Increased Rear Door Width for Reduced Passenger Seating

Each additional entry/exit door added to the left hand side of a heavy omnibus passenger cabin above the compulsory minimum front entry/exit door specified by *Australian Design Rule ADR58/00* reduces available occupiable passenger floor space by approximately 0.7m^2 (namely 2 seat or 4 standee spaces) for a minimum 850mm wide single entry/exit door, and approximately 1.15m^2 (4 seat or 7 standee spaces) for a 1200mm wide double width entry/exit door. Most Australian bus operators currently strive to maximise bus seating capacity and to achieve such, show a overly keen willingness not mirrored by their overseas counterparts, to reduce the number of doors and/or door widths to cram as many seats into bus cabins as Australian heavy vehicle regulations and design rules will permit.

Prior to the introduction of ultralow floor buses with wheelchair parking spaces on SEQ route services in late 1997, earlier built high floor 12.5m rigid and 18m articulated buses traditionally incorporated front and rear double width 1200mm wide doors with a seat free passenger standing area opposite the rear door. To recover lost seating capacity begrudgingly given over to wheelchair parking spaces, all ultralow floor wheelchair accessible 12.5m rigid, 14.5m rigid and 18m articulated buses built for SEQ bus operators since 1997 have double seats installed opposite their rear doors, and most standard 12.5m, and some high capacity extended 14.5m rigid buses now in operation have a single narrow 850mm wide rear door capable of streaming only a one-way channel of alighting passengers.

2.5.3 Trading Increased Aisle Width for Reduced Passenger Seating

Bus door and aisle widths have a profound impact on average dwell time during peak service periods when high standing loads inhibit the free movement of boarding and alighting passengers. On modern ultralow floor buses, the maximum forward cabin aisle width to the busier front door is ultimately determined by intrusion of the front steering axle wheel arches above flat floor level, where aisle widths narrow down to between 750 and 860mm.

Wheel arch intrusion onto the centre aisle proves to be even greater at the dual tyred rear axles on 12.5m and 14.5m rigid buses and at both the mid and rear axles on 18m pusher type articulated buses. It has been common practice in Australia therefore to step and ramp up the height of the rear cabin aisle and to plinth mount climb-on passenger seats above the aisle way to the aft of the rear door. This design affords rear floor crossover of the rear wheel arches, power transmission train and engine bay intrusions above the otherwise flat floor level available on ultralow floor buses, but results in reduced head clearance preventing standee use at the far rear and deep narrow aisle widths of between 540 and 590mm which only permit a one-way stream of passenger movements at any given time.

Such has become bus operator demand for maximum passenger seating in ultralow floor bus cabins, that some reputable Australian bus body manufacturers have resorted to continuously ramping their aisle ways, stepping up seat plinths and external window lines from the front to rear of cabin to gain an extra row of seats on the inclined floor hypotenuse. This design technique results in sunken wheelchair parking spaces, deep aisle ways and rear door step wells and climb-on plinth mount seats throughout most of the cabin. So while international chassis and body manufacturers strive passionately to crimp the last centimetre from their door step levels and to flatten their floor chassis rails and floor outrigger frames throughout the cabin, Australian bus body manufacturers have chosen the opposite design strategy of increasing floor levels in pursuit of maximum seat capacity.

Narrowing between the mid wheel arches on an ultralow floor 18m articulated bus cannot be so easily crossed over by raised aisles and continuous plinth mounted passenger seats as they are in the rear cabins of 12.5m and 14.5m rigid buses. Articulated bus mid axle wheel arches with climb-on opposing full width front facing twin passenger seats act as an effective constriction to boarding passenger movements from the front door to the entire rear trailer section during peak periods with high standing passenger loads, yet bus operators and bus builders remain steadfastly opposed to sacrificing passenger seats even at this most obvious choke point to passenger circulation.

Persisting bus operator demand to maximise passenger seating effectively thwarts widening of bus aisles for optimum circulation because bus body and moulded twin transit seat widths must comply in Australia with national heavy omnibus design rules and State legislation. *Australian Design Rule ADR43/04* and Queensland regulated heavy omnibus dimensional limits set the maximum exterior width of a heavy omnibus at 2.5m, while *Australian Design Rule ADR58/00* prescribes a minimum seat cushion width of 400mm with side to side elbow room. This results in a maximum flat floor aisle width between two parallel rows of forward facing moulded twin transit seats of between 450 and 615mm, depending on the vehicle's panelled structural wall thickness. Australian bus body manufacturers publish misleading wider aisle widths of up to 850mm between seat plinths to entice unwary new bus purchasers, but fail to mention the much narrower 450 to 615mm clear widths between stanchions, seat cushions, squabs and handgrips overhanging their recessed seat plinths.

Widening of aisle ways to reduce bus stop dwell time can only be achieved practically by sacrificing the number of seats in critical passenger aisle circulation and passenger storage spaces from 2 x 2 (= 4) seat widths down to 2 + 1 (=3) seat widths, and by reducing or eliminating seats placed opposite the rear door. Figure 4 below illustrates a common approach used by European and South East Asian high capacity bus operators to improve passenger aisle way circulation using a wide spill out aisle width either side of, 2 seats opposite, and side facing seats flanking the rear door on an 18m articulated bus. It will be noticed in this photograph how side facing seats have also been installed over the mid axle wheel arches on this vehicle to improve boarding passenger movements from the front door to the rear cabin saloon.

Figure 4: Rear Door Circulation Using Wide Aisle, 2 Seats Offside and Side Facing Seats Nearside

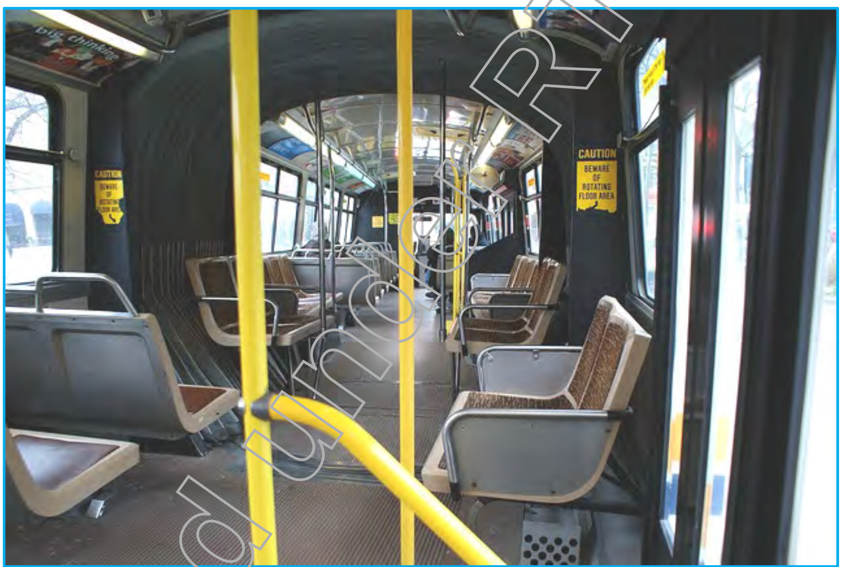
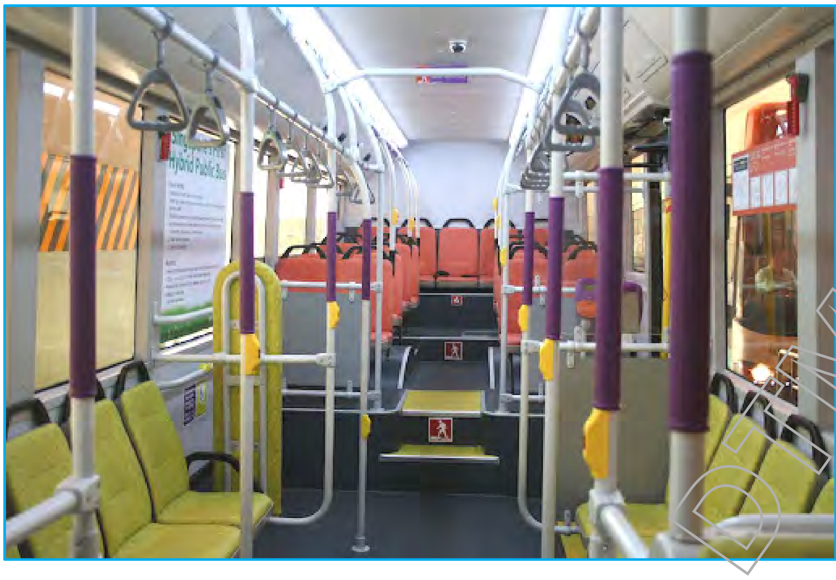


Figure 5 overleaf presents yet another overseas approach used on a 14.5m rigid bus with a stepped incline to the rear saloon similar to that on the Volvo and Scania 14.5m rigid buses operated in SEQ by Hornibrook and Brisbane Transport. The bus in this photograph has a normally unoccupied rear wheelchair parking bay, no fixed seats opposite, and side facing seats forward of the rear door which act as a standee circulation and temporary storage area for rear door alighting and boarding passengers.

In rapid passenger turnover high capacity bus operations characterised by short average trip lengths, mass transit agencies often elect to maximise passenger capacity and aisle way circulation, rather than maximising their passenger seat counts. It is particularly interesting to note a new emerging trend in USA capital city bus operations where transit agencies are actively removing passenger seats from their existing buses and installing so-called 'bum cushions' to enable more passengers to stand in comfort by leaning against these padded railings. Similar railing cushions have been installed in the aisles of the current Clarks Logan City 3 door articulated superbuses and on Sydney Buses and Brisbane Transport 14.5m rigid buses. They are considered by Australian operators to only be appropriate on short haul routes such as those operated on busways and transitways, but not for general route bus services.

Figure 5: Rear Door Circulation Using Wide Aisle, No Seats Offside, Side Facing Seats Both Sides



Ironically, the added vehicle capital cost and lost floor space so readily pursued by Australian bus operators and builders to pack ever more seats into route buses is rarely recouped when numerous seats go begging for occupants during off-peak services, and each additional seat installed adds significantly to the discomfort of standees crammed into narrow deep aisles and standing areas during peak services when luggage has to be continuously carried by standees and cannot be placed on narrow aisles for fear of trampling. The operator pays the ongoing fuel and maintenance cost of carrying the added weight of all unnecessary extra seats, the resultant loss of maximum seated plus standee carrying capacity and added dwell time at every peak service bus stop throughout the entire life of its maximum seated capacity vehicles.

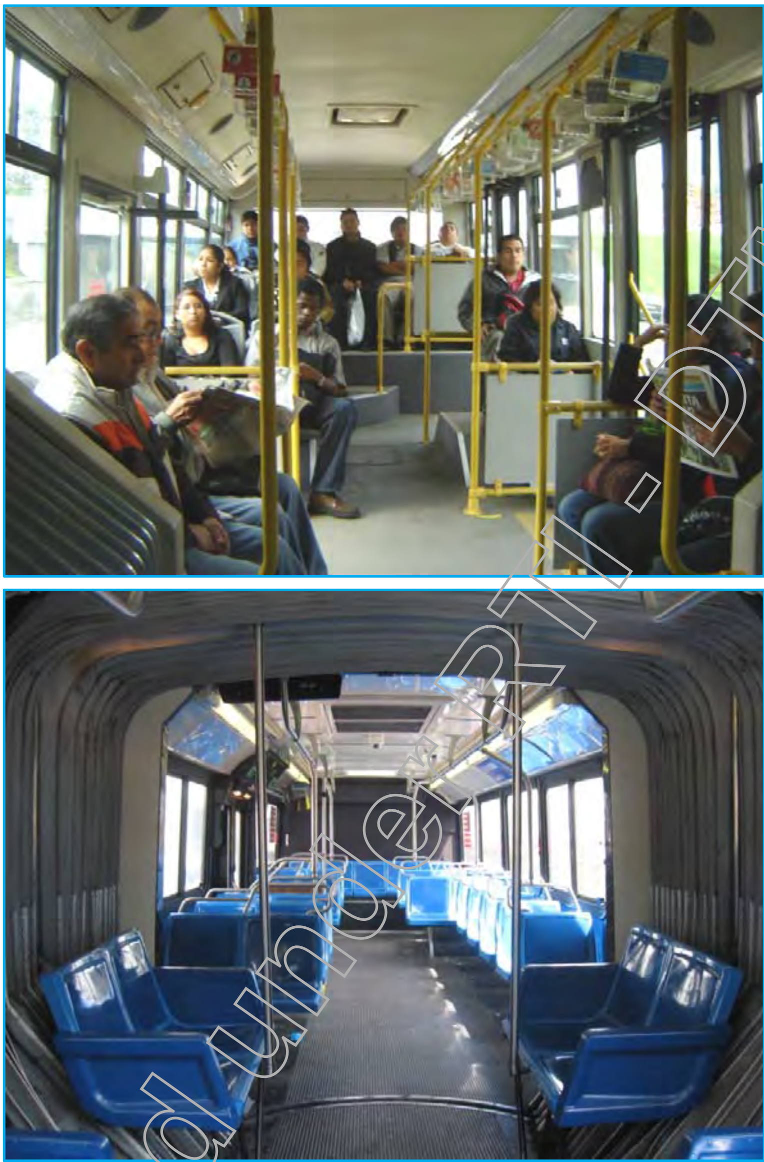
2.5.4 Bus Cabin Design Options to Minimise Dwell Time

Most European, South East Asian, North and South American high capacity mass transit operators do not strive to maximise passenger seating as bus operators so eagerly do in Australia, but elect instead to minimise stop dwell time and optimise both seated and standee capacity on their high capacity vehicles. Notable significant differences between overseas best practice and Australian bus cabin designs include:

- Two-Way All Door Boarding and Alighting: As illustrated earlier in Tables 2 and 3, two-way all door boarding and alighting greatly reduces dwell time by enabling concurrent two-way flow of passenger movements through doors and minimisation of aisle circulation distances to all available passenger seat and standing areas.
- Distributed Smartcard Readers: Strategic placement of one or two additional smartcard readers at locations other than immediately adjacent doorway accesses enables passengers to tag off and tag on whilst a high capacity bus is still in motion. It is also common practice overseas to install smartcard readers at high turnover bus stations and bus stops to facilitate off-vehicle smartcard tag on and tag off, as is already commonplace on SEQ railway stations.
- 100% Flat Aisle Cabins: Ultralow floor bus manufacturers design their chassis for flat aisle ways throughout the bus cabin, but this feature is rarely exploited by Australian bus operators looking to maximise saloon seating capacity. Where flat aisle ways levelled with floors under seats are maintained from front to rear of cabin, stepped or plinth mounted seats may need to be used to optimise rear cabin seating capacity, but the resulting high climb-on seats tend to only be used by younger or more able bodied passengers. The removal of aisle way steps and ramps to the rear greatly speeds up passenger movements to the aft of the rear door, reduces passenger slips trips and falls, maximises rear aisle way and seated head clearances and rear saloon standing capacity. Low floor heights also enable optional installation of accessible overhead luggage

shelves throughout the cabin, so standing can readily stow luggage off aisle ways and above dedicated standing areas.

Figure 6: Examples of 100% Flat Ultralow Floor Articulated Bus Cabin Aisle Ways



- Door Passenger Storage Areas: Best practice international mass transit bus drivers neither sell tickets, handle cash, credit passenger smartcards, nor monitor passenger smartcard tag-ons and tag-offs. Their primary focus is to board and alight passengers as quickly and safety as possible at bus stops, and to recommence driving as soon as possible to clear congested bus stop bays for other arriving buses. There are no holdover delays granted by drivers at stops for late arriving hailers and runners or to allow boarded passengers to become seated or move to standing areas. Wide open floor areas and step free aisle ways are deliberately designed to prevent trips and falls during bus acceleration and deceleration and to temporarily store passengers for fastest possible passenger unloading and loading.

  Wheelchair parking spaces with side facing flip-up seats are utilised in the forward section of the bus cabin to maximise temporary storage and standing areas for passengers using the front door, whilst side facing flip-up or no seats are positioned opposite rear doors to provide wide open areas for temporary passenger circulation, storage and standing. These best practice designs enable a large number of alighting passengers to assemble, tag off and queue in temporary door storage areas prior to buses arriving at stops. After doors open, they disembark en mass while embarking passengers board and refill their vacated door storage areas. Boarded passengers continue tagging on and moving off to seats and other standing areas after the driver has closed the doors and the bus has moved off from the stop. This passenger loading strategy not only reduces stop dwell time between door opening and closing, but converts otherwise wasted bus stop deceleration and acceleration times into concurrent passenger mobilisation time savings.

- Outward Opening Slide and Plug Doors: Outward opening slide and plug doors maximise door opening widths, safety, temporary passenger storage, and standing area adjacent to door accesses.

Figure 7: In-Vehicle Real Time Bus Arrival Passenger Cueing Sign

- Real Time Bus Arrival Passenger Cueing: Bus arrival times are displayed visually on passenger information display signs erected at bus stations and stops, and next stops are displayed in vehicles together with audio public address cues to prepare passengers for all door concurrent boarding and alighting.

2.5.5 Cabin Interior Floor Height

USA *Transport Research Board* analysis of best practice large city route bus operations has determined that step less ultralow floor buses reap up to a 20% improvement in peak boarding and alighting times at major BRT bus stations and kerbside stops compared to similar size high floor buses with stepped floor levels. As at 31 March 2012, some 72% of TransLink's urban fleet of 2027 route buses (excluding dedicated high floor school buses and coaches) were classified as low floor, wheelchair accessible. However, no low floor buses in the TransLink fleet are true 100% low floor throughout the cabin, as aisle ways are stepped and ramped up to a high floor level aft of the rear door, and in some cases, from forward of the rear door to further increase seating capacity.

To compensate operators for lost cabin floor area turned over to wheelchair ramp loaders and parking spaces, more and wider doors, and wheel arch, drive train and engine compartment intrusions into the cabin saloon, existing State and Territory and pending national heavy vehicle regulations grant considerably higher axle mass limits to ultralow floor buses not available to high floor buses and coaches with similar overall dimensions but higher passenger floor area.

To fit within the legislated heavy vehicle definition of an ultralow floor bus as applied by TMR bus inspectors in Queensland, the cabin floor level accessible to doors must be 550mm or lower above ground level for a continuous length equal to at least 70% of the vehicle's registered wheelbase. This floor level is taken to be the vehicle's normal floor height when driving, and not the reduced floor height obtained when buses are kneeled for wheelchair boarding at bus stops.

A bus with an fully raised front door entry and aisle level under 550mm capable of boarding wheelchairs to 2 dedicated wheelchair parking spaces may comply with the national *Disability Standards for Accessible Public Transport 2002* and be classified by its operator and builder as a low floor wheelchair accessible bus, but this does not necessarily qualify the bus for the higher axle mass limits granted to an ultralow floor wheelchair accessible bus. For example, the wheelchair accessible lower floor height on the Bustech double deck bus complies with the *Disability Standards for Accessible Public Transport 2002,* but has not been classified under the heavy vehicle regulation as an ultralow floor bus or attracted an additional tonne combined axle weight concession to carry an additional 15 passengers granted to the other 3 ultralow floor high capacity buses studied in this report.

100% ultralow floor high capacity buses exploit the advantage of reduced boarding and alighting times and the optional capability to place an additional door behind the rear axle, however 100% low floor configurations typically lose up to 4 passenger seats to wheel arch and other underfloor component intrusions in the rear saloon avoided by stepping and ramping up the rear aisle and floor level. Ultralow floor bus manufacturer workarounds to recover seat capacity on their 100% low floor buses have in past times included use of low profile tyres and/or hybrid electric drives, but these alternatives either reduce ride quality or add cost, weight, and maintenance complexity to the vehicle design. Notwithstanding the reduced seating capacity caused by 100% low floor cabins, most European mass transit operators still prefer such to reduce their mass transit station dwell times, improve their station loading capacities, minimise stop bay occupancy times and increase their average service speeds.

2.6 Bus Stop Geometric Treatments to Reduce Dwell Time

The geometry of a stop affects its average bus dwell times, particularly those for large size high capacity buses alighting and boarding a high average number of passengers per stop. The *TransLink Transit Authority Public Transport Infrastructure Manual - May 2012* provides detailed planning and design guidelines for locating stops and geometric layout drawings for newly constructed bus stations, premium and signature standard stops suitable for 14.5m and 18m long high capacity vehicles. Premium and signature standard bus stops incorporate large open obstruction free platform loading areas and generous linear kerb lengths for berthing 2 high capacity buses nose to tail with 5m separation distance, and remove the variability to stop dwell time encountered at older generation bus stops built prior to 1995 for 12.5m buses.

Lack of sufficient footpath loading area, adequate lead in and pull out tapers on indented stop bays, undersized stop zone length and inadequate clearance distance from intersections and regulated parking zones at old generation kerbside stops constructed for 12.5m long buses have been identified as significant impediments to future widespread deployment of 14.5m rigid and 18m articulated buses on most existing SEQ urban bus routes. Undersize platform stop bays, overly tight turning circles and narrow width off-road accesses to some old generation bus stations and interchanges designed for 12.5m long buses have also been identified, and are discussed in more detail in the infrastructure performance evaluation report.

For those bus station and interchange platforms and kerbside stops where high capacity vehicles can be accommodated, but include no provision for more than one high capacity bus to berth at a time, variability in stop dwell time arises when there is strong competition between randomly arriving buses for single stop bays. The variability in stop dwell time arising from competition between buses is by no means unique to high capacity vehicles and affects 12.5m standard buses similarly, but to a lesser extent.

At single bus length kerbside stops on CBD streets and inner city suburban bus stops on major city arterial and sub-arterial roads where numerous bus services converge randomly during the peak periods, buses may arrive at the single bus length stop to find it occupied by another vehicle, or occasionally a convoy of bunched buses. If the stop is located just beyond an intersection, a pedestrian crossing or on the far side of parked vehicles in a regulated parking zone, the arriving bus may not have an opportunity to remain stopped in the left traffic lane and be forced to pull in ahead of the signed stop zone. Whether able to pull in behind the stop zone, ahead of the stop zone, or wait in traffic until the stop zone has cleared, stop dwell time will inevitably be increased. Alighting passengers for the stop can generally disembark without delay at any makeshift set down, but the dwell time at an off zone makeshift stop increases in proportional to the number of passengers who have to relocate to board the bus.

Similarly, at busy bus stations and interchanges where shared stop bays are assigned to a number of regional routes, the assigned stop bay may be occupied by a late departing bus forcing an arriving bus to either circuit the facility, pull into the nearest unoccupied stop bay or hold over in a bus parking area until its allocated stop bay has been vacated. The impact on dwell time variability is similar to that earlier described for an occupied kerbside stop.

Peak period dwell time can be increased by bus competition even more at busy inner suburban lead stop busway stations than at single bus length kerbside stops, bus stations and interchanges with shared but route dedicated stop bays. While busy lead stop busway stations do not generally suffer from a lack of platform kerb space to alight and board passengers during peak periods, boarding passengers at busway stations have no real certainty as to where their arriving buses will actually berth on the platform.

With busway station capability to simultaneously berth from 3 to 5 vehicles and buses arriving in rapid succession then stopping nose to tail at random loading areas rendering their destination signs impossible to read from the lead stop, waiting passengers at the lead stop loading area may need to relocate by up to 50m along the platform to board their chosen buses through crowds, which in some cases, may be mobilising in the opposite direction to board their chosen buses. Surveys undertaken by the Queensland University of Technology at Mater Hill Busway Station in 2004 have shown that the average alighting time per passenger of around 2.1s remained unaffected by where arriving buses happen to berth on a lead stop busway station platform, but average boarding time per passenger increased very significantly from 4.8s/passenger at the lead stop loading area, to 5.9s/passenger at the second loading area, to 12.7s/passenger at the third.

The following stop treatments can substantially reduce peak period dwell time variability at inner city high capacity bus stops:

- Kerbside Bus Stops: Queensland *Road Rules* afford exclusive rights to urban route buses to park outside signed bus stops and bus zones across private driveways and pedestrian accesses, in front of fire hydrants, on bicycle lanes, and in clearway, loading, parking, taxi, postal and other regulated vehicle zones if stopped solely for the purpose of pick up or set down of passengers. The right of urban buses to stop in regulated zones other than bus stops and bus zones does not apply if regulatory signs controlling the zone prohibit buses of a particular type or size from stopping, or if the rear of the vehicle overhangs an intersection or pedestrian crossing.

  Kerbside bus stop treatments to improve high capacity bus stop dwell time are essentially geometric in nature and need to be selectively targeted. It will be shown later in this report that high capacity bus services become economic to operate on off-busway suburban routes of 10km or longer when 12.5m rigid buses experience recurring overloads during peak periods.

  Stop zones on major arterial and sub-arterial roads within 8km route distance of the CBD need a clear kerb space of around 25m to berth one high capacity bus during off-peak periods, but to also be capable of simultaneously berthing 2 buses during peak periods necessitating a total clear kerb space of around 40m, with the additional 15m clear kerb space located behind the designated stop zone.

Given most kerbside stop zones on major arterial and sub-arterial roads within 8km of the CBD will be signed as clearways or no parking zones during peak traffic periods, and the road rules cited above, the additional 15m clear kerb space required behind an old generation bus stop zone may be seconded from virtually any regulated kerbside traffic zone by a bus driver, provided that the rear of his/her bus does not overhang a pedestrian crossing or road intersection. High capacity bus treatments for many existing old generation arterial and sub-arterial kerbside stops should therefore involve little more than lengthening existing undersized bus stop zones to 25m, and/or relocating zones downstream where less than 15m exists behind the zone to an existing road intersection or pedestrian crossing.

For bus stops on arterial or sub-arterial roads located beyond 8km route distance from the CBD, the stop zone only needs to be increased to 25m length to berth a high capacity bus, and the typical geometric treatments required would be those defined for a new TransLink premium bus stop.

- Bus Station and Bus Interchange Stop Bays: Treatments to improve dwell time performance at route dedicated bus station and interchange stop bays are also geometric in nature, but are generally more costly to implement if the station or interchange was initially designed for and is only accessible off-road to 12.5m rigid buses. If the existing facility is accessible off-road with 2 platform stop zone spaces of 25m length each, one located behind the other; or with one stop zone of 25m length with 15m clear platform and linear kerb space behind, the stop zone is suitable for simultaneous berthing of 2 high capacity buses.

  Stop bay bus conflicts at stations and interchanges can (in theory) be eliminated during peak periods by scheduling 10 minute or longer intervals between arriving bus services sharing a bay, but the reliability of scheduled mixed service separations diminishes over time with increasing shared use and variability in upstream traffic conditions encountered by competing bus services using the shared stop bay.

  Though not ideal, one alternative to avoid having to upgrade an existing 12.5m rigid bus station or interchange inaccessible off-road to high capacity buses, may be to construct two high capacity vehicle kerbside bus stops on and opposite the existing facility road frontage. This solution is considered practical where the facility is located close to an existing signalised intersection or pedestrian crossing such that passengers can safely cross the road to reach the station or interchange from the far stop on the opposite side of the road.

- Busway Station Platform Loading Areas: Treatments to improve dwell time performance at lead stop busway station platforms are non-geometic and utilise electronic real time passenger information display signs similar to those distributed by companies such as INIT, TransLink's appointed supplier for the *Customer First* real time passenger information system currently under trial on Clarks Logan City bus services. The INIT real time passenger information system continuously tracks bus services and predicts their arrival times at each busway station. Approaching bus service destinations and route numbers are normally displayed on busway station passenger information signs in their predicted order of arrival at platforms from top to bottom.

  On arrival at stations, buses normally fill vacant loading bays from the rear of the platform, but may alternatively leap frog around stopped buses to berth in vacated loading areas closer to the lead stop. The standard operation of the INIT passenger information display system would need to be modified to predict the platform loading area most likely to be occupied by approaching buses, to continuously monitor stopped buses already on the platform and re-sort their destination display order in accordance with actual locations occupied from the front to rear of platform. This would provide real time visibility over both approaching and stopped bus services from front to rear of platform to waiting passengers enabling them to mobilise to their correct platform loading areas in advance of bus arrivals.

2.7 Policy Options to Reduce Dwell Time

One option available to TransLink when considering the conversion of 12.5m standard bus services to high capacity vehicle services would be to allow operators to claim additional running time and/or layover recovery time at termini under their *3G Contracts* for services operated by the larger size buses, but this option comes at a recurring monthly claim expense to TransLink as the service funder. Better options would involve changing existing operating policies to proactively reduce stop dwell time on all bus services such as through implementation of prepaid bus stops, stations and zones, prepaid routes, discontinuation of onboard paper ticket sales and *go card* top ups, and all door boarding. All of these alternative policy initiatives have been previously trialled by TransLink, and in some cases, have been partially implemented in certain segments of its bus, rail and ferry network.

2.7.1 Prepaid Bus Stops, Bus Stations and Zones

In late 2007, TransLink trialled prepaid ticket closed platform operations at Cultural Centre Busway Station. During the trial, the busway station operated similarly to a manned railway station where boarding passengers could not enter onto the platform without a valid ticket or *go card* check and were thereby prevented from purchasing paper tickets from or requesting *go card* top-ups by drivers aboard arriving buses. The trial was considered highly effective at reducing average busway station dwell times and PM peak outbound bus queue lengths across the Victoria Bridge, so further prepaid ticket closed platform operations were subsequently rolled out at South Bank, Mater Hill, Roma Street, King George Square, Upper Mt Gravatt and Eight Mile Plains Busway Stations in 2008 and 2009.

Due to TransLink budget constraints, the trial program had to be terminated in 2010, and dwell times have again increased at these busway stations with outbound buses again queuing back from the Cultural Centre Busway Station to North Quay and Queen Street Bus Station in the PM peak period, drawing numerous complaints from bus operators and passengers. It is understood that TransLink is currently working with Brisbane Transport to reintroduce other prepaid ticket initiatives to reduce bus dwell times at its inner busway stations.

Other Australian State and Territory capital city bus authorities have already introduced prepaid ticket bus stops, stations and zones. Since 2009 for instance, the entire Sydney CBD has operated as a prepaid bus zone between 7:00am and 7:00pm weekdays, and an additional 18 major bus stops surrounding the Sydney CBD have progressively been added in as prepaid ticket only stops.

Figure 8: Prepaid Ticket Closed Access High Capacity Vehicle BRT Station in Curitiba, Brazil

Manned prepaid ticket closed access stops and stations are commonplace on the South American BRT systems operated in Curitiba, Brazil and Bogotá, Colombia. Due to their extremely high passenger turnover volumes, upward of some 43 thousand passengers per hour in both CBD travel directions, passengers using these BRT systems are required to exit closed tubular stop platforms from one end, enter from the other and purchase tickets from an attendant prior to entry, making it unnecessary for drivers to issue tickets or collect fares aboard buses. The outcome of this prepaid ticketing strategy has been a dramatic cut in average passenger boarding, alighting and stop dwell times.

Given the considerably greater volume of passengers serviced by these two BRT systems relative to the passenger volumes serviced by Brisbane busways, it is of particular interest to note the disproportionately smaller footprints of South American BRT stations and stops compared with those in Brisbane as clearly illustrated by Figure 8 and Figure 9 respectively. These incredibly small footprint bus stop facilities have been achieved through the greatly improved bus operating efficiency resulting from off bus prepaid ticket sales and significantly reduced average stop dwell times.

Figure 9: Prepaid Ticket Closed Access BRT Kerbside Stop in Curitiba, Brazil

In the South American example depicted above in Figure 8, BRT stations are effectively operated in a manner similar to attended railway stations in South East Queensland. Given the 16.5km South East Busway with only 11 stations carries more passengers per weekday than the entire 740km CityRail network with some 145 stations located in South East Queensland, reconsideration of the existing policy to discontinue prepaid ticket sales at busway stations would appear to be justified, even if only manned by *go card* inspector/ticket sellers during the weekday PM peak periods.

While *Add Value Vending Machines* installed at all busway stations self-serve paper tickets, give change and credit *go cards,* the continued policy enabling unpaid passengers to board buses and request these services from the driver will never obviate paper ticket sales, cash handling and *go card* top-ups aboard buses or eliminate the resulting increase in stop dwell time incurred as a consequence which impacts high capacity buses in proportion to their larger loading capacities.

The hidden costs of on-bus ticket sales and *go card* top-ups provided for the convenience of arguably lazy and/or late running passengers who choose not to use website and agency *go card* crediting alternatives or readily available station add value vending machines include:

- Delay and inconvenience to all boarding and boarded passengers on those buses where drivers have to issue paper tickets, handle cash and top-up *go cards* before unpaid passengers can board,
- Extended stop occupancy causing delay and inconvenience to following buses trying to access the station platform and their waiting and boarded passengers,
- Excessive mobilisation of waiting passengers along the station platform to board buses pushed further back by occupied platform bus loading areas,
- Busway traffic congestion and inefficient utilisation of high cost busway assets,

- Increased fare evasion by regular passengers who wait until the driver is distracted before boarding and pretending to swipe their *go cards*,
- Increased peak period service late running and unreliability, and
- Increased customer dissatisfaction with slow and inefficient bus services and consequential patronage loss to the private motor vehicle.

2.7.2 Prepaid Bus Routes

TransLink trialled prepaid bus routes in 2008 on 3 bus routes operating in Brisbane and Logan City. The trial was again proven successful at reducing stop dwell times and improving service reliability. The trial initiative was strongly supported by bus drivers and customers when assessed after its completion by driver focus groups and onboard passenger surveys. As a result of the successful trial outcome, TransLink now has some 43 prepaid bus routes operating in its network. These prepaid routes only permit passengers to use *go cards* aboard buses or present prepaid transfer tickets to the driver when boarding. Passengers cannot purchase paper tickets on board buses.

In Sydney, after a similar successful outcome on the 'Bondi Bendy' prepaid Route 333 articulated bus trial, there are now some 47 other prepaid routes in operation across the city. In Melbourne, high frequency Route 601 operating between Huntingdale Station and Monash University has been similarly designated a prepaid only route.

2.7.3 Pay-on-Exit Paper Ticket Sales

Seattle, Washington USA operates a novel alternative to the prepaid route service on which passengers without prepaid smartcards or tickets may board buses in the CBD during the PM outbound peak, but must purchase a paper ticket from the driver before exiting the bus. This ticket payment strategy prevents boarding delays in the CBD heart where busy stations and bus stop bays need to be quickly recycled to make way for other arriving buses, and effectively transfers the delays incurred by ticket sales to outer suburban bus stops where the delays arguably cause less inconvenience to less passengers and reduced disruption to peak network operations and drivers.

Dwell time savings yielded from this novel ticketing strategy prove even greater on AM inbound peak services to the CBD. Passengers with unpaid tickets are again permitted to board buses at suburban stops to prevent blockages to door boarding channels and reduce stop dwell times, but must purchase tickets from the driver before alighting. On AM inbound peak services, there are typically very few, if any, boarding passengers at CBD stops and very high numbers of alighting passengers, so the driver can productively apply the CBD stop dwell time otherwise wasted while alighting passengers to completing his/her paper ticket sales.

While it will may be argued in the TransLink context that pay-on-exit appears to be a recipe for increased fare evasion and that passengers without tickets would simply exit through the bus rear door without paying a fare, irregular bus users are the passengers most likely to purchase tickets and are considered less likely candidates than habitual regular fare evaders who board and alight buses and trains without tagging *go cards* at unmonitored card interface devices.

2.7.4 All Door Boarding

It is demonstrated later in this report that all door boarding has the potential to significantly cut high capacity bus peak period stop dwell times. While all door boarding has been common practice on heavy and light rail transport modes for more than a century in Australia, there are no known implementations of all door boarding on revenue scheduled route bus services anywhere in Australia, other than on the Brisbane Transport *CityGlider* service. All gate boarding is also a well established practice on large city ferry operations such as Sydney Ferries. Newly built Brisbane City Council ferry terminals now incorporate dual ferry berths and boarding gates for *CityCats*, and all gate alighting and boarding have been used for peak period *CityCat* dockings at the Riverside Ferry Terminal for several years.

All door boarding has been commonplace on high capacity, high frequency, high turnover route bus services operated in many European and Asian cities for decades, and there is an increasing trend to adopt all door boarding in Canadian and United States capital city bus operations where transit agencies with budgetary constraints have come under increasing pressure to cut government public transport subsidies and increase transit service reliability and speed.

The practice of all door boarding on overseas buses was copied from ferry, heavy and light rail mass transit services operated alongside mass transit bus services by public transport authorities who operated multiple modes. Proof of payment smartcard and paper ticket checking by roving ticket inspectors and security police was also adopted coincidentally with all door boarding on mass transit buses and identical fines applied to fare evasion infringements to those imposed on ferry, heavy and light rail passengers. Ticket inspectors and security (transit police) officers conduct smartcard and prepaid ticket checks aboard all vehicle types and randomly patrol across all the different modes.

Appendix A provides a summary of international capital city mass transit operators who have already successfully implemented all door boarding on their buses in combination with proof of payment roving smartcard/prepaid ticket inspections and issue of infringement notices with hefty fines to proactively deter fare evasion.

2.7.4.1 History of All Door Boarding in South East Queensland

All door boarding has been adopted throughout Australia for passenger loading on heavy and light rail vehicles. To maximise its all door alighting and boarding passenger movements, Queensland Rail electric cars utilise 2 wide loading plug doors per carriage with car floors deliberately levelled to station platforms. In the SEQ context, heavy rail cars have been successfully using all door boarding since 1865, and the same practice will be adopted on Gold Coast light rail cars from 2014.

Mass transit all door boarding was first trialled on route buses in South East Queensland at *Brisbane Commonwealth Games* venues in 1982, and again at the *Sydney 2000 Olympic Games Football Tournament* hosted by Brisbane in September 2001. Mass transport fares to and from these major events were included in the venue admission ticket price, and the latter 2001 trial was considered highly successful both for its integrated event ticketing solution and the effectiveness of all door boarding in clearing very large crowds in the shortest possible time following the event. Since the 2001 trial, all major events hosted in SEQ have adopted both integrated event ticketing and all door boarding on TransLink route buses. In FY2010/11, TransLink provided safe fast travel to and from some 178 major cultural events, concerts and sporting fixtures, and used all door boarding to move in excess of two million passengers to and from the major venues.

In 2009, Brisbane City Council and TransLink launched the *CityGlider,* a high frequency, prepaid all door boarding route service between West End and Teneriffe Ferry Terminals via Adelaide Street. Later in December 2010, TransLink introduced another prepaid high frequency route service, the P88, operating between Eight Mile Plains and Indooroopilly via King George Square Bus Station. The P88 service was initially launched with all door boarding at King George Square Bus station only during the PM peak to minimise stop bay dwell time because the new service shared its busy platform loading doors with the equally popular and busy Moggill Routes 443 and 444.

It is understood Brisbane City Council has recently expressed its interest to TransLink to co-launch a new service dubbed the *MaroonGlider* which would operate similarly to the *CiyGlider* as an all door boarding prepaid only route. Given Council's interest in operating a second all door boarding prepaid only route, a logical extension of the concept would be to permit all door boarding on the two free inner city shuttle services - the *DownTown Loop* and *Spring Hill Loop*.

2.7.4.2 *CityGlider* Case Study

The *CityGlider* service is presently ranked the fourth busiest bus route in Brisbane. Seventeen 12.5m rigid buses finished in special *CityGlider* livery ply the route daily, supported by 3 spare buses finished in identical livery to cover random peak demand step-ins and service breakdowns.

Routes such as the *CityGlider* operated through high population density precincts with multiple trip generators are characterised by both high passenger catchment loads and high passenger turnover churn. As such, these routes do not necessarily justify deployment of high capacity vehicles because the maximum passenger capacity of a conventional 12.5m bus will rarely be reached if the route is short, high churn and high frequency. Brisbane City Council originally intended to operate the *CityGlider* service with 8 new 14.5m high capacity buses, but opted instead to reallocate 20 of its standard 12.5m rigid diesel buses to the route and operate the service on a 5 minute peak – 10/15 minute off-peak headway.

To enable all door boarding, *go card* onboard card interface devices already installed at *CityGlider* bus rear doors had to be reprogrammed to recognise both alighting tag off and boarding tag on transactions. Card interface device software reconfiguration for rear door boarding was identified as a standard option available on the *Cubic* smartcard ticketing system, and *CityGlider* bus conversions to all door boarding involved little more than a *Cubic* technician logging on at each bus driver console unit with a maintenance card, and selecting the all door boarding option from its drop down menu. The software reconfiguration process for all door boarding took around 1 minute per bus to activate, and all TransLink bus operators have been issued with *Cubic* maintenance cards so any operator can self-convert its bus *go card* ticketing system for all door boarding.

The MAN ultralow floor 12.5m diesel buses chosen by Council to operate the *CityGlider* service only have a single width, single channel rear door which has effectively prevented simultaneous boarding and alighting of passengers and has half the rear door passenger boarding rate of the front door. Rear door boarding on the *CityGlider* has not been well promoted to the public and there are no permanent decals at either bus door and within the bus cabin, or information at any *CityGlider* bus stop blades to advise new passengers that they can opt to board at the rear door. Consequently, MRCagney survey results have verified that only 1 in 4 passengers presently board the *CityGlider* buses via the rear door (refer Table 5).

2.7.4.2.1 Perceived Risk of Al Door Boarding Fare Evasion

Modelling described later in this report has determined that high capacity buses become increasingly more economic to operate on 15km and longer routes at all typical highway, motorway, arterial, sub-arterial and local road peak period average traffic speeds. Implementation of all door boarding is therefore considered the most important initiative available to TransLink to reduce stop dwell times and increase service speed, operating efficiency and competitiveness of high capacity bus services with the private motor vehicle on longer routes. These longer route services operate to sprawled outlying communities where two or more car ownership and commuting by private motor vehicle have become a way of life passed from one generation to the next and reinforced in each from early childhood.

TransLink has estimated it presently loses around $18 million per annum to fare evasion. A perceived risk of all door boarding on high capacity bus routes is the potential of a further increase in fare evasion.

When passengers are only permitted to board through the front door of a bus, the bus driver can be tasked with the added responsibilities of ticket seller, *go card* creditor and *go card* revenue protection guardian. With the exception of 6 cross river ferries, these added responsibilities are not passed to vehicle drivers on other TransLink public transport modes, where passengers neither have access to, nor are permitted by regulation, to interact with vehicle drivers. For other that cross river ferries, ferry crew members are tasked to sell tickets, top up *go cards* and monitor fare evasion at passenger loading gates, and on heavy rail (and light rail from 2014), station masters and roaming transit officers are tasked to sell paper tickets and monitor fare evasion. It is understood that TransLink has recently employed 33 new senior network officers to augment its roaming fare evasion patrols.

The *CityGlider* has recently experienced an unanticipated boost to peak period patronage with the opening and *CityCat* servicing of the newly reconstructed Teneriffe Ferry Terminal where a large number of passengers appear to be transferring from *CityCat* to *CityGlider* services in the morning peak, initially presumed to be motivated by the desire to reach preferred stop destinations in Fortitude Valley and the inner CBD not directly accessible by ferry. All *CityCat* ferry terminals in the lower reaches of the Brisbane River between Sydney Street, New Farm and Northshore, Hamilton are located within Zone 2, and this has raised new concerns that the unexpected increase in passenger transfers between the two transport modes at Teneriffe Ferry Terminal may be occurring not so much as a matter of passenger destination convenience, but to exploit rear door boarding and alighting on the *CityGlider* to evade paying a two zone *go card* fare.

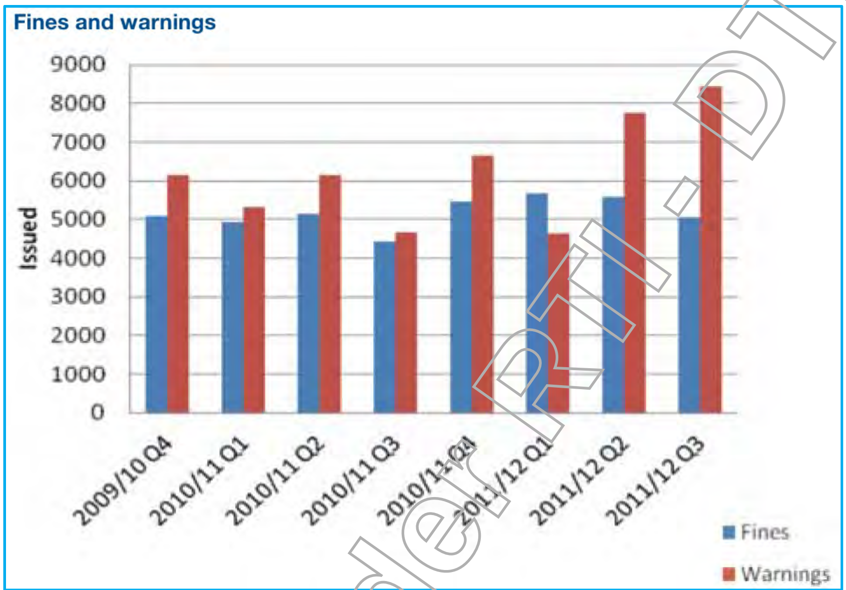
It is the considered view of the authors that endemic fare evasion is closely linked to the demographics and psychographics of residents living in particular socioeconomic service corridors, and the average incomes of passengers boarding *CityCats* in the lower reaches of the Brisbane River would not support the hypothesis that intermodal transfers to the *CityGlider* all door boarding service is significantly motivated by a 53¢ fare evasion. Evidence for this view has been found from previous analyses of the correlation between socioeconomic disadvantage and endemic fare evasion characterised on particular railway lines operated in the TransLink network; one notable example being the Beenleigh line.

Given TransLink's renewed vigour to tackle entrenched fare evasion on the bus network through the deployment of more transit officers, it is not unreasonable to expect that some of these transit officers could be deployed to specifically target standard bus routes converted to all door boarding high capacity vehicle routes to address the perceived increased risk of fare evasion. This has been the proof of payment strategy adopted by most overseas mass transit authorities to manage their all door boarding high capacity service roll outs described at rear in Appendix A. Most of the overseas mass transit operators nominated in Appendix A implemented all door boarding simultaneously with or shortly after their smartcard ticketing system roll outs to eliminate the traditional excuses that passengers normally posed when confronted without paid tickets by ticket inspectors, namely that they had no reasonable access to a prepaid ticket outlet. While there is no known research in TransLink on the reasons why particular SEQ passengers persist with evading fares, it could be reasonably assumed that a very small percentage of fare evaders are good citizens who just got caught on the rare occasion when they didn't happen to have the cash on hand to pay their ticket fares.

Fare evasion can occur for reasons other than a deliberate attempt by passengers to defraud the public transport provider of its rightful fare. One of the key reasons now better understood as to why fare evasion peaked on all door boarded Melbourne trams after the cessation of onboard conductors in 1998, was that the installed onboard ticket issuing machines that replaced conductors would not accept notes or credit/debit cards and therefore passengers had to have the necessary coins to self-purchase a ticket after boarding a tram. A similar finding occurred when all door boarding prepaid articulated bus routes were first trialled by London Transport prior to smartcard ticketing implementation where passengers could not buy tickets from drivers and had no readily accessible ticket channels from which to procure tickets at stops prior to boarding their buses.

TransLink no longer undertakes comprehensive fare evasion surveys to statistically measure the level of fare evasion by segment on particular transport modes, but does however record the number of fines and warnings issued by transit officers across its network as an indicator of the quarterly rise and fall in detected fare evasion. The number of fines and warnings is however unrelated to total passenger trips provided, the number of roving transit officers deployed, or the number of tagged passenger *go cards* and prepaid tickets checked; so meaningful comparisons of fare evasion between the different modes and service providers cannot be readily determined. In the example histogram appearing below at Figure 10, it would appear for example that total fines and warnings have increased in the past 2 quarters of FY2011/12, when this could merely reflect the increased number of transit officers deployed on train services to conduct ticket checks.

Figure 10: Histogram of TransLink Fines and Warnings (Source: *TransLink Tracker 2011-2012 Q3*)



Service reliability and efficiency have been consistently ranked in the 'high' category of target areas for improvement in TransLink bus service passenger customer satisfaction surveys. Because bus passengers in SEQ have always had to enter buses via the front door and conduct their ticket fare transactions with or in the presence of drivers, it could be argued that bus passengers, more so than rail or ferry passengers, have acquired a learnt behaviour to be honest and pay the ticket fare due. TransLink should be somewhat encouraged and comforted by the established behaviour of its existing bus passengers to not exploit all door boarding as a means to evading fare payment, given bus passengers are those most likely to appreciate faster and more reliable services that would flow from all door boarding.

2.7.4.2.2 Perceived Rear Door Safety Risk

The rear doors on high capacity buses may be obscured from the driver's view by standing passengers or acutely angled trailer articulations in the case of articulated buses. A safety concern often expressed in relation to all door boarding is that the bus driver will inadvertently close the rear door (or doors) on passengers still boarding the vehicle and not visible in either the interior or nearside exterior rear view mirror. It is common practice overseas for all passenger rear door boarding areas to be viewed on a driver's dashboard or overhead LCD monitor connected to closed circuit video cameras mounted opposite rear doors as have been fitted on the Clarks Logan City articulated superbuses and Bustech double deck bus.

In Paris, the passenger is able to remotely open bus rear doors when the vehicle is stopped or travelling at less than 3km/h as on Australian trams and trains, by pressing a button on the inside and outside of the rear door access. Feedback from TransLink's *Bus and Ferry Contracts* team has indicated that Brisbane Transport drivers on *CityGlider* buses have in the past simply forgotten to open the rear door to enable all door boarding. This issue could potentially be overcome by providing a single push button to open (but not close) the front and rear doors simultaneously and passenger operated door opening buttons similar to those fitted on Parisian buses.

2.7.5 Common Themes of Overseas All Door Boarding Implementations

Most of the transit agencies profiled in Appendix A introduced all door boarding on their high capacity bus services to improve service reliability and average speed, and to contain increasing operating costs.

San Francisco and Paris elected to allow all door boarding on all of their bus services, regardless of vehicle size or passenger demand. Vancouver and Ottawa only implemented all door boarding on their high capacity articulated and double deck bus services. In the case of Vancouver, all door boarding was limited to one particularly busy route, and only articulated buses were assigned to the route.

In all the overseas implementations investigated, the onus was placed on passengers to provide proof of purchase of a smartcard or valid ticket prior to boarding and to present such upon request to a transit agency appointed ticket inspector or security officer. Fines imposed for fare evasion were hefty, consistent across all travel modes managed by the transit agency, and considered a very strong deterrent to new and repeat offenders. Fare evasion monitoring was exclusively tasked to randomly deployed roving ticket inspectors and transit agencies increased the number of ticket inspectors in the lead up to the introduction of all door boarding services to mitigate the risk of elevated fare evasion.

No agencies chose to introduce prepaid only all door boarding services. They provided a mechanism for irregular passengers to still purchase tickets aboard buses using compulsory boarding at the front door for non-ticket holders and procurement of tickets from drivers. In some cases, tickets were sold onboard buses at a higher fare than a prepaid ticket bought off-vehicle, or the standard single trip fare electronically deducted from a prepaid smartcard.

Many transit agencies undertook all door boarding trials on targeted routes before proceeding to full scale rollout as a proof-of-concept verification to quantify benefits in terms of operating cost savings and travel time improvements, and to provide tangible evidence to politicians and other decision makers that safety and fare evasion risks could be appropriately managed. In all cases, the time and cost saving benefits yielded far outweighed the perceived costs of foregone ticket revenue, and quantification of benefits included passenger surveys to gauge customer responses to improved service reliability and speed.

All transit agencies undertook public advertising campaigns in the lead up to their introduction of all door boarding to educate customers on the benefits and fare rules, where to stand and how to distribute themselves evenly between doors at stops, and which door had to be used for ticket procurements. Mass communications about these new practices were continued well after the introduction of all door boarding or, typically coupled with marketing campaigns for new service launches to proactively discourage fare evasion.

2.7.6 Australian Reluctance to Adopt All Door Boarding

So why has all door boarding on buses operated in Australian cities never been adopted as it has been in many other overseas countries? The authors can only surmise that this is an historical artefact of the transition from trams with drivers and conductors to driver only buses in the early 1970s, and Australia's relatively short history with operating large scale, high capacity, high frequency mass transit bus services.

Up until 2009, TransLink's largest capital city bus operator, Brisbane Transport, only had a fledgling fleet of 9 articulated buses which it operated on a select few high demand routes. But in a relatively short space of just the past 3 years, Brisbane Transport has substantially grown its high capacity fleet to 158 buses, representing more than 13% of its total current fleet strength, and proposes to further increase its high capacity vehicle fleet composition to 15% by FY2013/14.

Brisbane does not stand alone in its quest to fast track in more high capacity vehicles in an effort to arrest continuing rises in fuel and driver costs and to address increasing passenger demand which edges ever closer to the maximum boarding capacity tipping point of conventional 12.5m rigid bus viability. Sydney, Perth, Adelaide, Hobart and Canberra have progressively grown their respective high capacity fleet strengths over the last 3 years, and similarly begun to taper off their retiring conventional low capacity bus replacements. This fleet replacement strategy has been driven to some extent by the need to retire old high floor 12.5m rigid bus ahead of pending national public transport DDA compliance deadlines falling due in 2017, and to avoid any unnecessary State enforced old age bus body structural rebuilds.

In Melbourne, the only Australian capital city to have retained trams as its public transport vehicle of choice, A class and Z class trams of between 15m to 16.5m in length now represent 45% of the entire Yarra Tram fleet mix. These larger size tram classes have a seating capacity of 42 – 48 passengers, and a total passenger carrying capacity of around 100 with standees. Melbourne too, mirrors the national trend to high capacity vehicle fleet growth witnessed in all its sister State and Territory capitals.

Unlike any of its sister capital cities, greater Brisbane has also rolled out new busways, preserved bus transitway corridors and conducted public transport infrastructure upgrades over the past decade under TransLink and its predecessors, and this has uniquely positioned the city as the mass transit leader within Australia. Brisbane, more so than any other Australian capital city, is now ideally poised to implement high capacity vehicle all door boarding and reap similar benefits to those already being enjoyed by world's best practice BRT mass transit bus operators.

2.7.6.1 Reported Benefits of All Door Boarding by Best Practice Mass Transit Agencies

This following summarises the benefits of all door boarding on high capacity buses reported by overseas best practice government mass transit agencies similar to TransLink:

- Reduced stop dwell times,
- Reduced service travel times,
- Increased average service speed,
- Improved service reliability,
- Reduced operator penalties for failing to meet on-time performance,
- Higher user customer satisfaction, particularly with operating efficiency,
- Reduced bus queuing and congestion at stations,
- Improved bus station and stop bay turnover, resulting in deferred or cancelled need for capital investment to continually increase network and stop capacity,
- Improved utilisation of bus cabin interior passenger spaces,
- Reduced passenger circulation within buses,
- Increased standee comfort,
- Reduced conflicts and assaults between drivers and passengers, and
- Reduced total operating costs.

2.7.6.2 Reported Disadvantages of All Door Boarding by Mass Transit Agencies

This flowing summarises the disadvantages of all door boarding on high capacity buses reported by overseas mass transit agencies similar to TransLink:

- Heightened risk of fare evasion if targeted deployment of transit officers is not undertaken on all door boarding bus services,
- Heightened risk of implementation failure if rollout is not supplemented with a public education advertising campaign to train passengers on correct boarding procedures, and
- Safety concerns for rear door boarding of passengers if rear doors are not video monitored at the driver's position when doors are opened and closed.

2.7.6.3 All Door Boarding Pre-Implementation Check List

Based on overseas mass transit operating experience, the authors recommend that all door boarding be selectively implemented by TransLink as follows:

- On all high capacity bus services,
- Using only low floor buses to minimise average passenger boarding and alighting times,
- Using only buses with a minimum of 2 or preferably 3 full width (1200mm) two flow channel doors, each fitted with *go card* readers in each passenger flow channel,
- Using only buses where *go card* readers have been preconfigured to enable mixed tag on and tag off transactions at all doors,
- Using only buses fitted with video cameras opposite each rear door whose views can be monitored from the driver's seated position with standees and in all ambient lighting conditions,
- Preferably on new buses fitted with exterior opening plug doors and passenger operated interior and exterior push buttons to reopen doors when the bus is stationary or moving at less than 3km/h,
- Preferably with symbolic decals fitted on or adjacent to all doors identifying to passengers that the vehicle is an all door boarding and alighting bus,
- Preferably on routes where high average passenger loads can be boarded and alighted at the minimum number of stations and stops,
- Preferably with station and bus stop signage providing passenger information that instructs passengers on how to use all door boarding buses,
- With a well publicised all door boarding passenger advertising campaign, periodically rerun after initial service launch to reinforce the rear door boarding and fare evasion fine message,
- With targeted deployment of transit officers on all door boarding routes to mitigate the risks of creeping higher fare evasion,
- With front door boarding to enable infrequent passengers to purchase a ticket from the driver, and
- Where TransLink elects to operate all door boarding bus services as prepaid only routes, with adequate ticket outlets or add value vending machines provided on stations for passengers to prepay their tickets, until such time that cashless *go card* boarding has been fully implemented.

3. Operational Assessments

In this Part 3, we analyse live data captured from *go card* transactions and onboard ride surveys carried out on 4 high capacity vehicle and 2 standard 12.5m rigid bus services. The statistical measurements obtained from these data analyses are then used to model high capacity performance and to determine the specific route characteristics on which each bus type performs best.

3.1 Average Bus Stop Boarding and Alighting Times

3.1.1 Measurement Methodology

Detailed analyses have been undertaken by MRCagney to determine the variation in average passenger boarding and alighting times between the 4 high capacity bus types and 2 standard bus types based on live data captured from aboard the vehicles by the TransLink *Cubic go card* ticketing system. Ticketing data was reviewed for the inbound and outbound travel directions during peak and off-peak service periods between 1 March and 8 April 2012.

Source data was obtained from a netBi structured query of passenger *go card* tag on and tag off transaction times at all bus door card interface devices then sorted from first to last by time, date and trip direction for each card interface device and bus stop. After extensive data cleansing and sequential logic testing, 507,500 boarding and 469,700 alighting transaction records were recovered from the 538,500 total *go card* transactions loaded from netBi, and from these, 184,500 boarding and alighting passenger counts derived per stop and used to compute the average boarding and alighting time measurements.

Approximately 13% of netBi source transaction records were deemed invalid and rejected. Source records were rejected in cases where more passenger alightings than boardings occurred during the stop sequence along the route, the service or route number remained unchanged either before or after a terminus stop (i.e. because drivers had forgotten to log off and back onto a new service at the DCU), transaction time stamps were reversed in relation to the stop sequence or had stopped (i.e. due to drivers turning back without logging off/on at the DCU and equipment breakdowns) and unmatched boarding and alighting counts at end termini (i.e. sum of boardings not equal to sum of alightings).

Boarding time per passenger at each bus stop was computed from the time difference between the first and last valid *go card* tag on divided by the total number of tag ons. Alighting time per passenger at each bus stop was similarly computed from the time difference between the first and last valid *go card* tag off divided by the total number of tag offs. Dwell time per passenger was calculated from the time difference between the first and last *go card* tag on OR tag off divided by the total number of tag ons AND tag offs.

Boarded passenger loads were calculated sequentially for every serially sorted stop group identifier along each bus trip by computing the cumulative difference between passenger Σtag-ons and Σtag-offs following each stop. Standing loads were estimated by subtracting the seating capacity for each vehicle type from its boarded passenger load after each stop. Seated and standing passenger load profiles were then generated for each trip and bus type, and the results statistically analysed.

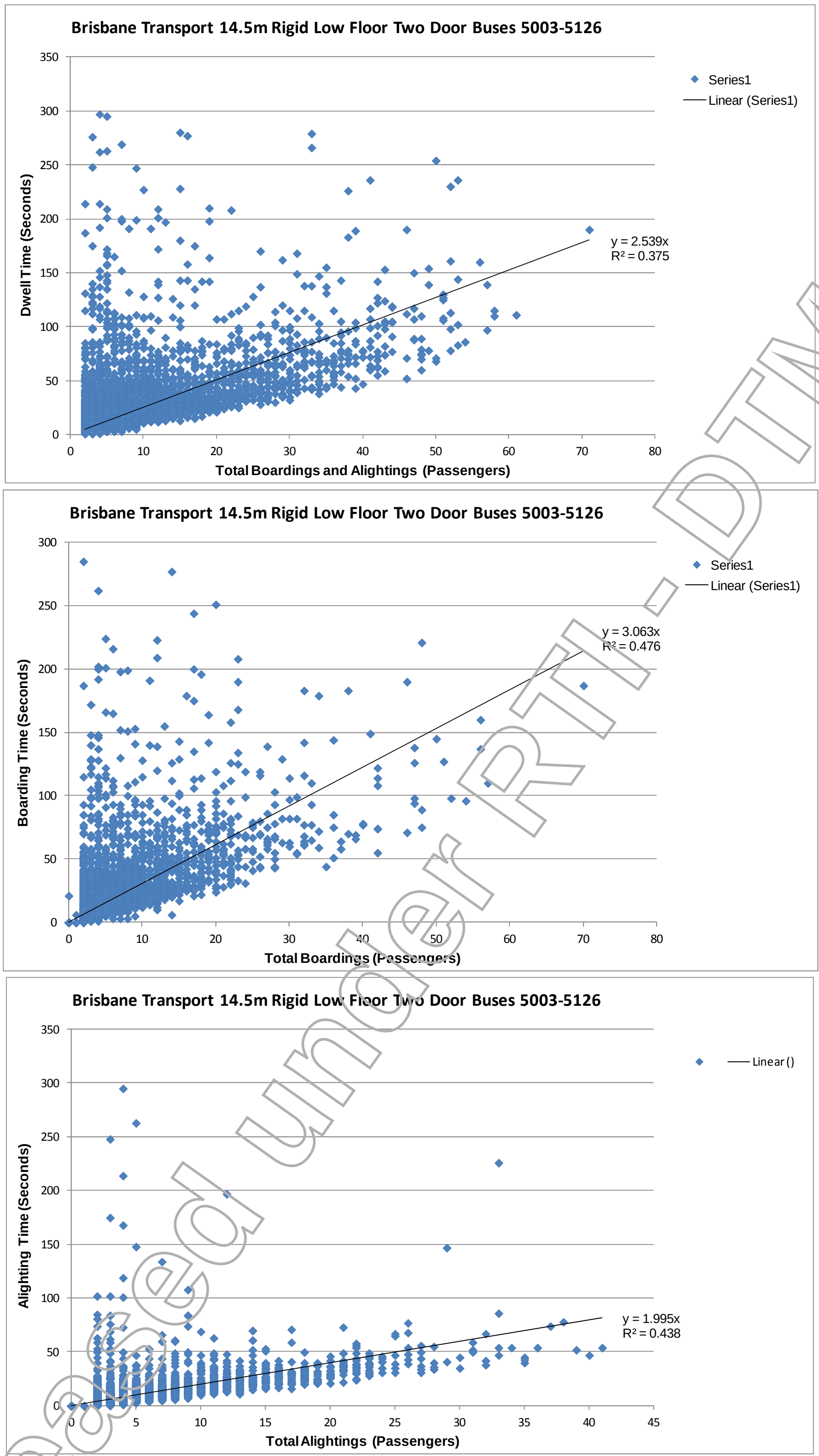
Our data analysts have recognised a number of potential error sources from using raw *go card* transaction data to assess bus operational performance as follows:

- Time delays caused by driver activated suspension lowering and raising and door opening and closing could not be measured from *go card* transactions and could not therefore be included in the measured final dwell times. The former were observed on ride surveys to occur rarely in live service - generally only when persons with disabilities sought driver assistance, and the latter was observed to add less than 3 seconds to overall bus stop dwell times;

- The ability of passengers to randomly tag off before buses had pulled into bus stops and to cancel tag ons by tagging off again within 20 seconds after leaving stops could not be detected and could result in the overestimation of actual bus stop dwell times. Occurrences of the latter event were however known to occur very infrequently in real live service;
- There was no practical way for our analysts to determine instances where buses were delayed at stations or stops while boarding passengers mobilised along platforms or to makeshift set downs because stops were already occupied by other buses at the time of arrival. On ride surveys, it was noticed that when this occurred, drivers tended to open their doors for alighting and boarding passengers but well before the latter actually began to board at front doors. This occurred frequently during the peak periods on inner city lead stop busway stations;
- There was no practical way for our analysts to determine instances where buses were delayed at stops when passengers interacted with the driver to ask questions, top-up *go cards,* procure paper tickets or seek front door boarding/alighting assistance as in the case of passengers with physical disabilities, all of which would act to increase *go card* transaction times recorded; and
- There was no practical way for our analysts to detect and count passengers who procured paper tickets. This type of error leads to an underestimation of the actual number of boarded and alighted passengers at stops and to longer average boarding times per passenger.

Final boarding, alighting and dwell times per passenger were computed using straight line regressions similar to those depicted below in Figure 11 for the Brisbane Transport 14.5m rigid high capacity bus. This statistical technique generates a best fit straight line relationship between measured passenger counts and times using the method of least square deviation to minimise the undesirable effects of random, unusual and extreme deviations illustrated by the coordinates appearing in the 3 scatter diagrams below and overleaf in Figure 11.

Figure 11: Straight Line Regression Results Obtained for Brisbane Transport 14.5m Rigid Buses



The bus types and routes analysed in the operational assessment survey were:

Two Door 12.5m Rigid Bus (Study Reference Standard Vehicle)

- Brisbane Transport Low Floor (LF) Buses 561 - 1055, Aspley Hypermarket to City Route 345
- Brisbane Transport High Floor (HF) Buses 320 – 539, Aspley Hypermarket to City Route 345
- Brisbane Transport Low Floor Buses 1030 - 1049, Teneriffe to West End Ferry Terminal CityGlider Route 60

- Two Door 12.5m Double Deck Bus
  - Hornibrook Bus Lines Bus 343, Redcliffe to City Route 315
- Two Door 14.5m Rigid Bus
  - Brisbane Transport Buses 5003 – 5126, Browns Plains to City Route 150
- Two Door 18m Articulated Bus
  - Clarks Logan City (LC) Buses 116 – 117, Loganholme Bus Station to City Route 555
  - Brisbane Transport (BT) Buses 1601 – 1630, Eight Mile Plains to City Route 111
- Three Door 18m Articulated Superbus
  - Clarks Logan City Buses 555 – 556, Loganholme Bus Station to City Route 555.

3.1.2 Results

The measured results of our statistical analyses appear overleaf in Table 4. Visual surveys were also conducted during the survey period at 5 busway stations and on 16 bus trips aboard the surveyed bus types to identify passenger boarding and alighting characteristics likely to affect the measured results. Our onboard observations are further discussed below in the key findings.

3.1.3 Key Findings

- The fastest average boarding, alighting and dwell times per passenger for the high capacity vehicles were measured on the Brisbane Transport two-door 18m articulated buses. Observations taken aboard all bus types surveyed suggest that this occurred on Brisbane Transport articulated buses primarily because alighting passengers positioned themselves at doors well in advance of busway station arrivals, then double streamed off at rear doors and in single file at front doors with minimal conflict to boarding passengers. The Brisbane Transport articulated bus Route 111 service surveyed had a very high incidence of concurrent passenger boarding and alighting and it was further noted that there was very little interaction on Brisbane Transport busway services between drivers and boarding passengers. Unlike either of the high capacity private bus operators, Brisbane Transport Route 111 drivers did not top up *go cards* and sold almost no paper tickets to boarding passengers.

Table 4: Measured Average Boarding, Alighting and Dwell Times per Passenger

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Average Boarding Time Per Passenger	2.7s (LF) 3.0s (HF)	3.0s	3.1s	3.1s	3.5s (LC) 2.6s (BT)	3.7s
Average Alighting Time Per Passenger	2.0s (LF) 2.0s (HF)	2.2s	2.6s	2.0s	2.1s (LC) 1.7s (BT)	2.0s
Average Dwell Time Per Passenger with No Standees	2.5s (LF) 2.9s (HF)	2.7s	3.0s	2.5s	2.9s (LC) 2.4s (BT)	2.9s
Average Dwell Time Per Passenger at >20% Standing Capacity	3.0s (LF) 3.1s (HF)	2.9s	Not Reached	3.3s	3.1s (LC) 2.8s (BT)	3.1s

- No significant differences in boarding, alighting and dwell time per passenger were measured between the Clarks Logan City two and three door articulated buses. Dwell time per passenger on the two Clarks articulated bus variants was found to be strongly dominated by their slow average boarding times rather than by faster average alighting times, which effectively negated the benefit of the Superbus double width middle alighting door.

Observations aboard the Clarks Logan City articulated buses and at busway stations uncovered a very high incidence of passenger interaction with drivers primarily for paper ticket purchases and *go card* top ups. Driver-passenger interactions were observed to not only block off one stream of boarding passengers at the double width front doors, but to set off conflicts in the freely streaming channel between alighting and boarding passengers. Comparison of boarding times per passenger between the near identically configured Brisbane Transport and Clarks Logan City two door articulated buses has highlighted that a Translink policy to eliminate paper ticket sales and *go card* top ups on buses would cut up to 1 second per passenger off average boarding times and half a second per passenger off front door average alighting times on the high capacity buses.

- Significantly higher average boarding times than alighting times per passenger were measured on all bus types. This suggests that dwell time at stops would be improved with concurrent all door alighting and boarding.
- The longest alighting times per passenger were observed on the double deck buses where passengers from the upper deck often continued to alight through the double width rear door in single file well after passengers on the lower deck had fully disembarked. At the high AM peak offloading stops in Fortitude Valley and the CBD, passengers alighting from the upper deck continued to disembark for periods of up to 10s after passengers on the lower deck had fully cleared. Boarding times on the double deck bus were found to be largely unaffected by upper deck use, but it was noticed that alighting times could be significantly delayed by passengers not descending the upper deck staircase until the double deck bus was stationary.
- Average alighting times per passenger were found to be similar between the older high floor 12.5m rigid buses with double width rear doors and two steps to the newer ultralow floor step-free 12.5m rigid buses with only single width rear doors. This indicates that the reduced rear door passenger alighting times afforded by an ultralow floor step free bus design have been effectively obliterated by the decision of bus operators to narrow rear doors on their standard rigid buses in an effort to regain two additional passenger seats.
- Marginally higher average boarding and alighting times per passenger were recorded on the all door boarding 12.5m low floor *CityGlider* buses than on the standard low floor 12.5m route buses. This was found to be due to the low concurrent utilisation of rear doors by boarding passengers, and the somewhat casual laid back nature of off-peak *CityGlider* users.

  Because this service has no fixed off-peak timetable and drivers can vary its pace by up to 5 minutes in each off-peak travel direction, it was found on 4 separate survey trips that the customer friendly *CityGlider* drivers repeatedly held over at bus stops for late arriving runner and hailer passengers, and most off-peak passengers made little or no effort to move to doors prior to bus stop arrivals. Further, because the *CityGlider* buses only had a single width rear door, those passengers who initially chose to board at the rear door had to wait until all onboard passengers had alighted, and in many cases relocated to the front door, or where they remained in the rear door queue, were still boarding well after passengers who boarded at the double width front door were already seated.

3.2 Passenger Alighting Preferences

3.2.1 Measurement Methodology

Passenger door alighting preferences have been summated and apportioned by percentage from netBi tag off records for all surveyed bus types and services, and have been observed from the data to be impacting on both average boarding and dwell times at bus stops. Alighting preference surveys were also conducted at five busway stations and on 16 separate bus trips to identify why passengers chose to alight at front doors and thereby delay boarding passengers, or at rear doors which enabled concurrent conflict-free boarding and alighting. All door boarding and alighting preferences were also observed on 4 Brisbane Transport *CityGlider* peak and off-peak services.

3.2.2 Results

Table 5 below summarises the measured passenger alighting preferences by door for each surveyed bus type. Passenger boarding preferences are also presented in the measured results for the all-door boarding Brisbane Transport *CityGlider* service and to the upper deck of the double deck bus.

3.2.3 Key Findings

While average boarding and alighting times per passenger are a valid measure of the efficiency of a given bus size and configuration to optimise concurrent passenger movements with minimal conflict, total bus stop dwell time was observed to be strongly impacted by passenger preferences to use specific bus doors when alighting. It can be proven mathematically that minimum total service dwell time at bus stops will be achieved when combined boarding and alighting movements occur concurrently without conflict in approximately equal time. This ideal only occurs under very specific operating conditions and real live services rarely meet these conditions with front door only boarding. The optimum conditions are derived by mathematical modelling later in the report.

For AM peak inbound bus services to stops dominated by passenger boardings, average dwell time per passenger converges toward the average boarding time per passenger. Total stop dwell time for most of the trip therefore becomes proportional to the total number of passengers boarded, and incidental concurrent passenger alightings from the rear door have no material effect on the total dwell time accumulated at most stops. For AM peak inbound services, the lowest total dwell time will therefore occur when all or most alighting passengers prefer to use the rear door.

Table 5: Passenger Alighting Preferences by Door for Each Surveyed Bus Type

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Percent Who Alighted at Front Door	31% (LF) 36% (HF)	27%	47%	19%	55% (LC) 52% (BT)	14%
Percent Who Alighted at Middle Door						44%
Percent Who Alighted at Rear Door	69% (LF) 64% (HF)	73%	53%	81%	45% (LC) 48% (BT)	42%
Percent Who Boarded at Rear Door		26%				
Percent Who Boarded to Lower Deck			49%			
Percent Who Boarded to			51%			

Upper Deck							

The opposite conditions prevail on PM peak outbound services to stops dominated by alightings where total bus stop dwell time becomes proportional to the total number of passengers disembarked. For PM peak outbound services, the lowest total dwell time will occur when alighting passengers prefer to alight equally at both doors, assuming both are double width doors.

These however were not the measured results obtained for most of the high capacity vehicles. Key findings from our survey measurements and visual observations of passenger alighting/boarding preferences were as follows:

- Passenger door alighting preferences measured on all bus types very closely correlated with the positioning of the rear doors relative to available onboard passenger seated and standing spaces and were unaffected by rear and/or middle door width in the case of the articulated superbus. Based on this finding, boarding and alighting times on single deck low floor high capacity buses with two doors would benefit from a more aftward positioning of rear doors and increased aisle width and standing space opposite rear doors to store their higher alighting passenger numbers relative to the standard rigid buses.
- The current Bustech double deck seating configuration suits limited stop and express long haul services which can exploit its high seating capacity. Given the seating capacity on the double deck bus was underutilised on the Hornibrook 315 commuter service and never reached anywhere close to full seating capacity utilisation, the double deck configuration would benefit most from an additional staircase off the upper deck to improve alighting times on shorter regular stop city commuter services.
- Concurrent passenger alightings from the Clarks Logan City three door articulated superbuses provided the shortest total trip alighting time and least conflict between boarding and alighting passenger streams. The middle and rear doors on the Clarks 3 door superbus were almost equally preferred by alighting passengers and only 1 in 7 passengers using this vehicle type chose to exit from the front door.
- 69% to 73% (more than 2 to 1) passengers preferred to alight from the rear door on a standard low floor rigid bus, where 81% (over 4 to 1) passengers preferred to exit from the rear door on the 14.5m rigid high capacity bus. Disproportionate use of the rear door to exit from 14.5m rigid buses was found to occur because its longer bus cabin layout placed 90% of all passenger seats and standee areas closer to the rear door than the front door. Cabin layout and rear door position were identified as the key reasons why 14.5m buses took longer to offload passengers en mass than rigid and articulated buses at the AM peak inbound stops in the CBD and other similar highly congested bus stops such as those at the Cultural Centre and UQ Lakes Bus Stations.
- It has been found that regular Hornibrook commuters were near evenly split on their preference for sitting on the upper and lower levels of the Bustech double deck bus. Our onboard observations found that the young and able bodied passengers under 40 years of age preferred to use the upper deck, whilst older passengers and those for whom the upstairs ride was no longer a novelty preferred the lower deck. It is nonetheless plausible that the upper deck would be popular on the Gold Coast 700 series routes, given the high proportion of tourists and regional visitors using these Surfside services. Double deck bus alighting times were found to suffer from extended stop dwell times caused by slow single file alighting down the staircase to the double width rear door, but as for the 14.5m rigid buses, highly extended stop dwells only occurred when a large number of passengers alighted en mass at high offloading stops and stations.

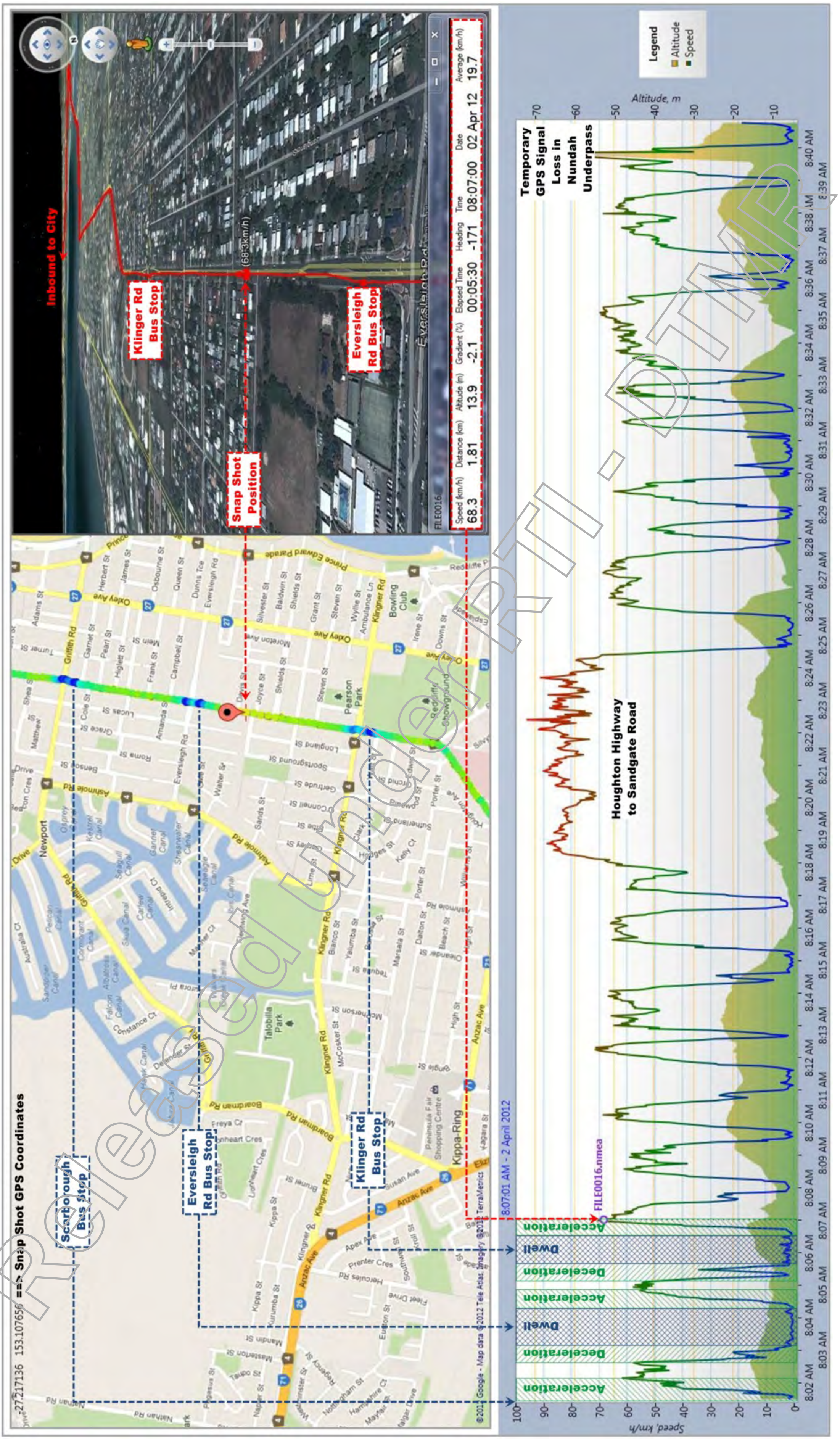
- Only 1 in 4 passengers on the *CityGlider* service chose to board at the rear door. It is considered this occurred because Brisbane bus passengers in the main have been conditioned over many decades only to board at the front door and because boarding passengers are reluctant to wait at the single width rear door for alighting passengers to fully disembark. It was noted on both peak and off-peak *CityGlider* trips that passengers who initially positioned themselves to board at the rear door frequently lost patience with alighting passengers from the narrow rear door and relocated to the front door boarding queue as it shortened. Single width rear doors appear to act as a strong deterrent to potential future all door boarding on standard low floor 12.5m rigid buses.

3.3 Average Deceleration, Acceleration and Speed

3.3.1 Measurement Methodology

Vehicle location and speed were measured on all bus types using a QStarz 66 channel, 5 acquisition/second high resolution differential GPS logger accurate to within +/- 2.5m resolution. Measurements were taken while riding aboard each bus type for 2 or 3 trips while in live passenger service. GPS logs were later downloaded from the logger and analysed using *ActiveGPX*, *Google Maps* and *Google Earth* to plot route and stop locations, speed and gradient charts similar to those illustrated in Figure 12 which were generated for the Hornibrook double deck bus on Route 315. *GPS Results* was also used to measure whole of trip average and best accelerations and decelerations to 50km/h and 90km/h.

Figure 12: Location, Speed and Gradient Charts Generated from GPS Log for Route 315



3.3.2 Results

Table 6 below presents the measured decelerations, accelerations and speeds recorded on each surveyed bus type.

Table 6: Measured Average Decelerations, Accelerations and Trip Speeds

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Typical Deceleration from 50km/h	-1.3 m/s²	-1.02 m/s²	-1.1 m/s²	-1.27 m/s²	-1.23 m/s²
Typical Deceleration from 90km/h	-0.86 m/s²	-0.64 m/s²	-0.72 m/s²	-0.64 m/s²	-0.8 m/s²
Average Trip Deceleration to Stop	-0.89m/s²	-1.04m/s²	-0.85m/s²	-0.6m/s²	-0.9m/s²
Typical Acceleration to 50km/h	1.1m/s²	0.76m/s²	0.96 m/s²	0.89m/s²	0.85 m/s²
Typical Acceleration to 90km/h	0.56m/s²	0.45 m/s²	0.54 m/s²	0.5 m/s²	0.48 m/s²
Average Trip Acceleration from Stop	0.9m/s²	0.7m/s²	0.76m/s²	0.67m/s²	0.8m/s²
Average Trip Speed	22km/h	41km/h	52km/h	43km/h	48km/h
Maximum Trip Speed	48km/h	92km/h	98km/h	92km/h	94km/h
Average/Maximum Speed	46%	45%	53%	47%	51%

3.3.3 Key Findings

Average deceleration to bus stops and acceleration back to incident left lane traffic speed (peak) or regulated traffic speed (off-peak) was determined to exhibit low variance for particular bus drivers, but not for particular bus types. It was found for instance that some drivers preferred to coast down to stops and accelerate off slowly, while others driving the same bus type were found to be more aggressive on the foot brake and throttle. The worst average acceleration and deceleration rates were measured on the 12.5m *CityGlider* off-peak services, and the results tabulated above were considered to reflect the norm of drivers' personal driving habits more so than optimum bus performance.

Key findings from the GPS measurements logged on each bus type were that:

- Average deceleration into bus stops and acceleration back to traffic speed fell inversely with increasing average traffic speed for all bus types.
- Of the high capacity vehicles, the fastest 50/90km/h to 0km/h deceleration and standstill to 50/90km/h acceleration rates were recorded on the 14.5m rigid bus and were similar to those measured for 12.5m standard low floor buses. When fully loaded and driven hard by more aggressive drivers, the 14.5m rigid buses outperformed all other bus types, including all standard high and low floor 12.5m rigid buses, for both combined foot braked plus retarder deceleration and take-off acceleration from bus stops.
- At stations and bus stops that boarded or alighted less than 4 passengers, the time taken to decelerate into and accelerate back out of the stop back to traffic speed typically exceeded the total bus stop dwell time.
- Average trip speeds were found to be around 48% of maximum service speed. In suburbs where bus stops were closely spaced within 450m, average speed fell to as little as 32% of the incident traffic speed, but on the busways where stations were spaced around 2.4km, average speed increased to 56% of the maximum busway speed (90km/h).

- Measured high capacity vehicle deceleration and acceleration results were found to be more closely related to stop spacing, driving performance and average traffic speed than to particular bus types or their manufacturer performance specifications.

3.4 Peak and Off-Peak Passenger Capacity Utilisation

3.4.1 Methodology

An assessment to determine the peak and off-peak passenger capacity utilisation on the different bus types was undertaken using data sourced from the Translink *go* card system. Data was collated for both the inbound and outbound directions during peak and off-peak operating periods between 1 March and 8 April 2012. The source data used was obtained from a netBi structured query of passenger *go* card tag on and tag off transaction times at all door onboard card interface devices to determine the boarded passenger loads on each route and trip, and the measured results discussed below therefore do not include passengers who boarded and purchased paper tickets.

The bus types and routes covered in our statistical analyses were identical to those earlier listed in Section 3.1.1. Seated and total (seated plus standing) passenger capacities for each bus type were obtained from bus manufacturer drawings and bus operators. Low floor (LF) and high floor (HF) standard rigid buses were separately assessed for Route 345, and Clarks Logan City (LC) and Brisbane Transport (BT) 18m articulated buses separately assessed for Routes 555 and 111 respectively.

The terms "peak" and "off-peak" where used in the table of results below do not strictly correlate with TransLink's defined AM/PM commuter peak and off-peak periods. It was found for instance that some bus loading peaks occurred on Route 345 during school runs, and before and after TransLink defined commuter peak periods on the longer 315, 150 and 555 routes.

When filtering the netBI ticket transaction data to assess the number of seated and standing passengers on each bus trip, it was assumed by our analysts that all seats were occupied before passengers began to stand and that the number of standees therefore equalled the difference between the boarded passenger load and bus type specific seating capacity. Observations made while travelling aboard bus services has indicated this assumption generally reflected how passengers distributed themselves between seated and standing areas, but it was noted that school and university students regularly chose to stand and socialise with friends, and passengers who boarded for short rides often chose to stand near rear exit doors when seats at the rear of the vehicle still remained unoccupied.

3.4.2 Results

Measured peak and off-peak passenger capacity utilisations for all surveyed bus types appear overleaf in Table 7.

3.4.3 Key Findings

- Only a very small percentage (2% to 7%) of high capacity vehicle weekday peak services carried standing loads as compared with the 12.5m standard rigid buses (typically 8% to 13%).
- For the high capacity vehicle peak weekday services on which passengers did stand, the average standing time varied between 9 and 18min, but for passengers who had to stand for most of the trip, the maximum standing time varied between 19 and 37 minutes. The worst case maximum standing time was very near to twice the average standing time for all high capacity buses.

- No double deck bus services were identified on which boarded passenger loads exceeded the bus seating capacity. It was presumed accordingly that no passengers ever stood on the double deck bus other than by personal choice.

Table 7: Measured Peak and Off-Peak Passenger Capacity Usage

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Seated Passenger Capacity	44 (LF) 47 (HF)	44	96	56	64 (LC) 63 (BT)	52
Maximum Passenger Capacity	75 (LF) 70 (HF)	69	116	92	90 (LC) 85 (BT)	95**
No of Services Operated Per Weekday	159 (LF) 159 (HF)	236	31	167	138 (LC) 199 (BT)	138
No of Peak Services Per Weekday with Standees	13 (LF) 21 (HF)	3	0	10	4 (LC) 4 (BT)	10
Percent of Services Per Weekday with Standees	8% (LF) 13% (HF)	1%	0%	6%	3% (LC) 2% (BT)	7%
Average Standees on Peak Services	10 (LF) 13 (HF)	8	0	10	9 (LC) 8 (BT)	10
Maximum Standees on Peak Services	34 (LF) 39 (HF)	38	0	44	39 (LC) 28 (BT)	40
Average Standing Time on Peak Services	13min (LF) 14min (HF)	8min	0min	18min	12min (LC) 9min (BT)	13min
Maximum Standing Time on Peak Services	27min (LF) 34min (HF)	25min	0min	37min	23min (LC) 19min (BT)	26min
Average No of Off-Peak Seats Occupied	17 (LF) 20 (HF)	11	26	23	24 (LC) 23 (BT)	23
Average Percent of Seat Capacity Used Off-Peak	39% (LF) 43% (HF)	25%	27%	41%	38% (LC) 37% (BT)	44%

Note: The Clarks Logan City 3 door *Superbus* was granted an exemption in its first year of operation to carry 112 passengers and is currently approved for 95 passengers. Future ultralow floor articulated superbuses with reduced seating are likely to have a capacity of around 112 – 115 passengers under proposed new *Heavy Vehicle National Regulation* axle load concessions.

- Only 27% - 44% of high capacity vehicle seats were occupied during off-peak services compared with 39% - 43% for the 12.5m standard rigid buses. Based on this and our preceding observations, all high capacity buses used on the services assessed could afford to reduce their seating capacity, increase their total (seated plus standing) capacity and improve their alighting, boarding and dwell times by widening of aisles and creation of standing areas opposite rear doors.
- Average and maximum standees and standing periods were found to be lowest on the high passenger turnover *CityGlider* and busway 111 routes. Our analysis methodology has demonstrated that driver overload reports and trip peak boarding counts do not provide accurate surrogates for the reliable determination of peak loading, overloading and overload duration, or for justifying replacement of standard 12.5m buses with high capacity buses based on such. Justification of high capacity bus deployment can only realistically be determined on high passenger turnover services by measuring cumulative tag ons and tag offs incrementally along trips measured after each bus stop and by measuring their whole-of-journey differences to calculate average and maximum standing loads and their standing durations.

3.5 Operational Performance Evaluation Model

3.5.1 Measurement Methodology

An operational performance evaluation model has been developed by MRCagney to compare the relative operating performance of the standard and high capacity vehicle types judged by the characteristics of the service routes to which they are proposed to be deployed. An overview of the assumptions and mathematical derivations used in the model is presented below. The evaluation model has been verified by comparison of output results with measured results obtained for the various bus types and services earlier listed in Section 3.1.1, but excluding the high passenger turnover *CityGlider* and South East Busway 111 routes for which the underlying assumptions could not be applied.

The performance evaluation model brings together all of the measured data gathered in the 4 preceding sections of this Part 3 and emulates both an AM peak inbound service whose stops are predominantly for passenger boardings and a PM peak outbound service whose stops are predominantly for passenger alightings. The model excludes concurrent passenger boardings and alightings, treating each as mutually exclusive so that inbound and outbound bus stop dwell times can be accurately estimated from measured boarding and alighting times per passenger applicable to each bus type, and so that the model results reflect those obtained for the worst case longest trip time.

3.5.2 Performance Evaluation Model Description

The operational performance model adopts the simplified speed-time graphs presented overleaf in 45km/h **Traffic Speed:** This is the typical peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb along a major highway such as the Bruce, Ipswich or Pacific Motorway. It is also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.

- 75km/h **Traffic Speed:** This is the typical peak period traffic speed achieved on TransLink busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It is also representative of the off-peak traffic speed between the CBD and an outer Brisbane or surrounding regional town or city suburb using a highway such as the Bruce, Ipswich or Pacific Motorway.

Figure 13 for an AM inbound peak trip and return PM outbound peak trip operated on a hypothetical bus route with 8 stops. To aid the reader in visualising the model concepts, the inbound speed-time graph shown in 45km/h **Traffic Speed:** This is the typical peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb along a major highway such as the Bruce, Ipswich or Pacific Motorway. It is also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.

- 75km/h **Traffic Speed:** This is the typical peak period traffic speed achieved on TransLink busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It is also representative of the off-peak traffic speed between the CBD and an outer Brisbane or surrounding regional town or city suburb using a highway such as the Bruce, Ipswich or Pacific Motorway.

Figure 13 should be compared with the GPS logged AM inbound peak speed-time chart appearing at Figure 12 which was rendered off the GPS log for the Hornibrook double deck Bus 343 travelling inbound along Route 315. The chart at Figure 12 has been labelled with some actual stop locations and marked up with corresponding colours to the inbound speed-time graph in 45km/h **Traffic Speed:** This is the typical peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb along a major highway such as the Bruce, Ipswich or Pacific Motorway. It is also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.

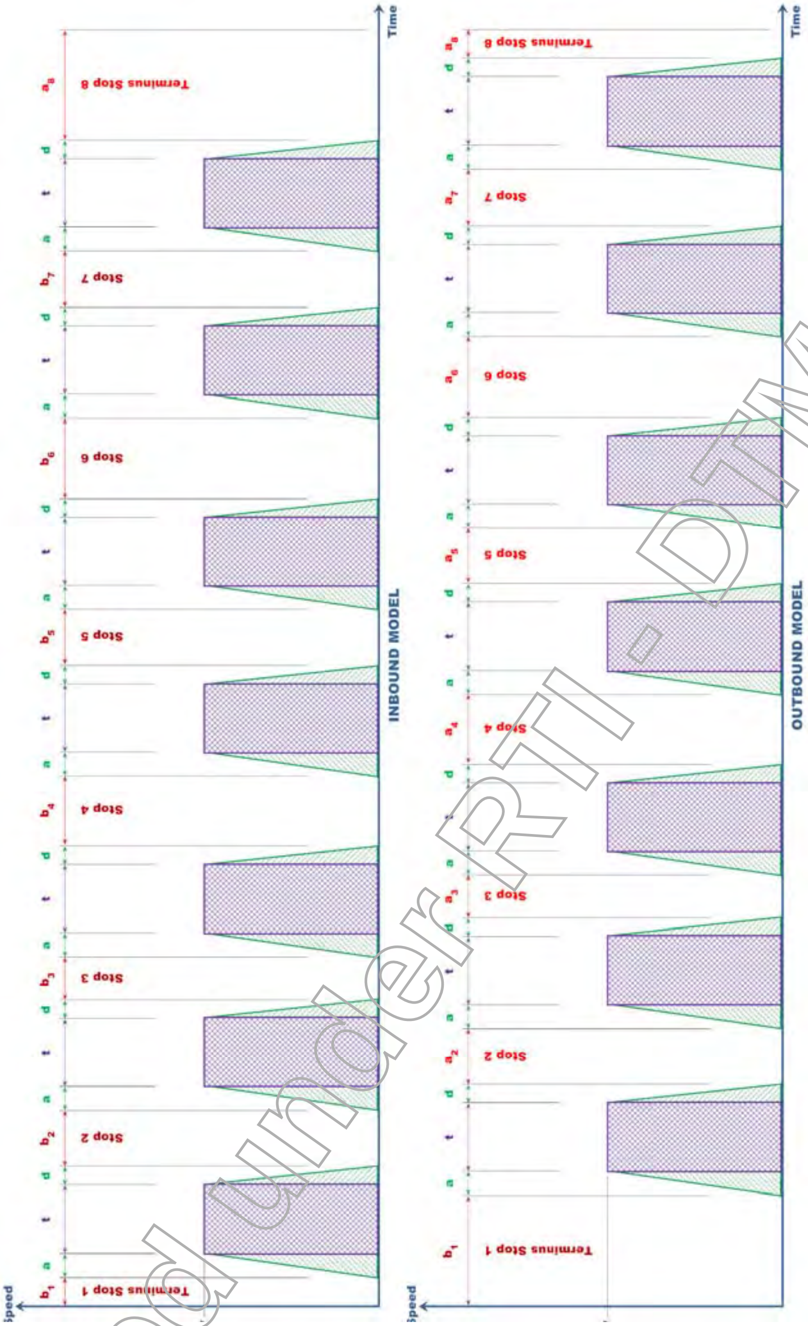
- **75km/h Traffic Speed:** This is the typical peak period traffic speed achieved on TransLink busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It is also representative of the off-peak traffic speed between the CBD and an outer Brisbane or surrounding regional town or city suburb using a highway such as the Bruce, Ipswich or Pacific Motorway.

Figure 13 as a quick visual aid to model interpretation.

Key assumptions, bus and route characteristics and derived mathematical equations used to evaluate the relative performance of each bus type follow:

- No of Bus Stops (n): For the inbound trip model speed-time graph shown in
- Figure 13, we have illustrated 7 boarding bus stops 1 through 7 with varying stop dwell times b_1, b_2, ..., b_7, and one alighting terminus stop 8 with dwell time a_8. Conversely, for the outbound trip model speed-time graph, we have indicated a single terminus boarding stop 1 with dwell time b_1, and 7 alighting stops 2 through 8 inclusive with varying stop dwell times a_2, a_3, ..., a_8. In both speed-time graphs, the total stops assumed was n = 8. The model tests routes with between n = 2 (one boarding terminus stop and one alighting terminus stop) and n = 32 total stops for each of the inbound and outbound travel directions.
- Traffic Speed (v): The model further tests each bus type's operational performance on the hypothetical route at 3 inbound/outbound traffic speeds selected from those published in the RACQ Brisbane City *Travel Time Survey – October 2010*:
  - **30km/h Traffic Speed:** This is the typical peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional suburb substantially via local roads then on a major city arterial or sub-arterial such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road. This traffic speed takes into account the higher travel speeds obtained while still driving through the outer suburbs on local roads and the typical slower speeds encountered during peak periods with traffic signals, congestion, stops and give-ways on major arterial or sub-arterial roads.
  - **45km/h Traffic Speed:** This is the typical peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb along a major highway such as the Bruce, Ipswich or Pacific Motorway. It is also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.
  - **75km/h Traffic Speed:** This is the typical peak period traffic speed achieved on TransLink busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It is also representative of the off-peak traffic speed between the CBD and an outer Brisbane or surrounding regional town or city suburb using a highway such as the Bruce, Ipswich or Pacific Motorway.

Figure 13: Speed-Time Graphs for Inbound and Outbound Bus Service Model



- Average Bus Stop Deceleration (*d*) and Acceleration (*a*) Time: Average bus stop deceleration and acceleration times are traffic speed dependent. The model adopts each bus type's measured average rates of deceleration (*ø*) and acceleration (*µ*) to determine the time actually expended decelerating into stops (*d*) and accelerating back out of stops (*a*) to the 3 above nominated average traffic speeds (*v*) tested by the model.
- Route Length (*l*): 5 hypothetical route lengths (*l* = 5km, *l* = 10km, *l* = 15km, *l* = 20km and *l* = 25km) are tested at the 3 nominated average traffic speeds (*v*) and cover the typical range of bus service route lengths operated by TransLink in South East Queensland.
- Passenger Carrying Capacity (*p*): The justification for deploying a high capacity bus size to any given route is the high capacity vehicle's capability to board a higher passenger load. To compare the different bus types on the 5 tested route lengths (*l*), the model forces each bus type to be loaded to its maximum (seated plus standing) passenger capacity (p).

Arguably, this model assumption disadvantages each high capacity vehicle type relative to the standard 12.5m reference vehicle since a higher average number of passengers needs to be boarded and alighted at bus stops in both travel directions as indicated below in Table 8. This incurs correspondingly higher cumulative dwell times for the high capacity vehicles at bus stops and the higher stop dwell times manifest themselves as longer overall trip times to complete any given route length (l). The relative performance of all 5 vehicle types has therefore been compared by their respective average service speeds, discussed shortly.

Table 8: Average Passenger Boardings and Alightings Per Stop

Average Passengers Boarded or Alighted Per Stop					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
2	75	116	92	88	112
3	38	58	46	44	56
4	25	39	31	29	37
6	15	23	18	18	22
8	11	17	13	13	16
11	8	12	9	9	11
16	5	8	6	6	7
23	3	5	4	4	5
32	2	4	3	3	4

- Average Travelling Time between Stops (t): All bus types have been assumed in the model to travel for an average period (t) between stops at the average traffic speed (v) depicted on Figure 13. The average travelling time (t) between stops has been calculated using Equation (ii) below derived as follows:

Let...

l = Route Length in metres
n = Total Number of Bus Stops on Route
v = Traffic Speed in metres/second
t = Average Travelling Time between Stops in seconds
$\o$ = Average Bus Stop Deceleration in metres/second^2
d = Average Bus Stop Deceleration Time in seconds
μ = Average Bus Stop Acceleration in metres/second^2
a = Average Bus Stop Acceleration Time in seconds

From the kinematic equations of linear motion and Figure 13, each bus travels a total trip distance of...

$$l = (n - 1) . [v.t + 0.5\, v^2 (1/\mu + 1/\o)] = (n - 1) . [v.t + 0.5\, v^2 (\o + \mu) / (\o . \mu)]$$

But $d = -v/-\o = v/\o$ and $a = v/\mu$, so...

$$l = (n - 1) . [v.t + 0.5\, v\, (d + a)] \qquad \text{......... (i)}$$

Therefore the average travelling time between stops is given by...

$$t = \frac{l}{(n - 1) . v} - \frac{(d + a)}{2} \qquad \text{......... (ii)}$$

- Boarding Time per Passenger (t_b): The model uses the measured average boarding time per passenger (t_b) listed in Table 4 for each bus type.

- Alighting Time per Passenger (t_a): The model uses the measured average alighting time per passenger (t_a) listed in Table 4 for each bus type.
- Total Bus Stop Dwell Time (T): The model assumes that boarding and alighting of passengers at bus stops are non-concurrent and mutually exclusive. This assumption enables the total dwell time at bus stops along the hypothetical route to be calculated from the total bus passenger load (p) being carried, irrespective of where passengers choose to board or alight. Mathematical proof of this assumption follows:

Referring to Figure 13, let...

n = Total Number of Bus Stops on the Route
p_b = Number of Passengers who Boarded at Bus Stop "s"
b_s = Average Dwell Time at Bus Stop "s" to Board Passengers in seconds
t_b = Average Boarding Time per Passenger in seconds
p_a = Number of Passengers who Alighted at Bus Stop "s"
a_s = Average Dwell Time at Bus Stop "s" to Alight Passengers in seconds
t_a = Average Alighting Time per Passenger in seconds
p = Passenger Carrying Capacity of the Bus Type Deployed to the Route
T = Total Dwell Time Accumulated at Bus Stops in seconds

For the inbound model shown in Figure 13...

$T = (b_1 + b_2 + ... + b_7) + a_8 = (p_1 + p_2 + ... + p_7) . t_b + p_8 . t_a$

But the total passengers who boarded the bus must equal the total passengers alighted, so...

$p = p_8 = p_1 + p_2 + ... + p_7$

For the inbound model case where boarding and alighting are non-concurrent and mutually exclusive, it follows that the total dwell time at all stops depends only on the total number of passengers boarded and not on the particular stops at which passengers actually board, i.e...

$T = p . (t_a + t_b)$ .... (iii)

For the outbound model shown in Figure 13...

$T = b_1 + (a_2 + a_3 + ... + a_8) = p_1 . t_b + (p_2 + p_3 + ... + p_8) . t_a$

But the total passengers who alighted from the bus must equal the total passengers boarded so...

$p = p_1 = p_2 + p_3 + ... + p_8$

For the outbound model case where boarding and alighting are non-concurrent and mutually exclusive, it follows that the total dwell time at all stops depends only on the total number of passengers alighted and not on the particular stops at which passengers actually alight, i.e...

$T = p . (t_a + t_b)$ .... (iv)

Because equations (iii) and (iv) are identical and neither contains the variable n = *number of stops*, when boarding and alighting are assumed non-concurrent and mutually exclusive, the total dwell time at bus stops on any given route length becomes independent of the total number of stops, the stops at which passengers actually board or alight, or the direction of travel.

- Average Service Speed (s): Average service speed is considered to be a key measure of bus operational performance. The faster a bus travels, the lower its cost to operate and the faster it can be reallocated to another following service. The more passengers a bus carries, the lower TransLink's subsidy to operate the bus service. The model therefore calculates whole-of-trip average service speed (*s*) for each bus type over the entire period from the first passenger boarding to the last passenger alighting, not merely over the period between origin terminus departure and destination terminus arrival which ignores the end termini dwell times. This forces the model to account for all stop dwell times along the trip irrespective of where passengers decide to board and alight and provides a realistic comparison of each bus type's average service speed with that of a private motor vehicle completing the same journey.

The performance model equation used to determine average service speed (*s*) takes into account the route length (*l*), number of stops (*n*), incident traffic speed (*v*), bus specific deceleration time (*d*) to stop and accelerate time (*a*) back to the incident traffic speed (*v*) from each stop, total travelling time between stops ($(n-1).t$) at traffic speed (*v*), and total dwell time (*T*) accumulated while boarding and alighting the maximum bus specific passenger load (*p*) at its bus specific average boarding (t_b) and alighting (t_a) times.

From equations (iii) and (iv) and Figure 13, whole-of-trip average service speed is given by...

$$s = \frac{l}{(n-1).(d+t+a)+T} = \frac{l}{(n-1).(d+t+a)+p.(t_a+t_b)} \qquad \text{.......... (v)}$$

And from equations (i), (ii) and (v)...

$$s = \frac{(n-1).[v.t+0.5\,v\,(d+a)]}{(n-1).(d+t+a)+p.(t_a+t_b)} = \frac{v.[t+0.5\,(d+a)]}{d+t+a+\frac{p.(t_a+t_b)}{n-1}} \qquad \text{.......... (vi)}$$

- **Traffic to Service Speed Ratio (*v/s*):** From a passenger perspective, the choice either to drive a private motor vehicle or to catch a bus to complete a similar length journey boils down to a comparison of the relative times between the competing travel modes available to complete the trip. Given the best possible trip time achievable by private motor vehicle is inversely proportional to traffic speed (*v*), the relative time taken to travel by bus or private motor vehicle equals the ratio of average traffic speed (*v*) to average service speed (*s*).

From equation (vi), the ratio of average traffic to average service speed is given by...

$$\frac{v}{s} = \frac{d+t+a+\frac{p.(t_a+t_b)}{n-1}}{t+0.5\,(d+a)} = \frac{\text{Bus Trip Time}}{\text{Car Trip Time}} \qquad \text{......... (vii)}$$

- **Average Bus Stop Spacing vs Longest Walk to Stop:** Also from a passenger perspective, the whole-of-journey time comparison between driving a private motor vehicle or catching a bus must include the walking time to reach the nearest available bus stop. For passengers travelling to and from the CBD, the inconvenience of walking to a bus stop will be weighed up against the time expended to find a CBD parking space and park the private motor vehicle, and the added on cost of CBD parking charges. There is of course a practical limit to how far and for how long any passenger is prepared to walk, but the psychological limit increases in proportion to the overall trip time. A longer walk to the nearest bus stop will for instance be more readily tolerated by outer suburb passengers if it appears to take a relatively small fraction of the anticipated overall trip time. The model therefore evaluates the additional trip time needed to walk a maximum distance equal to 60% of average bus stop spacing up to a limit of 1km, the latter of which equates to a 12 minute walk at an average Australian adult walking speed of 5km/h. Beyond this limit, most passengers have been assumed to bike or drive and park, or be driven to the nearest bus stop by others.

Average bus stop spacing and longest passenger walking distance are related to the bus route length and the average number of bus stops made along the route as illustrated below in Table 9. The total stops listed in the left hand column of Table 9 have been scaled logarithmically to reflect the inverse log relationship between walk-to-stop passenger catchment, stop spacing and service route length. Yellow shaded entries in Table 9 cover average stop spacings of 1km and greater where passengers would most likely park and ride or kiss and ride from their nearest available bus stop or bus station.

Table 9: Stop Spacing versus Longest Walk to Bus Stop for Different Route Lengths

	Average Stop Spacing and Longest Walk to Stop									
Bus Stops Per Trip	5 Kilometre Bus Route		10 Kilometre Bus Route		15 Kilometre Bus Route		20 Kilometre Bus Route		25 Kilometre Bus Route	
	Stop Spacing (m)	Longest Walk (m)	Stop Spacing (m)	Longest Walk (m)	Stop Spacing (m)	Longest Walk (m)	Stop Spacing (m)	Longest Walk (m)	Stop Spacing (m)	Longest Walk (m)
2	5000	1000	10000	1000	15000	1000	20000	1000	25000	1000
3	2500	1000	5000	1000	7500	1000	10000	1000	12500	1000
4	1667	1000	3333	1000	5000	1000	6667	1000	8333	1000
6	1000	600	2000	1000	3000	1000	4000	1000	5000	1000
8	714	429	1429	857	2143	1000	2857	1000	3571	1000
11	500	300	1000	600	1500	900	2000	1000	2500	1000
16	333	200	667	400	1000	600	1333	800	1667	1000
23	227	136	455	273	682	409	909	545	1136	682
32	161	97	323	194	484	290	645	387	806	484

Route trip time increases with route length, number of stops and bus type specific passenger loading capacity; so for any given route length, a balance is needed between the inconvenience to individuals of having too few bus stops causing a longer walk (or drive) time to bus stops and having too many bus stops which exacts a longer trip time penalty to all upstream boarded passengers using the service. To test the relative performance of each bus type, the model calculates the percent of maximum walking time to total journey time for each route length and number of stops shown in Table 9 from the perspective of the outer suburban upstream passengers most affected by a high count of downstream bus stops.

3.5.3 Operational Performance Evaluation Model Results

Table 10 through Table 14 inclusive compare the relative operating performances of a standard 12.5m rigid and the 4 high capacity bus types on 5 different service route lengths between 5km and 25km using front door only boarding. The evaluation model measures performance of each bus type over a range of bus stops from 2 to 32 along the route to board and alight passengers up to each vehicle's maximum (seated plus standing) capacity. The model assumes stops are evenly spaced but the evaluated results are unaffected by where stops are actually located along the route, provided every stop is used.

The maximum passenger capacities assigned to each bus type by the performance evaluation model were:

- 2 Door 12.5m Rigid Bus: 44 seated + 31 standing = 75 passengers,
- 2 Door 12.5m Double Deck Bus: 96 seated + 20 standing = 116 passengers,
- 2 Door 14.5m Rigid Bus: 56 seated + 36 standing = 92 passengers,
- 2 Door 18m Articulated Bus: 64 seated + 24 standing = 88 passengers, and
- 3 Door 18m Articulated Superbus: 52 seated + 60 standing = 112 passengers.

All model output results tabulated below apply equally to an AM peak inbound bus service boarding its maximum complement of passengers at the number of stops indicated less one for alighting, and to a PM peak outbound service alighting its maximum load of passengers at the number of stops indicated less one for boarding. Model results are unaffected by how many passengers actually board or alight at any given stop, provided that total loading capacity is reached on the bus type and passengers board and alight once only and non-concurrently.

All 5 route lengths, each with from 2 to 32 bus stops have been tested by the model at 3 average traffic speeds:

- 30km/h Traffic Speed: This is the typical peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb substantially along local, arterial and sub-arterial roads.
- 45km/h Traffic Speed: This is the typical peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb substantially on a multilane highway or motorway. It is also representative of the off-peak traffic speed achieved by car between the CBD and an outer Brisbane or surrounding regional town or city suburb on local, arterial and sub-arterial roads.
- 75km/h Traffic Speed: This is the typical peak period traffic speed achieved by buses on TransLink busways to the CBD, on major city ring roads and motorways circling the city, and on exclusive bus use transit, T2 and T3 highway or motorway lanes. It is also representative of the off-peak traffic speed achieved by motor car between the CBD and an outer Brisbane or surrounding regional town or city suburb using a major multilane highway or motorway.

Model results in the 5 tables following have been colour coded as follows for quick interpretation:

- Average Service Speed – This is the whole-of-trip speed achieved by each bus type averaged over the period from its first passenger boarding to its last passenger alighting.

Colour Code	At 30km/h Traffic Speed	At 45km/h Traffic Speed	At 75km/h Traffic Speed
< $^2/_3$ x Traffic Speed	< 20km/h	< 30km/h	< 50km/h
$^2/_3$ – $^3/_4$ x Traffic Speed	20 – 23km/h	30 – 34km/h	50 – 56km/h
> $^3/_4$ x Traffic Speed	> 23km/h	> 34km/h	> 56km/h

- Traffic to Service Speed Ratio – This is the ratio of time taken to travel on each bus type compared to the time taken to travel the same journey by private motor vehicle.

Colour Code	At 30km/h Traffic Speed	At 45km/h Traffic Speed	At 75km/h Traffic Speed
<33% Longer Time	< 1.33	< 1.33	< 1.33
33% – 50% Longer Time	1.33 – 1.5	1.33 – 1.5	1.33 – 1.5
>50% Longer Time	> 1.5	> 1.5	> 1.5

- Percent of Journey Spent Walking to Nearest Bus Stop – This is the percent of total journey time (walking time plus bus trip time) expended by a passenger walking to the nearest bus stop calculated at 60% of the average distance between stops and capped to 1km (i.e. 12 minutes maximum walking time). The percentages indicated in the tables apply to a passenger who completed the whole (or near whole) bus trip from the origin terminus to the destination terminus and thereby had to endure the worst case maximum total dwell time along the route at every downstream bus stop.

Colour Code		At 30km/h Traffic Speed	At 45km/h Traffic Speed	At 75km/h Traffic Speed
>33%	x Journey Time	> 33%	> 33%	> 33%
20% – 33%	x Journey Time	20% - 33%	20% - 33%	20% - 33%
<20%	x Journey Time	< 20%	< 20%	< 20%

Optimum (yellow/green) combinations of average service speed, traffic speed ratio and percent of trip walking time have been printed in bold text in Table 10 through Table 14 inclusive to illustrate the service operating conditions under which particular bus types were found to perform well.

Table 10: Operation Performance Comparison of Bus Types on a 5 Kilometre Bus Route

Comparison of Bus Types on 5 Kilometre Bus Route															
Bus Stops	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
Per Trip	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	19	1.60	43%	14	2.12	36%	17	1.79	40%	18	1.64	42%	14	2.08	37%
3	19	1.60	43%	14	2.13	36%	17	1.80	40%	18	1.66	42%	14	2.09	37%
4	19	1.61	43%	14	2.15	36%	17	1.81	40%	18	1.67	42%	14	2.10	36%
6	18	1.63	31%	14	2.18	25%	16	1.83	28%	18	1.69	30%	14	2.12	25%
8	18	1.65	24%	14	2.21	19%	16	1.85	22%	17	1.72	23%	14	2.14	19%
11	18	1.67	18%	13	2.25	14%	16	1.89	16%	17	1.75	17%	14	2.18	14%
16	17	1.72	12%	13	2.33	9%	15	1.94	11%	17	1.82	12%	13	2.23	10%
23	17	1.78	8%	12	2.43	6%	15	2.01	8%	16	1.90	8%	13	2.31	7%
32	16	1.85	6%	12	2.57	4%	14	2.10	5%	15	2.02	5%	12	2.41	5%
45 Kilometre/Hour Average Traffic Speed															
2	24	1.91	49%	17	2.69	40%	20	2.20	45%	23	1.98	48%	17	2.63	41%
3	23	1.93	48%	17	2.72	40%	20	2.23	45%	22	2.01	47%	17	2.66	40%
4	23	1.95	48%	16	2.76	39%	20	2.26	44%	22	2.05	47%	17	2.69	40%
6	22	2.00	35%	16	2.83	28%	19	2.33	32%	21	2.11	34%	16	2.75	28%
8	22	2.05	27%	15	2.90	21%	19	2.39	24%	21	2.18	26%	16	2.81	22%
11	21	2.12	20%	15	3.01	15%	18	2.48	18%	20	2.28	19%	16	2.90	16%
16	20	2.24	14%	14	3.19	10%	17	2.63	12%	18	2.45	13%	15	3.05	11%
23	19	2.41	9%	13	3.44	7%	16	2.85	8%	17	2.68	8%	14	3.26	7%
75 Kilometre/Hour Average Traffic Speed															
2	29	2.58	54%	19	3.90	43%	24	3.09	49%	27	2.73	52%	20	3.79	44%
3	28	2.70	53%	19	4.05	43%	23	3.23	48%	26	2.89	51%	19	3.91	43%
4	27	2.81	52%	18	4.20	42%	22	3.37	47%	25	3.04	50%	19	4.04	43%
6	25	3.04	37%	17	4.49	29%	21	3.64	33%	22	3.35	35%	17	4.29	30%

Table 11: Operation Performance Comparison of Bus Types on a 10 Kilometre Bus Route

Comparison of Bus Types on 10 Kilometre Bus Route															
Bus Stops	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
Per Trip	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	23	1.30	32%	19	1.56	28%	21	1.40	30%	23	1.32	31%	20	1.54	28%
3	23	1.30	32%	19	1.57	28%	21	1.40	30%	23	1.33	31%	19	1.54	28%
4	23	1.31	31%	19	1.57	28%	21	1.41	30%	22	1.33	31%	19	1.55	28%
6	23	1.32	31%	19	1.59	27%	21	1.42	30%	22	1.35	31%	19	1.56	28%
8	23	1.32	28%	19	1.60	24%	21	1.43	26%	22	1.36	27%	19	1.57	25%
11	22	1.34	21%	18	1.63	18%	21	1.44	20%	22	1.38	21%	19	1.59	18%
16	22	1.36	15%	18	1.66	13%	20	1.47	14%	21	1.41	15%	19	1.62	13%
23	22	1.39	11%	17	1.72	9%	20	1.50	10%	21	1.45	10%	18	1.65	9%
32	21	1.43	8%	17	1.78	6%	19	1.55	7%	20	1.51	7%	18	1.70	6%
45 Kilometre/Hour Average Traffic Speed															
2	31	1.45	38%	24	1.84	33%	28	1.60	36%	31	1.49	38%	25	1.81	33%
3	31	1.46	38%	24	1.86	33%	28	1.62	36%	30	1.51	37%	25	1.83	33%
4	30	1.48	38%	24	1.88	32%	28	1.63	36%	30	1.52	37%	24	1.84	33%
6	30	1.50	37%	23	1.92	32%	27	1.66	35%	29	1.56	37%	24	1.87	32%
8	30	1.53	34%	23	1.95	28%	27	1.69	31%	28	1.59	33%	24	1.90	29%
11	29	1.56	26%	22	2.01	21%	26	1.74	24%	27	1.64	25%	23	1.95	22%
16	28	1.62	18%	21	2.10	15%	25	1.82	17%	26	1.72	17%	22	2.03	15%
23	26	1.71	13%	20	2.22	10%	23	1.92	11%	24	1.84	12%	21	2.13	10%
32	25	1.82	9%	19	2.38	7%	22	2.06	8%	23	1.99	8%	20	2.27	7%
75 Kilometre/Hour Average Traffic Speed															
2	42	1.79	46%	31	2.45	38%	37	2.05	42%	40	1.87	45%	31	2.39	39%
3	41	1.85	45%	30	2.52	37%	35	2.11	42%	39	1.94	44%	31	2.46	38%
4	39	1.91	44%	29	2.60	37%	34	2.18	41%	37	2.02	43%	30	2.52	37%
6	37	2.02	43%	27	2.74	35%	32	2.32	39%	34	2.17	41%	28	2.65	36%
8	35	2.14	38%	26	2.89	31%	31	2.46	34%	32	2.33	36%	27	2.77	32%
11	32	2.31	28%	24	3.11	22%	28	2.66	25%	29	2.56	26%	25	2.96	23%

Table 12: Operation Performance Comparison of Bus Types on a 15 Kilometre Bus Route

Comparison of Bus Types on 15 Kilometre Bus Route															
Bus Stops	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
Per Trip	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	25	1.20	25%	22	1.37	23%	24	1.26	24%	25	1.21	25%	22	1.36	23%
3	25	1.20	25%	22	1.38	23%	24	1.27	24%	25	1.22	25%	22	1.36	23%
4	25	1.20	25%	22	1.38	22%	24	1.27	24%	25	1.22	25%	22	1.37	23%
6	25	1.21	25%	22	1.39	22%	23	1.28	24%	24	1.23	25%	22	1.37	23%
8	25	1.22	25%	21	1.40	22%	23	1.28	24%	24	1.24	24%	22	1.38	22%
11	24	1.22	23%	21	1.42	20%	23	1.30	22%	24	1.25	22%	22	1.39	21%
16	24	1.24	16%	21	1.44	14%	23	1.31	15%	24	1.27	16%	21	1.41	15%
23	24	1.26	12%	20	1.48	10%	22	1.34	11%	23	1.30	11%	21	1.44	10%
32	23	1.28	8%	20	1.52	7%	22	1.37	8%	22	1.34	8%	20	1.47	7%
45 Kilometre/Hour Average Traffic Speed															
2	35	1.30	32%	29	1.56	28%	32	1.40	30%	34	1.33	31%	29	1.54	28%
3	35	1.31	31%	29	1.57	28%	32	1.41	30%	34	1.34	31%	29	1.55	28%
4	35	1.32	31%	28	1.59	27%	32	1.42	30%	33	1.35	31%	29	1.56	28%
6	34	1.33	31%	28	1.61	27%	31	1.44	29%	33	1.37	30%	28	1.58	27%
8	33	1.35	31%	28	1.63	27%	31	1.46	29%	32	1.39	30%	28	1.60	27%
11	33	1.37	28%	27	1.67	24%	30	1.49	27%	32	1.43	27%	28	1.63	25%
16	32	1.41	20%	26	1.73	17%	29	1.54	19%	31	1.48	20%	27	1.68	18%
23	31	1.47	14%	25	1.81	12%	28	1.62	13%	29	1.56	14%	26	1.75	12%
32	29	1.54	10%	23	1.92	8%	26	1.71	9%	27	1.66	9%	24	1.85	9%
75 Kilometre/Hour Average Traffic Speed															
2	49	1.53	40%	38	1.97	34%	44	1.70	37%	48	1.58	39%	39	1.93	34%
3	48	1.57	39%	37	2.02	33%	43	1.74	36%	46	1.63	38%	38	1.97	34%
4	47	1.60	38%	36	2.07	33%	42	1.79	36%	45	1.68	37%	37	2.01	33%
6	45	1.68	37%	35	2.16	32%	40	1.88	35%	42	1.78	36%	36	2.10	32%
8	43	1.76	36%	33	2.26	31%	38	1.97	34%	40	1.89	35%	34	2.18	31%
11	40	1.87	32%	31	2.41	27%	36	2.11	30%	37	2.04	31%	32	2.31	28%
16	36	2.07	23%	28	2.65	18%	32	2.34	20%	33	2.30	21%	30	2.52	19%

Table 13: Operation Performance Comparison of Bus Types on a 20 Kilometre Bus Route

Comparison of Bus Types on 20 Kilometre Bus Route															
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	26	1.15	21%	23	1.28	19%	25	1.20	20%	26	1.16	21%	24	1.27	19%
3	26	1.15	21%	23	1.28	19%	25	1.20	20%	26	1.16	20%	24	1.27	19%
4	26	1.15	21%	23	1.29	19%	25	1.20	20%	26	1.17	20%	24	1.27	19%
6	26	1.16	21%	23	1.29	19%	25	1.21	20%	26	1.17	20%	23	1.28	19%
8	26	1.16	21%	23	1.30	19%	25	1.21	20%	25	1.18	20%	23	1.29	19%
11	26	1.17	20%	23	1.31	19%	25	1.22	20%	25	1.19	20%	23	1.29	19%
16	25	1.18	17%	23	1.33	15%	24	1.23	16%	25	1.20	17%	23	1.31	16%
23	25	1.19	12%	22	1.36	11%	24	1.25	12%	24	1.23	12%	23	1.33	11%
32	25	1.21	9%	22	1.39	8%	24	1.28	8%	24	1.25	8%	22	1.35	8%
45 Kilometre/Hour Average Traffic Speed															
2	37	1.23	27%	32	1.42	24%	35	1.30	26%	36	1.24	27%	32	1.41	24%
3	37	1.23	27%	31	1.43	24%	35	1.31	26%	36	1.25	26%	32	1.41	24%
4	36	1.24	27%	31	1.44	24%	35	1.32	25%	36	1.26	26%	32	1.42	24%
6	36	1.25	26%	31	1.46	24%	34	1.33	25%	35	1.28	26%	31	1.44	24%
8	36	1.26	26%	30	1.48	23%	33	1.35	25%	35	1.29	25%	31	1.45	24%
11	35	1.28	26%	30	1.50	23%	33	1.37	25%	35	1.32	25%	31	1.47	23%
16	35	1.31	22%	29	1.55	19%	32	1.41	20%	33	1.36	21%	30	1.51	19%
23	33	1.35	15%	28	1.61	13%	31	1.46	14%	32	1.42	15%	29	1.57	14%
32	32	1.41	11%	27	1.69	9%	29	1.53	10%	30	1.50	10%	28	1.63	10%
75 Kilometre/Hour Average Traffic Speed															
2	54	1.40	35%	43	1.73	30%	49	1.52	33%	52	1.43	34%	44	1.70	31%
3	53	1.42	34%	43	1.76	30%	48	1.56	33%	51	1.47	34%	43	1.73	30%
4	52	1.45	34%	42	1.80	29%	47	1.59	32%	50	1.51	33%	43	1.76	30%
6	50	1.51	33%	40	1.87	29%	45	1.66	31%	47	1.59	32%	41	1.82	29%
8	48	1.57	32%	39	1.95	28%	43	1.73	30%	45	1.66	31%	40	1.89	28%
11	45	1.66	31%	36	2.06	27%	41	1.83	29%	42	1.78	30%	38	1.98	27%
16	42	1.80	25%	33	2.24	21%	37	2.00	23%	38	1.97	23%	35	2.14	22%
23	37	2.00	17%	30	2.50	14%	33	2.24	15%	33	2.24	15%	32	2.36	15%

Table 14: Operation Performance Comparison of Bus Types on a 25 Kilometre Bus Route

Comparison of Bus Types on 25 Kilometre Bus Route															
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	27	1.12	18%	25	1.22	16%	26	1.16	17%	27	1.13	18%	25	1.22	16%
3	27	1.12	18%	24	1.23	16%	26	1.16	17%	27	1.13	18%	25	1.22	16%
4	27	1.12	18%	24	1.23	16%	26	1.16	17%	26	1.13	17%	25	1.22	16%
6	27	1.13	18%	24	1.24	16%	26	1.17	17%	26	1.14	17%	25	1.22	16%
8	27	1.13	18%	24	1.24	16%	26	1.17	17%	26	1.14	17%	24	1.23	16%
11	26	1.13	17%	24	1.25	16%	25	1.18	17%	26	1.15	17%	24	1.24	16%
16	26	1.14	17%	24	1.27	16%	25	1.19	17%	26	1.16	17%	24	1.25	16%
23	26	1.16	12%	23	1.29	11%	25	1.20	12%	25	1.18	12%	24	1.26	11%
32	26	1.17	9%	23	1.31	8%	25	1.22	9%	25	1.20	9%	23	1.28	8%
45 Kilometre/Hour Average Traffic Speed															
2	38	1.18	23%	34	1.34	21%	36	1.24	22%	38	1.20	23%	34	1.33	21%
3	38	1.19	23%	33	1.34	21%	36	1.25	22%	37	1.20	23%	34	1.33	21%
4	38	1.19	23%	33	1.35	21%	36	1.25	22%	37	1.21	23%	34	1.34	21%
6	37	1.20	23%	33	1.37	21%	36	1.27	22%	37	1.22	23%	33	1.35	21%
8	37	1.21	23%	33	1.38	21%	35	1.28	22%	36	1.24	23%	33	1.36	21%
11	37	1.22	23%	32	1.40	20%	35	1.30	22%	36	1.26	22%	33	1.38	21%
16	36	1.25	22%	31	1.44	20%	34	1.33	21%	35	1.29	22%	32	1.41	20%
23	35	1.28	16%	30	1.49	14%	33	1.37	15%	34	1.34	16%	31	1.45	14%
32	34	1.33	12%	29	1.55	10%	32	1.42	11%	32	1.40	11%	30	1.51	10%
75 Kilometre/Hour Average Traffic Speed															
2	57	1.32	31%	47	1.58	28%	53	1.42	30%	56	1.35	31%	48	1.56	28%
3	56	1.34	31%	47	1.61	27%	52	1.45	29%	54	1.38	30%	47	1.58	27%
4	55	1.36	31%	46	1.64	27%	51	1.47	29%	53	1.41	30%	47	1.61	27%
6	53	1.41	30%	44	1.70	26%	49	1.53	28%	51	1.47	29%	45	1.66	27%
8	52	1.46	29%	43	1.76	25%	47	1.58	27%	49	1.53	28%	44	1.71	26%
11	49	1.52	28%	41	1.84	25%	45	1.66	26%	46	1.62	27%	42	1.79	25%
16	46	1.64	27%	38	1.99	23%	42	1.80	25%	42	1.78	25%	39	1.91	24%
23	42	1.80	19%	34	2.20	16%	38	1.99	17%	38	2.00	17%	36	2.09	16%
32	37	2.01	13%	30	2.46	11%	33	2.24	11%	33	2.27	11%	32	2.32	11%

3.5.4 Key Findings

The relative operational performances of the 5 bus types during peak periods using front door only boarding have been ranked below in Table 15. Rankings take into account average trip speed, time taken to complete trips relative a standard 12.5m bus, bus stop deceleration/dwell/acceleration times and passenger perceptions of increased journey time to walk to stops and travel by bus relative to driving a private motor vehicle. Where different bus types performed similarly for the same route length, number of stops and traffic speed, they have been ranked equivalently.

Table 15: Ranking of Bus Types with Front Door Only Boarding

Route Length	Routes Operated at 30km/h	Routes Operated at 45km/h	Routes Operated at 75km/h
	Mixed Traffic on Local, Arterial and Sub-Arterial Roads during Peak Period	Mixed Traffic on CBD Radial Highway or Motorway during Peak Period OR Off-Peak in Mixed Traffic on Local, Arterial and Sub-Arterial Roads	City Ring Road, Busway or Highway Bus Transit Lane during Peak Period OR Off-Peak in Mixed Traffic on a CBD Highway or Motorway
5km	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
10km	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
15km	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 2) 2 : 2 Door 14.5m Rigid (Note 2) 3 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
20km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic (Note 3) 1 : 2 Door Double Deck (Note 3) 2 : 2 Door 18m Artic 3 : 2 Door 14.5m Rigid 4 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
25km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 4) 2 : 2 Door 14.5m Rigid (Note 4) 3 : 2 Door 12.5m Rigid

Note 1: Up to a Limit of 22 Boarding/Alighting Stops
Note 2: Up to a Limit of 10 to 15 Boarding/Alighting Stops
Note 3: Up to a Limit of 10 Boarding/Alighting Stops
Note 4: Up to a Limit of 5 Boarding/Alighting Stops

Key findings drawn from examination of the results in Table 10 through Table 15 inclusive were as follows:

- High Capacity Bus Performance Generally: Operational performance of all high capacity bus types improves with increasing route length, reducing bus stops and reducing traffic speed. The higher the bus passenger capacity and incident traffic speed, the more sensitive high capacity bus performance becomes to the total number of stops along the route.

  All high capacity buses perform poorly on routes of around 7.5km or less and these routes are considered better suited to higher frequency 12.5m rigid bus services.

  The smaller (90 passenger) capacity 14.5m rigid and two door articulated buses become competitive with 12.5m rigid buses on 10km routes operated during the peak on local, arterial and sub-arterial roads where average peak traffic speeds are 30km/h or less. Ironically, the slower and more congested the incident traffic speed, the better these two smaller high capacity vehicles perform against the 12.5m rigid bus, and their average travel speed and performance is virtually unaffected by how many bus stops are used to board and alight to maximum capacity.

The larger (114 passenger) capacity three door articulated and double deck buses become competitive with 12.5m rigid and high capacity 14.5m rigid and two door articulated buses on 15km routes when traffic speeds are 30km/h or lower, and the smaller (90 passenger) capacity 14.5m rigid and two door articulated buses become competitive with 12.5m rigid buses on all highway or motorway services for peak period traffic speeds of 45km/h or lower. The slower and more congested the highway or motorway traffic becomes, the more relative performance against a 12.5m rigid bus improves.

At high traffic speeds of 75km/h, all bus types, including 12.5m rigid buses, were found to perform poorly on routes of less than 25km against a private motor vehicle, and relative performance to the private motor car falls off sharply with increasing bus capacity and number of stops. The reasons are readily understood from a simple example. In the case say of the 3 door 18m articulated superbus, a competing private car travelling inbound at an average traffic speed of 75km/h gains a 13.3km head start on the high capacity bus in the time taken just to board and alight its full load of 112 passengers. A further 0.63km gain is made by a private car in the time taken to decelerate down and accelerate back up to 75km/h at each bus stop on the route. Thus for a fastest possible express service from the Logan Hyperdome Bus Station to the CBD, a motor car gains a head start on the 3 door 18m articulated superbus equivalent to the entire length of the South East Busway.

- 5km Route High Capacity Vehicle Performance: No bus type, including the 12.5m rigid bus, has performed particularly well on short routes of 5km length or less. Routes around this length can be found operating in Brisbane on the CBD centric *CityGlider*, between the CBD and inner city suburbs such as Paddington and New Farm, and on a number of district feeder and school services operated from outlying bus interchanges, busway stations and railway stations. The 2 door 18m articulated bus with its double width front and rear doors performed nearly as well as 12.5m rigid buses for routes with 11 stops or less on a 5km route, notwithstanding that the 2 door articulated bus boarded and alighted 13 more passengers in the near same overall trip time.

  Unsurprisingly, the average service speed for all bus types falls sharply with the increasing number of bus stops on short routes, but the ratio of time taken to travel on fully loaded buses compared with a private motor vehicle increases exponentially with increased traffic speed due to the higher proportion of trip time consumed by all bus types decelerating down from and accelerating back up to a higher average traffic speed. Table 10 illustrates for example that a typical rigid bus boarded to full capacity at 10 bus stops takes around 67% longer than a private motor vehicle to complete a 5km bus journey at peak period traffic speeds of 30km/hour but around 2.12 times longer during the off-peak when average traffic speeds increase to 45km/h.

  Because short 5km routes typically operate all stops with high churn loads better suited to a 12.5m rigid bus, no high capacity buses are recommended on routes of less than 7.5km.

- 10km Route High Capacity Vehicle Performance: The performance of the 14.5m rigid bus and 2 door articulated bus becomes similar to that of a 12.5m low floor rigid bus on a 10km route with 22 or less stops during peak traffic periods for suburban route services operated substantially on local, arterial and sub-arterial roads at 30km/h, notwithstanding the additional boarding and alighting of some 17 and 13 more passengers respectively in nearly the same overall trip time.

The 14.5m and 2 door articulated bus performance drops off sharply at higher peak period traffic speeds on 10km mixed traffic motorway and highway services relative to the 12.5m rigid bus when boarded to full capacity due to the combined effects of higher boarded passenger loads and longer deceleration and acceleration times at stops. Inspection of Table 11 reveals poor performance of all HCV bus types against that of a private motor vehicle on 10km routes at motorway and highway traffic speeds of 45km/h or higher, and the 12.5m rigid bus is preferred to high capacity buses for services operated in this high speed range.

- 15km Route High Capacity Vehicle Performance: All 5 high capacity vehicles begin to perform very well against the 12.5m rigid bus on a 15km route with 22 or less stops during peak traffic periods for services operated substantially on local, arterial and sub-arterial roads at 30km/h, notwithstanding the boarding and alighting of their respectively much greater passenger loads. At the 15km route length, the 14.5m rigid bus and 2 door articulated bus will almost keep pace with a 12.5m rigid bus timetable on a 45km/h motorway or freeway route with up to 16 stops and still board to their maximum capacities. The double deck and 3 door articulated buses with their higher boarding capacities of around 40 more passengers than a 12.5m rigid bus however still perform poorly at traffic speeds of 45km/h or higher.

  No bus type, including the 12.5m rigid, could be considered truly competitive with a private motor vehicle at highway bus only transit lane speeds of 75km/h. With as few as just 5 bus stops to board or alight passengers, the HCV buses take from 1.8 to 2.2 times longer than a private motor car to complete a 15km journey and with 10 stops, HCV buses take between 2 and 2.4 times longer than a private motor car.

- 20km Route High Capacity Vehicle Performance: On 20km routes, including those with a large number of stops, all bus types spend a high proportion of their trip travelling at traffic speed and the slowing effects of passenger alighting and boarding and stop deceleration and acceleration become significantly diminished. On 20km routes, the 14.5m bus and 2 door articulated bus can board and alight passengers to maximum capacity and complete their trips in near identical time to a 12.5m bus at all traffic speeds up to 45km/h.

  At the 20km/h route length and traffic speeds of 30km/h, the double deck and 3 door articulated bus emerge to compete not only with the 12.5m rigid bus, but with the 14.5m rigid and 18m articulated buses, boarding and alighting up to 116 passengers but taking only around 9% longer to complete the same trip. At this speed, these 2 very high capacity buses also begin to seriously compete with private motor cars, taking only around 30% longer to complete a 20km trip with 16 or less stops. Their performance begins however to lag seriously behind that of the 12.5m rigid, 14.5m rigid and 2 door articulated buses on 45km/h highway and motorway bus routes but retain reasonable passenger attraction in terms of competitiveness with the private motor car and with walking or driving distances to 10 or less bus stops along the route.

- 25km Route High Capacity Vehicle Performance: On 25km long routes, all HCV bus types perform well against both the 12.5m bus and the private motor car at speeds of up to 45km/h. On 25km or longer routes with up to 32 stops, the time saving advantage gained by driving into the CBD and paying to park in lieu of taking a bus becomes considerably harder to justify from a passenger perspective when high capacity buses can complete the trip in marginally longer times of 30% or less and walking or driving times to the nearest bus stop represent less than 20% of the total trip time.

  At this route length, the 14.5m rigid and 2 door articulated bus remain highly competitive with the 12.5m bus with up to 6 stops but quickly lose passenger appeal as the number of stops increase beyond this limit and total trip times increase from 50% longer for 8 stops up to 125% longer for 32 stops.

- 30km Route High Capacity Vehicle Performance: On 30km and longer routes, all high capacity buses outperform 12.5m rigid buses at all traffic speeds up to 75km/h, and become very serious competitors with the private motor car if the number of stops along the route is kept to 10 or less.

3.5.5 HCV Performance Outlook with Reducing Average Traffic Speed

RACQ Brisbane City *Travel Time Surveys* conducted over the past 7 years indicate average inbound and outbound traffic speeds along the city's main highways and motorways and major arterials and sub-arterials have been progressively falling at an average rate of around 2.5% pa and 4.75% pa respectively. The following differential equation demonstrates that this continuing downward trend in average Brisbane city road traffic speeds favours high capacity buses more so than 12.5m rigid buses when compared with competing motor car travel speeds.

From equations (ii) and (v)...

$$s = \frac{l}{(n-1).(d+t+a)+p.(t_a+t_b)} = \frac{l}{0.5\,(n-1).(d+a)+l/v+p.(t_a+t_b)}$$

Multiplying the numerator and denominator by "*v*" then gives...

$$s = \frac{l.v}{\{(0.5\,(n-1).(d+a)+p.(t_a+t_b)\}.v+l}$$

Differentiating with respect to traffic speed (*v*) then inverting gives...

$$\frac{ds}{dv} = \frac{l^2}{[\{(0.5\,(n-1).(d+a)+p.(t_a+t_b)\}.v+l]^2} = \frac{1}{[\{(0.5\,(n-1).(d+a)+p.(t_a+t_b)\}.v/l+1]^2}$$

$$\frac{dv}{ds} = [\{(0.5\,(n-1).(d+a)+p.(t_a+t_b)\}.v/l+1]^2 = \frac{\text{Change in Bus Trip Time}}{\text{Change in Car Trip Time}} \qquad \text{......... (viii)}$$

Equation (viii) clearly indicates that falling average traffic speed (*v*) will provide greatest advantage to those bus types with the highest passenger capacity (*p*) when operating at highest traffic speed (*v*) on the shortest route lengths (*l*). Based on RACQ travel time statistics for the past 7 years, average traffic speeds on Brisbane highway, motorway, arterial and sub-arterial bus routes are expected to fall by at least a further 10% below current traffic speeds in the forthcoming 4 year period out to 2016.

Table 16 contrasts the relative percent improvement in bus trip times against private motor car travel times anticipated over the next 4 years for bus routes with an average of 16 bus stops. It will be observed from Table 16 that high capacity bus performance benefits most from falling traffic speeds on high speed short routes.

Table 16: 4 Year Outlook for Standard and High Capacity Vehicles on a 16 Stop Bus Route

Comparison of Bus and Private Motor Vehicle Travel Times for 16 Stop Bus Routes															
Route Length (km)	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change
30 ==> 27 Kilometre/Hour Average Traffic Speed															
10	1.36	1.32	3%	1.66	1.59	4%	1.47	1.41	4%	1.41	1.36	4%	1.62	1.55	5%
15	1.24	1.21	2%	1.44	1.39	3%	1.31	1.28	3%	1.27	1.24	2%	1.41	1.36	3%
20	1.18	1.16	2%	1.33	1.29	3%	1.23	1.21	2%	1.20	1.18	2%	1.31	1.27	3%
25	1.14	1.13	1%	1.27	1.23	3%	1.19	1.17	2%	1.16	1.14	1%	1.25	1.22	3%
45 ==> 40.5 Kilometre/Hour Average Traffic Speed															
10	1.62	1.54	5%	2.10	1.96	7%	1.82	1.71	6%	1.72	1.63	5%	2.03	1.90	6%
15	1.41	1.36	3%	1.73	1.64	5%	1.54	1.48	4%	1.48	1.42	4%	1.68	1.60	5%
20	1.31	1.27	3%	1.55	1.48	4%	1.41	1.36	4%	1.36	1.31	3%	1.51	1.45	4%
25	1.25	1.22	3%	1.44	1.38	4%	1.33	1.29	3%	1.29	1.25	3%	1.41	1.36	3%
75 ==> 67.5 Kilometre/Hour Average Traffic Speed															
10	2.60	2.36	9%	3.48	3.13	10%	3.00	2.71	10%	2.95	2.65	10%	3.28	2.97	10%
15	2.07	1.91	8%	2.65	2.42	9%	2.34	2.14	9%	2.30	2.10	9%	2.52	2.31	8%
20	1.80	1.68	7%	2.24	2.07	8%	2.00	1.86	7%	1.97	1.82	7%	2.14	1.98	7%
25	1.64	1.54	6%	1.99	1.85	7%	1.80	1.68	6%	1.78	1.66	7%	1.91	1.79	6%

3.6 High Capacity Vehicle Dwell Time Reduction Options

3.6.1 Significance of Dwell Time to High Capacity Bus Performance

Table 15 above shows that high capacity buses perform well against conventional 12.5m rigid buses on routes of 15km or more whilst operating in typical peak period traffic conditions. While it is a useful exercise to compare the operational performance of high capacity buses with that of the standard 12.5m rigid bus, it is arguably more important to compare the performance of high capacity buses with that of the private motor vehicle with which all bus types, including 12.5m rigid buses, must compete for patronage. In this section, it will be demonstrated that bus stop dwell time plays a very significant role in high capacity bus performance and we will examine various TransLink options for reducing high capacity vehicle stop dwell times.

Table 17 below lists the total bus stop dwell time accrued by each bus type to non-concurrently board and alight passengers to maximum capacity (*p*) using front door only boarding. Each bus type is handicapped differently by its respective accrued dwell time to board and alight passengers relative to a private motor vehicle, but the handicap to all bus types increases with average traffic speed (*v*) because in a race to complete any given route length, the private motor vehicle gains increased separation distance from its rival buses proportional to the average traffic speed.

Table 17: Comparison of Full Capacity Boarding, Alighting and Dwell Times for Bus Types

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Passenger Capacity	75	116	92	88	112
Boarding Time per Passenger	2.7s	3.1s	3.1s	2.6s	3.7s
Alighting Time per Passenger	2s	2.6s	2s	1.7s	2s
Boarding Time to Fully Load	3.4 mins	6.0 mins	4.8 mins	3.8 mins	6.9 mins
Alighting Time of Fully Offload	2.5 mins	5.0 mins	3.1 mins	2.5 mins	3.7 mins
Cumulative Bus Stop Dwell Time	5.9 mins	11.0 mins	7.8 mins	6.3 mins	10.6 mins

Table 18 tabulates the average times expended by each bus type decelerating into and accelerating back out of bus stops at different average traffic speeds (v). Accrued delay spent decelerating and accelerating at bus stops further adds to the separation distance handicap between a bus and private motor vehicle.

Table 18: Comparison of Average Bus Stop Deceleration and Acceleration Times for Bus Types

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Bus Stop Deceleration and Acceleration Time at 30km/h	10.3s	18.0s	12.4s	14.9s	13.4s
Bus Stop Deceleration and Acceleration Time at 45km/h	19.3s	28.7s	24.5s	26.7s	24.3s
Bus Stop Deceleration and Acceleration Time at 75km/h	55.3s	70.4s	65.7s	74.2s	60.8s

Because buses remain stationary whilst dwelling at bus stops but continue progress towards their destinations whilst decelerating into and accelerating out of bus stops, cumulative total stop dwell times cannot simply be added to total bus stop deceleration and acceleration times to measure bus performance relative to a private motor vehicle. To enable a like-for-like comparison, measured deceleration and acceleration rates for each bus type used to determine their deceleration (d) and acceleration (a) times appearing in Table 18 have been linearised using straight line numerical integration. This mathematical manipulation of the area under the speed-time curve enables total stop dwell time to be added to half the total deceleration and acceleration time to assess the combined bus stop delay exacted by any given combination of average traffic speed (v) and number of stops (n) appearing on the route. The mathematical derivation of this simple relationship is as follows:

The total dwell time (T) each bus type remains stationary to board and alight passengers non-concurrently to maximum capacity has been earlier derived at equations (iii) and (iv) as...

$$T = p \cdot (t_a + t_b)$$

In this period, the competing private motor vehicle travels a distance (l_d) at the average traffic speed (v) given by...

$$l_d = v.T$$

Now from Figure 13, during the deceleration (d) and acceleration (a) periods based on linear (straight line) deceleration from traffic speed (v) to stop and linear acceleration back up to traffic speed (v), the distance travelled (l_{da}) by a competing motor vehicle while a bus decelerates and accelerates at all stops (n) is given by...

$$l_{da} = 0.5\, v\, (n - 1) \cdot (a + d)$$

Therefore the contribution of total bus stop deceleration and acceleration time to total bus stop delay time (viz. dwell + deceleration + acceleration) relative to a competing private motor vehicle with no stops becomes...

$$\frac{l_{da}}{l_{da} + l_d} = \frac{0.5\, v\, (n - 1) \cdot (a + d)}{0.5\, v\, (n - 1) \cdot (a + d) + v.T} = \frac{0.5\, (n - 1) \cdot (a + d)}{0.5\, (n - 1) \cdot (a + d) + T} \qquad \text{......... (ix)}$$

Calculated results based on equation (ix) have been tabulated overleaf in Table 19.

Table 19: Contribution of Bus Deceleration and Acceleration Time to Total Bus Stop Delay

	Contribution of Bus Deceleration and Acceleration Time to Total Bus Stop Delay									
	Two Door 12.5m Standard Rigid Bus		Two Door 12.5m Double Deck Bus		Two Door 14.5m Extended Rigid Bus		Two Door 18m Articulated Bus		Three Door 18m Articulated Superbus	
Dwell	5.9 mins Total		11.0 mins Total		7.8 mins Total		6.3 mins Total		10.6 mins Total	
Bus Stops Per Trip	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay
30 Kilometre/Hour Average Traffic Speed										
2	0.2 min	1%	0.3 min	1%	0.2 min	1%	0.2 min	2%	0.2 min	1%
3	0.3 min	3%	0.6 min	3%	0.4 min	3%	0.5 min	4%	0.4 min	2%
4	0.5 min	4%	0.9 min	4%	0.6 min	4%	0.7 min	6%	0.7 min	3%
6	0.9 min	7%	1.5 min	6%	1.0 min	6%	1.2 min	9%	1.1 min	5%
8	1.2 min	9%	2.1 min	9%	1.4 min	8%	1.7 min	12%	1.6 min	7%
11	1.7 min	13%	3.0 min	12%	2.1 min	12%	2.5 min	16%	2.2 min	9%
16	2.6 min	18%	4.5 min	17%	3.1 min	17%	3.7 min	23%	3.3 min	14%
23	3.8 min	24%	6.6 min	23%	4.6 min	23%	5.5 min	30%	4.9 min	19%
32	5.3 min	31%	9.3 min	30%	6.4 min	29%	7.7 min	38%	6.9 min	24%
45 Kilometre/Hour Average Traffic Speed										
2	0.3 min	3%	0.5 min	2%	0.4 min	3%	0.4 min	3%	0.4 min	2%
3	0.6 min	5%	1.0 min	4%	0.8 min	5%	0.9 min	7%	0.8 min	4%
4	1.0 min	8%	1.4 min	6%	1.2 min	7%	1.3 min	10%	1.2 min	5%
6	1.6 min	12%	2.4 min	10%	2.0 min	12%	2.2 min	15%	2.0 min	9%
8	2.3 min	16%	3.3 min	13%	2.9 min	15%	3.1 min	20%	2.8 min	12%
11	3.2 min	22%	4.8 min	18%	4.1 min	21%	4.4 min	26%	4.1 min	16%
16	4.8 min	29%	7.2 min	25%	6.1 min	28%	6.7 min	35%	6.1 min	22%
23	7.1 min	38%	10.5 min	32%	9.0 min	37%	9.8 min	44%	8.9 min	30%
32	10.0 min	46%	14.8 min	40%	12.7 min	45%	13.8 min	52%	12.6 min	37%
75 Kilometre/Hour Average Traffic Speed										
2	0.9 min	7%	1.2 min	5%	1.1 min	7%	1.2 min	9%	1.0 min	5%
3	1.8 min	14%	2.3 min	10%	2.2 min	12%	2.5 min	16%	2.0 min	9%
4	2.8 min	19%	3.5 min	14%	3.3 min	17%	3.7 min	23%	3.0 min	12%
6	4.6 min	28%	5.9 min	21%	5.5 min	26%	6.2 min	33%	5.1 min	19%
8	6.5 min	35%	8.2 min	27%	7.7 min	33%	8.7 min	41%	7.1 min	25%
11	9.2 min	44%	11.7 min	35%	10.9 min	41%	12.4 min	50%	10.1 min	32%
16	13.8 min	54%	17.6 min	44%	16.4 min	51%	18.6 min	60%	15.2 min	42%
23	20.3 min	63%	25.8 min	54%	24.1 min	61%	27.2 min	68%	22.3 min	51%
32	28.6 min	71%	36.4 min	62%	33.9 min	68%	38.3 min	75%	31.4 min	60%

Table 19 presents total bus stop deceleration and acceleration times for each bus type for different bus stop counts per trip, and the percentage contributions of these periods to total stop trip delay relative to a private motor vehicle with no stops. The entries in Table 19 show clearly that while total time expended by buses decelerating and accelerating at stops may in many cases be considerably higher than total dwell time, it is total stop dwell time that dominates bus performance relative to a competing private motor car. To further highlight the dominant role bus stop dwell time plays, the green shaded entries in Table 19 map all service conditions where total dwell time accounts for more delay than twice that due to total deceleration and acceleration time.

3.6.2 All Door Boarding Dwell Time Reduction Assessment

For the majority of city route services, highest demand for maximum passenger capacity occurs during the AM inbound commuter and school peaks and PM outbound school and commuter peaks. The resultant one-way flows of either all boarding or all alighting passengers at the majority of bus stops during AM inbound peak and PM outbound peak services gives rise to the non-concurrent passenger boarding and alighting conditions earlier emulated by the *Operational Performance Evaluation Model*.

Review of netBi ticketing data has shown that average bus stop dwell times improve in the off-peak relative to peak services, even when average boarding and alighting times per passenger were known to have increased. The underlying reason for this phenomenon has been identified as the increased incidence of concurrent passenger boarding and alighting that occurs predominantly during the off-peak service periods, viz. simultaneous alighting of passengers at the rear door while boarding passengers at front door. Consider an off-peak bus service on which passengers already boarded can freely alight at bus stops without conflict to boarding passengers when exiting via the rear bus door.

Let...

c = Percent of Boarded Passengers Alighted Concurrently without Conflict to Boarding Passengers

From equations (iii) and (iv) for worst case non-concurrent boarding and alighting, total dwell time (T) was given by...

$$T = p \cdot (t_a + t_b)$$

When c% of total boarded passengers can alight concurrently without conflict to boarding passengers, the total dwell time falls to...

$$T = p \cdot t_b + p \cdot (1 - c) \cdot t_a = p \cdot \{t_b + (1 - c) \cdot t_a\} \qquad \text{......... (x)}$$

Equation (x) illustrates why off-peak high passenger churn front door only boarded services can have lower average dwell times than peak services. On inbound and outbound peak services where passenger boarding and alighting demands are essentially one-way and tending to non-concurrent operating conditions (i.e. $c = 0$), it can be readily shown that a significant reduction in average dwell time can still be achieved but only with concurrent all door passenger boarding and alighting. Equation (x) provides the foundation for assessing how all door boarding would improve high capacity bus dwell time performance. We now consider each of the bus type variants operated with front door only boarding and all door boarding.

Let...

t_f = Total Time to Complete Passenger Movements (Boarded and Alighted) through Front Door

f_b = Percent of Passengers Boarded at Front Door

t_m = Total Time to Complete Passenger Movements (Boarded and Alighted) through Middle Door

m_a = Percent of Passengers Alighted at Middle Door

t_r = Total Time to Complete Passenger Movements (Boarded and Alighted) through Rear Door

r_a = Percent of Passengers Alighted at Rear Door

Case 1: Boarding at Front Door Only
Mixed Flow Alighting at Front and Rear Doors
Double Width (2 Flow Channel) Front and Rear Doors

Case 1 represents the current situation for all TransLink bus services operated in SEQ other than the *CityGlider* and applies to all bus types studied in this report other than the low floor 12.5m rigid bus with single width rear doors and the 3 door articulated superbus. It is assumed each bus type will be loaded to its maximum capacity (p). For Case 1, two-way passenger flow clashes occur at the front door so the time to board all passengers (p) through the front door is extended by the time taken to alight any passengers who choose to exit via the front door and block one or both front door boarding channels.

The total time taken to board and alight all passengers at the front door therefore is...

$$t_f = p \cdot t_b + p \cdot t_a \cdot (1 - r_a) = p \cdot \{t_b + t_a \cdot (1 - r_a)\} \qquad \text{......... (xi)}$$

The total time taken to alight passengers without clashes at the rear door is...

$$t_r = p \cdot t_a \cdot r_a \qquad \text{......... (xii)}$$

It will be noted that for non-concurrent boarding and alighting at both doors where $r_a = 1$, equations (xi) and (xii) simplify down to the earlier derived equations (iii) and (iv) for total dwell time (T), namely...

$T = t_f + t_r = p \ . \ \{t_b + t_a \ . \ (1 - 1) + t_a\} = p \ . \ (t_a + t_b)$

For balanced concurrent boarding and alighting through the front and rear doors in equal time...

$t_f = t_r = p \ . \ \{t_b + t_a \ . \ (1 - r_a)\} = p \ . \ t_a \ . \ r_a$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = \{1 + (t_b / t_a)\} / 2$ .... (xiii)

For all bus types with double width front and rear doors, the measured ratio of average boarding time to alighting time per passenger was $1.2 < t_b / t_a < 1.67$, indicating the optimum percentage of passengers alighting at the rear door would need to be $110\% < r_a < 133\%$. Clearly the current situation is highly unbalanced and not conducive to minimum dwell time concurrent front door boarding and alighting on any two door bus type. Equation (xiii) indicates however that the next best possible choice to minimise dwell time would occur if average boarding time per passenger could be reduced and alighting of all passengers was only permitted via the rear door (i.e. by making r_a =100%).

Case 2: Mixed Flow All Door Boarding and Alighting Double Width (2 Flow Channel) Front and Rear Doors

Case 2 looks at all door boarding with mixed passenger alighting and boarding flows at both double width 2 flow channel doors. It applies to all bus types being studied other than the low floor 12.5m rigid bus with single width rear doors and 3 door articulated superbus. It is again assumed for Case 2 that each bus type will be loaded to its maximum capacity (p). With 2 boarding doors, the number of passenger boarding channels is doubled but the number of alighting channels remains unchanged from Case 1.

The time to board passengers (p) through both the front door and rear door is extended by the time taken to alight passengers who choose to exit at each respective door, blocking either one or both door boarding channels at the door accesses. The total time taken to board and alight all passengers at the front door now becomes...

$t_f = p \ . \ t_b \ . \ f_b + p \ . \ t_a \ . \ (1 - r_a) = p \ . \ \{t_b \ . \ f_b + t_a \ . \ (1 - r_a)\}$ .... (xiv)

Similarly, the total time taken to board and alight all passengers at the rear door becomes...

$t_r = p \ . \ t_b \ .(1 - f_b) + p \ . \ t_a \ . \ r_a = p \ . \ \{t_b \ . \ (1 - f_b) + t_a \ . \ r_a\}$ .... (xv)

For minimum dwell time balanced concurrent boarding and alighting through the front and rear doors in equal times...

$t_f = t_r = p \ . \ \{t_b \ . \ f_b + t_a \ . \ (1 - r_a)\} = p \ . \ \{t_b \ . \ (1 - f_b) + t_a \ . \ r_a\}$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = \{1 + (2 f_b - 1) \ .(t_b / t_a)\} / 2$ and

$f_b = 1/2 + (2 r_a - 1) / (2 \ t_b / t_a)$ .... (xvi)

Equation (xvi) indicates that for minimum dwell balanced all door boarding and alighting, boarding counts at the front door must be matched to alighting counts at the rear door. For all bus types with double width front and rear doors, the measured ratio of average boarding time to alighting time per passenger was $1.19 < t_b / t_a < 1.67$. In this range, an infinite number of front door boarding percentages (f_b) and rear door passenger alighting percentages (r_a) exist which will satisfy equation (xvi) for minimum stop dwell time. Irrespective of average boarding and alighting times per passenger, balanced minimum dwell time on all bus types with double width rear doors will be achieved when $r_a = 0.5$, $f_b = 0.5$ and $f_b / r_a = 1$.

Case 3: Boarding at Front Door Only
Mixed Flow Alighting at Front, Middle and Rear Doors
Double Width (2 Flow Channel) Front, Middle and Rear Doors

Case 3 represents the current situation for the Clarks Logan City 3 door articulated superbus. It is again assumed this bus type will be loaded to its maximum capacity (p). For Case 3, two-way passenger flow clashes occur at the front door so the time to board all passengers (p) through the front door is extended by the time taken to alight passengers who choose to exit via the front door, thereby blocking one or both front door boarding channels.

Average boarding (t_b) and alighting (t_a) times per passenger used in Case 3 are those which have actually been measured on the 3 door articulated superbus. Review of measured passenger alighting preference split-ups listed in Table 5 for the 3 door articulated superbus indicate boarded passengers currently exit in almost equal counts through the middle and rear doors and this observation leads to the following 3 identities...

$m_a = r_a$

$m_a + r_a = 2\, r_a$

$t_m = t_r$

The total time taken to board and alight all passengers at the front door now becomes...

$$t_f = p \,.\, t_b + p \,.\, t_a \,.\, (1 - m_a - r_a) = p \,.\, \{t_b + t_a \,.\, (1 - 2\, r_a)\} \qquad \text{......... (xvii)}$$

It is noted that equation (xvii) limits $m_a = r_a <= 50\%$ as there cannot be negative alighting time. The total time taken to alight passengers concurrently at the middle and rear doors becomes...

$$t_m = t_r = p \,.\, t_a \,.\, m_a = p \,.\, t_a \,.\, r_a \qquad \text{......... (xviii)}$$

For minimum dwell time balanced boarding and alighting through the front door and concurrent alighting through both the middle and rear doors in equal time...

$$t_f = t_r = p \,.\, \{t_b + t_a \,.\, (1 - 2\, r_a)\} = p \,.\, t_a \,.\, r_a$$

Dividing both sides of the equation by "p" and rearranging gives...

$$r_a = m_a = \{1 + (t_b / t_a)\} / 3 \qquad \text{......... (xix)}$$

For the 3 door articulated superbus, the measured ratio of average boarding time to alighting time per passenger was $t_b / t_a = 1.85$, indicating the optimum percentage of passengers alighting at the middle and rear doors would need to be $m_a + r_a = 190\%$. Clearly the current situation is grossly unbalanced and not conducive to minimum dwell time concurrent front door boarding and alighting on the 3 door articulated superbus, and significantly more so than any of the double width 2 door bus types. Equation (xix) does however indicate that the next best possible choice to minimise dwell time would occur if average boarding time per passenger could be reduced and alighting of all passengers was only permitted via the middle and rear doors (i.e. making $m_a + r_a = 100\%$).

Case 4: Mixed Flow All Door Boarding and Alighting
Double Width (2 Flow Channel) Front, Middle and Rear Doors

Case 4 examines all door boarding with mixed passenger alighting and boarding flows at the front, middle and rear double width 2 flow channel doors on the 3 door articulated superbus. It is again assumed for Case 4 that the bus will be loaded to its maximum capacity (p). With 3 boarding doors, the number of passenger boarding channels is tripled but passenger alighting channels remain unchanged from Case 3.

Average boarding (t_b) and alighting (t_a) times per passenger used in Case 4 are again those which have actually been measured on the 3 door superbus and the following 3 identities earlier cited in Case 3 again apply...

$m_a = r_a$

$m_a + r_a = 2\, r_a$

$t_m = t_r$

The time to board passengers (p) through the front, middle and rear doors is extended by the time taken to alight passengers who choose to exit at each respective door, blocking either one or both door boarding channels at the relevant door. The total time taken to board and alight all passengers at the front door now becomes...

$t_f = p.\, t_b\, .\, f_b\, +\, p\, .\, t_a\, .\, (1 - m_a - r_a) = p\, .\, \{t_b\, .\, f_b + t_a\, .\, (1 - 2\, r_a)\}$ .... (xx)

It is noted that equation (xx) limits $m_a = r_a <= 50\%$ as there cannot be negative alighting time. The total time taken to board and alight all passengers concurrently at the middle and rear doors becomes...

$t_m = t_r = 0.5\, p\, .\, t_b\, .(1 - f_b)\, +\, p\, .\, t_a\, .\, m_a = p\, .\, \{0.5\, t_b\, .\, (1 - f_b) + t_a\, .\, r_a\}$ .... (xxi)

For minimum dwell time balanced concurrent boarding and alighting through the front, middle and rear doors in equal time...

$t_f\, =\, t_r\, =\, p\, .\, \{t_b\, .\, f_b\, +\, t_a\, .\, (1 - 2\, r_a)\}\, =\, p\, .\, \{0.5\, t_b\, .\, (1 - f_b) + t_a\, .\, r_a\}$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = m_a = \{2 + (3\, f_b - 1)\, .(\, t_b / \, t_a)\} / 6 <= 50\%$ and

$f_b = 1/3 + (6\, r_a - 2) / (3\, t_b/t_a),\;\; r_a = m_a <= 50\%$ .... (xxii)

Equation (xxii) indicates that for minimum dwell balanced all door boarding and alighting of passengers, boarding counts at the front door must be matched with alighting counts at the middle and rear doors.

For the 3 door articulated superbus, the measured ratio of average boarding time to alighting time per passenger was $t_b / t_a = 1.85$. An infinite number of front door boarding percentages (f_b) and middle (m_a) and rear (r_a) door passenger alighting percentages exist which will satisfy equation (xxii) for minimum stop dwell time. Irrespective of average boarding and alighting times per passenger, balanced minimum dwell time on the 3 door articulated superbus will be achieved when $r_a = m_a = 1/3,\ f_b = 2/3$ and $f_b / r_a = f_b / m_a = 2.$

Case 5: Boarding at Front Door Only
Double Width (2 Flow Channel) Front Door
Mixed Flow Alighting at Front and Rear Doors
Single Width (1 Flow Channel) Rear Door

Case 5 represents the current situation for most new ultralow floor 12.5m rigid buses now operated in SEQ. Whilst not a high capacity vehicle per se, Case 5 identifies the impact of single width rear doors on average stop dwell times and enables comparison of contemporary ultralow floor 12.5m rigid buses with similar size buses incorporating double width rear doors. It is again assumed that the 12.5m rigid bus will be loaded to its maximum capacity (p). For Case 5, two-way passenger flow clashes will occur at the front door so the time to board all passengers (p) through the front door will be extended by the time taken to alight passengers who choose to exit via the front door.

Average boarding (t_b) and alighting (t_a) times per passenger used in Case 5 are those which have actually been measured on the 12.5m rigid bus. Reference to Table 5 indicates that approximately 70% of Brisbane Transport low floor 12.5m rigid *CityBus* and *CityGlider* passengers currently alight at the rear door. Because the front door has 2 boarding and alighting channels and the rear door has only one alighting channel, different average alighting times per passenger apply at each door...

Let...
t_{af} = *Average Alighting Time per Passenger at Front Door*
t_{ar} = *Average Alighting Time per Passenger at Rear Door*

$t_{ar} = 2\ t_{af}$

Now if "p" passengers are alighted through both the front and rear doors, they split in the relative proportions of 30% front door alightings to 70% rear door alightings giving...

$p\ .\ t_a\ =\ 0.3\ p\ .\ t_{af} + 0.7\ p\ .\ t_{ar}$

$t_a =\ 0.3\ t_{af} + 1.4\ t_{af}\ = 1.7\ t_{af}$

$t_{af} = t_a\ /\ 1.7$

$t_{ar} = t_a /\ 0.85$

The total time taken to board and alight all passengers at the front door becomes...

$t_f = p\ .\ t_b\ +\ p\ .\ t_{af}\ .\ (1 - r_a) = p\ .\ \{t_b\ +\ t_a\ .\ (1 - r_a)\ /\ 1.7\}$ .... (xxiii)

The total time taken to alight passengers without clashes at the rear door becomes...

$t_r = p\ .\ t_{ar}\ .\ r_a = p\ .\ t_a\ .\ r_a\ /\ 0.85$ .... (xxiv)

For balanced concurrent boarding and alighting through the front and rear doors in equal time...

$t_f = t_r = p\ .\ \{t_b\ +\ t_a\ .\ (1 - r_a)\ /\ 1.7\} =\ p\ .\ t_a\ .\ r_a\ /\ 0.85$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = \{1 + 1.7\ (t_b\ /\ t_a)\}\ /\ 3$ .... (xxv)

For the low floor 12.5m rigid bus, the measured ratio of average boarding time to alighting time per passenger was $t_b\ /\ t_a\ =\ 1.35$, indicating the optimum percentage of passengers alighting at the rear door would need to be $r_a\ =\ 110\%$. Clearly the current situation is unbalanced and not conducive to minimum dwell time concurrent front door boarding and alighting on the standard 12.5m rigid bus. Equation (xxv) does however indicate that the next best possible choice to minimise dwell time would occur if average boarding time per passenger could be reduced and alighting of all passengers was only permitted via the rear door (i.e. by making r_a =100%).

Case 6: Mixed Flow All Door Boarding and Alighting Double Width (2 Flow Channel) Front Door Single Width (1 Flow Channel) Rear Door

Case 6 examines all door boarding with mixed passenger alighting and boarding flows at the double width two channel front door and single width single channel rear door on the standard 12.5m rigid bus. It is again assumed for Case 6 that the bus will be loaded to maximum capacity (*p*). With 2 boarding doors, the number of passenger boarding channels is increased by 150%, but passenger alighting channels remain unchanged from Case 5.

Average boarding (t_b) and alighting (t_a) times per passenger used in Case 6 are those which have actually been measured on the 12.5m rigid bus. Because the front door has 2 boarding and alighting channels and the rear door has only one boarding and alighting channel, different average alighting and boarding times per passenger will apply at each door. From Case 5...

$t_{af} = t_a / 1.7$

$t_{ar} = t_a / 0.85$

Let...

t_{bf} = *Average Boarding Time per Passenger at Front Door*

t_{br} = *Average Boarding Time per Passenger at Rear Door*

$t_{br} = 2\ t_{bf}$

Now the average boarding time per passenger at the front door is identical to the measured average boarding time per passenger so...

$t_{bf} = t_b$

$t_{br} = 2\ t_b$

The time taken to board passengers (*p*) through both the front door and rear door is extended by the time taken to alight passengers who choose to exit at each respective door. The total time taken to board and alight all passengers at the front door becomes...

$t_f = p\ .\ t_{bf}\ .\ f_b\ +\ p\ .\ t_{af}\ .\ (1 - r_a) = p\ .\ \{t_b\ .\ f_b\ +\ t_a\ .\ (1 - r_a) / 1.7\}$ .... (xxvi)

Similarly, the total time taken to board and alight all passengers at the rear door becomes...

$t_r = p\ .\ t_{br}\ .(1 - f_b)\ +\ p\ .\ t_{ar}\ .\ r_a = p\ .\ \{2\ t_b\ .\ (1 - f_b) + t_a\ .\ r_a / 0.85\}$ .... (xxvii)

For minimum dwell time balanced concurrent boarding and alighting through the front and rear doors in equal times...

$t_f\ =\ t_r\ =\ p\ .\ \{t_b\ .\ f_b\ +\ t_a\ .\ (1 - r_a) / 1.7\}\ =\ p\ .\ \{2\ t_b\ .\ (1 - f_b) + t_a\ .\ r_a / 0.85\}$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = \{1 + (5.1\ f_b - 3.4)\ .(\ t_b / t_a)\} / 3$ and

$f_b\ =\ 2/3 + (3\ r_a - 1) / (5.1\ t_b/t_a)$ .... (xxviii)

Equation (xxviii) indicates that for minimum dwell balanced all door boarding and alighting of passengers, boarding counts at the front door must be matched with alighting counts at the rear door. For the 12.5m rigid bus, the measured ratio of average boarding time to alighting time per passenger was $t_b / t_a = 1.35$. An infinite number of front door boarding percentages (f_b) and rear door passenger alighting percentages (r_a) exist which will satisfy equation (xxviii) for minimum stop dwell time. Irrespective of average boarding and alighting times per passenger, balanced minimum dwell time on all bus types with single width rear doors will be achieved when $r_a = 1/3$, $f_b = 2/3$ and $f_b / r_a = 2$.

3.6.3 All Door Boarding Analysis Results

Table 20 below presents the anticipated reduction in peak period dwell time for each bus type if all door boarding was to be implemented by TransLink. Measured average boarding and alighting times and passenger alighting preferences have been applied to each bus type using equation (xvi) for the 3 bus types with double width front and rear doors, equation (xxii) for the 3 door articulated bus, and equation (xxviii) for the standard 12.5m rigid ultralow floor bus.

The third and fourth rows appearing in Table 20 compare total trip dwell times for current front door only boarding with those expected if passenger alightings and boardings at front doors were completed concurrently and in equal time with passenger alightings and boardings at rear doors (or middle and rear doors in the case of the articulated superbus). Total trip dwell times shown in Table 20 assume all bus types are fully loaded to their respective maximum capacities during peak periods.

Table 20: Estimated Peak Period Balanced All Door Boarding Stop Dwell Times

Peak Period Balanced All Door Boarding Bus Stop Dwell Times										
Total Trip Dwell Time	Two Door 12.5m Standard Rigid Bus		Two Door 12.5m Double Deck Bus		Two Door 14.5m Extended Rigid Bus		Two Door 18m Articulated Bus		Three Door 18m Articulated Superbus	
Current Front Door Boarding	5.9 mins		11.0 mins		7.8 mins		6.3 mins		10.6 mins	
Balanced All Door Boarding	3.2 mins		5.5 mins		3.9 mins		3.2 mins		3.5 mins	
Percent of Passengers Who Choose to Alight at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 69% of Passengers Alighting at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 53% of Passengers Alighting at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 81% of Passengers Alighting at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 47% of Passengers Alighting at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 43% of Passengers Alighting at Middle and Rear Doors
0%	52%	5.3 mins	8%	8.2 mins	18%	6.4 mins	17%	4.3 mins	0%	5.2 mins
5%	54%	5.1 mins	12%	7.9 mins	21%	6.2 mins	21%	4.2 mins	3%	5.0 mins
10%	56%	5.0 mins	16%	7.7 mins	24%	6.1 mins	24%	4.1 mins	8%	4.8 mins
15%	59%	4.8 mins	21%	7.4 mins	27%	5.9 mins	27%	4.0 mins	14%	4.6 mins
20%	61%	4.7 mins	25%	7.2 mins	31%	5.8 mins	30%	3.8 mins	19%	4.4 mins
25%	63%	4.5 mins	29%	6.9 mins	34%	5.6 mins	34%	3.7 mins	24%	4.2 mins
30%	65%	4.4 mins	33%	6.7 mins	37%	5.5 mins	37%	3.6 mins	30%	4.0 mins
35%	67%	4.2 mins	37%	6.4 mins	40%	5.3 mins	40%	3.5 mins	35%	3.8 mins
40%	70%	4.1 mins	42%	6.2 mins	44%	5.2 mins	43%	3.3 mins	41%	3.7 mins
45%	72%	3.9 mins	46%	5.9 mins	47%	5.0 mins	47%	3.2 mins	46%	3.7 mins
50%	74%	3.8 mins	50%	5.7 mins	50%	4.9 mins	50%	3.2 mins	51%	4.1 mins
55%	76%	3.6 mins	54%	5.6 mins	53%	4.7 mins	53%	3.4 mins		
60%	78%	3.5 mins	58%	5.9 mins	56%	4.6 mins	57%	3.5 mins		
65%	80%	3.3 mins	63%	6.1 mins	60%	4.4 mins	60%	3.6 mins		
70%	83%	3.2 mins	67%	6.4 mins	63%	4.2 mins	63%	3.7 mins		
75%	85%	3.3 mins	71%	6.6 mins	66%	4.1 mins	66%	3.9 mins		
80%	87%	3.4 mins	75%	6.9 mins	69%	3.9 mins	70%	4.0 mins		
85%	89%	3.5 mins	79%	7.1 mins	73%	4.0 mins	73%	4.1 mins		
90%	91%	3.5 mins	84%	7.4 mins	76%	4.2 mins	76%	4.2 mins		
95%	94%	3.6 mins	88%	7.6 mins	79%	4.3 mins	79%	4.4 mins		
100%	96%	3.7 mins	92%	7.9 mins	82%	4.5 mins	83%	4.5 mins		

The percentage of passengers needed to board at the front door (f_b) to exactly balance delays caused by the percentage (r_a) of passengers who elect to alight at the rear door appears in the first column of Table 20 under each bus type. In the case of the 3 door articulated superbus, passenger alighting percentages have been assumed equal at the middle and rear doors based on measured passenger door alighting preferences, and therefore maximum alighting at the middle and rear door are limited to 50%.

Table 21: Comparison of Articulated Bus Front and All Door Boarding Performance on 5km Route

Comparison of Articulated Bus Performance on 5 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Boarding		All Door Boarding		Front Door Boarding		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	18	1.64	23	1.33	14	2.08	18	1.71
3	18	1.66	22	1.34	14	2.09	17	1.72
4	18	1.67	22	1.36	14	2.10	17	1.73
6	18	1.69	22	1.38	14	2.12	17	1.76
8	17	1.72	21	1.41	14	2.14	17	1.78
11	17	1.75	21	1.44	14	2.18	17	1.81
16	17	1.82	20	1.51	13	2.23	16	1.87
23	16	1.90	19	1.59	13	2.31	15	1.94
32	15	2.02	18	1.70	12	2.41	15	2.04
45 Kilometre/Hour Average Traffic Speed								
2	23	1.98	30	1.51	17	2.63	22	2.08
3	22	2.01	29	1.55	17	2.66	21	2.11
4	22	2.05	28	1.58	17	2.69	21	2.14
6	21	2.11	27	1.65	16	2.75	20	2.20
8	21	2.18	26	1.71	16	2.81	20	2.26
11	20	2.28	25	1.81	16	2.90	19	2.35
16	18	2.45	23	1.98	15	3.05	18	2.51
23	17	2.68	20	2.21	14	3.26	17	2.72
75 Kilometre/Hour Average Traffic Speed								
2	27	2.73	38	1.95	20	3.79	26	2.88
3	26	2.89	36	2.11	19	3.91	25	3.00
4	25	3.04	33	2.26	19	4.04	24	3.13
6	22	3.35	29	2.57	17	4.29	22	3.38

Table 22: Comparison of Articulated Bus Front and All Door Boarding Performance on 10km Route

Comparison of Articulated Bus Performance on 10 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Only		All Door Boarding		Front Door Only		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	23	1.32	26	1.17	20	1.54	22	1.36
3	23	1.33	26	1.17	19	1.54	22	1.36
4	22	1.33	25	1.18	19	1.55	22	1.37
6	22	1.35	25	1.19	19	1.56	22	1.38
8	22	1.36	25	1.20	19	1.57	22	1.39
11	22	1.38	25	1.22	19	1.59	21	1.41
16	21	1.41	24	1.25	19	1.62	21	1.43
23	21	1.45	23	1.30	18	1.65	20	1.47
32	20	1.51	22	1.35	18	1.70	20	1.52
45 Kilometre/Hour Average Traffic Speed								
2	31	1.49	36	1.26	25	1.81	29	1.54
3	30	1.51	35	1.27	25	1.83	29	1.56
4	30	1.52	35	1.29	24	1.84	29	1.57
6	29	1.56	34	1.32	24	1.87	28	1.60
8	28	1.59	33	1.36	24	1.90	28	1.63
11	27	1.64	32	1.41	23	1.95	27	1.68
16	26	1.72	30	1.49	22	2.03	26	1.75
23	24	1.84	28	1.61	21	2.13	24	1.86
32	23	1.99	26	1.76	20	2.27	23	2.00
75 Kilometre/Hour Average Traffic Speed								
2	40	1.87	51	1.48	31	2.39	39	1.94
3	39	1.94	48	1.55	31	2.46	37	2.00
4	37	2.02	46	1.63	30	2.52	36	2.06
6	34	2.17	42	1.79	28	2.65	34	2.19
8	32	2.33	39	1.94	27	2.77	32	2.32
11	29	2.56	35	2.17	25	2.96	30	2.51

Table 23: Comparison of Articulated Bus Front and All Door Boarding Performance on 15km Route

Comparison of Articulated Bus Performance on 15 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Only		All Door Boarding		Front Door Only		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	25	1.21	27	1.11	22	1.36	24	1.24
3	25	1.22	27	1.11	22	1.36	24	1.24
4	25	1.22	27	1.12	22	1.37	24	1.24
6	24	1.23	27	1.13	22	1.37	24	1.25
8	24	1.24	26	1.14	22	1.38	24	1.26
11	24	1.25	26	1.15	22	1.39	24	1.27
16	24	1.27	26	1.17	21	1.41	23	1.29
23	23	1.30	25	1.20	21	1.44	23	1.31
32	22	1.34	24	1.23	20	1.47	22	1.35
45 Kilometre/Hour Average Traffic Speed								
2	34	1.33	38	1.17	29	1.54	33	1.36
3	34	1.34	38	1.18	29	1.55	33	1.37
4	33	1.35	38	1.19	29	1.56	33	1.38
6	33	1.37	37	1.22	28	1.58	32	1.40
8	32	1.39	36	1.24	28	1.60	32	1.42
11	32	1.43	35	1.27	28	1.63	31	1.45
16	31	1.48	34	1.33	27	1.68	30	1.50
23	29	1.56	32	1.40	26	1.75	29	1.57
32	27	1.66	31	1.50	24	1.85	27	1.66
75 Kilometre/Hour Average Traffic Speed								
2	48	1.58	57	1.32	39	1.93	46	1.63
3	46	1.63	55	1.37	38	1.97	45	1.67
4	45	1.68	53	1.42	37	2.01	44	1.71
6	42	1.78	49	1.52	36	2.10	42	1.79
8	40	1.89	46	1.63	34	2.18	40	1.88
11	37	2.04	42	1.78	32	2.31	37	2.01
16	33	2.30	37	2.04	30	2.52	34	2.22

Table 24: Comparison of Articulated Bus Front and All Door Boarding Performance on 20km Route

Comparison of Articulated Bus Performance on 20 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Only		All Door Boarding		Front Door Only		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	26	1.16	28	1.08	24	1.27	25	1.18
3	26	1.16	28	1.09	24	1.27	25	1.18
4	26	1.17	28	1.09	24	1.27	25	1.18
6	26	1.17	27	1.10	23	1.28	25	1.19
8	25	1.18	27	1.10	23	1.29	25	1.19
11	25	1.19	27	1.11	23	1.29	25	1.20
16	25	1.20	27	1.13	23	1.31	25	1.22
23	24	1.23	26	1.15	23	1.33	24	1.24
32	24	1.25	26	1.18	22	1.35	24	1.26
45 Kilometre/Hour Average Traffic Speed								
2	36	1.24	40	1.13	32	1.41	35	1.27
3	36	1.25	40	1.14	32	1.41	35	1.28
4	36	1.26	39	1.15	32	1.42	35	1.29
6	35	1.28	39	1.16	31	1.44	35	1.30
8	35	1.29	38	1.18	31	1.45	34	1.32
11	35	1.32	37	1.20	31	1.47	34	1.34
16	33	1.36	36	1.25	30	1.51	33	1.38
23	32	1.42	35	1.30	29	1.57	31	1.43
32	30	1.50	33	1.38	28	1.63	30	1.50
75 Kilometre/Hour Average Traffic Speed								
2	52	1.43	61	1.24	44	1.70	51	1.47
3	51	1.47	59	1.28	43	1.73	50	1.50
4	50	1.51	57	1.32	43	1.76	49	1.53
6	47	1.59	54	1.39	41	1.82	47	1.60
8	45	1.66	51	1.47	40	1.89	45	1.66
11	42	1.78	47	1.59	38	1.98	43	1.75
16	38	1.97	42	1.78	35	2.14	39	1.91
23	33	2.24	37	2.05	32	2.36	35	2.13

Table 25: Comparison of Articulated Bus Front and All Door Boarding Performance on 25km Route

Comparison of Articulated Bus Performance on 25 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Only		All Door Boarding		Front Door Only		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	27	1.13	28	1.07	25	1.22	26	1.14
3	27	1.13	28	1.07	25	1.22	26	1.14
4	26	1.13	28	1.07	25	1.22	26	1.15
6	26	1.14	28	1.08	25	1.22	26	1.15
8	26	1.14	28	1.08	24	1.23	26	1.16
11	26	1.15	28	1.09	24	1.24	26	1.16
16	26	1.16	27	1.10	24	1.25	26	1.17
23	25	1.18	27	1.12	24	1.26	25	1.19
32	25	1.20	26	1.14	23	1.28	25	1.21
45 Kilometre/Hour Average Traffic Speed								
2	38	1.20	41	1.10	34	1.33	37	1.22
3	37	1.20	41	1.11	34	1.33	37	1.22
4	37	1.21	40	1.12	34	1.34	37	1.23
6	37	1.22	40	1.13	33	1.35	36	1.24
8	36	1.24	39	1.14	33	1.36	36	1.25
11	36	1.26	39	1.16	33	1.38	35	1.27
16	35	1.29	38	1.20	32	1.41	35	1.30
23	34	1.34	36	1.24	31	1.45	33	1.34
32	32	1.40	35	1.30	30	1.51	32	1.40
75 Kilometre/Hour Average Traffic Speed								
2	56	1.35	63	1.19	48	1.56	55	1.38
3	54	1.38	61	1.22	47	1.58	54	1.40
4	53	1.41	60	1.25	47	1.61	53	1.43
6	51	1.47	57	1.31	45	1.66	51	1.48
8	49	1.53	54	1.38	44	1.71	49	1.53
11	46	1.62	51	1.47	42	1.79	47	1.60
16	42	1.78	46	1.62	39	1.91	43	1.73
23	38	2.00	41	1.84	36	2.09	39	1.91
32	33	2.27	35	2.12	32	2.32	35	2.13

The second column appearing under each bus type in Table 20 shows the impact on its total trip dwell time if the percent of passengers needed to board at the front door is mismatched to the percent of passengers who currently prefer to alight at the rear door. The red shaded bands in the first and second columns under each bus type indicate where total trip dwell time is minimised and the percent of passengers boarded at the front door is balanced with the percent of passengers who currently prefer to alight at the rear door.

Table 21 through Table 25 inclusive compare the operational performances of the 2 door articulated bus and 3 door articulated superbus with front only and all door boarding on route lengths of 5km to 25km. The all door boarding results in Table 21 through Table 25 are based on minimum dwell times for ideally balanced concurrent boarding and alighting shown in Table 20 for the two articulated bus types, and therefore represent the most optimistic performance that could be expected.

3.6.4 Key Findings

- Table 20 demonstrates that all door boarding, if implemented with appropriate passenger boarding and alighting guidelines, could potentially cut total stop dwell times by a factor of as much as 2 for high capacity buses with double width rear doors, and as much as a factor of 3 for the articulated superbus with double width middle and rear doors. The dwell time benefit of all door boarding on standard low floor 12.5m buses drops lower to around a factor of 1.8 due to their narrow single width rear doors.
- The Case 2, 4 and 6 analyses has further demonstrated that the higher the bus carrying capacity, the greater its net dwell time reduction during the peaks when boarding and alighting flows essentially become unidirectional with non-conflicting door flow channels.

- The hidden catch with all door boarding is that minimum stop dwell time can only be achieved by matching the percentage of passengers who board at the front door of each bus type to the percentage of passengers who choose to alight from the rear door (or middle and rear doors), so that boarding and alighting times through every door are balanced (i.e. completed concurrently in equal time). Balancing of alighting passenger flows via specific doors can be induced through careful positioning of rear door(s) in relation to passenger seat and standing areas to influence passenger alighting preferences, and is discussed further in Section 3.6.5.

  If unbalanced, a bus must continue to dwell at each stop for the longest time taken to board and alight passengers at the door with the longest boarding and alighting queue. The first column under each bus type in Table 20 shows the corresponding front door boarding passenger percentages needed to precisely balance the alighting preferences of onboard passengers to achieve minimum dwell time. The second column under each bus type shows how boarding percentage mismatching at the front door impacts dwell time if onboard passenger alighting door preferences were to be sustained as at present.

  Based on current passenger rear door alighting preferences, the percentage of passenger boardings needed to balance out their exits via the front and rear doors would be:

  - 2 Door 12.5m Rigid Bus: 81% Front, 19% Rear
  - 2 Door 12.5m Double Deck Bus: 53% Front, 47% Rear
  - 2 Door 14.5m Rigid Bus: 70% Front, 30% Rear
  - 2 Door 18m Articulated Bus: 48% Front, 52% Rear
  - 3 Door 18m Articulated Superbus: 44% Front, 28% Middle, 28% Rear.

- The variation in average boarding and alighting times per passenger, door counts and door channels applicable to the 5 different bus types make it difficult to specify a single boarding and alighting policy to minimise dwell time for all door boarding.

  Review of Case 2 equation (xvi), Case 4 equation (xxii) and Case 6 equation (xxvii) shows however that each bus type has a unique front door boarding to rear door alighting percentage ratio (f_b / r_a) which is completely independent of bus specific average boarding and alighting times per passenger. The applicable ratios translate to:

  - 2 Door 12.5m Rigid Bus: 2/3 Front Boarding, 1/3 Rear Boarding
2/3 Front Alighting, 1/3 Rear Alighting
  - 2 Door 12.5m Double Deck Bus: 50% Front Boarding, 50% Rear Boarding
50% Front Alighting, 50% Rear Alighting
  - 2 Door 14.5m Rigid Bus: 50% Front Boarding, 50% Rear Boarding
50% Front Alighting, 50% Rear Alighting
  - 2 Door 18m Articulated Bus: 50% Front Boarding, 50% Rear Boarding
50% Front Alighting, 50% Rear Alighting
  - 3 Door 18m Artic Superbus: 1/3 Front Boarding, 1/3 Middle & 1/3 Rear Boarding
1/3 Front Alighting, 1/3 Middle & 1/3 Rear Alighting

  These ideal ratios for each bus type can be readily recognised as the ratios of their respective door flow channel counts. The appropriate policy to obtain near minimum dwell times at stops would be one which encourages bus operators to install double width doors on all buses, passengers to board and alight equally through all doors, and is supported by an advertising campaign prior to roll out to explain boarding door and queuing procedures to passengers.

- Table 20 indicates that irrespective of which doors onboard passengers elect to alight from, all door boarding will still significantly reduce stop dwell times. Current passenger rear door alighting preferences are already close to ideal for balanced all door boarding on the double deck and 2 door articulated buses, but considerably too high at rear doors on the other 3 bus types.

- Tables 21 to 25 summarise the extraordinary benefits of all door boarding to high capacity bus operational performance during peak periods. The common advantage to all high capacity bus types is significantly improved performance relative to a standard 12.5m rigid bus on all route lengths of 10km and longer at peak period traffic speeds of 45km/h or less, and for bus types other than the double deck bus, on route lengths 20km and longer at traffic speeds up to 75km/h.

  All door boarding has been found to favour the performance of the 3 door very high boarding capacity articulated superbus more than the 2 door articulated and 14.5m rigid lower boarding capacity buses. Albeit improved by all door boarding, the ranking of the double deck and 12.5m rigid bus performances slips relative to the other 3 high capacity buses because of the single channel alighting flow from the upper deck to the rear door on the former, and the single channel alighting and boarding flows through the narrow rear door on the latter. This has resulted in the changed rankings of all bus types appearing below in Table 26 compared to those in Table 15 for front door only boarding.

Table 26: Ranking of Bus Types with All Door Boarding

Route Length	Routes Operated at 30km/h	Routes Operated at 45km/h	Routes Operated at 75km/h
	Mixed Traffic on Local, Arterial and Sub-Arterial Roads during Peak Period	Mixed Traffic on CBD Radial Highway or Motorway during Peak Period OR Off-Peak in Mixed Traffic on Local, Arterial and Sub-Arterial Roads	City Ring Road, Busway or Highway Bus Transit Lane during Peak Period OR Off-Peak in Mixed Traffic on a CBD Highway or Motorway
5km	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
10km	1 : 2 Door 18m Artic 1 : 2 Door 14.5m Rigid 2 : 3 Door 18m Artic (Note 2) 2 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 3) 1 : 2 Door 14.5m Rigid (Note 3) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
15km	1 : 3 Door 18m Artic 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic 1 : 2 Door 14.5m Rigid 2 : 3 Door 18m Artic (Note 3) 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
20km	1 : 3 Door 18m Artic 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 4) 1 : 2 Door 14.5m Rigid (Note 4) 2 : 3 Door 18m Artic (Note 5) 3 : 2 Door 12.5m Rigid
25km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 3 Door 18m Artic (Note 5) 3 : 2 Door 12.5m Rigid

Note 1: Up to a Limit of 10 Boarding/Alighting Stops
Note 2: Up to a Limit of 20 Boarding/Alighting Stops
Note 3: Up to a Limit of 15 Boarding/Alighting Stops
Note 4: Up to a Limit of 8 Boarding/Alighting Stops
Note 5: Up to a Limit of 5 Boarding/Alighting Stops

- The most important benefit yielded through all door boarding is the significantly improved average traffic to service speed ratio afforded to high capacity bus services, making them much more competitive with a private motor vehicle on peak period inner suburban routes of 10km or more operated along major arterial, sub-arterial and local roads, and outer suburban and regional routes of 15km or more operated along highways, motorways, arterial, sub-arterial and local roads. Tables 21 to 25 indicate that with 20 or less stops, the lower capacity 2 door articulated and 14.5m rigid buses can complete their routes within less than a 25% - 40% longer journey time than a private motor car; and with 16 or less stops, the higher capacity 3 door articulated bus can complete its routes within less than a 30% - 50% longer journey time.

3.6.5 Cabin Rear Door and Seating Configuration

When bus cabin seating and standing area layouts were compared with the measured preferences of passengers to alight from the front, middle and rear doors earlier listed in Table 5, the reason for such (earlier cited amongst the key findings in Section 3.2.3) was that seated and standing passengers in the main simply chose to disembark via the nearest available door and had no personal habits or inclinations to head for any particular door to exit.

Up until the point where all passenger seats have filled, the cabin seating layout dictates the percentage of passengers who will choose to exit from the rear door. After all seats become fully occupied, observations have shown standees fill the aisle way from the front door to the rear door of the cabin as the number of standees progressively increase, but do not begin to spill over into the vacant aisle space behind the rear door until the forward aisle way and wheelchair parking areas have packed because of the low head clearance and ramped aisle way aft of the rear door. Standing has the effect of increasing the front door alighting percentage and reducing the percentage of rear door alighting in full highly crammed buses, but this effect is moderated by the large proportion of seated passengers to the aft of the rear door who disembark almost exclusively via the rear door.

It has been demonstrated by the equations earlier developed for Cases 1, 3 and 5 that minimum dwell time occurs for front door only boarding on all bus types when 100% of onboard passengers alight through the rear door (or middle and rear doors) other than when no passengers are boarding, in which case minimum dwell time occurs at each stop when onboard passengers alight evenly through all available door channels. One-way passenger boarding and passenger alighting flows occur during the peaks, so dwell times can only really be improved on outbound services by rear door and seating configurations which promote greater rear door alighting.

It has been demonstrated that all door boarding would, if implemented, significantly cut dwell times on all bus types, most particularly the 4 high capacity bus types. The balanced concurrent boarding equations developed for Cases 2, 4 and 6 also show that minimum dwell time occurs when all available door channels are used evenly and equally for both boarding and alighting passengers during the peaks. The following modifications to current bus rear door and seating configurations would influence passenger alighting choices to minimise total stop dwell time for all door boarding:

- 2 Door 12.5m Rigid Bus: The preferred modification to the rear door on the 12.5m rigid bus would be to shift it aftward by one seat row and widen it to a full width two channel door. This would equalise the midpoint seated and standing distances from the front and rear doors and balance passenger alighting and boarding similarly to other two door high capacity buses.
- 2 Door 12.5m Double Deck Bus: Full seated loads were never approached on this bus type while it was operating on the Redcliffe 315 service, and average boarding and alighting times could not therefore be accurately measured at anywhere near maximum boarded capacity.

Passengers on the 315 route service were observed to split evenly to available seating on the upper and lower decks until all seats were filled on the latter, but alighted disproportionally through the rear door from the upper and lower deck because seats on the latter are concentrated to the aft of the rear door.

At maximum capacity, passenger loads would tend to equalise on both decks of the double deck bus because no passengers can stand on the upper deck due to its low head clearance. The average alighting time per passenger from the upper deck is also double that for passengers on the lower deck due to the single flow channel upper deck stairway.

The optimum solution for the double deck bus would be to turn the upper deck staircase 180º at its current lower deck landing to encourage all alighting passengers from the upper deck to exit via the front door, leaving most passengers on the lower deck to exit via the rear door. If a second stairway was also introduced on the nearside of the double deck bus and the wheelchair parking bays placed on both sides of the lower deck, the double deck bus could maintain most of its existing high seating capacity with the loss of as few as 6 seat positions, balance its alighting and boarding times at both doors, and halve its average peak period bus stop dwell time.

- 2 Door 14.5m Rigid Bus: All but 8 passenger seats and most of the available aisle standing space on the current Brisbane Transport 14.5m rigid bus are located closer to the rear door than the front door, explaining why 81% of passengers on this bus head straight for the rear door when alighting.

  Current State and future national heavy vehicle maximum rear axle load, rear overhang and wheelbase length regulations prevent the 14.5m rigid bus rear tandem axle from being relocated further to the aft, but sufficient room exists to relocate the rear door closer to the rear wheel arches, and an additional 6 to 8 seats placed forward of the rear door to encourage more passengers to alight via the front door. This would provide a better, though not fully balanced configuration for minimising dwell times for both future all door boarding and existing front door only boarding and is analysed further in the next section.

- 2 Door 18m Articulated Bus: The physical requirement to begin ramping the aisle way immediately to the aft of the rear door prevents the rear door on both the Clarks Logan City and Brisbane Transport 2 door articulated buses from being relocated an additional seat pitch further aftward to obtain the ideal 50%:50% split needed for fully seated all door boarding, but current rear door and seating locations are near ideally split for fully seated plus standing passenger capacity. The 2 door articulated buses already enjoy measured rear door alighting percentages of between 45% and 48%, which would guarantee near balanced passenger boarding and alighting at both doors if all door boarding was to be implemented.

- 3 Door 18m Articulated Superbus: The current middle door, rear door, seating and standing area configurations encourage 86% of passengers to alight via the middle and rear doors which is well suited to front door only boarding. A need exists however to encourage 20% higher alighting at the front door for minimum dwell all door boarding. Should this policy be adopted in future, it would be preferable to relocate both the middle and rear doors further to the aft by one seat pitch. The physical requirement to begin ramping the aisle way immediately to the aft of the rear door prevents the rear door from being relocated an additional seat pitch further aftward, but the middle door could be relocated aftward by one seat pitch to reduce the mid section seated and standing capacity, and shift an additional 4 seats closer to the front door. This does not provide the ideal passenger splits for all door boarding, but moves them close enough to obtain near ideal passenger distributions under maximum seated and standing load conditions.

3.6.6 Passenger Circulation and Rear Door Storage

Boarding passenger flow through any bus door is constrained to the maximum rate at which already boarded upstream passengers can freely flow into and along bus aisle ways leading off door accesses. Additionally, alighting passengers need to be able to freely overtake other non-alighting standees in aisle ways and boarding passengers both in aisle ways and in door access channels, especially if all door boarding was to be implemented.

A common practice employed on fast turnaround, high churn, high capacity BRT bus services in many overseas cities is to announce the next bus stop name using visual next stop cue signs and audible public address messages with verbal prompts for passengers to begin moving to doors in advance of bus stop arrival. This practice, already commonplace on Queensland Rail train services, has the highly desirable effect of initiating passenger alighting movements during the vehicle's otherwise wasted deceleration period. Unlike rail cars however, buses have narrow aisle ways which obstruct alighting passenger movements to doors on buses with high standee loads, and most alighting passengers need to tag off *go cards* before alighting. To minimise stop dwell time, best practice overseas BRT bus operators create passenger storage areas at all bus doors and widen aisle ways to improve passenger circulation during peak periods when standee loads are high.

Passenger storage areas at doors yield bidirectional dwell time reduction benefits for both alighting and boarding passengers. For alighting passengers, they provide temporary standing areas where a large number of passengers can muster in advance of stop arrival and quickly exit as soon as doors open. For boarding passengers, they provide a temporary holding area where a large number of boarded passengers can temporarily gather without blocking access to other boarding passengers, then filter out to seats and adjoining standing areas after the bus is underway. With appropriate software modifications and strategically positioned onboard card interface devices, alighting passengers can begin tagging off *go cards* before reaching their bus stops, and boarding passengers can finish (or even commence) tagging on their *go cards* after leaving bus stops. The benefit of increased alighting and boarding efficiency created through improved aisle way circulation and creation of door passenger storage spaces can be as high as a 50% reduction in average stop dwell time, but the benefits from increased efficiency cannot be realised without a corresponding reduction in passenger seat capacity.

The greatest obstacle to reducing stop dwell time through improved passenger movement efficiency has been, and is likely to remain, the Australian bus operator obsession with cramming as many passenger seats into new bus cabins as the heavy vehicle regulations will permit. When applied to high capacity vehicles, this continuing doctrine of maximising bus seating capacity comes at a very high price given the following key findings of this study:

- 56% - 75% of passenger seats presently go unoccupied during off-peak services on all high capacity bus services, and over 40% of 12.5m rigid bus services. The cost of off-peak seat underutilisation is higher fuel consumption, higher bus maintenance, higher dead axle weight and lower combined bus seated plus standing capacity.
- All door boarding and improved passenger alighting/boarding efficiency are incompatible with the doctrine of maximum seating capacity. Currently, some 6 to 11 minutes would be consumed on every peak service just to board and alight passengers to full bus capacity, and around 6 minutes on low floor 12.5m rigid bus peak services. All door boarding and improved passenger alighting/boarding efficiency could potentially cut stop dwell times by factors of 2 to 3, reducing driver labour costs and the potential to increase service frequencies on HFP routes. But the most important benefit to peak services of a 200% or greater reduction in dwell time would be the increased competitiveness of all high capacity buses with the private motor vehicle.

- Every twin passenger seat installed in a bus cabin occupies approximately the same floor space as 4 standees. On peak services with highly crammed standing passenger loads, the price most often paid for 2 comfortably seated passengers is 4 very uncomfortable standees. Maximisation of seat capacity at the expense of aisle width does not consider the comfort needs of those less fortunate passengers left standing.

  Average standing periods measured on some ten thousands of peak services studied for this report have shown that a typical standee endures uncomfortable standing conditions for at least half the total trip time before finding a vacant seat to reoccupy, must throughout the time of standing shuffle back and forth and lean over seated passengers on narrow aisles to let other passengers alight, and carry personal belongings for most of the time to prevent trampling damage or tripping other passengers. It is arguably a misnomer that adding more bus seats improves passenger comfort and safety on city peak services with high standing loads.

Third Seating Layout: The third seating layout is an optimisation of the second layout and maximises seating forward of the rear door. By relocating both wheelchair bays to the nearside, a rear door storage area is created with a wide aisle way between the front and rear storage areas where both alighting and boarding passengers can easily pass other standees. The adjoined wheelchair bays also double as off-aisle shared overflow areas for both the front and rear storage areas. The drawback with this layout design only becomes evident when 2 wheelchairs need to board. More passengers have to move to make way for the second wheelchair to load and unload, and the 2 wheelchair occupants can no longer sit opposite each other.

Figure 14 overleaf illustrates 4 optional cabin seating layouts to improve aisle way passenger circulation and create a new rear door passenger storage area on a high capacity 14.5m rigid bus. The 14.5m rigid bus has an extremely high r_a = *80%* rear (i.e. 4 rear to 1 front) door passenger alighting preference which would need to shift to around an r_a = *50%* rear (i.e. 1 rear to 1 front) alighting preference to afford balanced minimum stop dwell for all door boarding. Third Seating Layout: The third seating layout is an optimisation of the second layout and maximises seating forward of the rear door. By relocating both wheelchair bays to the nearside, a rear door storage area is created with a wide aisle way between the front and rear storage areas where both alighting and boarding passengers can easily pass other standees. The adjoined wheelchair bays also double as off-aisle shared overflow areas for both the front and rear storage areas. The drawback with this layout design only becomes evident when 2 wheelchairs need to board. More passengers have to move to make way for the second wheelchair to load and unload, and the 2 wheelchair occupants can no longer sit opposite each other.

Figure 14 demonstrates how standee comfort could be significantly improved, total passenger carrying capacity increased and all door boarding dwell time reduced on a Brisbane Transport 14.5m rigid high capacity bus with a reduction of as few as 2 or 3 passenger seats.

- Top (Current) Seating Layout: The top layout in Third Seating Layout: The third seating layout is an optimisation of the second layout and maximises seating forward of the rear door. By relocating both wheelchair bays to the nearside, a rear door storage area is created with a wide aisle way between the front and rear storage areas where both alighting and boarding passengers can easily pass other standees. The adjoined wheelchair bays also double as off-aisle shared overflow areas for both the front and rear storage areas. The drawback with this layout design only becomes evident when 2 wheelchairs need to board. More passengers have to move to make way for the second wheelchair to load and unload, and the 2 wheelchair occupants can no longer sit opposite each other.

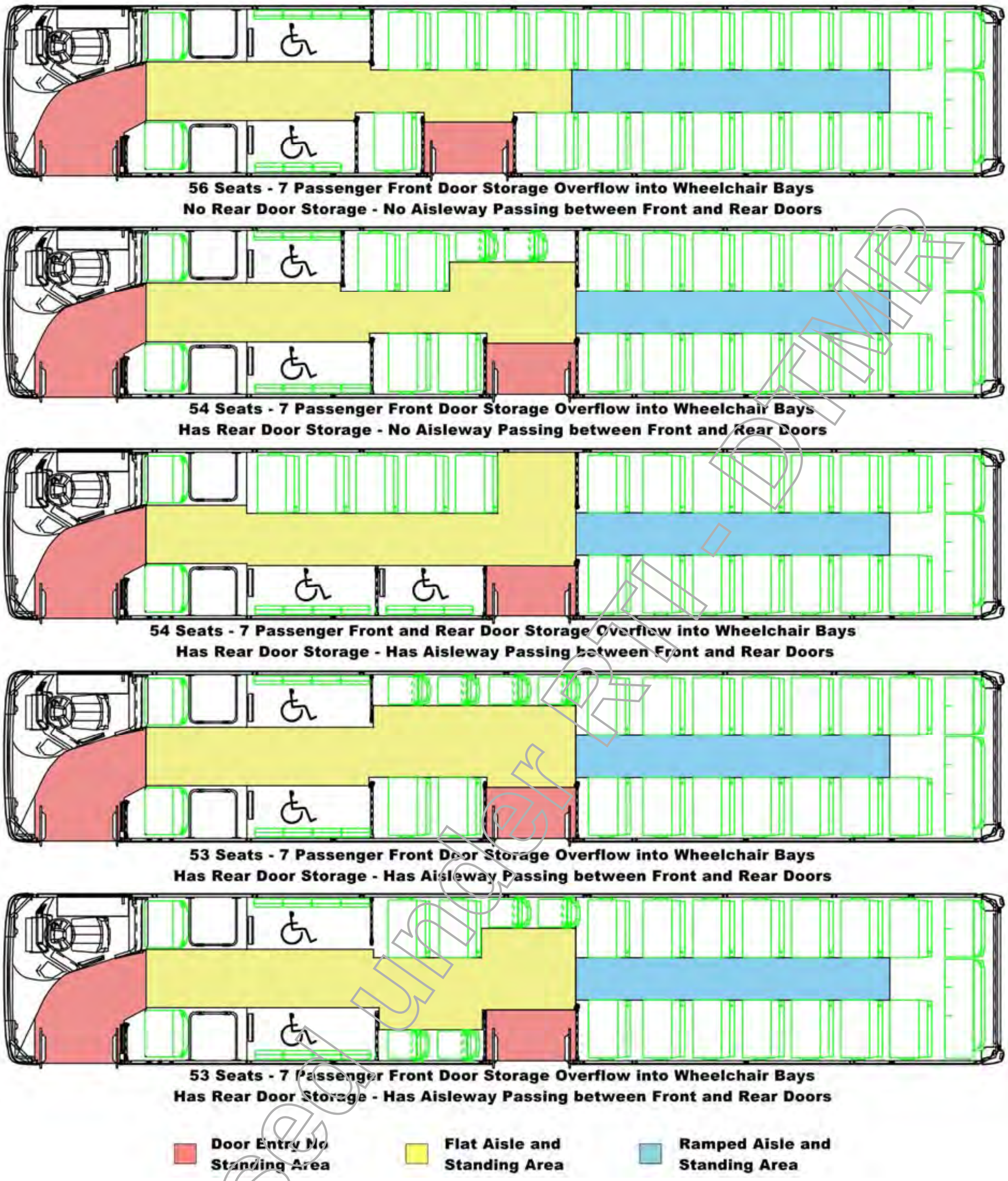
- Figure 14 is indicative of the current 14.5m rigid bus seating plan designed to maximise seating capacity to 56 seats. This layout has narrow aisles aft of the 2 wheelchair parking bays which effectively obstruct alighting passengers from easily passing other standees on the aisle, and no dedicated rear door passenger storage area. The yellow shaded area on the layout comprises flat low floor with no plinth mounted seats and is therefore well suited to standees. It includes a wide aisle front passenger door entry and storage area in front of the 2 wheelchair bays with off aisle passenger spill over into the 2 bays whether occupied or otherwise by seated passengers, but not when occupied by wheelchairs. The fourth seat in the extended wheelchair bay is reserved for a PWD carer but may be occupied by any passenger when not being used by a carer.

  The blue shaded aisle way on the layout to the aft of the rear door has a single high step up off the low floor area, and is then continuously ramped up to the rear with reducing head clearance, and flanked on both sides by climb-on high back plinth mounted seats. The blue shaded aisle way is typically avoided by standees until the yellow shaded flat floor area becomes full, but during peaks some standees may elect to stand in the rear aisle way and suffer the inconvenience of repeatedly moving to the rear door to allow seated passengers to alight in the hope of reoccupying their vacated seats. The red shaded areas are door entry no standing safety zones.

- Second Seating Layout: The rear door has been relocated aftward in the second and lower seating layouts to place more seats forward of the rear door. 2 twin passenger seats have been replaced by 2 single seats to create a large rear door passenger storage area but the narrow aisle way between the front and rear storage areas prevents alighting passengers from easily passing standees should they choose to exit by other than the nearest door.

- Third Seating Layout: The third seating layout is an optimisation of the second layout and maximises seating forward of the rear door. By relocating both wheelchair bays to the nearside, a rear door storage area is created with a wide aisle way between the front and rear storage areas where both alighting and boarding passengers can easily pass other standees. The adjoined wheelchair bays also double as off-aisle shared overflow areas for both the front and rear storage areas. The drawback with this layout design only becomes evident when 2 wheelchairs need to board. More passengers have to move to make way for the second wheelchair to load and unload, and the 2 wheelchair occupants can no longer sit opposite each other.

Figure 14: Improved Passenger Aisle Circulation and Rear Door Storage on a 14.5m Rigid Bus



- Fourth and Fifth Seating Layouts: The fourth and fifth seating layouts both maximise and join the two door passenger storage areas by placing opposing rows of twin and single passenger seats on either side of the front aisle, and restoring both wheelchair bays to their optimum positions for front door loading and unloading. These layouts require one wheelchair bay to be extended with a carer's seat in each at the cost of a third lost passenger seat relative to the original maximum seating capacity.

All of the above modified seating layouts 2 through 5 are suitable for all door boarding and have greater total seated and standing capacities than the original maximum seating capacity design. The fourth seating layout is considered to be close to optimised and could only be further improved by restoration of a near 100% flat floor aft of the rear door at a loss of a further 6 seats.

Modification for all door boarding and rear door storage areas on the articulated buses would involve little more than replacing twin seats fitted opposite and offside forward of the rear door to the turntable with single seats.

The double deck bus already has a joined front and rear door storage area, but cannot be fully optimised for all door boarding until the upper deck stairway is turned back 180° toward the front door, and preferably fitted with a second stairway to speed up alighting of passengers from the upper deck.

3.6.7 Onboard Ticket Sales and Go Card Top-Ups

Comparison of the measured average boarding time per passenger on the Clarks Logan City two and three door articulated buses with that of the Brisbane Transport two door articulated bus appearing at Table 4 has underscored how onboard ticket sales and *go card* top-ups extend trip stop dwell times on private operator bus services. Onboard ticket sales and *go card* top-ups added an additional second to the average boarding time per passenger, increasing it by 38% on the two Clarks Logan City articulated buses relative to a comparable Brisbane Transport articulated bus, and have extended the average stop dwell time per passenger by 0.5s, a relative increase of 21% on the Brisbane Transport articulated bus.

Comparison of the measured dwell times between the two Clarks Logan City articulated buses has further identified that the cumulative boarding delay at stops for driver paper ticket sales and *go card* top-ups has effectively negated out the time savings gained by having the third door on the articulated superbus.

Analyst notes from video recordings taken aboard the Clarks Logan City articulated buses and observations by MRCagney personnel travelling onboard the Logan Hyperdome 555 bus services reveal a high incidence of passenger interaction with Clark's bus drivers not observed on comparable Brisbane Transport bus services. These interactions were initiated in the main by passenger requests for paper tickets and *go card* top-ups. Driver-passenger interactions were repeatedly observed to not only block off one stream of boarding passengers at the double width front doors, but to occasionally set off flow conflicts in the free streaming channel between alighting and boarding passengers at the front door. Measured average alighting time per passenger on the two Clarks Logan City articulated buses has been found to be around 0.3 – 0.4s longer than for comparable Brisbane Transport 2 door articulated buses.

Onboard *go card* top-ups by regular bus commuters and students, rather than paper ticket sales to irregular bus users, has been identified as the more frequent cause of passenger-driver interaction delay. Translink has a well established network of several hundred add value vending machines, outlets and agencies where *go cards* can be credited off bus across South East Queensland, and a website where *go cards* can be either manually or automatically topped-up by credit card. Because high capacity buses carry a large number of passengers who are arguably being repeatedly inconvenienced by onboard *go card* top-ups, it is recommended that TransLink discontinue the current policy permitting go-card top-ups on private operator bus services. The requirement to reduce driver-passenger interaction on all door boarded high capacity bus services will be critical for balancing front door boarding and alighting with (middle and) rear door alighting and boarding to obtain minimum stop dwell times.

Appendix A

All Door Boarding and Proof of Payment Case Studies

San Francisco, California, USA

San Francisco Municipal Transportation Agency (SFMTA) will introduce all door boarding on its *Muni* bus routes, trolley coach and historic streetcar network from July 2012. At present, *Muni* buses are averaging just 13 km/h and struggling to achieve 80% on-time running performance, well below the minimum target of 85% on-time running performance benchmark set by the agency. Research has shown that many *Muni* bus routes were spending from 15% to 30% of total journey time dwelling at bus stops.

From July 2012, *SFMTA* will allow its passengers using the *Clipper* smartcard to board from the rear, while passengers requiring paper tickets must board from the front door and continue to purchase tickets from the bus driver. *Clipper* card readers have already been installed near the rear door on all vehicles to meet this need. The agency also has plans to increase enforcement to assure fare compliance. *Muni* plans to add another 10 fare inspectors to its current roster of 36 staff once the new all door boarding program has been implemented.

While *SFMTA* has concerns about the risk of increased fare evasion, the agency recognises that making its transit services more efficient will not only make them more attractive to regular *Muni* passengers, but all door boarding will have a significant effect on the bottom line of the agency's finances. A 2010 study found that speeding up services by just 1.6 km/h throughout the network would save $76 million annually for the agency.

This initiative has been supported by the *San Francisco Transit Riders Union*, a customer advocacy group that has long lobbied the agency for all door boarding. *SFMTA* intends to reinvest its travel time savings back into improving its service frequency and capacity, and *Muni* will become the first transit operator in North America to allow prepaid passengers to legally board through the rear door of every rail carriage and bus on its network. Currently, rear door boarding is only allowed on *Muni*'s light rail lines and some selected bus routes where a fare inspector is on hand to collect fares and check concession passes and transfer tickets.

According to a 2009 study undertaken by *SFMTA*, the fare evasion rate on *Muni's* light rail lines, which have employed roaming fare inspectors to monitor evasion for more than a decade, is less than half the rate it is on our *Muni* buses. On some *Muni* bus lines, more than 15% of riders don't pay a fare, and that number jumps to 55% for people who illegally board buses at the rear. Overall, *Muni* knows it loses an estimated $19 million to fare evasion every year, significantly less than its cost of $76 million to maintain service reliability.

San Francisco has taken the view that reducing stop dwell time through all door boarding was the best low cost alternative available to it to reducing journey travel times when compared to implementing other bus priority/dwell time reduction measures. The policy initiative is expected to induce a higher *Clipper* smartcard take-up rate as more customers appreciate the benefits of faster boarding through the rear door.

Vancouver, British Columbia, Canada

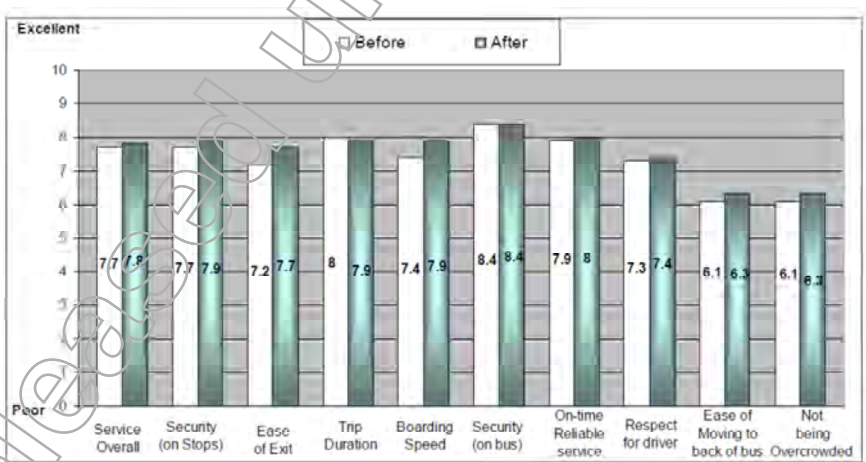
In 2007, the Greater Vancouver transit agency, *Translink*, undertook a 3 month trial of all door boarding on its 99 B-Line. Three door boarding had previously been allowed at the two termini of the 99 B-Line and on the Vancouver *Skytrain* only. Where non-articulated buses were deployed on the route, all customers could only board via the front door, and the all door boarding trial was adopted for high capacity articulated buses only.

220 physical assaults and serious verbal abuse attacks had been reported by bus drivers on the 99 B-Line in the 12 month period prior to the all door boarding trial, and a high percentage of these attacks were triggered when drivers attempted to collect ticket fares. The primary reason for the trial was to reduce the incidence rate of conflicts between bus drivers and passengers who refused to pay their ticket fares, and all door boarding was not specifically introduced to reduce stop dwell times.

During the trial, passengers who wanted to buy or validate tickets were still asked to board at the front door of the articulated buses, but other passengers with prepaid tickets could board the bus at the front, middle and rear doors.

Translink did not think fare evasion would be a significant issue during the trial because its $175 fine for being caught without a valid ticket would act as strong deterrent to fare evasion. The agency recruited an additional 40 transit police officers to augment its transit security workforce across the network to 150. The trial evaluation showed that at the busy stops along the route average dwell time per boarding and alighting fell from 5.8 seconds per passenger to 4.8 seconds, a reduction of 17%. The average total trip time between 6:00am and 6:00pm was also reduced by 8% in both the eastbound and westbound travel directions.

Market research was undertaken by Translink after the 3 month trial to gain an appreciation of what its regular customers had thought of all door boarding during the trial. The bar graphs below show customer responses to the trial which was considered a success, and Translink still operates all door boarding on all of its 99 B-Line articulated vehicles.



Translink commissioned two independent audits of its internal procedures for estimating fare evasion; the first conducted by KPMG in 2002, and the second by PricewaterhouseCoopers in 2008. Both audits found that Translink's fare evasion estimation methodology was sound and determined that fare evasion rates were around 4.8% and 2.5% respectively. The PriceWaterhouseCoopers audit report concluded that public and political perception of fare evasion was an order of magnitude (i.e. 10 times) higher than the actual fare evasion rate. Actual fare evasion has decreased in Vancouver as a result of increased random ticket inspection monitoring and hefty $175 fines for infringements.

Paris, France

Bus passengers in Paris can board any bus through any door, unless they want to purchase magnetic stripe tickets and pay higher cash fares to the driver than otherwise debited from smartcards, in which case they must board at the front door of the vehicle. Passengers who board buses at the middle or rear door may either tag on a *Navigo* smartcard at a card reader, or insert a prepaid magnetic stripe ticket into a validator. Both machines are collocated beside each other adjacent every bus access door.

Magnetic stripe tickets can be procured from the driver or off vehicle at agencies and public transport outlets, and are typically only used by itinerant city visitors and tourists, rather than regular Parisian bus commuters. Possession of either a tagged-on *Navigo* smartcard or a validated magnetic stripe ticket whilst boarded on any Paris bus constitutes the only satisfactory proof-of-payment of fare, and such are randomly and regularly monitored by a large contingent of roving ticket inspectors on all bus services.

Ottawa, Canada

Ottawa's BRT system permits rear door boarding on articulated buses for riders with valid proof of payment. As for the San Francisco *Muni* buses, customers must board at the front door if they need to purchase a ticket. Brisbane's busway system was modelled on the Ottawa BRT, but Brisbane never adopted Ottowa's long standing all door boarding policy.

Most of the buses operating on the Ottawa BRT are 18m articulated buses, but recently the transit agency *OC Transpo*, has initiated a trial of 3 Alexander Dennis Enviro500 double deck high capacity buses in an attempt to increase busway carrying and station loading capacity through vehicle changes rather that resorting to costly station platform extensions.

Passengers travelling on Ottowa BRT articulated or double deck buses and *O-Train* light rail vehicles are required to show proof of payment to transit fare and transit law enforcement officers upon request. Anyone unable to provide proof of payment is fined $150.

Western European Cities

Many cities in Western Europe have, for several decades, adopted uniform proof of payment ticketing and all door boarding policies on their heavy rail, light rail and bus services, generally in response to the shortage of drivers and conductors and the rising cost of operations.

Moscow, Russia

Proof of payment and all door boarding were introduced on Moscow buses in 1992.

Las Vegas, Nevada, USA

Proof of payment and all door boarding has been implemented on two major bus routes in Las Vegas.

Toronto, Canada

VIVA Buses in suburban Toronto provide off-vehicle ticket vending machines at its major stops and operates all door boarding on all of its bus services.

Portland, Oregon, USA

The Portland *Tri-Met* once operated all door boarding and universal proof of payment across its entire network but abandoned the policy in 1980. *Tri-Met* acknowledges it made a mistake to implement a universal all door boarding and proof of payment policy across its entire network, as it encompassed many routes that were neither frequent nor crowded at that time. As a result of the policy, *Tri-Met* ticket inspectors spent most of their paid time travelling on and waiting for partially loaded buses at stops with nothing to do, and the political and public credibility of its fare compliance enforcement was substantially tarnished.

Tri-Met's view now is that proof of payment fare evasion monitoring only really makes practical sense when targeted at busy peak period bus services randomly, and where inspectors can process a high number of ticket checks in a short period of time and move quickly onto other vehicles with minimum bus stop waiting time. Their current view of all door boarding and alighting is that it should be targeted at high capacity, high frequency services rather than universally across all bus services.

Czechoslovakia

Czechoslovakia has operated all door boarding on its city buses for many decades. Conductors were initially stationed onboard buses to sell tickets, but were replaced by random proof of payment inspectors in the late 1960's and early 1970's.

Los Angeles, California, USA

The *Metro Bus BRT Orange Line* in Los Angeles operates high capacity buses with all door boarding and *Metro Bus* claims to have reduced its fare evasion rate to just 0.8% using proof of payment random ticket inspections.

Appendix B

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Stage 1: Preliminary Draft Report - Appendices

Research & Analysis of High Capacity Vehicles

TransLink Transit Authority

Prepared by:

MRCagney Pty Ltd

5 July 2012

MRCagney

Document Information

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Quality Assurance Register

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1	Preliminary Draft	RB,JV,BP, MF,JH	BW	initials	27/06/2012

List of Appendices

Appendix A: Assessment of Bus Station Infrastructure

Technical Note

Subject:	Assessment of Bus Station Infrastructure		
Project:	Research and Analysis of High Capacity Vehicles		
Our file:	4749	Date:	25 May 2012
Status:	Preliminary Draft	Prepared by:	RB, JV

Table of Contents

1. Introduction

1.1 Background

MRCagney has been appointed by *TransLink Transit Authority (TransLink)* to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

1.2 Purpose of this Technical Note

The main purpose of this technical not is to provide a high-level assessment of the suitability of existing bus station infrastructure to accommodate HCVs within the next five years (ie. by 2017). This assessment was developed using a sample of bus stations as discussed in the following section.

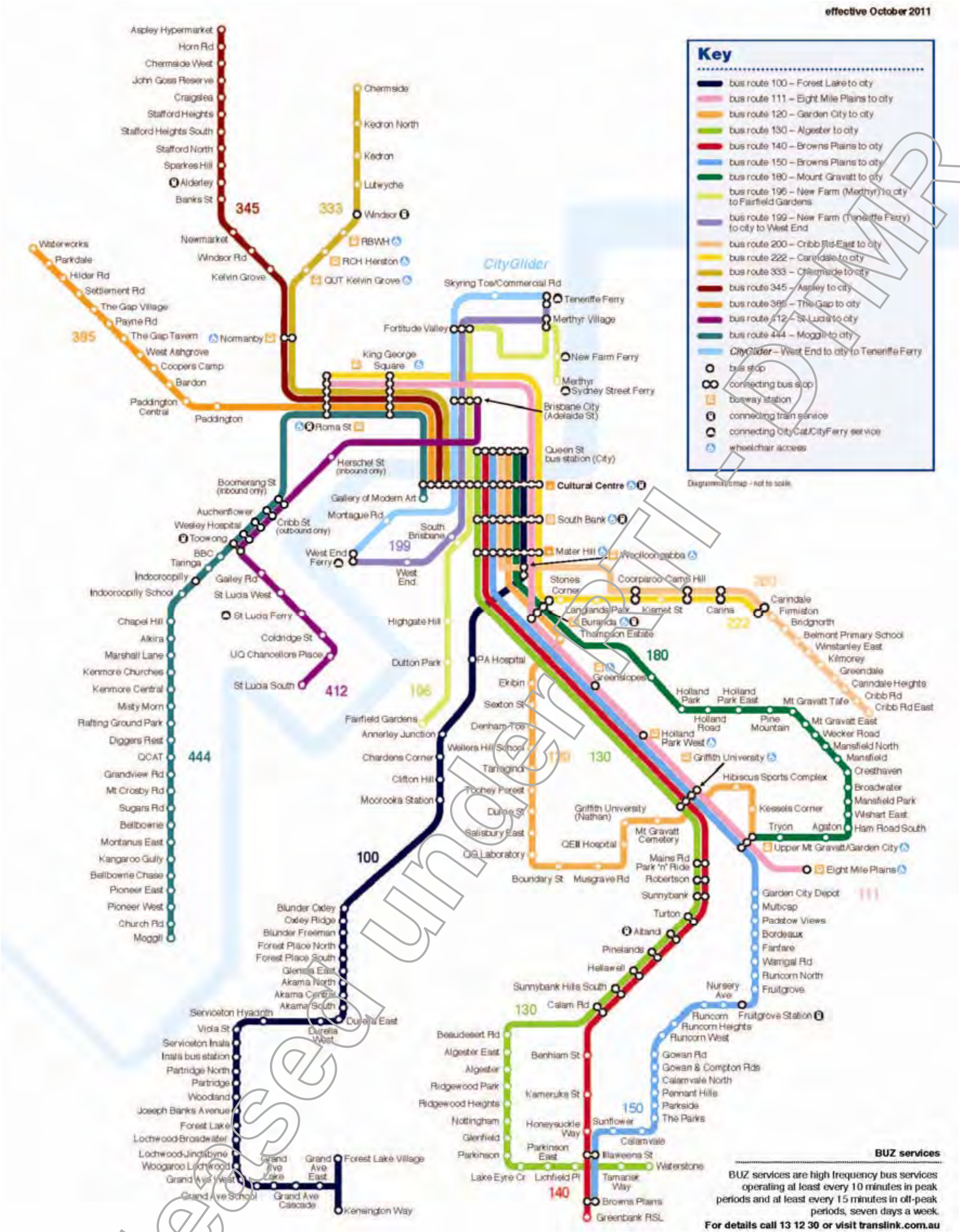
2. Station Infrastructure Assessment Methodology

To assess the impact HCVs might have on existing bus station infrastructure, the following assessment methodology was undertaken once bus stations along selected routes in the BUZ network were identified:

1. Assess manoeuvring at entry and exit point to the bus station from the external road network.
2. Assess manoeuvring around and through station.
3. Assess manoeuvring for entry and exit of each individual stop.
4. Determine if stops are adequate and if not can they be extended/reconstructed to accommodate buses.
5. Assess clearances and obstructions
6. Assess existing station infrastructure is clear of bus boarding areas

The assessments were conducted using aerial photography as station plans and design drawings were unavailable. The bus station infrastructure which was assessed was selected from the TransLink BUZ network as shown in the following figure.

Figure 1: TransLink BUZ Network



The following bus stations were assessed as a sample of SEQ's bus station infrastructure:

- Chermside
- Carindale
- Garden City
- Toombul
- Indooroopilly
- Aspley Hypermarket
- UQ Chancellors Place
- Inala Bus Station
- Capalaba
- Springwood
- Loganholme

3. Bus Station Infrastructure Assessment

3.1 Consolidated Summary of Findings

As part of this assessment, 69 bus stops were surveyed at eleven stations with the aggregated results presented in the following tables. For ease of reference the survey queries are grouped by general topic: shape, obstructions, turning, double-decker bus. The results are discussed below and presented in the following tables.

The majority of stops are either sawtooth 33% (or sawtooth island 12%), or island platform 22%. 62% of stops cannot be lengthened to accommodate 14.5 metre buses. A similar number, 64%, cannot be lengthened to accommodate 18m buses. However, for those stops at a station or park and ride with reserved bus standing or holdover bays 88% of bays are long enough and accessible for longer buses.

Nearly all stops do not have obstructions to the rear door, have a stop blade or sign that is clear of the kerb, and have a clear approach. Most stops allow a bus to stop parallel to a kerb, however 14% do not. Departure obstruction is a problem at 3% of stops, and a further 20% of stops would require an exit on full lock to clear obstructions. Of all stops 77% are clear of obstructions on exit. On entry or exit to the station there may be problems at 45% (five out of eleven) of the stations. A bus can enter and exit a stop safely at 55% of stops, with problems at 39%. Most kerbside areas have a hardstand area that is free of obstructions.

At 18% of stops the tail of a 14.5m bus would swing over the kerb or collide with street furniture. At 90% of stops a 14.5m rigid or 18m arctic bus would fit within the swept path turning template around a station for all road entries and exits. Only 7% of stops have hard left turns near an intersection, roundabout or island platform that would create difficulties when turning. Of all stops, 18% are underground or under a building and 4% pose a problem for entry by a double decker bus. At only 6% of stops are there double decker height clearance obstructions on arrival or departure sides of the stops

Stop Shapes and Lengths

Query	Item	#	Item	#	Item	#
Stop Shape	Central Platform	1.5%	Indented	2.5%	Indented in-line	8.5%
	In-line	8.5%	Island Platform	22%	Kerbside	12%
	saw tooth	33%	Sawtooth island	12%	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	38%	No	62%	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	36%	No	64%	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	88%	N/A	12%	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	98.5%	No	1.5%	---	---
Is Stop Blade or Sign clear of Kerb	Yes	98.5%	No	1.5%	---	---
Approach clear of obstructions	Yes	100%	No	0%	---	---
Departure clear of obstructions	Yes	77%	Problems on exit	3%	Only on full lock	20%
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	55%	No	39%	N/A	6%
Are there any obstructions for Buses entering or exiting Bus station	No	42%	Yes	46%	N/A	12%
Can bus stop parallel to kerb	Yes	86%	No	5.5%	N/A	8.5%
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	90%	No	10%	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	23%	No	65%	N/A	12%

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	18%	No	66%	N/A	16%
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	90%	No	10%	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	7%	No	93%	---	---

Double decker buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	14%	No	4%	N/A	82%
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	6%	No	94%	---	---

3.2 Summary of Findings by Station

The following is a review of bus stops by station.

3.2.1 Chermside Station

Chermside Station has 5 stops; all are island platforms. Three stops can be lengthened to accommodate 14.5m buses and 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter and exit the stop safely at 3 stops. Road works are required at Hamilton Rd intersection and internal road for buses to enter and exit safely at the other stops. The buses can stop parallel to the kerb at 3 stops.

At two stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. The left turn from Hamilton Rd requires a hard left turn that would cause the body skirt of a turning 14.5m bus to cross the island platform. There are no obstructions at the third rear door on the 18m arctic superbus.

There are no height clearance obstructions on arrival or departure sides of the stop.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Island Platform	5	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	2	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	2	No	3	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	5	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	5	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	5	No	0	Empty	0
Approach clear of obstructions	Yes	5	No	0	Empty	0
Departure clear of obstructions	Yes	5	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	3	No	2	N/A	0

Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	5	N/A	0
Can bus stop parallel to kerb	Yes	3	No	2	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	2	No	3	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	5	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	5	No	0	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	5	No	0		
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	5	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	5
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	5	---	---

3.2.2 Carindale Station

Carindale Station has 10 stops; all of which are sawtooth. Six stops can be lengthened to accommodate 14.5m buses and 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter the stops safely at 10 stops, but full lock is required for safe exit. If there is a bus in stop E, it is possible that the entrance to the station could be blocked. The buses can stop parallel to the kerb at 9 stops.

At 6 stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There is a column in the hardstand area at 4 stops that may obstruct passengers boarding. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. There are no obstructions at the third rear door on the 18m arctic superbus for the 5 stops where this applies.

A double decker bus is able to enter all stops. There are no height clearance obstructions on arrival or departure sides of the stop.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Sawtooth	10	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	6	No	4	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	6	No	4	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	10	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	10	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	10	No	0	Empty	0
Approach clear of obstructions	Yes	10	No	0	Empty	0
Departure clear of obstructions	Yes	0	Problems on exit	0	Only on full lock	10
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	6	No	0	N/A	4

Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	10	N/A	0
Can bus stop parallel to kerb	Yes	9	No	1	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	6	No	0	N/A	4
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	10	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	10	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	4	No	6	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	5	N/A	5

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	10	No	0	N/A	0
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	10	---	---

3.2.3 Garden City Station

Garden City Station has 15 stops; 5 are sawtooth, 4 are island platform and 6 are indented inline. 12 stops can be lengthened to accommodate 14.5m buses and 18m buses. Of all stops, 14 reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter the stops safely at 10 stops, and safely exit at 9. The exit taper at one stop is not long enough. From 6 stops buses can safely enter and exit the station. At 9 stops the manoeuvring room is tight if there is a bus in stop A. The buses can stop parallel to the kerb at all stops.

At 2 stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Inline	5	Island Platform	4	Indented Inline	6
Can stop be lengthened accommodate 14.5m Buses	Yes	12	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	12	No	3	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	14	N/A	1	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	15	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	15	No	0	Empty	0
Approach clear of obstructions	Yes	15	No	0	Empty	0
Departure clear of obstructions	Yes	13	Problems on exit	2	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	11	No	4	N/A	0

Are there any obstructions for Buses entering or exiting Bus station	No	6	Yes	9	N/A	0
Can bus stop parallel to kerb	Yes	15	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	2	No	13	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	15	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	15	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	15	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	15	N/A	

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	15
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	15	---	---

3.2.4 Toombul Station

Toombul Station has 6 stops; all are island platform. No stops can be lengthened to accommodate 14.5m buses and 18m buses. Reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses at all stops.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The 14.5m and 18m buses cannot manoeuvre into stops.

A 14.5 or 18m arctic bus will not fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are obstructions at no stops for the third rear door on the 18m arctic superbus.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Island Platform	6	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	0	No	6	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	0	No	6	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	6	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	6	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	6	No	0	Empty	0
Approach clear of obstructions	Yes	6	No	0	Empty	0
Departure clear of obstructions	Yes	6	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	0	No	6	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	0	N/A	6
Can bus stop parallel to kerb	Yes	0	No	0	N/A	6

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	0	N/A	6
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	0	No	6	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	6	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	6	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	6	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	6
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	6	---	---

3.2.5 Indooroopilly Station

Indooroopilly Station has 1 central platform and 2 kerbside stops. 2 stops can be lengthened to accommodate 14.5m buses and 18m buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter the stops safely at all stops, and safely exit at all stops. From 3 stops buses can safely enter and exit the station. The buses can stop parallel to the kerb at all stops.

At no stops will the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are obstructions at no stops for the third rear door on the 18m arctic superbus.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Central Platform	1	Kerbside	2	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	2	No	1	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	2	No	1	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	0	N/A	3	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	3	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	3	No	0	Empty	0
Approach clear of obstructions	Yes	3	No	0	Empty	0
Departure clear of obstructions	Yes	3	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	3	No	0	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	3	Yes	0	N/A	0

Can bus stop parallel to kerb	Yes	3	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	3	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	3	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	3	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	3	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	3	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	3	N/A	0
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	3	---	---

3.2.6 Aspley Hypermarket Station

Aspley Hypermarket Station has 4 sawtooth stops. 1 stop can be lengthened to accommodate 14.5m buses and 18m buses. At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. If there is a 14.5m or articulated bus in the front stop buses cannot leave. Buses in stop D can block the entrance to the station. The buses can stop parallel to the kerb at all stops.

At no stops will the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There one stop there is an obstruction for the third rear door on the 18m arctic superbus.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Saw Tooth	4	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	1	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	1	No	3	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	0	N/A	4	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	4	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	4	No	0	Empty	0
Approach clear of obstructions	Yes	4	No	0	Empty	0
Departure clear of obstructions	Yes	4	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	0	No	4	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	4	N/A	0
Can bus stop parallel to kerb	Yes	4	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	4	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	4	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	4	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	4	No		---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	1	N/A	3

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	4
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	4	---	---

3.2.7 UQ Chancellors Place Station

UQ Chancellors Place Station has 5 sawtooth stops. No stops can be lengthened to accommodate 14.5m buses or 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter the stops safely at all stops, and safely exit. From all stops buses can safely enter and exit the station. The buses can stop parallel to the kerb at all stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are no obstructions for the third rear door on the 18m arctic superbus.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Sawtooth	5	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	0	No	5	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	0	No	5	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	5	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	5	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	5	No	0	Empty	0
Approach clear of obstructions	Yes	5	No	0	Empty	0
Departure clear of obstructions	Yes	5	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	5	No	0	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	5	Yes	0	N/A	0

Can bus stop parallel to kerb	Yes	5	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	5	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	5	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	5	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	5	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	5	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	5
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	5	---	---

3.2.8 Inala Station

Inala Station has 1 inline and 4 sawtooth stops. Two stops can be lengthened to accommodate 14.5m buses and 1 stop can be lengthened to accommodate 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions and the blade or sign is clear of the kerb at 4 stops. The approach and departure are clear of obstruction at 5 stops. At two stops buses can enter and exit safely. At 3 stops buses cannot exit if a 14.5 metre or arctic bus is in the front stop. If there is a 14.5m bus or an arctic bus in stops B or C buses cannot pass on entry and exit to the station. The buses can stop parallel to the kerb at all stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At 4 stops there is clear hardstand area for passenger boardings, while the hardstand area is very narrow at one stop. There are no obstructions for the third rear door on the 18m arctic superbus at 4 stops, while there is a garden bed obstructing at one stop.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Inline	1	Sawtooth	4	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	2	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	1	No	4	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	5	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	4	No	1	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	4	No	1	Empty	0
Approach clear of obstructions	Yes	5	No	0	Empty	0
Departure clear of obstructions	Yes	5	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	2	No	3	N/A	0

Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	4	N/A	1
Can bus stop parallel to kerb	Yes	5	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	5	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	5	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	5	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	4	No	1	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	1	No	4	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	5
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	5	---	---

3.2.9 Capalaba Station

Capabala Station has 5 kerbside stops. 1 stop can be lengthened to accommodate 14.5m buses and 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions and the blade or sign is clear of the kerb. The approach and departure are clear of obstruction at all stops. At all stops buses can enter and exit safely. There are no obstructions to buses entering and exiting the station. Buses can stop parallel to the kerb at all stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are no obstructions for the third rear door on the 18m arctic superbus.

There are restrictions for double decker buses in relation to height clearance at 4 stops where the awning is close to the kerb.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Kerbside	5	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	1	No	4	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	1	No	4	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	5	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	5	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	5	No	0	Empty	0
Approach clear of obstructions	Yes	5	No	0	Empty	0
Departure clear of obstructions	Yes	5	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	5	No	0	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	5	Yes	0	N/A	0

Can bus stop parallel to kerb	Yes	5	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	5	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	5	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	5	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	5	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	5	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	5
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	4	No	1	---	---

3.2.10 Springwood Station

Springwood Station has 2 indented and 1 kerbside stops. No stops can be lengthened to accommodate 14.5m buses or 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions and the blade or sign is clear of the kerb. The approach and departure are clear of obstruction at all stops. At two stops buses can enter and exit safely. The remaining stop is not long enough. There are no obstructions to buses entering and exiting the station. Buses can stop parallel to the kerb at 2 stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. At 2 stops a 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits, while at the remaining stop the rear of a bus would stick out. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are no obstructions for the third rear door on the 18m arctic superbus at any stop.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Indented	2	Kerbside	1	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	0	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	0	No	3	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	3	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	3	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	3	No	0	Empty	0
Approach clear of obstructions	Yes	3	No	0	Empty	0
Departure clear of obstructions	Yes	3	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	2	No	1	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	3	Yes	0	N/A	0

Can bus stop parallel to kerb	Yes	2	No	1	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	2	No	0	N/A	1
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	2	No	1	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	3	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	3	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	3	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	3
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	3	---	---

3.2.11 Loganholme Station

Loganholme Station has 8 sawtooth island platform stops. No stops can be lengthened to accommodate 14.5m buses or 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions and the blade or sign is clear of the kerb. The approach and departure are clear of obstruction at all stops, though departure requires full lock at 4 stops. At 1 stop buses can enter and exit safely. At 4 stops full lock is required to depart and if an articulated bus or a 14.5m bus is in the stop in front then the departure is blocked. 3 stops are too short for the arctic bus. There are no obstructions to buses entering and exiting the station. Buses can stop parallel to the kerb at all stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. At 8 stops a 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are no obstructions for the third rear door on the 18m arctic superbus at any stop.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Sawtooth island platform	8	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	0	No	8	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	0	No	8	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	8	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	8	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	8	No	0	Empty	0
Approach clear of obstructions	Yes	8	No	0	Empty	0
Departure clear of obstructions	Yes	4	Problems on exit	0	Only on full lock	4
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	1	No	7	N/A	0

Are there any obstructions for Buses entering or exiting Bus station	No	7	Yes	0	N/A	1
Can bus stop parallel to kerb	Yes	8	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	8	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	8	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	8	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	8	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	8	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	8	N/A	0
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	8	---	---

4. Summary and Conclusions

This technical note reviews a sample of bus stations to represent SEQs infrastructure. This analysis included a total of 69 stops and was for the following stations:

- Chermside
- Carindale
- Garden City
- Toombul
- Indooroopilly
- Aspley Hypermarket
- UQ Chancellors Place
- Inala Bus Station
- Capalaba
- Springwood
- Loganholme

Our analysis of stations was based on a desktop analysis of aerial photos and plans where available. While suitable for a high level analysis of a network, an on-site review of each station is recommended to verify our results on the ground prior to confirming any routes or operations for HCVs.

Key aggregate findings are outlined here:

- About two thirds of stops cannot be lengthened to accommodate 14.2 or 18 metre buses.
- Nearly all reserved bus standing or holdover bays are long enough and accessible for HCVs.
- Nearly all stops do not have obstructions at the rear door, a stop blade/sign that is obscured.
- Nearly all stops offer a clear approach, however 20% of stops require exit on full lock and a further 3% present obstruction on exit.
- Slightly over half of stops are located in stations where there are no obstacles to entry and exit of the station.
- Buses can enter and exit 55% of stops safely.
- At 18% of stops, the tail of a 14.5m bus would swing over the kerb or collide with street furniture.
- At 90% of stops a 14.5m or 18m arctic bus would fit within the swept path turning template around a station for all road entries and exits.
- Double decker buses do not have problems for height clearance at most stops.

The ability for the stations along existing BUZ routes to accommodate HCVs without upgrades varies considerably. Route planning will need to be influenced by a ground-verified knowledge of the capacity of individual stops to accommodate HCVs that this technical note begins to deliver.

Attachment 1: Audit Results

Site Location	Stop Number	Zone Number	Direction of Travel	Stop Shape	Lenght Parallel to Kerb	Can stop be lengthened accommodate 14.5m Buses	Can stop be lengthened accommodate 18.0m Buses	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely. (14.5m & 18.0m)	Are there any obstructions for Buses entering or exiting Bus station	Can bus stop parrallel to kerb	Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Will a 14.5m rigid or 18.om artic bus fit within the swept path turning template around station from all road entries to all road exits	If an underground or under building station, will a double decker bus be able to enter	Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Is the kerbside area used by passengers to board and exit all doors a hardstandand free of obstructions	Are there third rear door obstructions on the 18.0m artic superbus	Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	General Observations
Chermside A	301652	3/4		Island Platform	55m (Stops A & B)	Y	Y	Y	Y	Y	Y	Y	Y	Y - Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit	Y	N	Y	n/a	N	Y	N	Y -Left turn from Hamilton Rd	Y	Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit
Chermside B	301650	3/4		Island Platform	55m (Stops A & B)	Y	Y	Y	Y	Y	Y	Y	Y	Y - Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit	Y	N	Y	n/a	N	Y	N	Y -Left turn from Hamilton Rd	Y	Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit
Chermside C	301651	3/4		Island Platform	55m (Stops D, E & F)	N	N	Y	Y	Y	Y	Y	Y	Y - Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit	Y	N	Y	n/a	N	Y	N	Y -Left turn from Hamilton Rd	Y	Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit
Chermside D	301655	3/4		Island Platform	55m (Stops D, E & F)	N	N	Y	Y	Y	Y	Y	N	Y - Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit	N	Y	Y	n/a	N	Y	N	Y -Left turn from Hamilton Rd	Y	Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit
Chermside E	301653	3/4		Island Platform	55m (Stops D, E & F)	N	N	Y	Y	Y	Y	Y	N	Y - Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit	N	Y	Y	n/a	N	Y	N	Y -Left turn from Hamilton Rd	Y	Roadworks required at Hamilton Rd intersection and internal road for buses (14.5 & 18.0m) to enter and exit
Carindale A	306446	3		Saw Tooth	20	Y	Y	Y	Y	Y	Y	Full lock required to leave stop	Y	Y - If a bus is in Stop E possible that the entrance could be blocked	Y	Y	Y	Y	N	N - Column in hardstand area	N/A	N	Y	
Carindale B	306447	3		Saw Tooth	19	Y	Y	Y	Y	Y	Y	Full lock required to leave stop. If an Articulated bus is in the stop in front stops departure is blocked	y	Y - If a bus is in Stop E possible that the entrance could be blocked	Y	Y	Y	Y	N	N - Column in hardstand area	N	N	Y	
Carindale C	306448	3		Saw Tooth	19	Y	Y	Y	Y	Y	Y	Full lock required to leave stop	y	Y - If a bus is in Stop E possible that the entrance could be blocked	Y	Y	Y	Y	N	N - Column in hardstand area	N	N	Y	
Carindale D	306449	3		Saw Tooth	9	N	N	Y	Y	Y		Full lock required to leave stop	N/A	Y - If a bus is in Stop E possible that the entrance could be blocked	Y	N/A	Y	Y	N	N - Column in hardstand area	N/A	N	Y	
Carindale E	306450	3		Saw Tooth	13.5	N	N	Y	Y	Y	Bus cannot enter stop due to design	Full lock required to leave stop. If an Articulated bus is in the stop in front stops departure is blocked	N/A	Y - If a bus is in Stop E possible that the entrance could be blocked	N	N/A	Y	Y	N	N - Column in hardstand area	N/A	N	Y	
Carindale F	306445	3		Saw Tooth	22.5	Y	Y	Y	Y	Y	y	Full lock required to leave stop	y	Y - If a bus is in Stop E possible that the entrance could be blocked	Y	Y	Y	Y	N	N - Front area has gully grate in hardstand area	N	N	Y	
Carindale G	306444	3		Saw Tooth	19.5	Y	Y	Y	Y	Y	y	Full lock required to leave stop	y	Y - If a bus is in Stop E possible that the entrance could be blocked	Y	Y	Y	Y	N	y	N	N	Y	
Carindale H	306443	3		Saw Tooth	11	N	N	Y	Y	Y	y	Full lock required to leave stop. If an Articulated bus is in the stop in front stops departure is blocked	N/A	Y -If a bus is in Stop E possible that the entrance could be blocked	Y	N/A	Y	Y	N	y	N/A	N	Y	
Carindale I	306441	3		Saw Tooth	11.5	N	N	Y	Y	Y	y	Full lock required to leave stop. If an Articulated bus is in the stop in front stops departure is blocked	N/A	Y - If a bus is in Stop E possible that the entrance could be blocked	Y	N/A	Y	Y	N	y	N/A	N	Y	
Carindale J	306442	3		Saw Tooth	30	Y	Y	Y	Y	Y	y	Full lock required to leave stop. If an Articulated bus is in the stop in front stops departure is blocked	y	Y - If a bus is in Stop E possible that the entrance could be blocked	Y	Y	Y	Y	N	y	N	N	Y	
Garden City A	300518	3		IN-Line	12.5	N	N	Y	Y	Y	y	y	N - To Short	Y - Manoeuvring tight if bus in Stop A	Y	N	Y	n/a	N	Y	N	N	Y	To short
Garden City B	300511	3		IN-Line		N	N	Y	Y	Y	y	y	N - To Short - Pedestrian crossing at rear	Y - Manoeuvring tight if bus in Stop A	Y	N	Y	n/a	N	Y	N	N	Y	To short Pedestrian croossing at rear
Garden City C	300513	3		IN-Line	98	Y	Y	Y	Y	Y	y	y	Y	Y - Manoeuvring tight if bus in Stop A	Y	N	Y	n/a	N	Y	N	N	Y	
Garden City D	300512	3		IN-Line		Y	Y	Y	Y	Y	Y	Y	Y	Y - Manoeuvring tight if bus in Stop A	Y	N	Y	n/a	N	Y	N	N	Y	
Garden City E	300510	3		IN-Line		Y	Y	Y	Y	Y	Y	Y	Y	Y - Manoeuvring tight if bus in Stop A	Y	N	Y	n/a	N	Y	N	N	Y	
Garden City F	300514	3		Island Platform		N	N	Y	Y	Y	Y	Y	N - To Short - Pedestrian crossing at rear	Y - Manoeuvring tight if bus in Stop A	Y	N	Y	n/a	N	Y	N	N	Y	To short Pedestrian croossing at rear
Garden City G	300515	3		Island Platform	93	Y	Y	Y	Y	Y	Y	Y	Y	Y - Manoeuvring tight if bus in Stop A	Y	N	Y	n/a	N	Y	N	N	Y	
Garden City H	300516	3		Island Platform		Y	Y	Y	Y	Y	Y	Y	Y	Y - Manoeuvring tight if bus in Stop A	Y	N	Y	n/a	N	Y	N	N	N/A	
Garden City I	300517	3		Island Platform		Y	Y	Y	Y	Y	Y	Exit taper not long enough existing buses hitting kerb	Y	Y - Manoeuvring tight if bus in Stop A	Y	Y	Y	n/a	N	Y	N	N	Y	Bus has to leave on full lock
Garden City J	300519	3		Indented in-line	70	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	n/a	N	Y	N	N	Y	
Garden City K	300520	3		Indented in-line		Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	n/a	N	Y	N	N	Y	
Garden City L	300524	3		Indented in-line		Y	Y	Y	Y	Y	Y	Exit taper short	Y	N	Y	Y	Y	n/a	N	Y	N	N	Y	Bus has to leave on full lock
Garden City M	300523	3		Indented in-line	91	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	n/a	N	Y	N	N	Y	
Garden City N	300522	3		Indented in-line		Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	n/a	N	Y	N	N	Y	
Garden City O	300521	3		Indented in-line		Y	Y	Y	Y	Y	Y	Y	N - Close to sognals	N	Y	N	Y	n/a	N	Y	N	N	Y	Close to signals
Toombul A	300076	2/3		Island Platform	55m (Stops A, B & C)	N	N	Y	Y	Y	Northbound buses (14.5m & 18.0m) cannot enter station	Y	N - 14.5m & 18.0m Buses canot manoeuvre into stops	N/A	N/A	N/A	N - 14.5m & 18.0m Buses cannot enter station when heading to north	n/a	N	Y	N	N	Y	Site very tight for manoeuvring. Road widening required for buses to enter station.
Toombul B	300077	2/3		Island Platform	55m (Stops A, B & C)	N	N	Y	Y	Y	Northbound buses (14.5m & 18.0m) cannot enter station	Y	N - 14.5m & 18.0m Buses canot manoeuvre into stops	N/A	N/A	N/A	N - 14.5m & 18.0m Buses cannot enter station when heading to north	n/a	N	Y	N	N	Y	Site very tight for manoeuvring. Road widening required for buses to enter station.
Toombul C	300080	2/3		Island Platform	55m (Stops A, B & C)	N	N	Y	Y	Y	Northbound buses (14.5m & 18.0m) cannot enter station	Y	N - 14.5m & 18.0m Buses canot manoeuvre into stops	N/A	N/A	N/A	N - 14.5m & 18.0m Buses cannot enter station when heading to north	n/a	N	Y	N	N	Y	Site very tight for manoeuvring. Road widening required for buses to enter station.
Toombul D	300078	2/3		Island Platform	55m (Stops D, E & F)	N	N	Y	Y	Y	Northbound buses (14.5m & 18.0m) cannot enter station	Y	N - 14.5m & 18.0m Buses canot manoeuvre into stops	N/A	N/A	N/A	N - 14.5m & 18.0m Buses cannot enter station when heading to north	n/a	N	Y	N	N	Y	Site very tight for manoeuvring. Road widening required for buses to enter station.

Toombul E	300079	2/3		Island Platform	55m (Stops D, E & F)	N	N	Y	Y	Y	Northbound buses (14.5m & 18.0m) cannot enter station	Y	N - 14.5m & 18.0m Buses canot manoeuvre into stops	N/A	N/A	N/A	N - 14.5m & 18.0m Buses cannot enter station when heading to north	n/a	N	Y	N	N	Y	Site very tight for manoeuvring. Road widening required for buses to enter station.
Toombul F	300259	2/3		Island Platform	55m (Stops D, E & F)	N	N	Y	Y	Y	Northbound buses (14.5m & 18.0m) cannot enter station	Y	N - 14.5m & 18.0m Buses canot manoeuvre into stops	N/A	N/A	N/A	N - 14.5m & 18.0m Buses cannot enter station when heading to north	n/a	N	Y	N	N	Y	Site very tight for manoeuvring. Road widening required for buses to enter station.
Indooroopilly A	303898	2/3		kerbside	23	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	No - 4.0m clearance	N	Y	N	N	N/A	
Indooroopilly B	303899	3/2		central platform	14	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	No - 4.0m clearance	N	Y	N	N	N/A	Too short
Indooroopilly C	303900	3/2		kerbside	27	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	No - 4.6m clearance	N	Y	N	N	N/A	
Aspley Hypermarket A	302989	4		Saw tooth	14.2	N	N	Y	Y	Y	Y	Y	No if 14.05m or acticulated bus in front stop bus cannot leave	Y - Bus in Stop D could block entrance	Y	N	Y	n/a	N	Y	n/a	N	n/a	
Aspley Hypermarket B	302988	4		Saw tooth	14.4	N	N	Y	Y - Stop has sign at rear of stop	Y	Y	Y	No if 14.05m or acticulated bus in front stop bus cannot leave	Y - Bus in Stop D could block entrance	Y	N	Y	n/a	N	Y	n/a	N	n/a	
Aspley Hypermarket C	302987	4		Saw tooth	15.1	N	N	Y	Y	Y	Y	Y	No if 14.05m or acticulated bus in front stop bus cannot leave	Y - Bus in Stop D could block entrance	Y	N	Y	n/a	N	Y	n/a	N	n/a	
Aspley Hypermarket D	302986	4		Saw tooth	30	Y	Y	Y	Y	Y	Y	Y	No if 14.05m or acticulated bus in front stop bus cannot leave	Y - Bus in Stop D could block entrance	Y	N	Y	n/a	N	Y	N	N	n/a	Only Stop D Suitable for 14.5m or Artic. Buses
UQ Chancellors Place A	303579	2		Sawtooth	11.8	N	N	Y	Y	Y	Two rounabouts to manouvre through very tight	Y - Two rounabouts to manouvre through very tight	Y	N	Y	N	Y - Two rounabouts to manouvre through very tight	n/a	N	Y	N	N	Y	Stop to short
UQ Chancellors Place B	303583	2		Sawtooth	11.8	N	N	Y	Y	Y	Two rounabouts to manouvre through very tight	Y - Two rounabouts to manouvre through very tight	Y	N	Y	N	Y - Two rounabouts to manouvre through very tight	n/a	N	Y	N	N	Y	Stop to short
UQ Chancellors Place C	303582	2		Sawtooth	14	N	N	Y	Y	Y	Two rounabouts to manouvre through very tight	Y - Two rounabouts to manouvre through very tight	Y	N	Y	N	Y - Two rounabouts to manouvre through very tight	n/a	N	Y	N	N	Y	Stop to short
UQ Chancellors Place D	303581	2		Sawtooth	13	N	N	Y	Y	Y	Two rounabouts to manouvre through very tight	Y - Two rounabouts to manouvre through very tight	Y	N	Y	N	Y - Two rounabouts to manouvre through very tight	n/a	N	Y	N	N	Y	Stop to short
UQ Chancellors Place E	303580	2		Sawtooth	14	N	N	Y	Y	Y	Two rounabouts to manouvre through very tight	Y - Two rounabouts to manouvre through very tight	Y	N	Y	N	Y - Two rounabouts to manouvre through very tight	n/a	N	Y	N	N	Y	Stop to short
Inala Bus Station A	300550	5		Sawtooth	15	N	N	Y	Y	Y	Y	Y	Y	Y - If 14.5 or Artic in Stops B or C buses cannot pass	Y	N	Y	n/a	N	Y	N	N	Y	Too short
Inala Bus Station B	300549	5		Sawtooth	13	N	N	Y	Y	Y	Y	Y	N - Canot exit if 14.5m or artic bus in front stop	Y - If 14.5 or Artic in Stops B or C buses cannot pass	Y	N	Y	n/a	N	Y	N	N	Y	Too short
Inala Bus Station C	300548	5		Sawtooth	12	N	N	Y	Y	Y	Y	Y	N - Canot exit if 14.5m or artic bus in front stop	Y - If 14.5 or Artic in Stops B or C buses cannot pass	Y	N	Y	n/a	N	Y	N	N	Y	Too short
Inala Bus Station D	300547	5		Sawtooth	15	Y	N	Y	Y	Y	Y	Y	N - Canot exit if 14.5m or artic bus in front stop	Y - If 14.5 or Artic in Stops B or C buses cannot pass	Y	N	Y	n/a	N	Y	N	N	Y	
Inala Bus Station E	300546	5		In-Line	27	Y	Y	No Gully pit and garden bed in way	No - close to kerb	Y	Y	Y	Y	N/A	Y	N	Y	n/a	N	N - Very narrow	Y -Garden Bed	N	Y	Narrow hardstand
Capalaba Platform A	400302	5		Kerbside with large island platform	32	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N/A	Y - Awning close to kerb	Y	N	N - Yes but bus can turn clear of them	Y	
Capalaba Platform B	400303	5		Kerbside with large island platform	36	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N/A	Y - Awning close to kerb	Y	N	N - Yes but bus can turn clear of them	Y	
Capalaba Platform C	400304	5		Kerbside with large island platform	33	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N/A	Y - Awning close to kerb	Y	N	N - Yes but bus can turn clear of them	Y	
Capalaba Platform D	400301	5		Kerbside with large island platform	29	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N/A	Y - Awning close to kerb	Y	N	N - Yes but bus can turn clear of them	Y	
Capalaba Platform E	400376	5		Kerbside in bus lane	30	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Springwood Platform 1	200337	5		Indented	37	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Springwood Platform 2	201026	5		Kerbside	32	N	N	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Springwood Platform 3	200338	5		Indented	21.5	N	N	Y	Y	Y	Y	Y	N - Stop not long enough	N	N	N/A	No Back would stick out	N/A	N	Y	N	N	Y	
Loganholme Stop A	200599	6		Sawtooth Island Platform	14	N	N	Y	Y	Y	Y	Y	N - To short for artic	N/A	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Loganholme Stop B	200600	6		Sawtooth Island Platform	20	N	N	Y	Y	Y	Y	Full lock required to leave stop. If an Articulated bus or 14.5m bus is in the stop in front stops departure is blocked	N - Full lock required to leave stop. If an Articulated bus or 14.5m bus is in the stop in front stops departure is blocked	N	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Loganholme Stop C	200601	6		Sawtooth Island Platform	12	N	N	Y	Y	Y	Y	Full lock required to leave stop. If an Articulated bus or 14.5m bus is in the stop in front stops departure is blocked	N - Full lock required to leave stop. If an Articulated bus or 14.5m bus is in the stop in front stops departure is blocked	N	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Loganholme Stop D	200602	6		Sawtooth Island Platform	14	N	N	Y	Y	Y	Y	Y	Y	N	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Loganholme Stop E	201134	6		Sawtooth Island Platform	13.5	N	N	Y	Y	Y	Y	y	N - To short for artic	N	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Loganholme Stop F	200596	6		Sawtooth Island Platform	19	N	N	Y	Y	Y	Y	Full lock required to leave stop. If an Articulated bus or 14.5m bus is in the stop in front stops departure is blocked	N - Full lock required to leave stop. If an Articulated bus or 14.5m bus is in the stop in front stops departure is blocked	N	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Loganholme Stop G	200597	6		Sawtooth Island Platform	12	N	N	Y	Y	Y	Y	Full lock required to leave stop. If an Articulated bus or 14.5m bus is in the stop in front stops departure is blocked	N - Full lock required to leave stop. If an Articulated bus or 14.5m bus is in the stop in front stops departure is blocked	N	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	
Loganholme Stop H	200598	6		Sawtooth Island Platform	13.5	N	N	Y	Y	Y	Y	Y	N - To short for artic	N	Y	N	Y	N/A	N	Y	N	N - Yes but bus can turn clear of them	Y	

Appendix B: Assessment of Bus Stop Infrastructure

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Technical Note

Subject:	Assessment of Bus Stop Infrastructure
Project:	Research and Analysis of High Capacity Vehicles
Our file:	4749 Date: 25 May 2012
Status:	Draft Prepared by: RB, JV

Table of Contents

1. Introduction

1.1 Background

MRCagney has been appointed by *TransLink Transit Authority (TransLink)* to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

1.2 Purpose of this Technical Note

The main purpose of this technical note is to provide a high-level assessment of the suitability of existing bus stop infrastructure to accommodate HCVs within the next five years (i.e. by 2017). This estimate was developed using a sample of bus routes as is discussed in the following section.

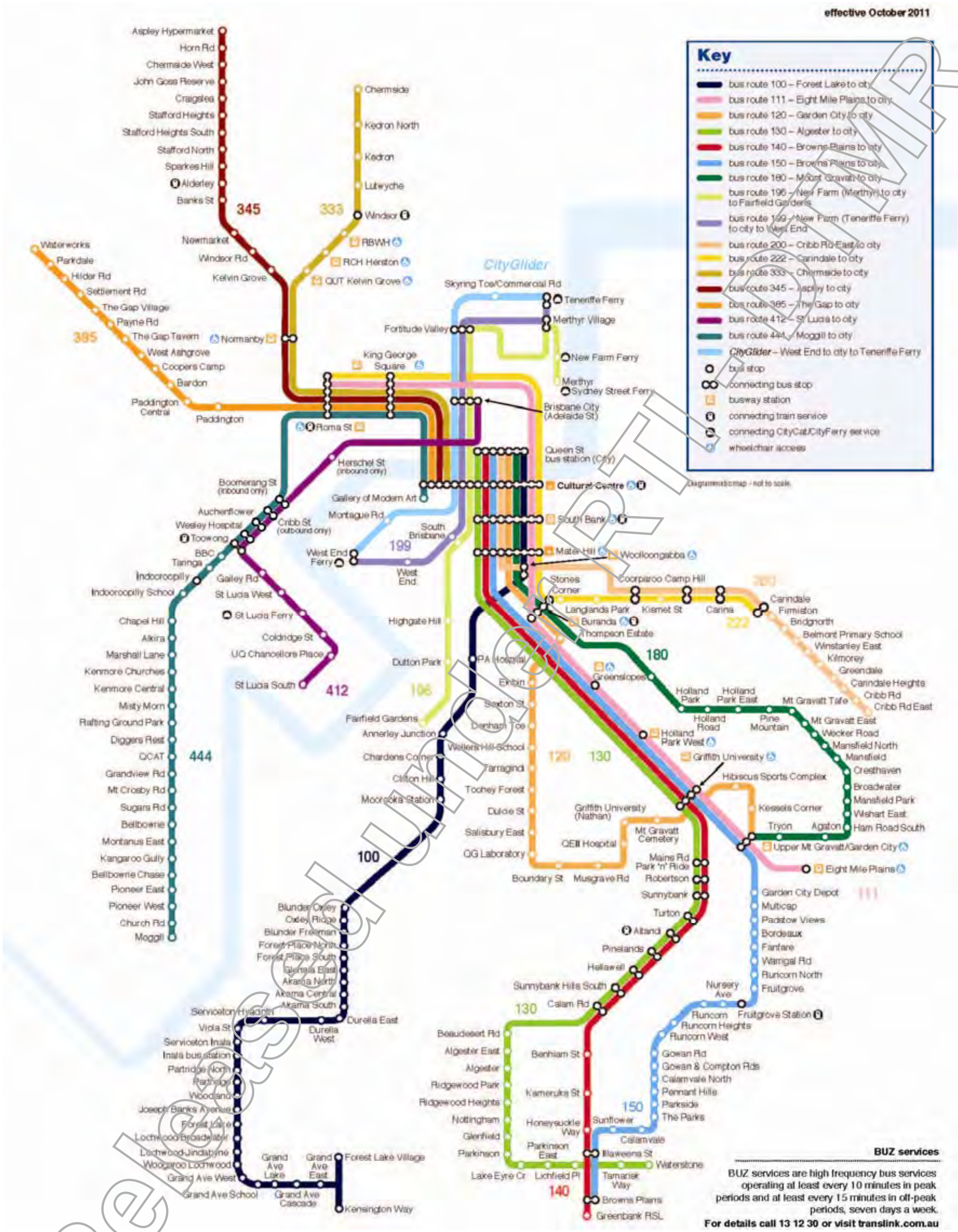
2. Infrastructure Assessment Methodology

To assess the impact HCVs might have on existing bus stop infrastructure, the following assessment methodology was undertaken.

1. All bus stops along selected routes in the BUZ network were identified
2. The type of bus stop was identified using Chapter 2 of the Public Transport Infrastructure Manual (June 2007)
3. The ability for HCVs to enter and exit stops was assessed using AutoTURN software with a TransLink 14.5m Rigid Bus Tag Steer as the design vehicle.
4. Using available aerial imagery, the following attributes of each bus stop were assessed:
   a. The stop shape, length, length of any tapers using available aerial imagery
   b. Pavement line marking
   c. Whether the stop could be lengthened. If it was possible, to what length could it be extended? Could it be lengthened to 65m to allow a 14.5m rigid and an 18m articulated bus to park together and easily manoeuvre out of the stop?
   d. Whether the rear door of the bus was clear of obstructions
   e. If the Stop Blade or Sign was clear of the kerb
   f. If the rubbish bin was clear of the kerb
   g. Were the approaches and departures clear of obstructions
   h. Could the bus stop allow a 14.5m rigid enter and exit the stop safely? (Where bus stops were not clearly marked out, it was assessed whether bus stops could be lengthened to allow the design vehicle to exit safely.
   i. Could the bus stop allow
   j. Were there Regulatory signs before and after the bus stop
   k. Could the bus stop parallel to the kerb
   l. Did the bus stop have a hardstand area clear of obstructions for all doors
   m. Any general observations made.

The bus stop infrastructure which was assessed was selected from the TransLink BUZ network as shown in the following figure. The routes within the BUZ network were considered to provide a reasonable sample of routes which are likely to run HCVs within the next five years.

Figure 1: TransLink BUZ Network



The bus stops on the following BUS routes were assessed as a sample of SEQ's bus stop infrastructure:

- Bus route 100 – Forest Lake to city
- Bus route 140 – Brown Plains to city
- Bus route 150 – Brown Plains to city
- Bus route 130 – Algester to city

- Bus route 120 – Garden City to city
- Bus route 180 – Mount Gravatt to city
- Bus route 385 – The Gap to City

3. Bus Stop Infrastructure Assessment

3.1 Summary of findings

As part of this assessment, 444 bus stops were surveys and the aggregated results are as follows:

Aggregated Survey Results

Stop Type	Regular	91%	Premium	8%	No image	0%
Stop Shape	Kerbside	88%	Indented	9%	Indented(other)	3%
Can the stop be lengthened?	Yes	19%	No	31%	N/A	50%
Is rear door clear of obstructions?	Yes	76%	No	15%	No image	9%
Is Stop Blade or Sign clear of Kerb?	Yes	95%	N/A	2%	No image	3%
Is approach clear of obstructions?	Yes	99%	No	1%	N/A	0%
Is departure clear of obstructions?	Yes	99%	No	1%	N/A	0%
Can the bus stop allow buses to enter and exit safely?	Yes	99%	No	1%	N/A	0%
Can bus stop parallel to kerb?	Yes	99%	No	1%	N/A	0%
Does the stop have a hardstand area clear of obstructions for all doors?	Yes	31%	No	21%	N/A	0%
	Front only	42%	No hardstand	1%		
Is the bus stop >=65m length?	Yes	0%	No	37%	N/A	63%
If the bus stop can be extended, can the stop be extended to 65m?	Yes	49%	No	46%	N/A	5%
Are there road markings at the stop?	No	77%	Rear only	4%	No image	4%
	Both front and rear	12%	Front only	3%		

Of the 444 stops, 8% are premium and the rest are regular stop types. The stop shape most common is kerbside, with only 12% being indented. We were only able to determine that 19% of stops can be lengthened.

The rear door was identified as being clear of obstructions in 76% of stops, while it was obstructed in 15%. The air photos did not reliably show the balance of stops. Nearly all stops were clear of obstructions on approach and departure and allowed a bus to enter and exit the stop safely. Also at nearly every stop, the bus could stop parallel to the kerb.

Nearly one third of all stops had a hardstand area clear of obstruction for all doors, with 21% being obstructed. At 42% of stops only the front doors were clear of obstructions.

No stops were identified as being longer than 65 metres which would make them capable of use by HCV. However half of stops could be extended to 65m. At 77% of stops there were no road markings, while 12% had markings at both rear and front.

3.2 Bus route 100 – Forest Lake to City

Route 100 travels from Forest Lake to the City and has 68 total stops. Most of the stops are regular, while three of them are premium stops. Most stops are kerbside stops, while only 11 are indented. There are no turnaround stops. For only 16 stops was it able to be determined that they could be lengthened. For 51 stops we were unable to determine this.

For 66 stops it was determined that the rear door was clear of obstructions. For all stops it was determined that the stop blade or sign is clear of the kerb. Also for all stops it was determined that the approach and departure are clear of obstacles. Only one stop presented difficulties for a bus safely entering or exiting the stop. Only one stop presented difficulties for a bus stopping parallel to a kerb.

Only 16 stops have a hardstand area clear of obstruction for all doors, while 34 had a front only hardstand. There are 15 stops without a hardstand clear of obstruction for all doors.

Of all stops 21 are less than 65 metres in length. It appears 38 stops can be extended to 65 metres, while 28 cannot. There are no road markings at 53 stops, both front and rear markings at 11 and rear only at 2.

Route 100

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	65	Premium	3	Park&Ride	0	No image	0
Stop Shape	Kerbside	57	Indented	11	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	16	No	1	N/A	51	No image	0
Is rear door clear of obstructions	Yes	66	No	2	N/A	0	No image	0
Is Stop Blade or Sign clear of Kerb	Yes	68	No	0	N/A	0	No image	0
Approach clear of obstructions	Yes	68	No	0	N/A	0	No image	0
Departure clear of obstructions	Yes	68	No	0	N/A	0	No image	0
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	67	No	1	N/A	0	No image	0
Can bus stop parallel to kerb	Yes	67	No	1	N/A	0	No image	0
Does the stop have a hardstand area clear of obstructions for all doors	Yes	16	No	15	N/A	0	No image	0
	Front Only	34	No Hardstand	0	None	3	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	21	N/A	47		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	38	No	28	N/A	2		
Are there road markings at the stop?	No	53	Rear only	2	N/A	2		
	Both front and rear	11	Front only	0				

3.3 Bus route 140 – Brown Plains to City

Bus route 140 travels from Brown Plains to the City, with 32 stops. Of all stops 29 are regular, 1 is premium and 2 are park and rides. Of these 30 are kerbside stops, while 2 are indented.

Only 15 stops were determined to be able to be lengthened, while 6 were not. There were 11 stops where we could not determine this. All stops had a rear door clear of obstructions, an approach and departure clear of obstructions. For all stops a bus was determined to be able to safely enter and exit the stop safely and the bus could stop parallel to the kerb.

Of all stops 21 had a hardstand area clear of obstructions for all doors, while 2 did not. There were 9 stops that had a clear hardstand area for front doors only. 17 stops could not be lengthened while we could not determine this for the remainder.

Of all stops 17 are less than 65 metres in length. It appears 15 stops can be extended to 65 metres, while 13 cannot. There are no road markings at 16 stops, both front and rear markings at 12.

Route 140

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	29	Premium	1	Park&Ride	2	No image	0
Stop Shape	Kerbside	30	Indented	2	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	15	No	6	N/A	11	No image	0
Is rear door clear of obstructions	Yes	32	No	0	N/A	0	No image	0
Is Stop Blade or Sign clear of Kerb	Yes	32	No	0	N/A	0	No image	0
Approach clear of obstructions	Yes	32	No	0	N/A	0	No image	0
Departure clear of obstructions	Yes	32	No	0	N/A	0	No image	0
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	32	No	0	N/A	0	No image	0
Can bus stop parallel to kerb	Yes	32	No	0	N/A	0	No image	0
Does the stop have a hardstand area clear of obstructions for all doors	Yes	21	No	2	N/A	0	No image	0
	Front Only	9	No Hardstand	0	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	17	N/A	15		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	15	No	13	N/A	4		
Are there road markings at the stop?	No	16	Rear only	0	N/A	4		
	Both front and rear	12	Front only	0				

3.4 Bus route 150 – Brown Plains to City

Bus route 150 also travels from Brown Plains to the City with 45 stops. There are 4 indented stops while the balance is kerbside stops. We determined that 6 stops could be lengthened and that 7 could not. We were not able to determine whether the remaining 33 could be altered for length.

For 4 stops the rear door was clear of obstructions while 2 were not. We could not determine whether 10 stops were clear of obstructions. For 41 stops the stop blade or sign is clear of the kerb, but for 5 we were unable to determine this.

All stops were clear of obstructions for approach and departure, the bus was able to enter and exit the stop safely and the bus could stop parallel to the kerb. In terms of a hardstand area clear of obstructions for all doors 22 stops had this for the front only, 15 for all doors and 7 did not have this. We were unable to determine this for one stop.

Of all stops 14 are not greater than 65m. There are 29 stops which may be lengthened and 12 which cannot. There are 43 stops with no road markings and we could not determine this for the balance.

Route 150

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	44	Premium	1	Park&Ride	0	No image	1
Stop Shape	Kerbside	42	Indented	4	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	6	No	7	N/A	33	No image	0
Is rear door clear of obstructions	Yes	34	No	2	N/A	0	No image	10
Is Stop Blade or Sign clear of Kerb	Yes	41	No	0	N/A	2	No image	3
Approach clear of obstructions	Yes	45	No	0	N/A	0	No image	1
Departure clear of obstructions	Yes	45	No	0	N/A	0	No image	1
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	45	No	0	N/A	0	No image	1
Can bus stop parallel to kerb	Yes	45	No	0	N/A	0	No image	1
Does the stop have a hardstand area clear of obstructions for all doors	Yes	15	No	7	N/A	0	No image	1
	Front Only	22	No Hardstand	0	None	0	Unknown	1
Is the bus stop >=65m length?	Yes	0	No	14	N/A	32		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	29	No	12	N/A	5		
Are there road markings at the stop?	No	43	Rear only	0	N/A	46		
	Both front and rear	0	Front only	0				

3.5 Bus route 130 – Algester to City

Bus route 130 travels from Algester to the City with 74 stops. There are 66 regular stops, 6 premium stops and 2 park and ride stops. Of these stops 66 are kerbside while 8 are indented. We were able to determine that 7 stops could be lengthened, 19 could not and were unable to determine whether the remaining 48 could be lengthened or not.

Nearly all stops have a blade or sign clear of the kerb, while 1 does not and we were unable to determine this for 7 stops. For 71 stops the departure is clear of obstructions, while 72 stops the approach is also clear. We could not determine this for 2 stop in each category. We determined that the bus can stop parallel to the kerb at 73 stops, but could not tell for 1 stop.

At 23 stops the hardstand area is clear of obstructions for all doors, but this is not the case for 10 stops. The front doors were clear for 37 stops. We could not determine this for 4 stops.

14 bus stops were less than 65 metres in length. We could not determine the length of 60 stops. 46 stops could be lengthened, while 26 could not. 64 stops had no road markings, 7 had both front and rear markings and 1 stop had rear and another front only.

Route 130

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	66	Premium	6	Park&Ride	2	No image	0
Stop Shape	Kerbside	66	Indented	8	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	7	No	19	N/A	48	No image	0
Is rear door clear of obstructions	Yes	54	No	10	N/A	0	No image	10
Is Stop Blade or Sign clear of Kerb	Yes	66	No	1	N/A	4	No image	3
Approach clear of obstructions	Yes	72	No	0	N/A	0	No image	2
Departure clear of obstructions	Yes	71	No	1	N/A	0	No image	2
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	72	No	0	N/A	0	No image	2
Can bus stop parallel to kerb	Yes	73	No	0	N/A	0	No image	1
Does the stop have a hardstand area clear of obstructions for all doors	Yes	23	No	10	N/A	0	No image	4
	Front Only	37	No Hardstand	0	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	14	N/A	60		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	46	No	26	N/A	2		
Are there road markings at the stop?	No	64	Rear only	1	N/A	1		
	Both front and rear	7	Front only	1				

3.6 Bus route 120 – Garden City to City

Bus Route 120 travels from Garden City to the City with 61 stops. Of all stops 59 are regular and 2 are premium. There are 57 kerbside stops and 4 indented. Only 5 stops were able to be lengthened, while 23 were not able to be and we could not determine this for 33 stops.

At 39 stops the rear door is clear of obstructions, while it is obstructed at 23 stops. We could not determine this for 33 stops. At 57 stops the blade or sign is clear of the kerb, but we could not determine this at 4 stops.

At 58 stops the approach is clear of obstructions, while 1 approach is impeded and we could not determine this either way for 2 stops. At 59 stops the departure is clear of obstructions, while we could not determine this for 2 stops. For 58 stops the bus was able to stop parallel to the kerb, but not at one stop and we could not determine this at 2 stops.

The hardstand area is clear of obstructions at 15 stops, not clear at 18 stops and is clear for the front only at 24 stops. We could not determine this for 4 stops.

10 stops are less than 65 metres in length and we could not determine this for the balance. 31 stops can be lengthened to 65 metres, while 23 cannot. There are road markings on both front and rear at 2 stops, no markings at 51 stops and one stop has rear markings and another front markings.

Route 120

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	59	Premium	2	Park&Ride	0	No image	0
Stop Shape	Kerbside	57	Indented	4	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	5	No	23	N/A	32	No image	1
Is rear door clear of obstructions	Yes	39	No	16	N/A	0	No image	6
Is Stop Blade or Sign clear of Kerb	Yes	57	No	0	N/A	1	No image	3
Approach clear of obstructions	Yes	58	No	1	N/A	0	No image	2
Departure clear of obstructions	Yes	59	No	0	N/A	0	No image	2
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	57	No	2	N/A	0	No image	2
Can bus stop parallel to kerb	Yes	58	No	1	N/A	0	No image	2
Does the stop have a hardstand area clear of obstructions for all doors	Yes	15	No	18	N/A	0	No image	4
	Front Only	24	No Hardstand	0	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	10	N/A	51		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	31	No	23	N/A	7		
Are there road markings at the stop?	No	51	Rear only	1	N/A	6		
	Both front and rear	2	Front only	1				

3.7 Bus route 180 – Mount Gravatt to City

Bus Route 180 travels from Mount Gravatt to the City with 98 stops. Of all stops 87 are regular and 11 are premium. Most stops are kerbside while only 5 are indented. We determined that 30 stops could be lengthened, 46 could. We were not able to determine this for 22 stops.

At 70 stops the rear door is clear of obstructions, while it is impeded at 18. We could not determine this at 10 stops. At 95 stops the blade or sign was clear of the kerb, and we could not determine this for 3 stops.

Only 1 stop had an approach that was not clear of obstructions and all stops had a departure that was clear of obstructions. At all stops the bus was able to enter and safely exit the stop safely. For 96 stops the bus could stop parallel to the kerb, but not at 1 stop and we could not determine this for another 1 stop. The hardstand area was clear of obstructions for all doors at 29 stops, not clear at 15 stops and clear for the front only at 44 stops. One stop did not have a hardstand. We were not able to determine this for 9 stops.

60 stops are less than 65 metres while we could not determine this measurement for 37 stops. Of all stops 39 might be lengthened to 65 metres while 52 cannot be. There are 74 stops without road markings, 4 with front and rear markings, 4 with rear only and 5 with front only markings.

Route 180

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	87	Premium	11	Park&Ride	0	No image	0
Stop Shape	Kerbside	83	Indented	5	Turnaround	0	Indented(other)	10
Can stop be lengthened	Yes	30	No	46	N/A	22	No image	0
Is rear door clear of obstructions	Yes	70	No	18	N/A	0	No image	10
Is Stop Blade or Sign clear of Kerb	Yes	95	No	0	N/A	0	No image	3
Approach clear of obstructions	Yes	97	No	1	N/A	0	No image	0
Departure clear of obstructions	Yes	98	No	0	N/A	0	No image	0
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	98	No	0	N/A	0	No image	0
Can bus stop parallel to kerb	Yes	96	No	1	N/A	0	No image	1
Does the stop have a hardstand area clear of obstructions for all doors	Yes	29	No	15	N/A	0	No image	9
	Front Only	44	No Hardstand	1	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	60	N/A	37		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	39	No	52	N/A	6		
Are there road markings at the stop?	No	74	Rear only	4	N/A			
	Both front and rear	4	Front only	5				

3.8 Bus route 385 – The Gap to City

Bus Route 385 travels from the Gap to the City with 65 stops. Of all stops 54 are regular and 11 are premium stops. There were 54 kerbside stops, 8 indented, 1 turnaround and 2 indented (other). We determined that 7 stops could be lengthened, 34 could not and we could not determine this for 24 stops.

At 43 stops the rear door was clear of obstruction, while it was not clear at 19 and we could not determine this for 3 stops. At all stops the blade or sign was clear of the kerb. At 64 stops the bus had an approach and departure clear of obstructions, but we could not determine this at 1 stop. The bus could enter and exit safely at 64 stops but not at 1 stop. At 64 stops the bus could stop parallel to the kerb, but not at 1 stop.

The hardstand area was clear of all obstructions for all doors at 20 stops, not clear at 27, the front door was clear only at 15 stops and we were not able to determine this for 3 stops.

26 stops are less than 65 metres in length while 1 is greater than 65 metres. 16 stops can be extended to 65 metres, while 48 cannot. There are 11 stops with markings at the front and rear, 5 with front only and 10 with rear only. We could not determine this for 38 stops.

Route 385

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	54	Premium	11	Park&Ride	0	No image	0
Stop Shape	Kerbside	54	Indented	8	Turnaround	1	Indented(other)	2
Can stop be lengthened	Yes	7	No	34	N/A	24	No image	0
Is rear door clear of obstructions	Yes	43	No	19	N/A	0	No image	3
Is Stop Blade or Sign clear of Kerb	Yes	65	No	0	N/A	0	No image	0
Approach clear of obstructions	Yes	65	No	0	N/A	0	No image	0
Departure clear of obstructions	Yes	64	No	0	N/A	0	No image	1
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	64	No	0	N/A	0	No image	1
Can bus stop parallel to kerb	Yes	64	No	1	N/A	0	No image	0
Does the stop have a hardstand area clear of obstructions for all doors	Yes	20	No	27	N/A	0	No image	3
	Front Only	15	No Hardstand	0	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	1	No	26	N/A	38		
Can the stop be extended to 65m?	Yes	16	No	48	N/A	1		
Are there road markings at the stop?	No	0	Rear only	10	N/A	38		
	Both front and rear	11	Front only	5				

4. Summary and Conclusions

This technical note reviews bus routes 100, 140, 150, 130, 120, 180 and 385 to assess the capacity of existing stop infrastructure along these routes to accommodate HCVs. These routes were selected as representative of the overall network.

Our analysis of stops is based on a desktop review of aerial photos. While suitable for a high level analysis of a network, an on-site review of each stop is recommended to verify our results on the ground prior to confirming any routes for HCVs. We were unable to perform an aerial photo analysis on a proportion of stops for key categories (i.e. ability to lengthen a stop) because of photo quality or obscured stop images.

Our overall findings are summarised as follows:

- Overall results indicate that stops are nearly all clear of obstructions on approach and on departure of buses.
- Most stops are regular kerbside stops.
- Many stops are unable to be lengthened; however we were unable to assess this for nearly half of all stops.
- The blade or sign is clear of the kerb at nearly all stops and the rear door would be clear at nearly three quarters of all stops.
- Nearly all stops allow buses to stop parallel to the kerb.
- Nearly one third of all stops had a hardstand area clear of obstruction for all doors, with 21% being obstructed. At 42% of stops only the front doors were clear of obstructions.
- Only one stop appears to be greater than 65 metres in length.
- Half of stops can be lengthened to 65 metres.
- Three quarters of stops have no road markings at front or rear.

The ability for the 444 stops along existing BUZ routes to accommodate HCVs without upgrades varies considerably and we were unable to determine some measurements for all stops. Route planning will need to be influenced by a ground-verified knowledge of the capacity of individual stops to accommodate HCVs that this technical note begins to deliver.

Attachment 1: Audit Results

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
	Route 100																			
	Forest Lake Bvd	300555	5	Premium	South-North	Indented	Yellow Line Marking	55	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	20	No	Yes	Yes
	Forest Lake Bvd	300425	5	Regular	North-South	Indented	Yellow Line Marking	40	Yes	Yes	yes	yes	Yes	Yes	Yes	25	20	No	yes	Yes
	Kensington Way	303041	5	Regular	West-East	Indented	None	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	20	No	Yes	Front Only
	Kensington Way	303042	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Grand Ave East	303043	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Grand Ave East	303053	5	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave Cascade	303044	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave Cascade	303052	5	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave Lake	303045	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Grand Ave Lake	303051	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave School	303046	5	Regular	East-West	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Grand Ave School	303050	5	Regular	West-East	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Grand Ave West	303047	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave West	303049	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Woogaroo - Lochwood	303048	5	Regular	North-South	Indented	None	45	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	20	No	Yes	Yes
	Woogaroo - Lochwood	300599	5	Regular	West-East	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Lochwood Jindabyne	300603	5	Regular	East-West	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Lochwood - Jindadyne	300600	5	Regular	West-East	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Lochwood Broadwater	300602	5	Regular	East-West	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Lochwood Broadwater	300601	5	Regular	West-East	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Forest Lake A	300556	5	Regular	South-North	Indented	None	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	30	No	Yes	Yes
	Forest Lake B	300423	5	Regular	North-South	Indented	None	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	30	No	Yes	Yes
	Forest Lake B	300597	5	Regular	South-North	Indented	None	37	Yes	Yes	Yes	Yes	Yes	Yes	Yes	15	15	No	Yes	Yes
	Joseph Banks Ave	300557	5	Regular	West-East	Indented	Lane Marking	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	15	No	Yes	Front Only
	Joseph Banks Ave	300422	5	Regular	East-West	Indented	Yellow Line Marking	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	15	No	Yes	No
	Woodland	300558	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Woodland	300552	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Partridge	300559	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Partridge	300551	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Partridge North	300529	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Partridge North	300544	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Serviceston Inala	300680	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Serviceston Inala	300679	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	None
	Viola Street	300681	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Viola Street	300678	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	None
	Serviceston Hyacinth	300682	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Serviceston Hyacinth	300682	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Kev Hoopwer Park	300683	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Kev Hoopwer Park	300676	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Durella West	300684	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Durella West	300693	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Durella East	300692	5	Regular	SW-NE	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Durella East	300685	5	Regular	NE-SW	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Akama South	300686	5	Regular	SE-NW	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Akama South	300691	5	Regular	NE-SW	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Akama Central	300690	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Akama Central	300687	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Akama North	300689	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Akama North	300688	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Glenala East	300666	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Glenala East	300695	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Blunder - Glenala	300655	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Forest Place Sth	300665	5	Regular	North-South	Kerbside	None	15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	12	No	Yes	Yes
	Forest Place Sth	300656	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Blunder - Freeman	300663	5	Regular	North-South	Indented	Yellow Line Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	15	Yes	Yes	Yes
	Blunder - Freeman	300658	5	Regular	South-North	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Oxley Ridge	300662	4	Regular	North-South	Kerbside	Lane Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Oxley Ridge	300659	4	Regular	South-North	Kerbside	Lane Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Blunder Oxley	300660	4	Regular	South-North	Kerbside	Yellow Line Marking	15	Yes	Yes	Yes	Yes	Yes	Yes	No	17	24	No	No	Front Only
	Blunder Oxley	300661	4	Regular	North-South	Kerbside	Lane Marking	15	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	None
	Moorooka Station	304027	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Moorooka Station	304028	3	Regular	South-North	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Clifton Hill	304034	2	Regular	North-South	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Clifton Hill	306281	2	Regular	North-South	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Annerley Junction	306289	2	Premium	South-North	Kerbside	Yellow Line Marking	50	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Annerley Junction	306279	2	Premium	North-South	Kerbside	Yellow Line Marking	50	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	PA Hospital	306271	2	Regular	North-South	Indented	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10	10	Yes	Yes	Yes
	PA Hospital	306294	2	Regular	South-North	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Route 140																			
	Greenbank RSL Stop B	201053	6	Park&Ride	West-East	Kerbside	Yellow Line parking	20	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
	Greenbank RSL Stop A	201054	6	Park&Ride	West-East	Kerbside	Yellow Line parking	20	Yes	Yes	yes	yes	yes	yes	yes	n/a	n/a	Yes	Yes	No
	Illaweena St	305475	5	Regular	North-South	Kerbside	Lane Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	35	No	Yes	Yes
	Illaweena St	305440	5	Regular	South-North	Kerbside	Lane Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	35	No	Yes	Yes
	Honeysuckle Way	305474	5	Regular	North-South	Kerbside	Lane Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	30	No	Yes	Yes
	Honeysuckle Way	305441	5	Regular	South-North	Kerbside	Lane Marking	15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	25	No	Yes	Yes
	Kameruka St	305443	5	Regular	South-North	Kerbside	Lane Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	25	No	Yes	Yes
	Kameruka St	305472	5	Regular	South-North	Kerbside	Lane Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	18	No	Yes	Yes
	Benham St	305471	5	Regular	North-South	Kerbside	Lane Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	15	35	No	Yes	Yes
	Benham St	305444	5	Regular	South-North	Kerbside	Lane Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	25	No	Yes	Yes
	Calam Rd	305489	5	Regular	South-North	Indented	Lane Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	20	Yes	Yes	Yes
	Calam rd	305476	5	Regular	North-South	Kerbside	Yellow Line parking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	15	30	Yes	Yes	Yes
	Sunnybank Hills South	305490	5	Regular	South-North	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Sunnybank Hills South	305521	5	Regular	Noth-South	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Hellawell	305520	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Hellawell	305491	5	Regular	South-North	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Pinelands	305517	4	Regular	North-South	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Pinelands	305493	4	Regular	South-North	Kerbside	Lane Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Altandi	306070	4	Premium	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
	Altandi	306356	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Pristina Street	306075	4	Regular	South-North	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Pristina Street	306069	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Turton Street	306179	4	Regular	South-North	Kerbside	None	N/a	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	yes	Yes	Yes
	Turton Street	306068	4	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	yes	Yes	Yes
	Elva Street	306076	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Elva Street	306067	4	Regular	North-South	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Sunnybank	306355	4	Regular	South-North	Kerbside	Yellow Line Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Sunnybank	306066	4	Regular	North-South	Kerbside	Yellow Line Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Robertson	306078	4	Regular	South-North	Kerbside	None	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Robertson	306064	4	Regular	North-South	Kerbside	None	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Mains Rd Park & Ride	300502	4	Regular	South-North	Indented	None	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	20	Yes	Yes	Yes
	Mains Rd Park & Ride	307092	4	Regular	Norh-South	kerbside	Lane Marking	55	No	Yes	Yes	Yes	Yes	Yes	Yes	25	N/A	Yes	Yes	Yes
	Route 150																			
Honeysuckle Wy	Sunflower	305386	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Honeysuckle Wy	Sunflower	305387	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Honeysuckle Wy	Calamvale	305385	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Honeysuckle Wy	Calamvale	305388	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Honeysuckle Wy	The Parks	305384	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Gowan Rd	The Parks	305390	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Gowan Rd	Parkside	305392	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Gowan Rd	Parkside	305411	5	Regular	North-South	Indented	None	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	18	No	Yes	Yes
Gowan Rd	Pennant Hills	305393	5	Regular	South-North	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Pennant Hills	305410	5	Regular	North-South	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Calam North	305395	5	Regular	South-North	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Calam North	305408	5	Regular	North-South	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Gowan - Compton	305407	5	Regular	North-South	Kerbside	Yellow Line Marking	30	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Gowan - Compton	305396	5	Regular	South-North	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Gowan Rd	305439	5	Regular	South-North	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Gowan Rd	Gowan Rd	305397	5	Regular	North-South	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Gowan Rd		305438	5	Regular	South-North	Kerbside	Yellow Line Marking	20	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Nemies Rd	Runcorn East	305436	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nemies Rd	Runcorn West	305398	5	No Image	No Image	Kerbside	None	N/A	N/A	No Image	No Image	No Image	No Image	No Image	No Image	N/A	N/A	No Image	No Image	No Image
Nemies Rd		305431	5	Regular	West-East	Kerbside	None	N/A	No	No image	N/A	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Nemies Rd	Runcorn Heights	305399	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nemies Rd	Runcorn Heights	305430	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nursery Ave	Runcorn	305432	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nursery Ave	Runcorn	305435	5	Regular	South-North	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nursery Ave	Nursery Avenue	305433	5	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nursery Ave	Nursery Avenue	305434	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Beenleigh Rd	Fruitgrove Station	306187	4 and 5	Regular	West-East	Indented	Yellow Line Marking	45	No	Yes	No image	*	Yes	Yes	Yes	10	5.5	No Image	Yes	Yes
Beenleigh Rd	Fruitgrove Station	306216	5 and 4	Regular	East-West	Indented	Yellow Line Marking	50	No	Yes	No image	*	Yes	Yes	Yes	10	8	No Image	Yes	Yes
Warrigal Rd	Fruitgrove	306186	4	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Fruitgrove	306217	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Runcorn North	306185	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Warrigal Rd	Runcorn North	306218	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Warrigal Rd	Warrigal Road	306184	4	Regular	North-South	Kerbside	None	N/A	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Unknown
Warrigal Rd	Warrigal Road	306219	4	Premium	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Warrigal Rd		306183	4	Regular	South-North	Kerbside	Yellow Line Marking	20	Yes	No image	N/A	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Fanfare	306182	4	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Fanfare	306220	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Warrigal Rd	Bordeaux	306181	4	Regular	North-South	Kerbside	Yellow Line Marking	20	Yes	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Bordeaux	306221	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Padstow Views	306222	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Padstow Views	306180	4	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Padstow Rd	Multicap	306259	4	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Padstow Rd	Multicap	306242	4	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Logan Rd	81	306243	4	Regular	South-North	Indented	White Line Marking	25	Yes	No image	Yes	N/A	Yes	Yes	Yes	15	18	No	Yes	No
Macgregor St	Garden City Depot	305979	4 and 3	Regular	East-West	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Macgregor St	Garden City Depot	305981	4 and 3	Regular	West-East	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Route 130																			
Illaweena St	Waterstone	305382	5	Regular	West-East	Kerbside	None	N/A	N/A	No image	No	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Illaweena St	Waterstone	305380	5	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Illaweena St	Tamarisk Way	307080	5	Regular	East-West	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Illaweena St	Tamarisk Way	307081	5	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Lichfield Place	307096	5	Regular	West-East	Kerbside	None		N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Lichfield Place	307097	5	Regular	East-West	Indented	Yellow Line Marking	36	Yes	Yes	Yes	N/A	Yes	Yes	Yes	15	16	No	Yes	Yes
Algester Rd	Parkinson East -92	303079	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Parkinson East -92	303078	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Algester Rd	Lake Eyre Crescent - 91	303077	5	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	*Yes
Algester Rd	Lake Eyre Crescent - 91	303080	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Parkinson East -90	303076	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Algester Rd	Parkinson	303081	5	Regular	South-North	Indented	None	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	12	No	Yes	Yes
Algester Rd	Glenfield	303082	5	Regular	South-North	Kerbside	Yellow Line Marking	22	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Glenfield	303075	5	Regular	North-South	Kerbside	Yellow Line Marking	22	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Algester Rd	Nottingham	303074	5	Regular	North-South	Kerbside	Yellow Line Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Algester Rd	Nottingham	303083	5	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*Yes
Ridgewood Rd		303092	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	N/A	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Ridgewood Heights	303112	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Ridgewood Rd	Ridgewood Heights	303093	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Helica Street - 85a	303094	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Ridgewood Park	303111	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Ridgewood Park	303095	5	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Ridgewood Rd	Wollybutt Street - 84	303104	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Ridgewood Rd	Wollybutt Street - 84	303096	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Algester - 83	303097	5	Regular	West-East	Indented	White Line Marking	29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	7	9	No	Yes	Front Only
Ridgewood Rd	Algester - 83	303103	5	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Ridgewood Rd	Rapanea Street - 82	303102	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
Ridgewood Rd	Rapanea Street - 82	303098	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Limewood Place - 81	303101	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Ridgewood Rd	81	303099	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Satinwood Street - 80	303100	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Algester East - 79	303116	5	Regular	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Algester East - 79	303069	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	*Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Algester Central - 78a	303117	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Algestor Central - 78a	303068	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Delforest Drive - 78	303118	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Algester Rd	Beaudesert Road - 76	303067	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Algester Rd	Beaudesert Road - 76	303119	5	Regular	South-North	Kerbside	None	N/A	N/A	No image	No image	*	No Image	No image	No image	N/A	N/A	*	Yes	No Image
Beaudersert Rd		305470	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	N/A	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Beaudersert Rd		305445	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	N/A	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Compton Rd		305488	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Compton Rd		305487	5	Regular	East-West	Indented	Yellow Line Marking	25	Yes	Yes	N/A	N/A	Yes	Yes	Yes	18	14	No	Yes	Front Only
Calam Rd	Calam Rd	305489	5	Premium	South-North	Indented	None	40	No	Yes	Yes	Yes	Yes	Yes	Yes	18	15	Yes	Yes	Yes
Calam Rd	Calam Rd	305476	5	Premium	North-South	Indented	Yellow Line Marking	30	No	No image	No image	Yes	Yes	*No	Yes	17	N/A	Yes	Yes	Yes
Calam Rd		305522	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Calam Rd	Sunnybanks Hill South	305490	5	Regular	South-North	Kerbside	None	N/A	No	No image	No image	*	No Image	No image	No image	N/A	N/A	No image	No image	No Image
Calam Rd	Sunnybanks Hill South	305521	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Calam Rd	Hellawell	305520	4 and 5	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Calam Rd	Hellawell	305491	5 and 4	Regular	South-North	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Pinelands Rd		305119	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Pinelands Rd	Barney Street 71-70	305492	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Pinelands Rd	Barney Street 71-70	305518	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Pinelands Rd	Pinelands	305517	4	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Pinelands Rd	Pinelands	305493	4	Regular	South-North	Indented	White Line Marking	42	No	Yes	Yes	Yes	Yes	Yes	Yes	6	0	No	Yes	Front Only
Mains Rd		306074	4	Regular	South-North	Kerbside	White Line Marking	16	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Mains Rd		306073	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Mains Rd	Runcorn School-68b	306072	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Mains Rd	Runcorn School-68b	306071	4	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Mains Rd	Altandi - 68	306070	4	Premium	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Mains Rd	Altandi - 68	306356	4	Premium	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Mains Rd	Pristina Street - 67	306075	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Mains Rd	Pristina Street - 67	306069	4	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Mains Rd	Turton Street - 80	306179	4	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Mains Rd	Turton Street - 80	306068	4	Regular	North-South	Kerbside	None	N/A	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Mains Rd	Elva Street - 65	306076	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Mains Rd	Elva Street - 65	306067	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Mains Rd	Sunnybank	306066	4	Premium	North-South	Kerbside	White Line Marking	27	Yes	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Mains Rd	Sunnybank	306355	4	Premium	South-North	Kerbside	Yellow Line Marking	34	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Mains Rd	Musgrave Road - 63	306077	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Mains Rd	Musgrave Road - 63	306065	4	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Mains Rd	Robertson - 4	306064	4	Regular	North-South	Kerbside	None	N/A	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Mains Rd	Robertson	306078	4	Regular	South-North	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*No
Mains Rd	Mains Rd. Park & Ride	300502	4 and 3	Park&Ride	South-North	Indented	White Line Marking	38	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	16	Yes	Yes	Yes
Mains Rd	Mains Rd. Park & Ride	307092	3 and 4	Park&Ride	North-South	Indented	Yellow Line Marking	*	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Route120																			
Kessels Rd	Cremin Street 45/60	300426	4	Regular	West-East	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Kessels Rd	Cremin Street 45/60	305727	4	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Kessels Corner - 44	306079	3	Regular	South-North	Kerbside	Yellow Line Marking	18	Yes	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Logan Rd	Mt Gravatt Corner - 44	305923	3	Regular	North-South	Kerbside	Yellow Line Marking	29	Yes	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Logan Rd	Kessels Corner - 43	305922	3	Regular	North-South	Kerbside	Yellow Line Marking	30	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Logan Rd	Upper Mt Gravatt School - 43	305984	3	Regular	South-North	Kerbside	Yellow Line Marking	60	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	St Bernards - 42	305921	3	Regular	North-South	Kerbside	Yellow Line Marking	18	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	St Bernards - 42	306080	3	Regular	South-North	Indented	Yellow Line Marking	29	No	Yes	Yes	Yes	Yes	Yes	Yes	8	11	No	Yes	Yes
Klumpp Rd		305677	3	Regular	East-West	Indented	Yellow Line Marking	31	No	Yes	N/A	N/A	Yes	Yes	Yes	9	11	Yes	Yes	Yes
Klumpp Rd	Klump-Dawson - 42	305676	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Klumpp Rd	Hibiscus	305678	3	Premium	East-West	Indented	Yellow Line Marking	50	No	Yes	Yes	Yes	Yes	Yes	Yes	21	13	Yes	Yes	Yes
Klumpp Rd	Hibiscus	305675	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Klumpp Rd	Mt Gravatt Cemetry	305143	3	Regular	West-East	Kerbside	Yellow Line Marking	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Klumpp Rd	Mt Gravatt Cemetry	305144	3	Regular	East-West	Kerbside	Yellow Line Marking	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Griffith Rd	Recreation Road - 55a	305142	3	Regular		Indented	Yellow Line Marking	No image	No	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image
Troughton Rd	QEII Hospital	300498	4 and 3	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	*No	N/A	N/A	No	Yes	Front Only
Troughton Rd	QEII Hospital	300434	3 and 4	Regular	North-South	Kerbside	Yellow Line Marking	25	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Troughton Rd	QEII Hospital - 37	300497	4 and 3	Premium	South-North	Kerbside	Yellow Line Marking	24	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*No
Troughton Rd	Musgrave Rd	300435	3 and 4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Troughton Rd	Musgrave Rd - 39	300496	4 and 3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Musgrave Rd	Musgrave Rd	300436	3	Regular	East-West	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Musgrave Rd	Mandarin Street - 54	300495	3	Regular	West-East	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Musgrave Rd	Mossop Street - 54	300437	4 and 3	Regular	East-West	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Musgrave Rd	Boundary	300438	3	Regular	East-West	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Musgrave Rd	Boundary	300494	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Musgrave Rd	Orange Grove Rd - 54b	300439	4 and 3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Musgrave Rd	Orange Grove Rd - 54b	300493	3	Regular	West-East	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Q G Laboratory	305139	3 and 4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Q G Laboratory	305140	4 and 3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Orange Grove Rd	Aldi - 52	305138	3 and 4	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Aldi - 52	305141	4 and 3	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Salisbury East - 51	305137	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Orange Grove Rd	Salisbury East - 51	305146	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Orange Grove Rd	52A	305147	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Orange Grove Rd	52A	305136	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Orange Grove Rd	Dulcie Street - 52	305135	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Orange Grove Rd	Dulcie Street - 52	305148	3	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Toohey Forest - 53	305134	3	Regular	North-South	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Toohey Rd	Toohey Forest - 53	305133	3	Regular	South-North	Kerbside	None	N/A	No	No	Yes	N/A	No	Yes	No	N/A	N/A	No	No	No
Toohey Rd	53	307082	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	No image	N/A	Yes	Yes	Yes	N/A	N/A	No image	Yes	No image
Toohey Rd	Tarragindi - 44/48	305099	3 and 2	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
Toohey Rd	Tarragindi - 44/48	305156	2 and 3	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No image
Toohey Rd	Bramston Street - 47	305157	2	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Toohey Rd	Bramston Street - 47	305155	2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Toohey Rd	Chamberlain Street -46a	305158	2	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Toohey Rd	Chamberlain Street -46a	305154	2	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Toohey Rd	Wellers Hill School - 47a	305159	2	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Toohey Rd	Wellers Hill School - 47a	305153	2	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Toohey Rd	Weller Road - 45	305152	2	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Toohey Rd	Weller Road - 45	305160	2	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Toohey Rd	Denham Terrace - 44/41	305106	2	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Toohey Rd	Denham Terrace - 44/41	305105	2	Regular	South-North	Kerbside	None	N/A	N/A	No	Yes	No	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Sexton St	Sexton Street	305187	2	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Sexton St	Sexton Street	305185	2	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Sexton St		305188	2	Regular	East-West	Kerbside	None	N/A	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image
Sexton St		305184	2	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Ekibin Rd	Ekibin - 30	306342	2	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Ekibin Rd	Ekibin - 30	306340	2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Earl St	18	305241	2	Regular	South-North	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Earl St	Thompson Estate 17	305222	2	Regular	South-North	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Earl St	Thompson Estate 17	305221	2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
	Route 180																			
Kessels Rd	Cremin Street 45/60	300426	4	Regular	West-East	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Kessels Rd	Cremin Street 45/60	305727	4	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Mt Gravatt-Capalaba Rd	Tryon - 61	305726	3	Regular	West-East	Indented(other)	White Line Marking	34	Yes	Yes	Yes	N/A	Yes	Yes	Yes	11	10	No	Yes	Yes
Mt Gravatt-Capalaba Rd	Tryon - 61	305734	3	Premium	West-East	Indented(other)	White Line Marking	32	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	N/A	Yes	Yes	Yes
Mt Gravatt-Capalaba Rd		305735	3	Regular	West-East	Kerbside	None	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Mt Gravatt-Capalaba Rd	62/78	305725	3	Regular	East-West	Indented(other)	White Line Marking	28	No	Yes	Yes	N/A	Yes	Yes	Yes	16	18	No	Yes	No
Mt Gravatt-Capalaba Rd		305724	3	Regular	East-West	Indented	White Line Marking	28	Yes	No image	No image	N/A	Yes	Yes	Yes	10	0	No image	No image	No Image
Mt Gravatt-Capalaba Rd		305176	3	Regular	West-East	Kerbside	None	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Mt Gravatt-Capalaba Rd	Agaton	305717	3	Regular	West-East	Indented(other)	White Line Marking	26	Yes	No	Yes	Yes	Yes	Yes	Yes	22	22	No	Yes	Front Only
Mt Gravatt-Capalaba Rd	Agaton	305723	3	Regular	East-West	Indented(other)	White Line Marking	44	No	No image	Yes	Yes	Yes	Yes	Yes	9	22	N/A	Yes	No
Mt Gravatt-Capalaba Rd		305718	3	Regular	West-East	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Mt Gravatt-Capalaba Rd	Ham Road South	305719	3	Regular	West-East	Indented(other)	White Line Marking	25	Yes	No	Yes	Yes	Yes	Yes	Yes	15	13	No	Yes	Front Only
Mt Gravatt-Capalaba Rd	Ham Road South	305722	3	Regular	East-West	Indented(other)	White Line Marking	32	Yes	No	Yes	Yes	Yes	Yes	Yes	7	16	No	Yes	Front Only
Mt Gravatt-Capalaba Rd	Wishart East	305720	3	Regular	West-East	Indented(other)	White Line Marking	23	No	Yes	Yes	Yes	Yes	Yes	Yes	16	14	Yes	Yes	Yes
Mt Gravatt-Capalaba Rd	Wishart East	305721	3	Regular	East-West	Indented(other)	White Line Marking	31	No	Yes	Yes	Yes	Yes	Yes	*Yes	11	0	No	Yes	Yes
Broadwater Rd	Mansfield Park	305682	3	Regular	West-East	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Broadwater Rd	Mansfield Park	305681	3	Regular	East-West	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Broadwater Rd		305680	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Broadwater Rd	Broadwater	305698	3	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Broadwater Rd	Broadwater	305697	4	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Broadwater Rd	Broadwater Creek - 75	305696	3	Regular	West-East	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Broadwater Rd	Broadwater Creek - 75	305683	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cresthaven Drive	Cresthaven - 74	305617	3	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	*Yes	*Yes	N/A	N/A	No	Yes	Yes
Cresthaven Drive	Cresthaven - 74	305618	3	Regular	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cresthaven Drive	Salandra Street - 6c/73	305615	3	Regular	North-South	Kerbside	Yellow Line Marking	25	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No Hardstand
Cresthaven Drive	Salandra Street - 6c/73	305619	3	Regular	South-North	Kerbside	Yellow Line Marking	28	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Aminya St	Mansfield - 67a	305612	3	Regular	East-West	Kerbside	Yellow Line Marking	22	No	No image	No image	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No Image
Aminya St	Mansfield - 67a	305620	3	Regular	West-East	Kerbside	Yellow Line Marking	23	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Balamara St	Balamara Street - 67	305611	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Olivella St	Olivella Street - 66	305621	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Olivella St	Olivella Street - 66	305610	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Luprena Street	Arura Street - 65	305609	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Luprena Street	Arura Street - 65	305622	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Luprena Street	Mansfield North	305606	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Luprena Street	Mansfield North	305623	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Wecker Rd	Wecker Rd Business Centre-63	305700	3	Regular	East-West	Kerbside	None	33	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Wecker Rd	Wecker Rd Business Centre-63	305605	3	Premium	West-East	Kerbside	Yellow Line Marking	20	Yes	No	Yes	N/A	*No	Yes	Yes	N/A	N/A	Yes	*No	No
Wecker Rd	Wecker Rd - 6	305604	3	Regular	West-East	Kerbside	Yellow Line Marking	22	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Wecker Rd	Wecker Rd - 6	305701	3	Regular	East-West	Kerbside	Yellow Line Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Wecker Rd	Grevillea Oval - 61	305702	3	Regular	West-East	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Wecker Rd	Grevillea Oval - 61	305063	3	Premium	East-West	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cavendish Rd	Mt Gravatt East - 60	305281	3	Regular	South-North	Kerbside	Yellow Line Marking	22	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cavendish Rd	Mt Gravatt East - 60	305280	3	Regular	North-South	Indented	Yellow Line Marking	23	No	Yes	Yes	Yes	Yes	Yes	Yes	7	7	Yes	Yes	Yes
Cavendish Rd	Seton College - 56/59	305279	3	Regular	North-South	Indented(other)	Yellow Line Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	17	0	Yes	Yes	Yes
Cavendish Rd	Seton College - 56/59	305278	3	Regular	South-North	Kerbside	Yellow Line Marking	26	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cavendish Rd	Mt Gravatt TAFE - 55	304974	3	Regular	North-South	Kerbside	Yellow Line Marking	*	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Cavendish Rd	Mt Gravatt TAFE - 55	305323	3	Regular	South-North	Kerbside	Yellow Line Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No Image
Cavendish Rd	Coolibah Street - 54	304975	3	Regular	South-North	Kerbside	Yellow Line Marking	23	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Cavendish Rd	Coolibah Street - 54	304973	3	Regular	North-South	Kerbside	*	*	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cavendish Rd	Coolong Street - 53	304976	3	Regular	South-North	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No Image
Cavendish Rd	Coolong Street - 53	304972	3	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No Image
Cavendish Rd	Pine Mountain - 52	304971	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cavendish Rd	Pine Mountain - 52	304977	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cavendish Rd	Oates Avenue - 51	304978	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*No
Cavendish Rd	Oates Avenue - 51	304970	3	Regular	North-South	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cavendish Rd	Crystal Street - 50	305282	2	Regular	East-West	Kerbside	Yellow Line Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Cavendish Rd	Crystal Street - 50	304969	3	Regular	West-East	Kerbside	Yellow Line Marking	*20	Yes	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cavendish Rd	Turquoise Street - 49/63	305283	3	Regular	East-West	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cavendish Rd	Turquoise Street - 49/63	304968	3	Regular	West-East	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Cavendish Rd	Holland Park East - 42	304964	2 and 3	Regular	West-East	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cavendish Rd	Holland Park East - 42	304965	3 and 2	Regular	East-West	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cavendish Rd	Cavendish Rd High School 41	304963	2 and 3	Regular	North-South	Kerbside	Yellow Line Marking	27	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Cavendish Rd	Cavendish Rd High School 41	304966	3 and 2	Regular	South-North	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	*Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cavendish Rd	Cavendish Rd Reservoir - 40	304962	2 and 3	Regular	North-South	Kerbside	White Line Marking		No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Holland Rd	Bus Stop - 45	305253	3 and 2	Regular	North-South	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Holland Rd	Bus Stop - 45	305252	3 and 2	Regular	South-North	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Holland Rd	Holland Road - 44	305251	2 and 3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Holland Rd	Holland Road - 44	305254	3 and 2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
Holland Rd	Bus Stop - 43	305255	3 and 2	Regular	North-South	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Holland Rd	Bus Stop - 43	305250	2 and 3	Regular	South-North	Kerbside	Yellow Line Marking	14	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Holland Rd	Bus Stop - 43A	305256	3 and 2	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Logan Rd	Barter Avenue - 30	305994	3 and 2	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Logan Rd	Barter Avenue - 30	305907	2 and 3	Regular	North-South	Kerbside	Yellow Line Marking	24	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Logan Rd	Holland Park - 29	305995	3 and 2	Premium	South-North	Indented	Yellow Line Marking	29	Yes	No	Yes	Yes	Yes	Yes	Yes	11	0	Yes	Yes	No
Logan Rd	Holland Park - 29	305906	2 and 3	Premium	North-South	Indented	Yellow Line Marking	24	No	No	Yes	Yes	Yes	Yes	Yes	5	0	Yes	Yes	No
Logan Rd	Harold Street - 28	306084	2	Regular	South-North	Kerbside	Yellow Line Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Harold Street - 28	305905	2	Regular	North-South	Kerbside	Yellow Line Marking	29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Logan Rd	Swain Street - 27	305904	2	Regular	North-South	Kerbside	Yellow Line Marking	22	No	Yes	Yes	Yes	Yes	*Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Swain Street - 27	306085	2	Regular	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	C B Mott Park - 26	305903	2	Regular	North-South	Kerbside	Yellow Line Marking	24	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	C B Mott Park - 26	306086	2	Regular	South-North	Kerbside	Yellow Line Marking	28	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Raff Ave - 25	305902	2	Regular	North-South	Kerbside	Yellow Line Marking	25	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Greenslopes Mall - 25/24	306087	2	Premium	South-North	Kerbside	Yellow Line Marking	29	No	No image	No image	N/A	Yes	Yes	Yes	N/A	N/A	No image	Yes	No Image
Logan Rd	Greenslopes Mall - 25/24	305901	2	Premium	North-South	Kerbside	Yellow Line Marking	29	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Logan Rd	Donaldson Street - 23	306088	2	Regular	South-North	Kerbside	Yellow Line Marking	22	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Donaldson Street - 23	305900	2	Regular	North-South	Kerbside	Yellow Line Marking	10	Yes	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Greenslopes - 22	305899	2	Premium	North-South	Indented	Yellow Line Marking	26	No	Yes	Yes	Yes	Yes	Yes	Yes	7	12	Yes	Yes	Yes
Logan Rd	Greenslopes - 22	306089	2	Premium	South-North	Kerbside	Yellow Line Marking	33	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*Yes
Logan Rd	Greenslopes School - 21	306090	2	Regular	South-North	Kerbside	Yellow Line Marking	43	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Logan Rd	Greenslopes School - 21	306336	2	Regular	North-South	Kerbside	Yellow Line Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Bradsley Ave - 20	306335	2	Regular	North-South	Kerbside	Yellow Line Marking	29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Bradsley Ave - 20	306091	2	Regular	South-North	Kerbside	Yellow Line Marking	27	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Logan Road North - 19	306092	2	Premium	South-North	Kerbside	Yellow Line Marking	24	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Logan Road North - 19	306334	2	Premium	North-South	Kerbside	Yellow Line Marking	12.5	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cornwall St	Cleveland Street 18a	305223	2	Regular	West-East	Kerbside	Yellow Line Marking	21	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cornwall St	Baron Street 18	305242	2	Regular	West-East	Kerbside	Yellow Line Marking	28	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Juliette St	Beatrice Street - 19	305219	2	Regular	East-West	Kerbside	Yellow Line Marking	15	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Juliette St	Baron Street 18	305220	2	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Route 385																			
	Waterworks	302658	3	Regular	0	Turnaround	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	N/A	Yes	Yes
Waterworks Rd	Parkdale	302657	3	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Parkdale	302656	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Waterworks Rd	Petmar-Waterworks	302837	3	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Waterworks Rd	Petmar-Waterworks	302826	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Waterworks Rd	Hilder Road - 46	302835	3	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Waterworks Rd	Hilder Road - 46	302838	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	Settlements Rd - 36	302834	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Settlements Rd - 36	302839	3	Regular	West-East	Indented	Yellow Line Marking	37	No	Yes	Yes	Yes	Yes	Yes	Yes	9	11	Yes	Yes	No
Waterworks Rd	Gap Uniting Church - 35	302840	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	Gap Uniting Church - 35	302833	3	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	Gap High School - 34	302841	3	Regular	West-East	Kerbside	Yellow Line Marking	19	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	*Yes
Waterworks Rd	Gap High School - 34	302832	3	Premium	East-West	Indented	Yellow Line Marking	73	No	Yes	Yes	Yes	Yes	Yes	Yes	20	17	Yes	Yes	Yes
Waterworks Rd	The Gap Village - 33	302842	3	Premium	West-East	Kerbside	Yellow Line Marking	37	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	The Gap Village - 33	302993	3	Premium	East-West	Kerbside	Yellow Line Marking	29	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Waterworks Rd	Jevons Street - 32	302843	3	Regular	West-East	Kerbside	None	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Waterworks Rd	Jevons Street - 32	302831	3	Regular	East-West	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Waterworks Rd	Payne Road - 31	302825	3	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Waterworks Rd	Payne Road - 31	302830	3	Regular	East-West	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Waterworks Rd	Cooinda Street - 30	302829	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Waterworks Rd	Cooinda Street - 30	302826	3	Regular	West-East	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Waterworks Rd	Kilmaine Street - 29	302827	3	Regular	North-South	Kerbside	None	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	Glenquarie Place - 29	302828	3	Regular	East-West	Indented	Yellow Line Marking	23	No	Yes	Yes	Yes	Yes	Yes	Yes	16	12	No	Yes	Front Only
Waterworks Rd	Greenlanes Road - 28/27	302994	3	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Acton Street - 27	302790	3	Regular	East-West	Kerbside	Yellow Line Marking	31	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Firhill Street - 26	302789	3	Regular	East-West	Kerbside	Yellow Line Marking	29	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Waterworks Rd	Firhill Street - 26	302844	3	Regular	West-East	Kerbside	Yellow Line Marking	*	Yes	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Monoplane Street - 25	302788	3	Regular	East-West	Indented	None	21	No	Yes	Yes	N/A	Yes	Yes	Yes	0	15	No	Yes	Yes
Waterworks Rd	West Ashgrove - 24	302737	3	Regular	North-South	Kerbside	Yellow Line Marking	15	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Coopers Camp Rd	West Ashgrove	302736	3	Regular	South-North	Kerbside	Yellow Line Marking	21	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	36a	302738	3	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Coopers Camp Rd	Coopers Camp - 29	302723	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	Coopers Camp - 29	302740	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	28	302741	3	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	28	302722	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	27	302742	2	Regular	North-South	Kerbside	Yellow Line Marking	20	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Coopers Camp Rd	27	302721	2	Regular	North-South	Kerbside	Yellow Line Marking	17	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	26	302720	2	Regular	East-West	Kerbside	Yellow Line Marking	33	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Jubilee Tce	Bardon - 15	302878	2	Regular	East-West	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Jubilee Tce	Bardon - 15	302859	2	Regular	West-East	Kerbside	Yellow Line Marking	*	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Macgregor Tce	Macgregor Tce-Tooth-14	302860	2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Macgregor Tce	Macgregor Tce-Tooth-14	302877	2	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Perrott Avenue - 13	302876	2	Regular	East-West	Kerbside	Yellow Line Marking	23	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Perrott Avenue - 13	302861	2	Regular	West-East	Indented(other)	Yellow Line Marking	17	No	Yes	Yes	N/A	Yes	*Yes	*Yes	17	0	Yes	Yes	Yes
Latrobe Tce	Gilday Street - 12	302875	2	Regular	East-West	Kerbside	Yellow Line Marking	30	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Gilday Street - 12	302862	2	Regular	West-East	Kerbside	Yellow Line Marking	20	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Trammie's Corner - 11	302874	2	Premium	East-West	Indented	Yellow Line Marking	15	No	No image	Yes	Yes	Yes	Yes	Yes	6	8	Yes	Yes	No Image
Latrobe Tce	Trammie's Corner - 11	302863	2	Premium	West-East	Kerbside	Yellow Line Marking	24	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Paddington Central	302873	2	Premium	East-West	Indented	Yellow Line Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0	8	Yes	Yes	No
Latrobe Tce	Paddington Central	302864	2	Premium	West-East	Indented	Yellow Line Marking	*	No	No	Yes	Yes	Yes	Yes	Yes	*	*	Yes	*No	No
Latrobe Tce	Old Ithaca Fire Station - 9	302872	2	Regular	East-West	Indented	Yellow Line Marking	30	No	Yes	Yes	N/A	Yes	Yes	Yes	11	0	Yes	Yes	No
Latrobe Tce	Old Ithaca Fire Station - 9	302865	2	Regular	West-East	Kerbside	Yellow Line Marking		No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Old Paddo Post Office - 8	302871	2	Regular	South-North	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Given Tce	Old Paddo Post Office - 8	302866	2	Regular	West-East	Kerbside	Yellow Line Marking	17	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Given Tce	Great George - 7	302870	2	Regular	East-West	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Given Tce	Great George - 7	302867	2	Regular	West-East	Kerbside	Yellow Line Marking	18	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Given Tce	Paddo Tavern - 6	302869	2	Regular	East-West	Kerbside	Yellow Line Marking	13	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Given Tce	Paddo Tavern - 6	302868	2	Regular	West-East	Kerbside	Yellow Line Marking	20	Yes	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
Given Tce	Paddington - 5	302996	2	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Given Tce	Paddington - 5	302995	2	Premium	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Caxton St	Caxton Street - 4	306487	1	Premium	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Caxton St	Caxton Street - 4	306488	1	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Petrie Tce	Windmill Café - 3	306486	1	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Upper Roma St	Upper Roma Street - 3	307127	1	Premium	West-East	Indented(other)	None	42	No	Yes	Yes	*	Yes	No image	No image	5	0	N/A	Yes	No
Upper Roma St	Upper Roma Street - 2	306483	1	Premium	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	N/A	Yes	Yes

Appendix C: Impacts of HCV Loadings on Pavement Performance

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Technical Note

Subject:	Impact of HCV Loadings on Pavement Performance
Project:	Research and Analysis of High Capacity Vehicles
Our file:	4749 Date: 18 June 2012
Status:	Preliminary Draft Prepared by: BP

Table of Contents

1. Introduction

1.1 Background

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

1.2 Purpose of this Technical Note

The main purpose of this technical note is to provide a high-level discussion of the impacts that HCVs would have on pavements.

2. Impacts of HCVs on the Pavement Deterioration

Pavement designs are based on the cumulative number of heavy vehicles in the design lane. In some cases the design lane may not be the most heavily trafficked lane, such as when designing inside widening of a multi-lane carriageway.

Different types of vehicles cause different types of damage to pavements. Vehicle loading damage on highway pavement corresponds closely to axle weight and configuration.

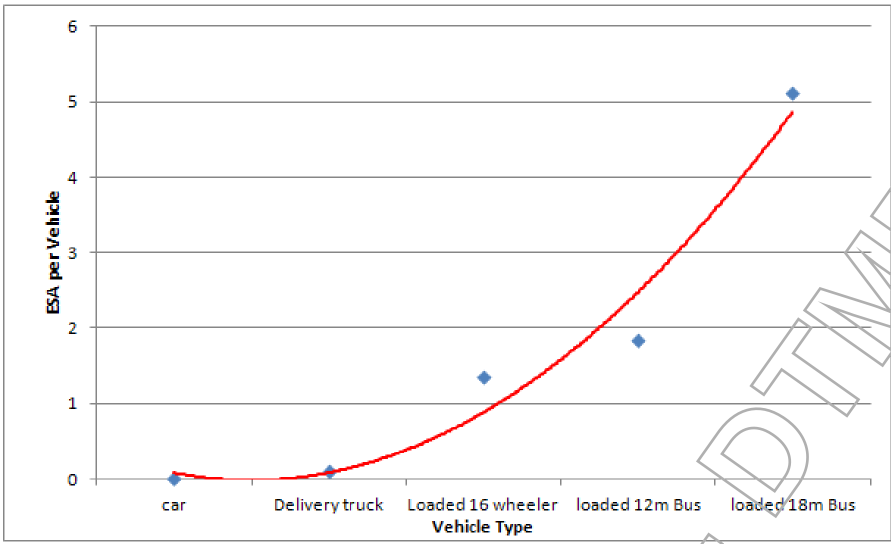
Many studies have been done to reveal the relationship between trucks and pavement damage which can be used to inform the impacts of HCVs will have on pavements. Suspension type and characteristics, as well as tire type and configuration, are major contributors to pavement deterioration.

2.1.1 HCV Pavement Failure

The factors that contribute to failure for flexible pavements can generally be categorized in two groups; vehicle factors and pavement factor. Most arterial and collector pavement deterioration is associated with vehicle use or loads. Loads are the vehicle forces exerted on the pavement by automobiles, trucks and buses. These forces create stress and deformation within the pavement structure. Repeated loading creates fatigue and resulting distress in the pavement. Excessive loading can lead to rapid deterioration of the pavement structure evidenced by cracking and distortion of the pavement surface. Damage caused by vehicles goes up exponentially with weight. A single large truck can cause as much damage as several thousand automobiles.

Buses typically have an even larger load impact than heavy trucks due to the limited number of axles and tires they employ to distribute their weight. The increase in damage level with load is not linearly proportional. It takes the shape of the exponential function with a power constant value range from 4 to 6. Under the fourth power rule one bus overloaded by 25% does as much damage to the road as two buses. This is shown in the following figure which presents the number of equivalent standard axles (ESAs) for different vehicle types.

Figure 1: Equivalent Standard Axle Loadings for Different Vehicle Types



2.1.2 Increased Loads Accelerate Pavement Failure

The loads imposed by vehicles on Brisbane streets have increased historically both in magnitude and frequency. Industry efficiencies have led to an increase in the size of trucks and their loads. Truck demand has increased rapidly. Arterial streets that serve Brisbane's industrial areas have the highest volume of medium and heavy truck trips today and in the future. Brisbane surface streets carry much of the truck freight that access Port facilities and truck freight terminals.

With anticipated increasing demand for public transport the frequency of bus movements is expected to increase. The sum result of these factors is an increased load demand on key freight routes and transit corridors and accelerated pavement failure.

2.1.3 Growth rate and cumulative traffic volumes

In accordance with recent growth and the predicted doubling of the road freight task from 2000 to 2020 (DOTARS, 2002), all motorways (including ramps), highways and arterial roads are required to be designed with a minimum heavy vehicle growth rate of 4% per annum, unless detailed traffic modelling is undertaken which specifically considers the future freight task for the pavement being designed.

Buses are also classified as heavy vehicles, and research has shown that heavy vehicles are mainly responsible for pavement damage and costs incurred to rectify the damage. Buses differ from trucks in load distribution, suspension, and travel characteristics. Buses do cause significant damage on pavements, which based on the estimated bus ESA's is often comparable to the damage caused by trucks.

Buses have a unique travel characteristic: they frequently stop at bus stops. Research has shown that this action causes great damage to the pavement at bus stops.

The number of ESA's that a pavement can carry decreases with a decrease in speed. Thus, at sections where HCV buses stop, the pavement will deteriorate faster compared with other sections of the road.

AUSTROADS (2004a) defines a standard axle as a Single Axle with Dual Tyres (SADT) applying a load of 80 kN to the pavement. This load is applied over four tyres so each tyre is providing a downward force of 20 kN. Huang (2004) provides a calculation to determine the contact area of each tyre. Following AUSTROADS in assuming a tyre pressure of 750 kPa the equation determines a contact area of 0.0267 m2, or an equivalent rectangle of 136 mm by 197 mm, Pavement design is directly influenced by the expected number of heavy axle loadings, as opposed to the gross vehicle weight, as multiple axles help spread the load on the pavement and reduce the impact. However, loading is not even across axles, and typically the rear axle on a two-axle vehicle will carry 70 to 75 percent of the gross vehicle weight. Note that even small increases in weight on an axle can cause disproportionately large amounts of damage to the pavement structure.

For the purposes of design, the traffic volume is represented by the number of equivalent standard axles (ESAs) typically using a design period of 20 years for flexible pavements and 40 years for concrete pavements. When comparing different pavement structures, a whole-life analysis of the alternatives is required to produce an equitable comparison.

Because it has been well established that light vehicles contribute very little to structural deterioration, only heavy vehicles are considered in pavement design. Traditionally, the term 'commercial vehicle' has been used to denote these vehicles. In conformance with Austroads terminology, the term 'heavy vehicle' is now adopted. The damage caused to a pavement by the passage of a heavy vehicle depends not only on its gross weight but also on how this weight is distributed to the pavement. In particular, it depends on:

- the number of axles on the vehicle
- the manner in which these axles are grouped together -- into axle groups
- the loading applied to the pavement through each of these axle groups – the axle group load.

For pavement design purposes, the following (heavy vehicle) axle group types are identified:

- single axle with single tyres (SAST)
- single axle with dual tyres (SADT)
- tandem axle with single tyres (TAST)
- tandem axle with dual tyres (TADT)
- tri-axle with dual tyres (TRDT)
- quad-axle with dual tyres (QADT).

2.2 Assumed Pavement Types

Pavement materials can be classified into essentially four categories according to their fundamental behaviour under the effects of applied loadings:

- Unbound granular materials, including modified granular materials
- Bound (cemented) granular materials
- Asphaltic Concrete
- Cement Concrete

The surfacing materials can also be classified into essentially three categories or types:

- Sprayed bituminous seals
- Asphaltic concrete and bituminous micro-surfacing
- Cement Concrete

However the granular pavement comprises the majority of the Brisbane Council road network as it is considered to provide the lowest whole of life costs and enables ready access for installation and maintenance of utilities. The design life for flexible pavements is 20 years while the design life for rigid pavements is 40 years. Arterial routes which serve as bus routes must be designed for the estimated traffic loads derived from approved traffic studies with a minimum traffic loading of 3.7×10^6 equivalent standard axles for road type F and 1.0 x 10^7 equivalent standard axles for road type G. Similarly, suburban routes serving as bus routes must have a minimum traffic loading of 7.5 x 10^5 equivalent standard axles.

2.3 Impacts of HCV's on the Design Life

When the axle mass limits as outlined above are applied to the Standard Axle Repetition formula as outlined in the *Pavement Design Guide (Austroads, 2004a)* it becomes quite clear that the equivalent design axles for the proposed HCV buses increase significantly and could prematurely decrease (by up to 5 years) the design life of the pavement resulting in increased maintenance. In particular where chosen HCV routes are 75% of their design life they should undergo specific pavement evaluation to determine their current condition status.

3. Summary and Conclusions

The performance of HCV route pavements will be a function of load frequency and existing pavement design life. In order to combat the significant surface stresses of the setdown areas these should be constructed in concrete.

Pavement deterioration caused by HCVs will accelerate the need for greater pavement maintenance and a comprehensive Pavement Management program should be established to confirm whole of life costs for pavement rehabilitation or reconstruction.

Attachment 1: Legislated Axle Mass Limits

The following tables provide the axle mass limits proposed for the various bus configurations (as identified in the Legislation and Policy Background Report completed as part of this study).

Table 2: Permitted Axle Mass Limits for 2 Door 12.5m Standard Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Buses)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Buses)
Rear Drive Axle with Dual Tyres	10t (High Floor) 11t (Ultra-Low Floor)	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	15t (High Floor) 16t (Complying or Ultra-low Floor)	No Higher Mass Limit Permitted	15t (High Floor) 16t (Complying or Ultra-low Floor)

Table 3: Permitted Axle Mass Limits for 2 Door 14.5m Extended Rigid Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Upper Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	Non-Compliant	No Higher Mass Upper Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Tandem Axle Group with Dual Drive Tyres and Single Steer Axle with Single Tyres	Non-Compliant	14t **	13t ** (Standing Permitted) 14t ** (Complying Bus)
Gross Mass	Non-Compliant	20t	19t (Standing Permitted) 20t (Complying Bus)

Table 4: Permitted Axle Mass Limits for 2 Door 12 - 12.5m Double Deck Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
<<< Single Steer Front Axle >>>			
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Drive Dual Tandem Axle Group Fitted with Two Tyres	16.5t **	17t **	16.5t **
Gross Mass	22.5t	23t	22.5t
<<< Twin Steer Front Axle >>>			
Twin Steer Front Axle with Single Tyres	10t (Non-Load Sharing) 11t (Load Sharing)	No Higher Mass Limit Permitted	10t (Non-Load Sharing) 11t (Load Sharing)

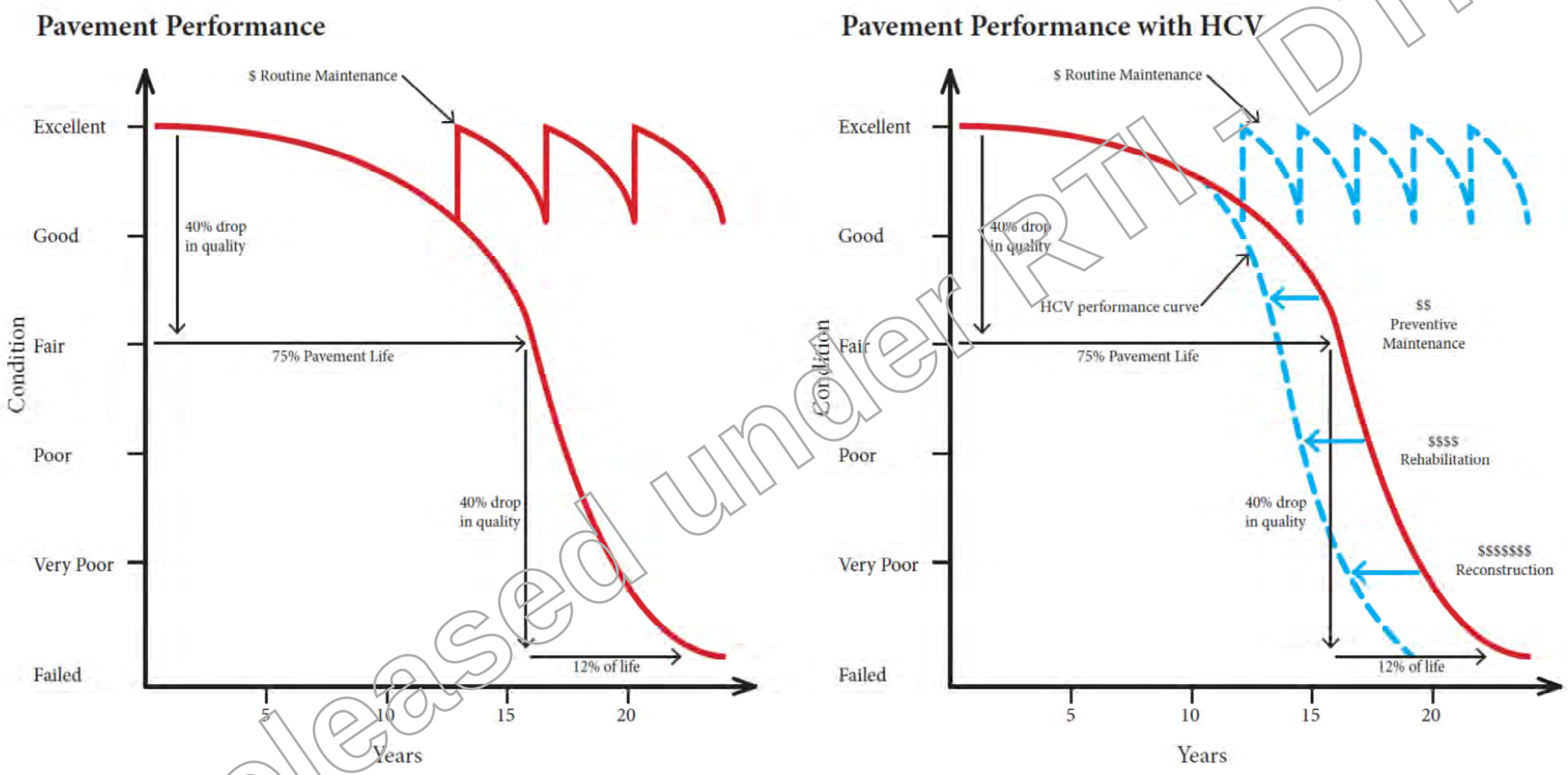
Rear Drive Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t
Gross Mass	20t	No Higher Mass Limit Permitted	20t (Non-Load Sharing) 21t (Load Sharing)

**S55 of the Queensland Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010 stipulates that heavy omnibus axles in an axle group other than a twin steer axle group must relate to each other through a load-sharing suspension system with effective damping characteristics on all axles of the group such that no axle carries over 10% more than the mass it would carry if the load was divided equally.

Table 5: Permitted Axle Mass Limits for 2 and 3 Door 18m Articulated Buses

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limits	Draft Heavy Vehicle National Regulation General Mass Limits
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Mid Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Rear Axle with Single Steer Tyres (High Floor)	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	22t	No Higher Mass Limit Permitted	22t (High Floor) 26t (Ultra-low Floor)

Attachment 2: Example Illustration of the Impact of HCVs on Pavements and Maintenance



Stage 1: Preliminary Draft Report

Research & Analysis of High Capacity Vehicles

TransLink Transit Authority

Prepared by:

MRCagney Pty Ltd

5 July 2012

Document Information

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Table of Contents

1. Introduction

1.1 Background

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis on the use of High Capacity Vehicles *(HCV)* within the *TransLink* network. The intention of the study is to gain a concise and consistent understanding of the different types of HCV available and the implications of deploying within the TransLink network, with a view to inform future fleet procurement strategies for the next five years.

The definition of a HCV is effectively any bus that is larger and more capacious than a single-deck, 12.5m rigid route bus, which has been the standard vehicle specification for urban bus operations throughout Australia for the past few decades.

Because of the common adoption of 12.5m buses, most bus infrastructure throughout south-east Queensland has been built to accommodate this size of vehicle. This includes bus stations, busways, bus depots and roadside bus stops. The use of larger vehicles has the clear potential for incompatibility with some of this existing infrastructure in terms of both physically fitting within a space designed for a standard bus, but also being able to manoeuvre into and out of that space.

The use of HCVs is also impacted by legislative and operational restrictions. 12.5m rigid buses and 18m articulated buses are standard vehicle designs with Federal regulations, and can be driven without constraint on most roads. The situation is more complicated with 14.5m extended rigid buses, which require a road to have been specifically assessed and approved as being able to accommodate this design of vehicle. Different driver licence categories may also be needed to operate a HCV, depending on its specification.

Throughout the world, a vast array of vehicle designs and specifications exist for buses that classify as HCVs, up to the 26m double articulated buses used in some European and South American countries. However, this study is focussed on those vehicles that are readily available in the Australian market and already in use or trial by TransLink operators.

The high capacity vehicle types nominated by *TransLink* for this study are:

- Two Door 12.5m Double Deck Buses;
- Two Door 14.5m Extended Rigid Buses;
- Two Door 18m Articulated Buses; and
- Three Door 18m Articulated “Superbuses”.

These vehicles are assessed against standard 12.5m rigid buses, as the base for comparison.

1.2 Objectives of this Report

The objectives of this report are to document the findings of Stage 1 of this study, namely:

- Present key findings of a legislative and policy review which may impact on the use of HCVs;
- Identify and discuss the potential infrastructure requirements and constraints related to the use of HCVs within TransLink’s network; and

- Discuss the impacts of various HCV types on operational aspects such as boarding and alighting times.

Stage 2 of this study will include an assessment of where in the TransLink network HCVs should be deployed in the future and the financial implications of doing so.

1.3 Report Structure

The structure of our report is as follows:

- Section 2: High Capacity Vehicle Types - The scope of this project is limited to technology available within the Australian market. This section will discuss the HCVs currently in operation in Australia as well as and potential HCV types available within Australia.
- Section 3: Legislation and Policy Background – This section summarises some of the key findings from our review of legislation, standards, land use and public transport plans.
- Section 4: Infrastructure Assessment – This section summarises our review of the potential impacts and constraints on bus infrastructure as a result of running HCVs on particular routes
- Section 5: Operational Assessment – This discusses the findings of our boarding, alighting and dwell time analysis

2. High Capacity Vehicle Types

2.1 Why Use High Capacity Vehicles?

High capacity buses are typically both cheaper (on a per-passenger-capacity basis) to purchase, and to operate (especially as the cost of driver labour is such a high component of operational cost in Australia). For this reason, there may be an argument for using larger vehicles rather than increasing frequency. This is especially true for peak period services, where a single bus may be at capacity, but demand is insufficient to justify doubling capacity by deploying a second bus.

However, the use of higher capacity vehicles may be a doubled-edged sword. In order for smaller vehicles to provide higher network capacity, higher frequency services must be provided. This provides the added benefit of reduced wait times for passengers, which in turn adds to the attractiveness of the service, but only up to a point. For example, 15 minute headways are far more attractive than 30 minutes, but 1 minute headways may not be any more attractive than 2 minutes. It is suggested that the threshold to justify higher capacity vehicles is when headways are within the range of 5 to 10 minutes. This will be investigated further in Stage 2 of this study.

2.2 Vehicle Types in Use in Brisbane

This section discusses the HCVs currently in operation in Australia and their manufacturers, along with a brief review of HCV designs which may become available within Australia in the near future.

The focus on the Australian market relates to the short-term focus of this study, and the need to identify which vehicles could be procured and deployed into the TransLink network within the next five years. Whilst a number of excellent bus designs are available or being developed overseas, the importation of these vehicles is not straightforward due to the differing vehicle design standards that apply in each country, and the challenges involved in having these vehicles approved for use in Australia.

The following is a general discussion of the buses being assessed in this study, including standard 12.5m rigid buses as the basis for comparison.

2.2.1 Standard (12.5m) Rigid Buses

The most widely used vehicle in south-east Queensland and throughout Australia is the standard 12.5m rigid bus, typically with a front and rear door. Depending on seating configurations, a 12.5m bus can carry as many as 75 people (seated and standing capacity combined), although the legal carrying capacity of the bus is often governed by total axle loads, not physical internal space. Design improvements over the last decade have resulted in significant weight reductions in the vehicles themselves, allowing increases in legal carrying capacity.

As 12.5m buses have been the mainstay of urban bus networks in Australia for at least 20 years, their operation and maintenance costs are relatively low. Existing depot infrastructure is typically designed around the needs of this size of bus, and maintenance personnel are well accustomed to them. CNG fuelled buses tend to have slightly higher maintenance costs compared to diesel.

Approximate purchase cost of these vehicles is $450,000 per vehicle[1], including air conditioning.

Figure 2.1: Standard 12.5m buses at Cultural Centre Busway Station

2.2.2 Extended (14.5m) Rigid Buses

Extended length (14.5m) rigid buses have been traditionally used for long-distance passenger coaches, but began to be used for urban services in the mid 1990's. To accommodate the higher vehicle mass, a second rear axle is used to distribute the loads. Originally, both rear axles were fixed, resulting in poor manoeuvrability which limited the useability of these vehicles. Over the last five years, the use of a steering rear axle has become commonplace, significantly improving the manoeuvrability of 14.5m buses, resulting in their rapid adoption into fleets around Australia.

The additional 2m length enables a higher carrying capacity with up to 100 people (standing and seating) able to be accommodated. A 14.5m bus has relatively low capital cost (approximately $550,000) which means they are cheaper on a per-person-capacity basis than standard 12.5m buses. Operating costs are only marginally higher than 12.5m buses, but lower on a per-person-capacity basis.

Due to the length of the vehicle and their increased turning circle, 14.5m buses are unable to operate on many smaller roads. Under current legislation, the largest rigid vehicle permitted to operate on roads in Australian states and territories is 12.5m. The larger 14.5m buses are currently permitted to operate on what is known as Restricted Area Concessions or Controlled Access Permits. A current Federal review of heavy vehicle legislation is likely to change this situation.

[1] Vehicle cost estimates based on MRCagney's recent experience with different public transport operators throughout Australia. It is not based on the cost of vehicles from a specific manufacturer.

Figure 2.2: 14.5m extended rigid tag-steer bus operated by Brisbane Transport

2.2.3 Double Decker Buses

Double decker urban route buses are common in many parts of the world, including the UK and Hong Kong. The classic London Routemaster double decker bus is possibly the most iconic bus design of all time.

Although relatively uncommon in Australasia, double decker buses provide a cost effective high capacity vehicle (approximately $650,000 per vehicle). Double decker buses are currently being trialled in both Sydney and south east Queensland to determine their suitability for wider deployment. Trials of double decker buses are also planned for Auckland in late 2012.

The carrying capacity of a 12.5m long, double decker bus is up to 120 people (both seated and standing) and results in a marginally better cost per-person-capacity than the 14.5m extended rigid buses. The upper deck is obviously restricted to able bodied passengers only.

The recent increase in interest for these vehicles relates to their higher carrying capacity, whilst still only requiring the kerb space of a standard 12.5m bus. This results in reduced congestion in constrained bus stations and bus stops, particularly in inner-CBD areas.

A trade-off is slower boarding and alighting speeds, both due to the need for passengers to traverse the stairs within the vehicle, and at stops where very large volumes of passengers board or alight. The most suitable use of these buses in Queensland may be routes with infrequent stops, or routes that have little turnover of passengers along length (such as peak period express services).

The height of these vehicles also prevents their operation in areas of low bridges, overhanging building awnings or low overhanging trees.

Figure 2.3: Prototype double decker bus built by Bustech in Queensland

2.2.4 Articulated (18m) Buses

Articulated buses have a significant carrying capacity as well as the potential for swift boarding and alighting times. Due to the length of the bus as many as five doors can be provided on an articulated bus, although three doors is the maximum used in Australia. In the TransLink network, most articulated buses are two door, whilst Logan City Bus Service operates three door "Superbus" articulated buses.

The length of articulated buses can be problematic, consuming valuable kerb space in city centre areas, requiring long bus stops and larger bus interchanges.

Carrying up to 115 passengers (seated and standing) and costing approximately $750,000 per vehicle, this bus represents a higher capital cost than 14.5m extended rigid vehicles or 12.5m double deckers on a per-person-capacity basis.

The different designs of articulated bus used by Brisbane Transport and Logan City Bus Service result in different passenger capacities of 100 and 112 respectively.

Figure 2.4: 18m Articulated bus operated by Brisbane Transport.

2.3 HCVs Manufactured in Australia

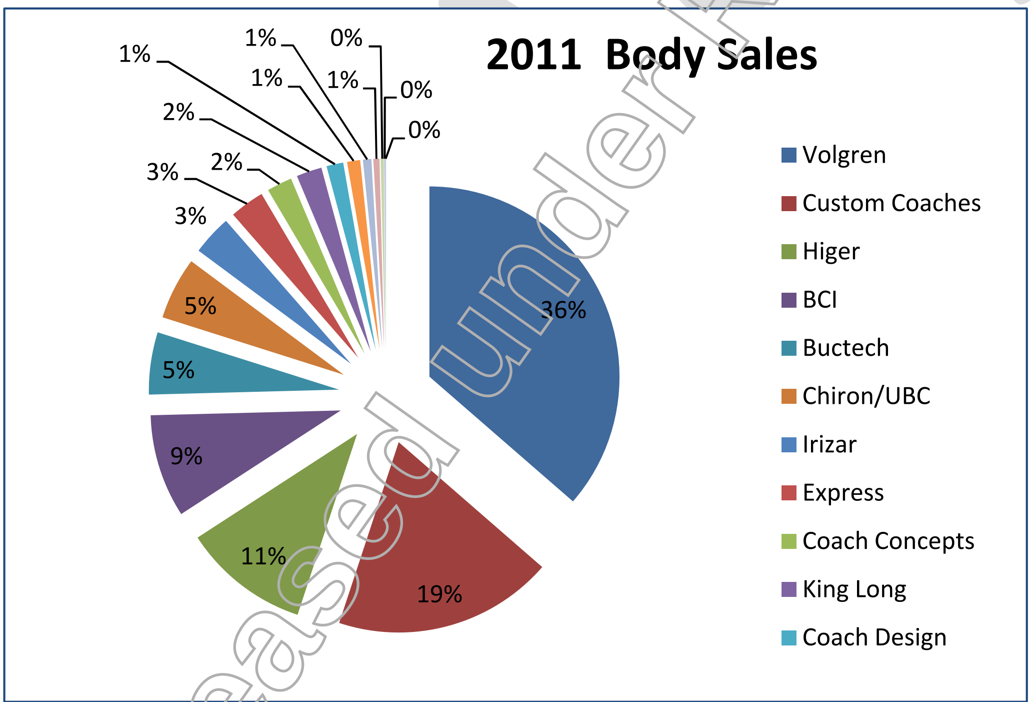
The following Australian bus manufacturers have been identified who currently produce HCVs:

Bus Builder	Location	High Capacity Vehicles
Bustech	Gold Coast	Double Decker
Custom Coaches	Sydney & Adelaide	18m articulated
Denning	Brisbane	Double Decker
Volgren	Brisbane & Melbourne	14.5m extended rigid 18m articulated

According to New Bus Search Magazine, the top twenty buyers for 2011 were lead by New South Wales Transit (152) and Brisbane City Council (133), proving that low floor route service operations still command the largest slice of the bus supply pie. Notably both of these operators are government owned.

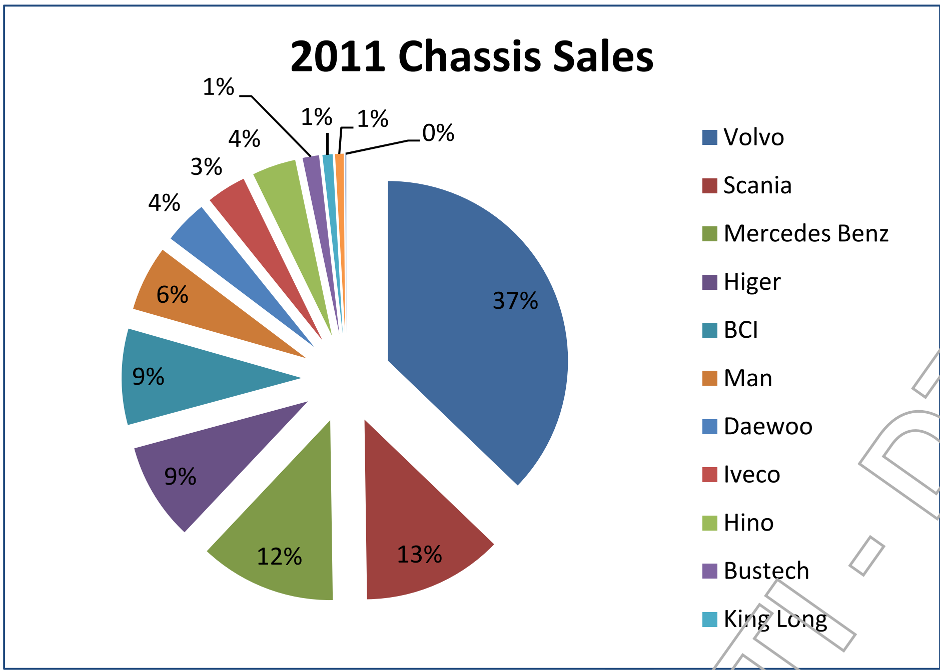
The following figure shows bus sales by body builders in Australia 2011. This shows that Volgren had more than 36% of the market share.

Figure 2.5: Bus sales by body builder in Australia 2011



The following figures presents chassis sales in Australia in 2011 where Volvo had more than 37% of the market share.

Figure 2.6: Chassis Sales in Australia 2011



2.4 Future Australian HCVs (concepts)

2.4.1 Double Articulated Buses

It is understood Custom Coaches are working on the CB80 Bi Artic, a 24m bi-articulated HCV, as per the concept design below.

Figure 2.7: Custom Coaches concept design for the CB80 Bi Artic

According to Custom Coaches, the CB80 Bi Artic is designed for Bus Rapid Transit (BRT) solution and is developed for current and future plans to introduce BRT solutions in Australia. The stated operational benefits of this vehicle design include high passenger capacity (200 plus), multi wheelchair access and low cost of operation.

Although the Heavy Vehicle Regulations have been amended to allow articulated vehicles' increased mass loading, it is unknown if such a vehicle would be permitted on Australian roads, as they may not meet the amended standards.

Previous investigation by TransLink determined a number of potential issues which would prevent their use on the existing Busway infrastructure.

2.4.2 Extended Double Decker Bus

BusTech has indicated that they are developing a prototype for a 14.5m, four axle, two staircase, three door Double Deck bus that may be capable of carrying over 150 passengers. This design is particularly interesting as it may have better manoeuvrability than a standard 14.5m extended rigid bus, due to a twin front axle as well as a tag steer twin rear axle. The presence of a second staircase will improve passenger unloading times and reduce dwell times at stops, as will the presence of a third door. The combination of these design features means that it would represent an idealised scenario in terms of passenger capacity and efficiency of operation.

2.5 Potential Imported HCVs

2.5.1 Articulated Vehicles

Australian chassis and body makers are likely to experience increases competition in the near future from recent entrants into the Australian market, notably from China.

Also, the recent part sale of Volgren to Brazilian bus manufacturer, Marcopolo, is also likely to influence the availability of new model vehicles in the Australian market. Based in Brazil, Marcopolo also operates South Africa, Argentina, China, Colombia, Egypt, India, Mexico, and Russia. Of interest is the 21m articulated 4 door vehicle produced by Marcopolo especially for bus rapid transit (busway), known as the Viale BRT, as per the design below. 49 of these buses were recently put into service the new Transoeste BRT system in Brazil. However the width of this vehicle is 2.6m and would not meet ADR specifications without modifications to the design. It is also based on a high-floor chassis which is incompatible with TransLink infrastructure.

Figure 2.8: A 21m articulated VIALE BRT bus by Marcopolo

2.5.2 Double Deckers

The 2.55m wide low-floor Enviro500 can carry up to 125 people (100 seats), is just under 12.0m in length, and under 4.4m in height. These buses are currently deployed in the UK, Hong Kong, Dublin and Las Vegas.

Figure 2.9 Enviro500 Double Deck bus

The Enviro500 was road tested in Queensland in 2008[2]. At present the Enviro500 buses are 2.55m wide and would need to be redesigned to 2.5m to meet Australian Design Rules (ADR).

The trend in Europe at the moment is on consolidating manufacturing locations and increasing 'completely built-up' (CBU) vehicles entering the Australian market, built to local tonnage and dimension specifications under the ADR.

CBU vehicles are likely to increase in the Australian market from 2012 from China and Malaysia, with new products from the Middle East and Europe. The risk associated with imported products, even if built to ADR specifications, is some importers build for markets with shorter bus life cycles than Australia. Most buses built in Australia are built to specifications to exceed a 20 year life span. Managing the supply chain for spare parts can become increasingly difficult in these circumstances unless very large volumes of a single make and model of bus are imported.

[2] An independent review of this road test is available at http://www.alexander-dennis.com/highway-to-the-city.php.

3. Legislation and Policy Background

A comprehensive review was undertaken of legislation, standards, land use and public transport plans and policies, and road and transport infrastructure programs which will impact on the future deployment and operation of the high capacity vehicles in South East Queensland. The following is a brief summary of some of the findings and insights found during the document reviews undertaken for this report.

3.1 Impacts of the draft Heavy Vehicle National Law

3.1.1 New axle limits

New axle mass limits proposed in the draft *Heavy Vehicle National Regulation* are highly favourable to future deployment of ultralow floor high capacity route buses, most notably the rear pusher type articulated buses. Provided axle mass limits are not exceeded, the Australian vehicle design rules and Queensland regulations provide considerable flexibility in the way high capacity route bus cabin layouts can be configured. Bus seating can be optionally maximised to reduce passenger standing on long trips or alternatively reduced to maximise mass transit total carrying capacity on short trips. The distance for which continuous passenger standing is permitted on urban route bus services has recently been extended to 20km.

3.1.2 Impacts on 14.5m rigid buses

14.5m rigid high capacity route buses are 2m over length relative to contemporary *Australian Design Rules*, and as such, are not permitted under existing State or Territory road use management regulations to be registered and driven on public roads. They are however permitted to operate route bus services in some States and Territories under short term concessional access permits issued by the road authority in each jurisdiction.

14.5m rigid buses have now been formally recognised in the new draft Heavy Vehicle National Regulation and classified as an over length special class of heavy vehicle, subject to the proposed new higher mass limit (HML) axle weight restrictions and HML area permits which effectively restrict the areas and roads on which these buses can be driven. HML area permits will replace the current Department of Transport and Main Roads (DTMR) gazetted concessional ccess permits expiring on 30 June 2012.

By 2013, after the *Heavy Vehicle National Law* has been enacted across all Australian States and Territories, only the *National Heavy Vehicle Regulator*, in consultation with individual State and Territory road authorities, will be empowered to declare HML areas and routes on which 14.5m rigid buses will be permitted to operate. National HML area permits will enable Gold Coast school and route bus services operated with 14.5m rigid buses to continue across the Queensland-NSW border.

Road authorities such as DTMR have previously had the power under State and Territory legislation to arbitrarily set different heavy vehicle dimension and axle mass limits for special heavy vehicle types that currently include 14.5m rigid buses. Consequently, 14.5m rigid bus concessional wheelbase and rear overhang length limits now vary considerably between the 3 Eastern States and ACT, and 14.5m rigid route buses built to meet these concessional length limits in each jurisdiction are also significantly different. The draft *Heavy Vehicle National Regulation* has not yet resolved the uniform wheelbase and rear overhang limits for 14.5m buses.

3.1.3 Impact on double deckers

The draft *Heavy Vehicle National Regulation* has lifted the overall height limit on double deck buses to 4.4m to enable higher interior head clearances on both passenger decks, but has to date neither recognised ultralow floor double deck buses as an emerging new category of Australian heavy route omnibus, nor proposed higher general axle mass limits for PWD accessible ultralow floor double deck buses, similar to those already given to other PWD accessible bus sizes. There are 8 bridges in South East Queensland with clearances equal to or less than 4.4m.

Double deck buses are currently exempted from the stringent ADR59 structural rollover strength requirements applicable to all other heavy omnibus types. Consequently ADR59 exemptions for closed roof double deck urban route and school buses are anticipated to cease in future.

3.2 Additional legislative impacts and constraints

3.2.1 DTMR *Notified Roads*

None of the 4 subject high capacity buses selected for the study was considered appropriate candidates for the 30 DTMR steep incline - no standing *Notified Roads* located in South East Queensland. School and route bus services on DTMR *Notifed Roads* should be operated using 12.5m rigid ADR68 *Complying Buses* fitted with structurally anchored seats, seat belts and child constraints.

3.2.2 Environmental noise emissions

High capacity hybrid diesel-electric buses are becoming increasingly more popular in European, SE Asian and USA capital cities because of their considerably faster take off acceleration from stops, lower fuel consumption and exhaust emissions in stop-start traffic conditions, and quieter operation relative to comparable high capacity diesel buses. Diesel-overhead electric and diesel-L-ion battery or supercap electric buses travelling through noise sensitive route sectors in these overseas cities must under local planning laws operate by electric motor only whilst located in CBD office districts, residential suburbs and public road tunnels. Environmental noise immission laws, rather than heavy vehicle noise emission rules, may restrict high capacity diesel buses from entering noise sensitive commercial, residential, health and education precincts under proposed future Queensland EPA environmental noise planning limits. Only traffic noise generated on State main roads are exempted from these limits.

3.3 Existing Policies and Standards

3.3.1 Connecting SEQ 2031

In late 2011, DTMR published *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland* in response to desired regional outcomes 8, 10 and 12 of the *South East Queensland Regional Plan 2009 – 2031. Connecting SEQ 2031* describes sweeping changes to both the structure and operation of the rail and bus network in South East Queensland called *UrbanLink,* which is based on the mass transit trunk and feeder operating concept.

3.3.2 UrbanLink

The proposed *UrbanLink* backbone is comprised of high speed long haul railway, busway and transitway spines radiating out from the Brisbane CBD to surrounding regional and sub-regional transport nodes called hubs, complemented by the new *GoldLinQ* light rail and *CoastConnect* coastal bus sub-spines on the Gold and Sunshine Coasts, with each sub-spine connected by high frequency cross-country connector and local bus services to the high-speed heavy rail corridors to the Brisbane CBD. A new form of bus service, called *ExpressLink*, is also envisaged in *Connecting SEQ 2031* that will provide 6am – 9pm express bus services between major outlying rail and bus station hubs in Greater Brisbane to other major transport nodes in adjoining SEQ regions, and from country railway stations to places of high employment.

High capacity buses are considered the optimum vehicle for carrying the high passenger loads expected on new *UrbanLink* cross-city, high frequency trunk and *ExpressLink* cross-country bus services proposed to be operated between regional activity centres.

UrbanLink implementation will involve conversion of hundreds of existing *TransLink* single seat bus journeys to split trunk and local feeder journeys, so that existing buses can be freed up to deliver higher frequency local district feeder services with greater area coverage. The effect of this structural reform to the way the SEQ bus network currently operates will be a transfer of multiple combined local district passenger loads to the proposed new high frequency trunk rail and bus spines.

A large number of early works planning, design and construct programs has been sighted in the State's current infrastructure funding programs to extend Brisbane busways and create multiple new bus priority transitways and corridors for the new *UrbanLink* bus network. *Connecting SEQ 2031* indicates that the development of these corridors will be packaged with the staged conversion of existing single seat bus services to trunk and feeder bus services, but there appears to be no planning or programs currently in place to deliver the additional fleet needed to operate the new trunk services along these priority bus corridors.

3.3.3 Austroads bus bay design standards

The Queensland Road Planning and Design Manual and national Austroads Guide to Road Design Manual used by DTMR and SEQ Local Governments to design indented bus bays only have drawings suitable for 12m rigid and 18m articulated buses, but no drawings for 14.5m rigid buses.

Other documents, including the *Code of IDAS* and *TransLink Infrastructure Manual* will need to be amended for high capacity buses.

4. Infrastructure Assessment

4.1 Busways

The Brisbane busways have been designed to a standard that allows the use of HCVs.

The design standards for the South East Busway were developed in the 1990's and inherently allow the use of articulated vehicles. This is one of the reasons why busway stations use linear platforms instead of independent bays (e.g. sawtooth). Linear platforms allow any bus to access it, irrespective of length.

Vertical clearance within the busways was designed to be high enough to be able to install power catenary if future upgrading to light rail or trolley bus were to occur. As such, adequate vertical clearance for double decker buses is provided (which has been operationally tested on the South East and Boggo Road Busways).

The increased manoeuvring space required for 14.5m buses means that some pinch points do exist. The portal of the busway at Melbourne Street is well known to provide difficulty for these buses, and is to undergo modification to address this. King George Station has two tight roundabouts which may cause some difficulties for 14.5 rigid buses which do not have increased steering locks.

4.2 Bus Stations, Interchanges and Park & Rides

Our study reviewed a sample of bus stations to represent SEQs infrastructure. This analysis included a total of 69 stops and was for the following stations:

- Aspley Hypermarket
- Capalaba
- Carindale
- Chermside
- Garden City
- Inala Bus Station
- Indooroopilly
- Loganholme
- Springwood
- Toombul
- UQ Chancellors Place

Our analysis of stations was based on a desktop analysis of aerial photos and plans where available. Our review was intended to provide a high-level assessment of the potential impacts of running HCVs through a bus station. It is therefore recommended that an on-site review of each station is recommended to verify our results on the ground prior to confirming any routes or operations for HCVs.

Key findings of our review can be summarised as follows:

- About two-thirds of stops cannot be lengthened to accommodate 14.5 or 18 metre buses.
- Nearly all reserved bus standing or holdover bays are long enough and accessible for HCVs.
- Very few stops have obstructions at the rear door, such as a stop blade/sign.
- Nearly all stops offer a clear approach, however 20% of stops require exit on full lock and a further 3% present obstruction on exit.
- Slightly over half of stops are located in stations where there are no obstacles to entry and exit of the station.
- Buses can enter and exit 55% of stops safely.
- At 18% of stops, the tail of a 14.5m bus would swing over the kerb or collide with street furniture.
- At 90% of stops a 14.5m or 18m arctic bus would fit within the swept path turning template around a station for all road entries and exits.
- Double decker buses do not have problems for height clearance at most stops.

The ability for the stations along existing BUZ routes to accommodate HCVs without upgrades varies considerably. Route planning will need to be influenced by a ground-verified knowledge of the capacity of individual stops to accommodate HCVs that this technical note begins to deliver.

4.3 Bus Stops

Our study reviewed BUZ Routes 100, 140, 150, 130, 120, 180 and 385 to assess the capacity of existing bus stop infrastructure along these routes to accommodate HCVs. These BUZ routes were selected as representative of the overall network that HCVs may potentially operate on in the next five years.

Our analysis of stops is based on a desktop review of aerial photos. While suitable for a high level analysis of a network, an on-site review of each stop is recommended to verify our results on the ground prior to confirming any routes for HCVs. We were unable to perform an aerial photo analysis on a proportion of stops for key categories (i.e. ability to lengthen a stop) because of photo quality or obscured stop images.

Our overall findings are summarised as follows:

- Overall results indicate that stops are nearly all clear of obstructions on approach and on departure of buses.
- Most stops are regular kerbside stops.
- Many stops are unable to be lengthened; however we were unable to assess this for nearly half of all stops.
- The blade or sign is clear of the kerb at nearly all stops and the rear door would be clear at nearly three quarters of all stops.
- Nearly all stops allow buses to stop parallel to the kerb.
- Nearly one third of all stops had a hardstand area clear of obstruction for all doors, with 21% being obstructed. At 42% of stops only the front doors were clear of obstructions.
- Only one stop appears to be greater than 65 metres in length.

- Half of stops can be lengthened to 65 metres.
- Three quarters of stops have no road markings at front or rear.

The ability for the 444 stops along existing BUZ routes to accommodate HCVs without upgrades varies considerably and we were unable to determine some measurements for all stops. Route planning will need to be influenced by a ground-verified knowledge of the capacity of individual stops to accommodate HCVs that this technical note begins to deliver.

4.4 Inter Modal Services

The performance of HCVs for intermodal services can be assessed like any other interchange location. The key issue is the larger passenger volumes boarding or alighting from any one bus, compared to a standard bus.

For alighting passengers, this should not cause a problem as passengers exit the vehicle from one or more doors in a steady stream. This regulates the flow of passengers so that walkways, stairways, overbridges etc should be able to accommodate the demand.

It is passengers waiting to board that have the potential to cause congestion, if the waiting area hasn't been designed for the larger volume of passengers (up to 120 versus 75 on a standard bus). Accumulations of such high loadings are unusual for feeder bus services, but could occur if multiple services (e.g. rail) arrive at a station within a short period of time. Although the assessment of which routes should be selected for deployment of HCVs will not be undertaken until Stage 2 of this study, initial review of the network suggests it unlikely that a HCV would feed to rail.

No instances of HCV buses feeding to ferry services are likely to occur.

HCVs, by their nature, are unlikely to feed into other bus services other than to low volume feeder buses at suburban locations. For example, to function effectively as a feeder system, two or more partially-loaded local services might arrive at a bus station for passengers to connect to a HCV based service. This would, by design, only occur at stations where there is the physical capacity available to accommodate HCVs which would include adequate passenger waiting areas.

4.5 Pavement Impacts

Pavement designs are based on the cumulative number of heavy vehicles in the design lane. In some cases the design lane may not be the most heavily trafficked lane, such as when designing inside widening of a multi-lane carriageway. Different types of vehicles cause different types of damage to pavements. Vehicle loading damage on highway pavement corresponds closely to axle weight and configuration.

Many studies have been done to reveal the relationship between trucks and pavement damage which can be used to inform the impacts of HCVs will have on pavements. Suspension type and characteristics, as well as tire type and configuration, are major contributors to pavement deterioration.

Buses typically have an even larger load impact than heavy trucks due to the limited number of axles and tires they employ to distribute their weight. The increase in damage level with load is not linearly proportional. It takes the shape of the exponential function with a power constant value range from 4 to 6. Under the fourth power rule one bus overloaded by 25% does as much damage to the road as two buses. The performance of HCV route pavements will be a function of load frequency and existing pavement design life. In order to combat the significant surface stresses of the setdown areas these should be constructed in concrete.

Pavement deterioration caused by HCVs will accelerate the need for greater pavement maintenance and a comprehensive Pavement Management program should be established to confirm whole of life costs for pavement rehabilitation or reconstruction.

5. Operational Assessments

5.1 Average Bus Stop Boarding and Alighting Times

5.1.1 Methodology

An assessment to determine the variation in boarding and alighting was undertaken using data sourced from the *go* card system. Data was gathered for the inbound and outbound directions during peak and off-peak operating periods between 1 March and 8 April 2012.

Source data was obtained from a netBi structured query of passenger *go* card tag-on and tag-off transaction times at all bus door card interface devices, then sorted from first to last by time, date and trip direction for each card interface device and bus stop. After extensive data cleansing and sequential logic testing, only 184,500 of the 538,500 *go* card transactions loaded from netBi were deemed valid and used to compute the average time measurements.

There are a number of potential sources of error from using *go* card data for this assessment:

- The ability to tag-off before the bus has pulled into a stop results in an overestimation of dwell time.
- There is no way to determine instances where the bus was delayed whilst a passenger interacted with the driver (e.g. asking questions), which may increase the span of time between *go* card transactions recorded.
- Alighting passengers with paper tickets are not recorded, creating an underestimation of the number of alighting passengers (i.e. making the average alighting time appear higher).

The bus types and routes covered in the survey were:

- Two Door 12.5m Rigid Bus (Study Reference Standard Vehicle)
  - Brisbane Transport Low Floor Buses 561 - 1055, Aspley Hypermarket to City Route 345
  - Brisbane Transport High Floor Buses 320 – 539, Aspley Hypermarket to City Route 345
  - Brisbane Transport Low Floor Buses 1030 - 1049, Teneriffe to West End Ferry Terminal CityGlider Route 60
- Two Door 12.5m Double Deck Bus
  - Hornibrook Bus Lines Bus 343, Redcliffe to City Route 315
- Two Door 14.5m Rigid Bus
  - Brisbane Transport Buses 5003 – 5126, Browns Plains to City Route 150
- Two Door 18m Articulated Bus
  - Clarks Logan City Buses 116 – 117, Loganholme Bus Station to City Route 555
  - Brisbane Transport Buses 1601 – 1630, Eight Mile Plains to City Route 111
- Three Door 18m Articulated Superbus

- Clarks Logan City Buses 555 – 556, Loganholme Bus Station to City Route 555

5.1.2 Results

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Average Boarding Time Per Passenger	2.7s (LF) 3.0s (HF)	3.0s	3.1s	3.1s	3.5s (LC) 2.6s (BT)	3.7s
Average Alighting Time Per Passenger	2.0s (LF) 2.0s (HF)	2.2s	2.6s	2.0s	2.1s (LC) 1.7s (BT)	2.0s
Average Dwell Time Per Passenger with No Standees	2.5s (LF) 2.9s (HF)	2.7s	3.0s	2.5s	2.9s (LC) 2.4s (BT)	2.9s
Average Dwell Time Per Passenger at >20% Standing Capacity	3.0s (LF) 3.1s (HF)	2.9s	Not Reached	3.3s	3.1s (LC) 2.8s (BT)	3.1s

5.1.3 Conclusions

- The fastest average boarding, alighting and dwell times per passenger for the high capacity vehicles were measured on the Brisbane Transport two-door 18m articulated buses. Observations taken aboard all bus types surveyed suggest that this occurred on the Brisbane Transport articulated buses primarily because alighting passengers positioned themselves at doors well in advance of busway station arrivals, and double streamed off at rear doors and in single file at the front doors with minimal passenger flow conflicts. The Route 111 service had a very incidence of concurrent passenger boarding and alighting and it was noted that there was very little interaction on Brisbane Transport busway services between drivers and boarding passengers.
- No significant differences in boarding, alighting and dwell times per passenger were measured between the Clarks Logan City two and three door articulated buses. Dwell time per passenger on the two Clarks articulated buses was found to be strongly dominated by slow boarding times rather than fast alighting times which effectively negated the benefit of the Superbus dual double width alighting doors.
- Significantly higher average boarding times than alighting times per passenger were measured on all bus types. This suggests that dwell time at stops would be improved by all door boarding.
- The longest alighting times per passenger were observed on the double deck buses where passengers from the upper deck continued to alight from the double width rear door in single file well after passengers on the lower deck had disembarked. At the high AM offloading stops in Fortitude Valley and CBD, passengers alighting from the upper deck continued to disembark for up to 10s after passengers on the lower deck had fully cleared. Boarding times on the double deck bus were largely unaffected by upper deck use, but it was found that alighting times could be significantly impacted by less able bodied passengers who blocked others and delayed descending the upper deck staircase until the bus had fully stopped.
- Average alighting times per passenger were found to be similar between the older high floor 12.5m rigid buses with double width rear doors and two steps to the newer low floor step-free 12.5m rigid buses with single width rear doors.

- Marginally higher average boarding and alighting times per passenger were recorded on the all door boarding 12.5m low floor CityGlider buses than on the standard 12.5m route buses. This was found to be due to the low utilisation of the rear door by boarding passengers, and the casual laid back nature of off-peak CityGlider passengers. Because this service has no fixed off-peak timetable, it was found on 4 observation trips that CityGlider drivers repeatedly held over at bus stops for late arriving and hailing passengers, and most onboard passengers made little effort to move to doors prior to bus stop arrivals. Further, because the CityGlider only has a single width rear door, those passengers who elected to board at the rear door had to wait until all onboard passengers had alighted, and in many cases, were still boarding after passengers using the double width front doors were boarded and seated.

5.2 Passenger Alighting Preferences

5.2.1 Methodology

Passenger alighting preferences were summated and apportioned by percentages from netBi tag-off records for all bus types and services and have been observed from the data to impact on both boarding and dwell times at bus stops. Alighting surveys were also conducted at five busway stations and on 16 separate bus trips to identify why passengers chose to alight at front doors delaying boarding passengers, or at rear doors enabling concurrent conflict-free boarding and alighting. All door boarding and alighting was also observed on 4 Brisbane Transport CityGlider services.

5.2.2 Results

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Percent Who Alighted at Front Door	31% (LF) 36% (HF)	27%	47%	19%	55% (LC) 52% (BT)	14%
Percent Who Alighted at Middle Door						44%
Percent Who Alighted at Rear Door	69% (LF) 64% (HF)	73%	53%	81%	45% (LC) 48% (BT)	42%
Percent Who Boarded at Rear Door		26%				
Percent Who Boarded to Upper Deck			49%			
Percent Who Boarded to Upper Deck			51%			

5.2.3 Conclusions

Where boarding and alighting times per passenger are a measure of the high capacity bus configuration efficiency in enabling concurrent passengers movements, the total bus stop dwell time is effected by passenger preferences to use specific doors for alighting. Minimum total service dwell time is achieved when mixed passenger boarding and alighting movements occur concurrently in approximately equal times.

For AM inbound services to stops predominated by boardings, average dwell time per passenger converges to the average boarding time per passenger, total stop dwell time becomes proportional to the number of passengers boarded, and concurrent alightings from rear doors have no material effect on total dwell time. The opposite occurs for PM outbound services to stops predominated by alightings.

- It was observed that concurrent passenger alightings from the Clarks Logan City three door articulated Superbuses provided the shortest total alighting time and least conflict between boarding and alighting passenger streams. The middle and rear doors on the Clarks Superbus were equally preferred by alighting passengers and only 1 in 7 passengers chose to exit from the front door.
- 69 – 73% (more than 2 to 1) passengers preferred to alight from the rear door on a standard low floor rigid bus, where 81% (4 to 1) passengers preferred to exit from the rear door on a 14.5m rigid bus. Disproportionate use of the rear door to exit from 14.5m rigid buses was found to occur because the larger bus cabin layout has placed 90% of all passenger seats and standing areas closer to the rear door than the front door. Cabin layout was identified as the key reason why 14.5m buses take longer to offload passengers en mass than rigid and articulated buses at AM peak inbound stops in the CBD and other highly congested stops such as Cultural Centre and UQ Lakes Bus Station.
- It has been found that passengers are evenly split on their preference for sitting on the upper and lower decks of the double deck bus. Our onboard observations found that young and able bodied passengers under 40 years of age preferred the upper deck while older passengers and those for whom the upstairs ride was no longer a novelty preferred the lower deck. The double deck bus suffers from extended stop dwell times caused by alighting from the upper deck to the rear door but as for the 14.5m rigid buses, extended dwells are more pronounced when a large number of passengers alight en mass at stops.
- Only 1 in 4 passengers on the CityGlider service choose to board at the rear door. This probably occurs because Brisbane bus passengers have been conditioned to board at the front door and because passengers are reluctant to wait at the single width rear door for alighting passengers to fully disembark. It was noted on CityGlider trips that passengers waiting to board at the rear door frequently lost patience with alighting passengers and moved to the front door queue as it shortened. Single width rear doors appear to acts as a strong passenger deterrent to rear door boarding.

5.3 Average Deceleration, Acceleration and Speed

5.3.1 Methodology

Bus acceleration and deceleration were measured using a 60 channel, 5Hz high resolution differential GPS logger accurate to within +/- 0.5m resolution. Measurements were obtained by riding aboard each bus type for 2 or 3 trips while in active service. GPS Logs were downloaded from the DGPS logger and analysed using ActiveGPX and Google Maps to review routes and stop locations as illustrated below for the GPS log recorded on Route 315.

5.3.2 Results

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Typical Deceleration from 50km/h	-1.3 m/s²	5.3.2.1 -1.02 m/s²	-1.1 m/s²	-1.27 m/s²	-1.23 m/s²
Typical Deceleration from 90km/h	-0.86 m/s²	-0.64 m/s²	-0.72 m/s²	-0.64 m/s²	-0.8 m/s²
Average Trip Deceleration to Stop	-0.89m/s²	-1.04m/s²	-0.85m/s²	-0.6m/s²	-0.9m/s²
Typical Acceleration to 50km/h	1.1m/s²	0.76m/s²	0.96 m/s²	0.89m/s²	0.85 m/s²
Typical Acceleration to 90km/h	0.56m/s²	0.45 m/s²	0.54 m/s²	0.5 m/s²	0.48 m/s²
Average Trip Acceleration from Stop	0.9m/s²	0.7m/s²	0.76m/s²	0.67m/s²	0.8m/s²
Average Trip Speed	22km/h	41km/h	52km/h	43km/h	48km/h
Maximum Trip Speed	48km/h	92km/h	98km/h	92km/h	94km/h
Average/Maximum Speed	46%	45%	53%	47%	51%

5.3.3 Conclusions

- Average deceleration to bus stops and acceleration back to incident left lane traffic speed (peak) or regulated traffic speed (off-peak) traffic speed was found to have a low variance for each particular bus driver, but not for each bus type. It was found that some drivers preferred to coast into stops and accelerate off slowly, while others were observed to be more aggressive on the brake and throttle. The worst average acceleration and deceleration rates were measured on the CityGlider off-peak services and the results tabulated above reflect in-service driving habits more so than bus performance.
- Average deceleration to bus stops and acceleration back to incident traffic speed was found to increase inversely with traffic speed for all bus types.
- Of the high capacity vehicles, the fastest 50/90km/h to 0km/h deceleration and 0km/h to 50/90km/h acceleration rates were recorded on the 14.5m rigid bus and were similar to those measured for 12.5m standard low floor buses. When fully loaded and driven hard by more aggressive drivers, the 14.5m rigid buses outperformed all other bus types, including standard 12.5m buses, for bus stop braking deceleration and take-off acceleration.
- At stations and bus stops that boarded or alighted less than 3 passengers, the time taken to decelerate into and accelerate out of the stop back to traffic speed typically exceeded the total bus stop dwell time.
- Average trip speeds were found to be around 48% of maximum service speed. In suburbs where bus stops were closely spaced within 450m, average speed fell to as little as 32% of the incident traffic speed, but on the busways where stations were spaced around 2.4km, average speed increased to 56% of the maximum busway speed (90km/h). Measured HCV deceleration and acceleration results were found to be more closely related to stop spacing, driver performance and average traffic speed than to particular bus types.

5.4 Peak and Off-Peak Capacity Usage

5.4.1 Methodology

An assessment to determine the peak and off-peak capacity usage on the different bus types was undertaken using data sourced from the *go* card system. Data was gathered for both the inbound and outbound directions during peak and off-peak operating periods between 1 March and 8 April 2012. The source data used was obtained from a netBi structured query of passenger *go* card tag-on and tag-off transaction times at all bus door card interface devices to determine the boarded passenger loads on each route and trip, and the results obtained below therefore do not include passengers who boarded and purchased paper tickets.

The bus types and routes covered in the statistical analyses were identical to those earlier listed in Section 5.1.1. Seated and total (seated plus standing) capacities for all bus types were obtained from their respective bus manufacturer drawings and bus operators. Low floor (LF) and high floor (HF) standard rigid buses were separately assessed for Route 345, and Clarks Logan City (LC) and Brisbane Transport (BT) 18m articulated buses separately assessed for Routes 555 and 111 respectively.

The terms "peak" and "off-peak" where used in the table of results below do not strictly correlate with TransLink's defined AM/PM commuter peak and off-peak periods. It was found for instance that some bus loading peaks occurred regularly on Route 345 during the AM and PM school runs, and before and after defined commuter peak periods on the longer 315, 150 and 555 routes.

When filtering the netBI transaction data to assess the number of seated and standing passengers on each bus trip, it was assumed that all seats were occupied before passengers began to stand and that the number of standees equalled the difference between the boarded passenger load and bus type seating capacity. Observations made while travelling on a broad cross-section of bus services has indicated this assumption generally reflected how passengers distributed themselves between seated and standing areas, but it was noted that school and university students regularly chose to stand and socialise with their friends, and that passengers who boarded for short rides frequently chose to stand near rear exit doors when seats at the rear of the vehicle remained unoccupied.

5.4.2 Results

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Seated Passenger Capacity	44 (LF) 47 (HF)	44	96	56	64 (LC) 63 (BT)	52
Maximum Passenger Capacity	75 (LF) 70 (HF)	62	116	92	90 (LC) 85 (BT)	112
No of Services Operated Per Weekday	159 (LF) 159 (HF)	236	31	167	138 (LC) 199 (BT)	138
No of Peak Services Per Weekday with Standees	13 (LF) 21 (HF)	3	0	10	4 (LC) 4 (BT)	10
Percent of Services Per Weekday with Standees	8% (LF) 13% (HF)	1%	0%	6%	3% (LC) 2% (BT)	7%
Average Standees on Peak Services	10 (LF) 13 (HF)	8	0	10	9 (LC) 8 (BT)	10
Maximum Standees on Peak Services	34 (LF) 39 (HF)	38	0	44	39 (LC) 28 (BT)	40
Average Standing Time on Peak Services	13min (LF) 14min (HF)	8min	0min	18min	12min (LC) 9min (BT)	13min
Maximum Standing Time on Peak Services	27min (LF) 34min (HF)	25min	0min	37min	23min (LC) 19min (BT)	26min
Average No of Off-Peak Seats Occupied	17 (LF) 20 (HF)	11	26	23	24 (LC) 23 (BT)	23
Average Percent of Seat Capacity Used Off-Peak	39% (LF) 43% (HF)	25%	27%	41%	38% (LC) 37% (BT)	44%

5.4.3 Conclusions

- Only a very small percentage (2% - 7%) of high capacity bus weekday peak services carried standing loads as compared with the 12.5m standard rigid buses (typically 8% - 13%). For the high capacity bus peak weekday services on which passengers stood, the average standing time varied between 9 – 18min, but for passengers who stood for most of the trip, the maximum standing time varied between 19 – 37 minutes. In all cases, the worst case maximum standing time was very near to twice the average standing time.

- No double deck bus passenger loads were identified on which boarded passenger loads exceeded bus seating capacity.
- Only 27% - 44% of the high capacity vehicle seats were occupied during the off-peaks compared with 39% - 43% for the 12.5m standard rigid buses. On the basis of this and the preceding conclusions, all high capacity buses used on the services assessed could afford to reduce their seating capacity, increase their total (seated plus standing) capacity and improve their alighting, boarding and dwell times by widening of aisles and standing areas adjacent to rear doors.
- Average and maximum standees and standing periods were found to be lowest on the high passenger turnover CityGlider and 111 routes. Our analysis has clearly demonstrated that driver overload reports and trip peak boarding counts do not provide accurate surrogates for the determination of peak loading, overloading and overload duration or for the justifying replacement of standard 12.5m buses with high capacity buses. These can only realistically be determined on high passenger churn services by measuring cumulative tag-ons and tag-offs incrementally along each trip after every bus stop and assessing their whole-of-journey differences to calculate average and maximum standing loads and durations.

5.5 Capacity Impact of Vehicle Type on Stops and Stations

5.5.1 Individual Stops

At individual stops, or bus stations that comprise a number of independent stops, the capacity of the stop can be measured either in terms of the number of passengers per hour, or number of buses per hour that can be served.

The assessment of this capacity can be undertaken using the methodology in the Transit Capacity and Quality of Service Manual (TCQSM). A detailed summary of this methodology is contained in the relevant Technical Note.

The TCQSM methodology calculates the number of buses per hour that a stop can accommodate, by calculating the dwell time required for each bus, and the amount of time needed between one bus departing a stop and the next bus entering it. Dwell time includes components such as door opening and closing time and the time needed for passengers to board and/or alight. The time required between buses can either be very simple in segregated locations such as a busway, or more complex where access to a stop is affected by passing traffic.

A number of sensitivity tests were done to determine how the different vehicle types perform at an independent stop which has been designed to accommodate that size of vehicle:

- A full load of passengers boards each bus, no passengers alight, front door boarding only.
- A full load of passengers boards each bus, no passengers alight, all-door boarding available.
- Only 10 passengers board each bus, no passengers alight, front door boarding only.
- Only 10 passengers board each bus, no passengers alight, all-door boarding available.

These results are presented in the table below, where an average boarding time of 3.0s has been used for single door boarding (which is recommended as a default value in the TCQSM, and also matches the observed speed for TransLink services). For all door boarding, the recommended boarding rates are 2.0s for two door buses, and 1.6s for three door buses.

	Standard 12.5m Rigid	Double Deck 12.5m Rigid	Extended 14.5m Rigid	BT 2 door, 18m Articulated	LCBS 3 door, 18m Articulated
Bus length (m)	12.5	12.5	14.5	18	18
Capacity (pax)	75	116	92	85	112
Full Load Boarding, No Alighting, Front Boarding Only					
Buses per Hour	7.1	4.6	5.8	6.3	4.8
Pax Per Hour	528.9	536.7	532.9	531.5	536.2
Full Load Boarding, No Alighting, All Door Boarding					
Buses per Hour	10.4	6.8	8.5	9.2	8.8
Pax Per Hour	777.5	794.4	786.2	783.0	981.5
10 pax per bus Board, No Alighting, Front Boarding Only					
Buses per Hour	41.8	41.8	41.8	41.8	41.8
Pax Per Hour	417.8	417.8	417.8	417.8	417.8
10 pax per bus Board, No Alighting, All Door Boarding					
Buses per Hour	55.9	55.9	55.9	55.9	64.6
Pax Per Hour	559.0	559.0	559.0	559.0	646.4

- It can be seen that the number of passengers per hour that can served per hour is roughly the same across all vehicles for single-door boarding, when loading either full or partial loads onto each bus.
- The number of buses per hour that can be served varies when full loading occurs, simply because more buses are required to serve a continuous stream of passengers.
- When all-door boarding is introduced, marked increases in capacity result. When loading partial loads (10 pax per bus), all-door boarding offers a 34% increase in capacity on all two door buses, and a 55% increase in capacity on three-door articulated buses.
- When using all-door boarding to load full bus loads, the increase in capacity is around 46-48% for all two door buses, and 83% for a three door bus.

The conclusion from this is that the single greatest contributor to individual stop capacity is the number of doors available for boarding. The same is true if passengers are alighting.

It is worth noting, that the use of wide (double) rear doors on a bus achieves the same result as using two rear doors (like a three door bus).

5.5.2 Station Platforms including Busways

Bus stations, such as those provided on the busway, which are designed as a continuous length of kerb, are capable of accommodating a mixture of bus types and sizes, as buses queue behind each other at the platform.

Each type of bus utilises a different amount of platform space: inherently we know that a 55m busway platform can accommodate more 12.5m buses at one time than 18m articulated buses. But each bus type has a defined number of passengers it can carry, that can then be assessed per metre of the length of the bus. Because each bus loses the same amount of space at the front for the driver area, and at the rear due to the engine, it seems logical that the longer the bus, the more efficient it becomes in terms of passengers per metre that it can carry. For example, a queue of 100m of articulated buses would be expected to hold more passengers than a queue of 100m of 12.5m buses.

However, some of the length of a busway platform is lost by the space required between stopped buses. This space needs to be long enough so that a bus can move independently away from the platform without colliding with the bus in front. Each bus type manoeuvres differently and has a different amount of clear space that it needs in front of it. A 12.5m rigid bus (single or double decker) requires a 5m gap between buses. Articulated buses also require 5m between buses.

In the case of the 14.5m extended rigid buses, the more distance that is provided, the less pronounced is the rear tail swing issue that occurs. With a 5m gap, the tail swing is 700mm – large enough to conflict with street furniture and waiting passengers. If that gap is increased to 8m, the tail swing reduces to 300mm – the same as a 12.5m bus. This increased gap required between buses begins to negate some of the benefit of using the larger bus.

The table below presents the hypothetical performance of standard 55m busway platforms for each bus type, in accordance with the TCQSM methodology, for the same scenarios undertaken for single stops. The two options for 14.5m buses are considered; using the minimum 5m gap between buses that generates the safety issue from the rear tail swing, and the longer 8m gap which negates this issue.

	Standard 12.5m Rigid	Double Deck 12.5m Rigid	Extended 14.5m Rigid	Extended 14.5m Rigid	BT 2 door, 18m Articulated	LCBS 3 door, 18m Articulated
Bus length (m)	12.5	12.5	14.5	14.5	18	18
Gap between buses	5m	5m	5m	8m	5m	5m
Capacity (pax)	75	116	92	92	85	112
Passengers per metre of bus	6.00	8.88	6.76	6.76	5.56	6.22
Passengers per m of platform (inc gap)	4.29	6.34	4.36	4.09	3.70	4.87
Buses fitted into 55m platform	3	3	3	2	2	2
Full Load Boarding, No Alighting, Front Boarding Only						
Buses per Hour	18.7	12.3	15.4	10.7	11.6	8.9
Pax Per Hour	1401.6	1422.2	1412.3	985.9	983.2	991.9
Full Load Boarding, No Alighting, All Door Boarding						
Buses per Hour	27.5	18.1	22.6	15.8	17.0	16.2
Pax Per Hour	2060.3	2105.0	2083.4	1454.5	1448.6	1815.7
10 pax per bus Board, No Alighting, Front Boarding Only						
Buses per Hour	110.7	110.7	110.7	77.3	77.3	77.3
Pax Per Hour	1107.2	1107.2	1107.2	773.0	773.0	773.0
10 pax per bus Board, No Alighting, All Door Boarding						
Buses per Hour	55.9	55.9	55.9	55.9	55.9	64.6
Pax Per Hour	559.0	559.0	559.0	559.0	559.0	646.4

These results show us how the different bus types perform to the standard design of a busway platform of 55m in length. The longer articulated buses show a noticeable reduction in the number of buses and passengers per hour that can be served. This is due to the ability to only fit two buses into a platform at once, which also occurs if the longer gap between 14.5m extended rigid buses is enforced.

From this we can conclude that in order for 14.5m buses to safely serve busway stations, one of two things must happen:

- The standard length of a busway platform must be increased from 55m to 60m; or
- A clear zone of 700mm from the kerb edge needs to be marked on busway platforms to warn passengers of the dangers of manoeuvring buses. This would be similar to how the platform edges at rail stations are presented.

The use of all-door boarding again yields notable increases in capacity of 47% for all two door buses, and 83% for three door buses. Even with all-door boarding, the increase in capacity for a three door articulated bus doesn't allow it to offer the capacity of a smaller rigid vehicle.

It is suggested that if all door boarding were to occur on a double decker bus, the benefit would be partially reduced as only one staircase is available, which would become a choke point for the two streams of boarding passengers.

Stage 1: Summary Report

Research & Analysis of High Capacity Vehicles

TransLink Transit Authority

Prepared by:

MRCagney Pty Ltd

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Table of Contents

1. Introduction

1.1 Background

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis on the use of High Capacity Vehicles *(HCVs)* within the *TransLink* network. The intention of the study is to gain a concise and consistent understanding of the different types of HCV available and the implications of deploying them within the TransLink network, with a view to inform future fleet procurement strategies for the next five years.

The definition of a HCV is effectively any bus that is larger and more capacious than a single-deck 12.5m rigid route bus, which has been the standard vehicle specification for urban bus operations throughout Australia for the past few decades.

Because of the common adoption of 12.5m rigid buses, most bus infrastructure throughout South East Queensland has been built to accommodate this size of vehicle. This includes bus stations, busways, bus depots and roadside bus stops. The use of larger vehicles has the clear potential for incompatibility with some of this existing infrastructure in terms of both physically fitting within a space designed for a standard bus, but also being able to manoeuvre into and out of that space.

The use of HCVs is also impacted by legislative and operational restrictions. 12.5m rigid buses and 18m articulated buses are standard vehicle sizes under State and Commonwealth regulations and can be driven without constraint on most roads. The situation is more complicated with 14.5m extended rigid buses, which require a road to have been specifically assessed and approved as being able to accommodate this design of vehicle. Different driver licence categories may also be needed to operate a HCV, depending on its specification.

Throughout the world, a vast array of vehicle designs and specifications exist for buses that classify as HCVs, up to the 26m double articulated buses used in some European and South American countries. However, this study is focussed on those vehicles that are readily available in the Australian market and already in use or undergoing trial by TransLink operators.

The high capacity vehicle types nominated by *TransLink* for this study are:

- Two Door 12.5m Double Deck Buses;
- Two Door 14.5m Extended Rigid Buses;
- Two Door 18m Articulated Buses; and
- Three Door 18m Articulated “Superbuses”.

These vehicles have been assessed against standard 12.5m rigid buses, as the base for comparison.

1.2 Objectives of this Report

While this report is not a deliverable under this project, this report is intended to summarise the findings of Stage 1 of this study. The detailed analysis undertaken as part of Stage 1 can be found in the appendices of this report. This summary report will:

- Present key findings of a legislative and policy review which may impact on the use of HCVs;

- Identify and discuss the potential infrastructure requirements and constraints related to the use of HCVs within TransLink's network; and
- Discuss the impacts of various HCV types on operational aspects such as boarding and alighting times.

Stage 2 of this study will include an assessment of where in the TransLink network HCVs should be deployed in the future and the financial implications of doing so.

1.3 Report Structure and Appendices

The structure of our report is as follows:

- Section 2: High Capacity Vehicle Types - The scope of this project is limited to technology available within the Australian market. This section will discuss the HCVs currently in operation in Australia as well as potential HCV types likely to be available within Australia.
- Section 3: Legislation and Policy Background – This section summarises some of the key findings from our review of legislation, standards, land use and public transport plans. The complete Legislation and Policy Background Report can be found in Appendix A
- Section 4: Transport Infrastructure Assessment – This section summarises our review of the potential impacts and constraints on bus infrastructure as a result of running HCVs on particular routes. Our review involved the compilation of several technical notes and reports. Appendix B presents technical notes developed on the potential impacts of HCVs of bus stop, stations and pavements. Appendix C presents the Depot Evaluation Report which assesses the suitability of 16 existing bus depots in South East Queensland.
- Section 5: Operational Assessment – This discusses the findings of our boarding, alighting and dwell time analyses. The complete performance evaluation report can be found in Appendix D

2. High Capacity Vehicle Types

2.1 Why Use High Capacity Vehicles?

High capacity buses are typically both cheaper to purchase (on a dollar per passenger carried basis), and to operate (on a dollar per passenger-kilometre basis) when loaded to capacity if driver labour is the highest component of the vehicle operating cost. For these reasons, there may be an argument for using larger vehicles rather than increasing frequency. This is especially true for peak period services, where a single bus may be at capacity, but demand is insufficient to justify doubling capacity by deploying a second bus.

However, the use of higher capacity vehicles may be a doubled-edged sword. In order for smaller vehicles to provide higher network capacity, higher frequency services must be provided. This provides the added benefit of reduced waiting times for passengers at stops, which in turn adds to the attractiveness of the service, but only up to a point. For example, 15 minute headways are far more attractive to passengers than 30 minute headways, but a 1 minute headway may not be any more attractive than a 2 minute headway. It is suggested that the threshold to justify higher capacity vehicles is when headways are within the range of 5 to 10 minutes. This will be investigated further in Stage 2 of this study.

2.2 Vehicle Types in Use in Brisbane

This section discusses the HCVs currently in operation in Australia and their manufacturers, along with a brief review of HCV designs which may become available within Australia in the near future.

The focus on the Australian market relates to the short-term focus of this study, and the need to identify which vehicles could be procured and deployed into the TransLink network within the next five years. Whilst a number of excellent bus designs are available or being developed overseas, the importation of these vehicles is not straightforward due to the differing vehicle design standards that apply in each country, and the challenges involved in having these vehicles approved for use on Australian roads.

The following is a general discussion of the buses being assessed in this study, including the standard 12.5m rigid bus used as their basis for comparison.

2.2.1 Standard 12.5m Rigid Buses

The most widely used vehicle in South East Queensland and throughout Australia is the standard 12.5m rigid bus, typically fitted with double width front and rear doors. Depending on seating configurations, a 12.5m bus can carry as many as 75 passengers (seated and standing), although the legal carrying capacity of the bus is governed by total axle loads, not physical internal space. Structural design improvements over the last two decades have resulted in significant weight reductions in the vehicles themselves, allowing increases in legal carrying capacity. The advent of ultralow floor (LF) wheelchair accessible buses has however forced bus drive trains to the rear and transferred increased tare load to the rear axle.

As 12.5m buses have been the mainstay of urban bus networks in Australia for at least 50 years, their fuel efficiency, operating and maintenance costs have steadily improved and are relatively low compared with other public transport modes. Existing depot infrastructure has typically been designed around the needs of this size of bus, and maintenance personnel are well accustomed to them. Compressed natural gas (*CNG*) fuelled buses tend to have slightly higher whole of life maintenance costs compared to diesel buses.

Approximate purchase cost of these vehicles is $450,000 per vehicle[1], including air conditioning.

Figure 2.1: Standard 12.5m Buses at Cultural Centre Busway Station

2.2.2 Extended (14.5m) Rigid Buses

High floor (HF) 14.5m extended rigid buses have been traditionally used for long-distance passenger coaches, but low floor versions only began being used for Australian urban bus services in the mid 2000's. To accommodate their higher gross vehicle mass, a single tyred rear tandem axle was adopted on this vehicle type to distribute its rear axle load over 6 tyres. Originally, both axles in the tandem rear axle group were fixed and non-steering, resulting in wide swept paths and poor manoeuvrability at intersection turns and indented stops which limited the utility of these vehicles. Over the last five years, the use of a tag steer rear tandem axle has become commonplace, significantly improving the manoeuvrability of 14.5m extended rigid buses and resulting in their rapid adoption in capital city bus fleets across Australia.

The additional 2m length of the 14.5m vehicle enables a higher carrying capacity with up to 92 people (seated and standing) to be accommodated. 14.5m buses can be built for a relatively low capital cost (approximately $550,000) which means they are cheaper on a per passenger carrying capacity basis than standard 12.5m rigid buses. Operating costs are also marginally higher than for 12.5m standard buses, but again lower when compared on a per passenger carrying capacity basis.

Due to the increased length, swept path width and turning circle of the vehicle, 14.5m rigid buses are unable to operate freely on many public roads. Under current legislation, the longest rigid vehicle permitted to operate freely on any road in Australian States and Territories is 12.5m. The larger 14.5m

[1] Vehicle cost estimates based on MRCagney's recent experience with different public transport operators throughout Australia. This is not based on the cost of standard buses from any specific manufacturer.

buses are currently permitted to operate on what are known as State or Territory road authority declared *Restricted Area Concessions* or *Controlled Access Permits*. A current federal review of heavy vehicle legislation is likely to change this situation, transferring the power to grant these authorisations to the national *Heavy Vehicle Regulator,* but will still limit the prescribed areas or roads on which 14.5m buses will be permitted to operate.

Figure 2.2: 14.5m Extended Rigid Tag Steer Bus operated by Brisbane Transport

2.2.3 Double Deck Buses

Double deck urban route buses are common in many parts of the world, including the UK and Hong Kong. The classic *London Routemaster* double deck bus is arguably the most iconic bus design of all time and has been in operation since before the second world war.

Although relatively uncommon in Australasia, double deck buses provide a very cost effective high capacity vehicle (approximately $700,000 per vehicle). Double deck buses are currently being trialled in both Sydney and South East Queensland to determine their suitability for wider deployment. Trials of double deck city buses are also planned for Auckland beginning in late 2012.

The total carrying capacity of a 12.5m long double deck bus is up to 116 passengers (both seated and standing) and results in a better operating cost per passenger-kilometre than the 14.5m extended rigid bus. The upper deck is however restricted to able bodied seated passengers only.

Growing recent interest in these vehicles relates not only to their higher passenger carrying capacity, but their kerbside parking footprint which is essentially identical to that of the standard 12.5m bus. This results in reduced congestion in constrained bus stations and bus stops, particularly in inner-CBD areas. Unlike 14.5m rigid buses, there are no regulations which restrict the areas and roads on which double deck buses can be operated, but in practice, their service routes are highly constrained by low clearance rail bridges, untrimmed low hanging tree branches and structures such as poles, posts and awnings built out to kerb lines in older city suburbs.

An operating trade-off which materially affects double deck buses is slower passenger boarding and alighting times, due both to the need for passengers to traverse the narrow upper deck stairway within the vehicle, and at stops where very large volumes of passengers need to alight. The most suitable use of these buses in Queensland may be routes with infrequent stops, or routes that have little turnover of passengers (such as peak period express services).

Figure 2.3: Prototype Double Deck Bus built by Bustech in Queensland

2.2.4 Articulated (18m) Buses

Articulated buses combine high passenger carrying capacity with swift passenger boarding and alighting times. Due to their length, as many as 4 doors can be fitted on an 18m articulated bus, although 3 double width doors is the maximum used in Australia. In the TransLink network, most existing articulated buses are 2 door, whilst Clarks Logan City Bus Service operates two 3 door articulated “Superbuses”.

The length of articulated buses proves problematic, hogging valuable bus stop kerb space in city centres, and requiring longer bus stops at stations and bus interchanges. Carrying up to 112 passengers (seated and standing) and costing approximately $750,000 per vehicle, the articulated bus incurs a significantly higher capital outlay than 14.5m extended rigid vehicles or 12.5m double deck buses on a per passenger carrying capacity basis.

Based on outgoing Queensland axle mass limits, the Brisbane Transport 2 door CNG articulated and Logan City Bus Service 3 door diesel superbuses presently have legal passenger carrying capacities of 88 and 95 respectively, but the latter has operated under a temporary 12 month TMR authorisation with a 112 passenger carrying capacity. Ultralow floor articulated buses will be granted an additional 1 tonne mid and rear dual tyred axle load concession under the proposed heavy vehicle national regulations and future 3 door ultralow floor articulated buses with reduced seating are likely to attain a passenger carrying capacity of up to 115 passengers.

Figure 2.4: Two Door 18m CNG Articulated Bus Operated by Brisbane Transport.

2.3 High Capacity Vehicles Manufactured in Australia

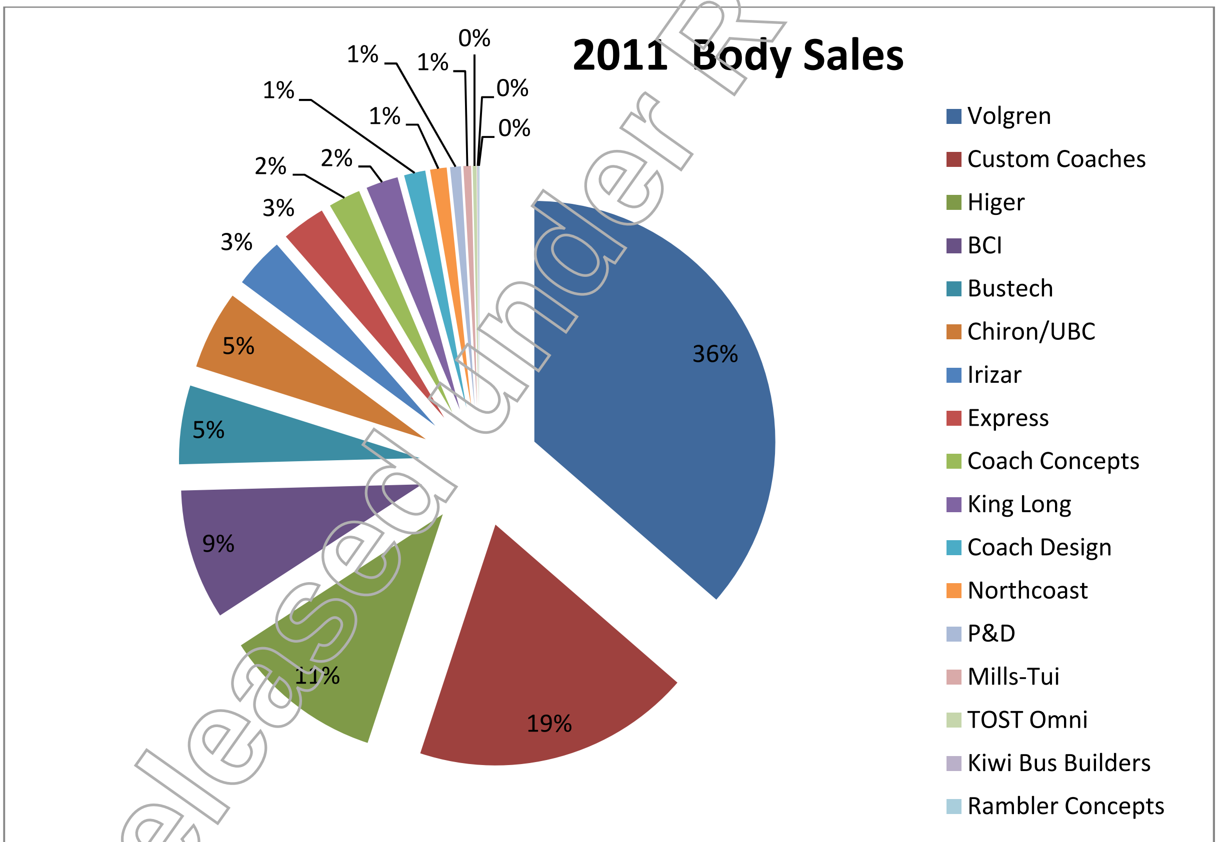
The following Australian bus body manufacturers produce high capacity vehicles.

Bus Builder	Location	High Capacity Vehicle Body Types
Bustech	Gold Coast	Double Decker
Custom Coaches	Sydney and Adelaide	18m Articulated
Denning	Brisbane	Double Decker
Volgren	Brisbane and Melbourne	14.5m Extended Rigid and 18m Articulated

According to *New Bus Search Magazine*, the top twenty buyers of buses and coaches in 2011 were led by the New South Wales State Transit Authority (152 sales) and Brisbane City Council (133 sales), proving that low floor route service operations still command the largest slice of the bus build pie. Notably both of these operators were government owned.

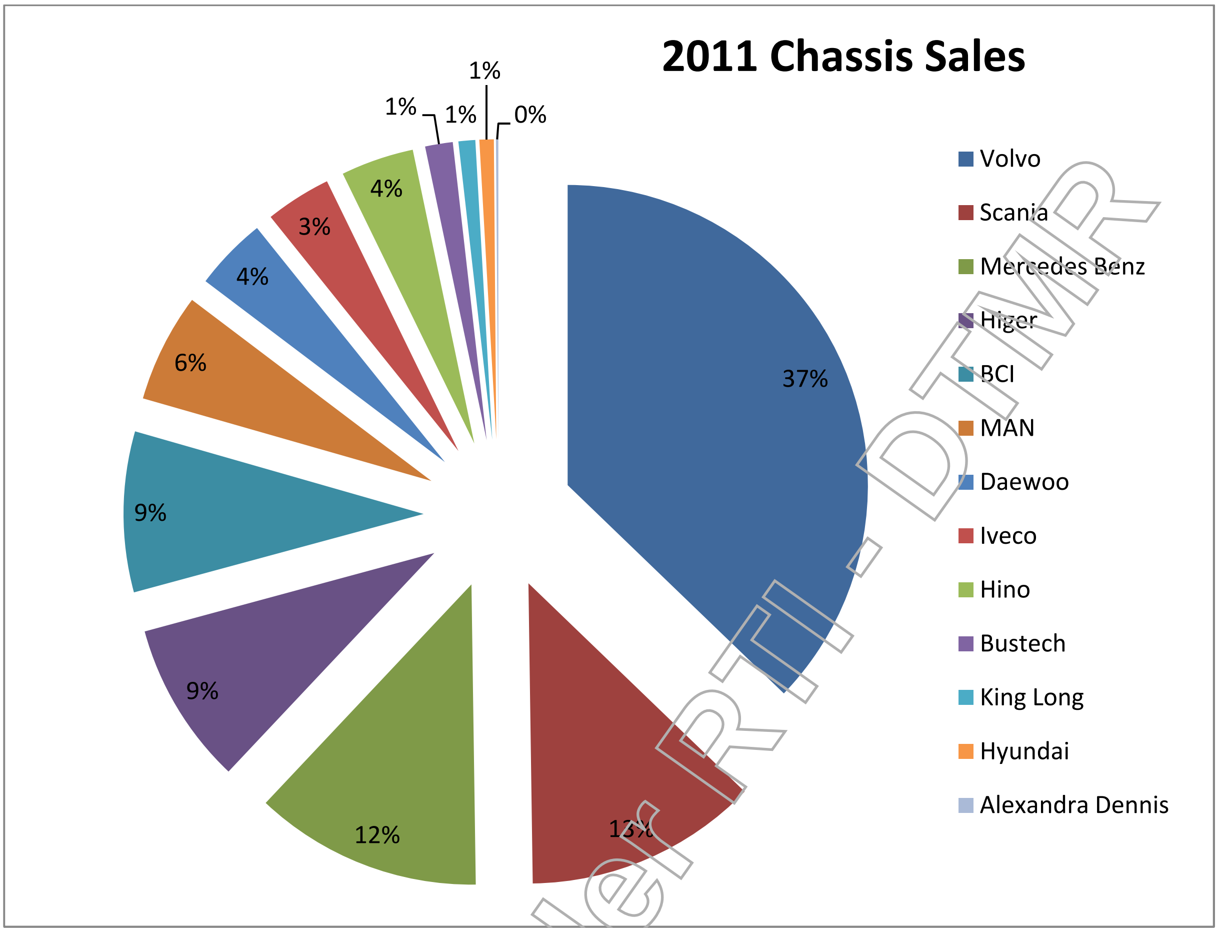
The following pie chart further illustrates total bus sales percentages for all bus body manufacturers in Australia during 2011. The chart indicates that Volgren commanded 36% of the total bus build market.

Figure 2.5: Bus Builder Sales in Australia for 2011



The following figures presents chassis sales in Australia in 2011 where Volvo had more than 37% of the market share.

Figure 2.6: Chassis Sales in Australia 2011

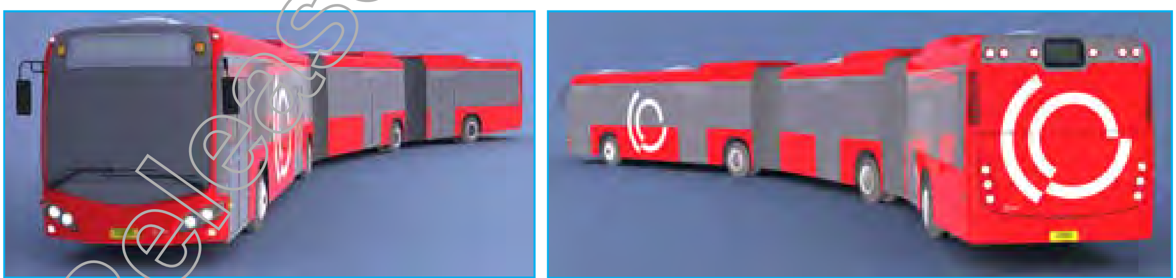


2.4 Future Australian High Capacity Vehicles (Concepts)

2.4.1 Double Articulated Buses

It is understood Custom Coaches is currently working on the concept design of its new *CB80 Bi-Artic*, a 24m bi-articulated high capacity bus similar to that illustrated below in Figure 2.7.

Figure 2.7: Custom Coaches Concept Design for the *CB80 Bi-Artic*



According to Custom Coaches, its *CB80 Bi-Artic* is being designed specifically for Bus Rapid Transit (BRT) applications across Australia, and the operational benefits of this vehicle design will include a very high passenger carrying capacity (200 plus), multi-wheelchair loading capability and low cost of operation.

Albeit the new *Heavy Vehicle National Regulation* has been amended to permit higher axle mass loading on ultralow floor articulated buses, the regulation strictly applies to conventional 18m long articulated buses and it is unknown whether a 24m long vehicle would be permitted on Australian roads.

Previous investigation by TransLink determined a number of potential issues with bi-articulated buses which would prevent their potential use on existing Busway infrastructure.

2.4.2 Extended Double Deck Bus

Bustech has indicated that they are developing a prototype for a 14.5m, four axle, two staircase, three door double deck bus that may be capable of carrying over 150 passengers. This design is particularly interesting as it may have better manoeuvrability than a standard 14.5m extended rigid bus, due to a twin front steer axle as well as a tag steer twin rear axle. The presence of a second staircase should reduce passenger alighting and dwell times at stops, as would the incorporation of a third door. The combination of these design features means that it would represent an idealised scenario in terms of passenger capacity and efficiency of operation.

2.5 Outlook for Imported High Capacity Vehicles

2.5.1 Articulated Vehicles

Long established European high capacity bus chassis and Australian bus body manufacturers are likely to experience increased competition in the coming decade from recent entrants into the Australian bus market, most notably those headquartered in China.

The recent part sale of Australia's largest bus builder, Volgren to Brazilian bus manufacturer, Marcopolo, is also likely to influence availability of new model vehicles emerging in the Australian market. Based in Brazil, Marcopolo also operates in South Africa, Argentina, China, Colombia, Egypt, India, Mexico and Russia. Of interest is the 4 door 21m articulated vehicle already being produced in large volume by Marcopolo for bus rapid transit (busway) applications, known as the *Viale BRT* depicted in Figure 2.8 below. 49 of these high capacity buses were recently put into service on the new *TransOeste BRT* system in Brazil. The width of their current model articulated vehicle is 2.6m and would therefore not comply with contemporary Australian (Vehicle) Design Rules (ADRs) without significant modification to the design. The current design also utilises a high-floor chassis which would be incompatible with existing TransLink roadside bus stop and station infrastructure.

Figure 2.8: 4 Door 21m Articulated *Viale BRT* Bus Manufactured by Marcopolo

2.5.2 Double Deck Buses

The 2.55m wide Alexander Dennis ultralow-floor *Enviro500* double deck bus can carry up to 125 passengers and boasts 100 seats. These buses are just under 12.0m in length and the 4.4m height limit proposed in the new *Heavy Vehicle National Regulation* and are currently being rolled out in the UK, Hong Kong, Dublin and Las Vegas.

Figure 2.9: Alexander Dennis Enviro500 Double Deck Bus

The Enviro500 was road tested in Queensland in 2008[2] but the existing vehicle width would need to be reduced by 50mm to 2.5m to comply with standing Australian Design Rules (ADR).

2.5.3 Overseas trends

An emerging trend by European bus manufacturers has been to consolidate their offshore manufacturing plant locations and increase the number of 'completely built-up' (CBU) vehicles entering the Australian market using vehicle designs customised to meet Australian axle loading and dimensional limits set by the ADRs.

CBU vehicles manufactured in China and Malaysia are likely to increase their Australian bus market share from 2012, with new products also emerging on the market from the Middle East and South America. A known risk associated with imported CBU buses built to comply with ADR specifications, is that some reputable large manufacturers build for markets with shorter expected bus life cycles than those commonly accepted by mainstream Australian bus operators. Most buses manufactured for Australia are

[2] An independent review of this road test is available at http://www.alexander-dennis.com/highway-to-the-city.php.

designed and constructed for an economic life in excess of 20 years. Managing ongoing service support and the supply chain for CBU bus spare parts could become increasingly difficult in these circumstances unless very large volumes of a single bus make and model were to be imported by multiple operators.

3. Legislation and Policy Background

A comprehensive review has been undertaken into legislation, standards, land use and public transport plans and policies, and road and transport infrastructure programs which would impact on the future deployment and operation of high capacity vehicles in South East Queensland. The following is a brief summary of some of the key insights and findings drawn from the legislation and policy review. The complete report can be found in Appendix A.

3.1 Impacts of the Draft Heavy Vehicle National Law

3.1.1 New Heavy Vehicle Axle Mass Limits

New axle mass limits defined in the draft *Heavy Vehicle National Regulation* and summarised in the tables below appear highly favourable to future deployment of ultralow floor high capacity route buses, most notably the rear pusher type articulated buses. Provided the axle mass limits listed in the relevant table are not exceeded, Australian vehicle design rules and Queensland regulations provide considerable flexibility in the way high capacity route bus cabin layouts can be configured. Bus seating can be optionally maximised to reduce passenger standing on long trips or alternatively reduced to maximise total mass transit passenger carrying capacity on short trips. Effective from 9 December 2011, the distance for which continuous passenger standing is permitted on route buses used for school services has been extended to 20km under s11(d)(iv) of the *Transport Operations (Passenger Transport) Standard 2010*.

The current version draft *National Heavy Vehicle Regulation* broadly differentiates heavy route omnibuses into 5 categories:

- Complying Buses – are heavy omnibuses which comply with Australian passenger safety standards ADR44/02, ADR59/00 and ADR68/00 and are fitted with power-train retarders. All existing *TransLink* route buses other than double deck buses must comply with ADR44/02 and ADR59/00, and most existing route buses fitted with automatic transmissions invariably have inbuilt power-train retarders. ADR68/00 however strictly applies to heavy omnibuses specifically designed for and operated with all passengers seated on structurally anchored, strongly built, crash-resistant passenger seats equipped with individual occupant seat belts or infant child restraints.

  Some 30 roads within *TransLink*'s SEQ public transport network boundaries are currently classified by *Department of Transport and Main Roads (TMR)* as *Notified Roads,* considered too steep for school and route buses to safely navigate with standing passengers. Complying 12.5m rigid buses and high floor coaches would be considered suitable for operating school and rural route services on TMR *Notified Roads,* but the roads identified in TMR published maps are considered unsuitable for any of the 4 subject high capacity buses,
- Ultralow Floor Route Buses – must have 2 axles, places for standees and a stairless entry for passengers. This definition deliberately excludes 14.5m rigid and double deck route buses,
- Ultralow Floor Articulated Buses – must have passenger access and rotary movement between their articulated sections, places for standees and a stairless entry for passengers. These include all new model 18m articulated buses and the articulated superbuses,
- Class 2 Restricted Access Buses - cover oversize, over mass 14.5m rigid route buses which are to use the new national axle higher mass limits, and

- Other Buses – cover double deck buses and most existing 10 year and older high floor 12.5m rigid route buses, coaches and articulated buses presently operating *TransLink* scheduled school and route bus services in South East Queensland.

Notwithstanding the general mass limits prescribed in the draft *National Heavy Vehicle Regulation* or the higher mass limits permitted by the *National Heavy Vehicle Regulator* in concert with individual State and Territory road authorities, the *Gross Vehicle Mass (GVM)* specified by the bus chassis manufacturer for each heavy vehicle axle, its road wheels and tyres may not be exceeded.

Permitted Axle Mass Limits for 2 Door 14.5m Extended Rigid Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Upper Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	Non-Compliant	No Higher Mass Upper Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Tandem Axle Group with Dual Drive Tyres and Single Steer Axle with Single Tyres	Non-Compliant	14t **	13t ** (Standing Permitted) 14t ** (Complying Bus)
Gross Mass	Non-Compliant	20t	19t (Standing Permitted) 20t (Complying Bus)

Permitted Axle Mass Limits for 2 Door 12 to 12.5m Double Deck Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
<<< Single Steer Front Axle >>>			
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Drive Dual Tandem Axle Group Fitted with Two Tyres	16.5t **	17t **	16.5t **
Gross Mass	22.5t	23t	22.5t
<<< Twin Steer Front Axle >>>			
Twin Steer Front Axle with Single Tyres	10t (Non-Load Sharing) 11t (Load Sharing)	No Higher Mass Limit Permitted	10t (Non-Load Sharing) 11t (Load Sharing)
Rear Drive Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t
Gross Mass	20t	No Higher Mass Limit Permitted	20t (Non-Load Sharing) 21t (Load Sharing)

**S55 of the Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* stipulates that heavy omnibus axles in an axle group other than a twin steer axle group must relate to each other through a load-sharing suspension system with effective damping characteristics on all axles of the group such that no axle carries over 10% more than the mass it would carry if the load was divided equally.

Permitted Axle Mass Limits for 2 and 3 Door 18m Articulated Buses

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limits	Draft Heavy Vehicle National Regulation General Mass Limits
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Mid Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Rear Axle with Single Steer Tyres (High Floor)	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	22t	No Higher Mass Limit Permitted	22t (High Floor) 26t (Ultra-low Floor)

3.1.2 Impacts of Draft Heavy Vehicle National Regulation on 14.5m Rigid Buses

14.5m rigid high capacity route buses are 2m over length relative to contemporary *Australian Design Rules*, and as such, are not permitted under existing State or Territory road use management regulations to be registered and driven on public roads. They are however permitted to operate route bus services in some States and Territories under short term concessional access permits issued by the relevant road authority in each jurisdiction.

14.5m rigid buses have now been formally recognised in the new draft *Heavy Vehicle National Regulation* and classified as an over length special class of heavy vehicle, subject to the proposed new higher mass limit (HML) axle weight restrictions and HML area permits which effectively restrict the areas and roads on which these vehicles can be driven. HML area permits will replace the current TMR gazetted concessional access permits expiring on 30 June 2012.

By 2013, after the *Heavy Vehicle National Law* has been enacted across all Australian States and Territories, only the *National Heavy Vehicle Regulator*, in consultation with individual State and Territory road authorities, will be empowered to declare HML areas and routes on which 14.5m rigid buses will be permitted to operate. National HML area permits would for example enable Gold Coast school and route bus services operated with 14.5m rigid buses to continue across the Queensland-NSW border.

Road authorities such as TMR have previously had the power under State and Territory legislation to arbitrarily set different heavy vehicle dimension and axle mass limits for special heavy vehicle types that currently include 14.5m rigid buses. Consequently, 14.5m rigid bus concessional wheelbase and rear overhang length limits now vary considerably between the 3 Eastern States and ACT, and 14.5m rigid route buses built to meet these concessional length limits in each jurisdiction are also significantly different. The draft *Heavy Vehicle National Regulation* has not yet resolved the uniform wheelbase and rear overhang limits for 14.5m buses but the *National Heavy Vehicle Regulator* has confirmed that existing Queensland registered 14.5m rigid buses will not be forced to retrospectively comply with the new national wheelbase and rear overhang dimensional limits which will apply nationally to newly built buses.

3.1.3 Impact on of Draft Heavy Vehicle National Regulation on Double Deck Buses

The draft *Heavy Vehicle National Regulation* has lifted the overall height limit on double deck buses to 4.4m to enable higher interior head clearances on both passenger decks, but has to date neither recognised ultralow floor double deck buses as an emerging new category of Australian heavy omnibus, nor proposed higher general axle mass limits for *People with Disabilities (PWD)* accessible ultralow floor double deck buses, similar to those applicable to other PWD accessible bus sizes.

There are 8 heavily trafficked road bridges in South East Queensland listed in the table below with clearances known to be equal to or less than 4.4m. These exclude numerous other low clearance railway bridge crossings on local roads under the Ipswich Railway Line between Darra and the Brisbane CBD where double deck buses could not be driven off bus routes when, for instance, dead running between termini and depots.

Low Clearance Bridges under 4.5m Height within TransLink Bus Route Service Boundaries

Bridge	Road	Suburb	Signed Clearance Height
Railway	Park Road	Milton	3.3m
Railway	Oxley Road	Corinda	3.6m
Railway	Annerley Road	Woolloongabba	3.8m
Railway	Muriel Avenue	Rocklea	3.8m
Railway	Cribb Street	Milton	3.9m
Pacific Motorway	Main Street	Beenleigh	4.0m
Railway	Countess Street	Petrie Terrace	4.4m
Hawthorne Street	Pacific Motorway Southbound Access On Ramp	Woolloongabba	4.4m

Double deck buses are currently exempted from the stringent ADR59 structural rollover strength requirements applicable to all other Australian heavy omnibus types. Consequently ADR59 exemptions for closed roof double deck urban route and school buses are anticipated to cease in future.

3.2 Additional Legislative Impacts and Constraints on High Capacity Vehicles

3.2.1 TMR Notified Roads

None of the 4 subject high capacity buses selected for the study was considered an appropriate candidate for use on the 30 TMR steep incline - no standing *Notified Roads* located in South East Queensland. School and route bus services on TMR *Notifed Roads* should be operated using 12.5m rigid ADR68 *Complying Buses* fitted with structurally anchored seats, seat belts and child constraints.

3.2.2 Environmental Noise Imissions

High capacity hybrid diesel-electric buses are becoming increasingly more popular in European, SE Asian and USA capital cities because of their considerably faster take off acceleration from stops, lower fuel consumption and exhaust emissions in stop-start traffic conditions, and quieter operation relative to comparable high capacity diesel buses. Diesel-overhead electric and diesel-Lion battery or supercap electric buses travelling through noise sensitive route sectors in these overseas cities must under local planning laws operate by electric motor only whilst located in CBD office districts, residential suburbs and public road tunnels. Environmental noise immission laws, rather than heavy vehicle noise emission rules, may restrict high capacity diesel buses from entering noise sensitive commercial, residential, health and education precincts under proposed future Queensland EPA environmental noise planning limits. Only traffic noise generated on State main roads are exempted from these limits.

3.3 Existing Policies and Standards

3.3.1 Connecting SEQ 2031

In late 2011, TMR published *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland* in response to desired regional outcomes 8, 10 and 12 of the *South East Queensland Regional Plan 2009 – 2031. Connecting SEQ 2031* describes sweeping changes to both the structure and operation of the rail and bus network in South East Queensland called *UrbanLink,* which is based on the mass transit trunk and feeder operating concept.

3.3.2 UrbanLink

The proposed *UrbanLink* backbone is comprised of high speed long haul railway, busway and transitway spines radiating out from the Brisbane CBD to surrounding regional and sub-regional transport nodes called hubs, complemented by the new *GoldLinQ* light rail and *CoastConnect* coastal bus sub-spines on the Gold and Sunshine Coasts, with each sub-spine connected by high frequency cross-country connector and local bus services to high-speed heavy rail corridors to the Brisbane CBD.

High capacity buses are considered the optimum vehicle for carrying the high passenger loads expected on new *UrbanLink* cross-city, high frequency trunk and cross-country bus services proposed to be operated between regional activity centres.

UrbanLink implementation will involve conversion of some existing *TransLink* single seat bus journeys to split trunk and local feeder journeys, so that existing buses can be freed up to deliver higher frequency local district feeder services with greater area coverage. The effect of this structural reform to the way the SEQ bus network currently operates will be a transfer of multiple combined local district passenger loads to the proposed new high frequency trunk rail and bus spines.

A large number of early works planning, design and construct programs has been sighted in the State's current infrastructure funding programs to extend Brisbane busways and create multiple new bus priority transitways and corridors for the new *UrbanLink* bus network. *Connecting SEQ 2031* indicates that the development of these corridors will be packaged with the staged conversion of existing single seat bus services to trunk and feeder bus services, but there appears to be no planning or programs currently in place to deliver the additional fleet needed to operate the new trunk services along these priority bus corridors.

3.3.3 Bus Stop Bay Design Standards

The Queensland *Road Planning and Design Manual* and national *Austroads Guide to Road Design Manual* used by TMR and SEQ Local Governments to design indented bus bays only have drawings suitable for 12m rigid and 18m articulated buses, but no drawings for 14.5m rigid buses.

Other documents, including the *Code of IDAS* and *TransLink Public Transport Infrastructure Manual* will need to be amended for high capacity buses.

4. Transport Infrastructure Assessment

This section summarises our assessment of the potential impacts of HCVs on bus infrastructure. Further details on the infrastructure assessments can be found in Appendix B and Appendix C.

4.1 Busways

The Brisbane busways have been designed to a standard that allows the use of HCVs.

The design standards for the South East Busway were developed in the 1990's and inherently allow the use of articulated vehicles. This is one of the reasons why busway stations use linear platforms instead of independent bays (e.g. sawtooth). Linear platforms allow any bus to access it, irrespective of length.

Vertical clearance within the busways was designed to be high enough to be able to install power catenary if future upgrading to light rail or trolley bus were to occur. As such, adequate vertical clearance for double decker buses is provided (which has been operationally tested on the South East and Boggo Road Busways).

The increased manoeuvring space required for 14.5m buses means that some pinch points do exist. The portal of the busway at Melbourne Street is well known to provide difficulty for these buses, and is expected to undergo modification in the future to address this. King George Station has two tight roundabouts which may cause some difficulties for 14.5 rigid buses which do not have increased steering locks.

4.2 Bus Stations, Interchanges and Park & Rides

Our study reviewed a sample of bus stations to represent SEQs infrastructure. This analysis included a total of 69 stops and was for the following stations:

- Aspley Hypermarket
- Capalaba
- Carindale
- Chermside
- Garden City
- Inala Bus Station
- Indooroopilly
- Loganholme
- Springwood
- Toombul
- UQ Chancellors Place

Our analysis of stations was based on a desktop analysis of aerial photos and plans where available. Our review was intended to provide a high-level assessment of the potential impacts of running HCVs through a bus station. It is therefore recommended that an on-site review of each station is recommended to verify our results on the ground prior to confirming any routes or operations for HCVs.

Key findings of our review can be summarised as follows:

- About two-thirds of stops cannot be lengthened to accommodate 14.5 or 18 metre buses.
- Nearly all reserved bus standing or layover bays are long enough and accessible for HCVs.
- Very few stops have obstructions at the rear door, such as a stop blade/sign.
- Nearly all stops offer a clear approach, however 20% of stops require exit on full lock and a further 3% present obstruction on exit.
- Slightly over half of stops are located in stations where there are no obstacles to entry and exit of the station.
- Buses can enter and exit 55% of stops safely.
- At 18% of stops, the tail of a 14.5m bus would swing over the kerb or collide with street furniture.
- At 90% of stops a 14.5m or 18m arctic bus would fit within the swept path turning template around a station for all road entries and exits.
- Double decker buses do not have problems for height clearance at most stops.

The ability for the stations along existing BUZ routes to accommodate HCVs without upgrades varies considerably. Route planning will need to be influenced by a ground-verified knowledge of the capacity of individual stops to accommodate HCVs that this study begins to deliver.

4.3 Bus Stops

Our study reviewed BUZ Routes 100, 140, 150, 130, 120, 180 and 385 to assess the capacity of existing bus stop infrastructure along these routes to accommodate HCVs. These BUZ routes were selected as representative of the overall network that HCVs may potentially operate on in the next five years.

Our analysis of stops is based on a desktop review of aerial photos. While suitable for a high level analysis of a network, an on-site review of each stop is recommended to verify our results on the ground prior to confirming any routes for HCVs. We were unable to perform an aerial photo analysis on a proportion of stops for key categories (i.e. ability to lengthen a stop) because of photo quality or obscured stop images.

Our overall findings are summarised as follows:

- Overall results indicate that stops are nearly all clear of obstructions on approach and on departure of buses.
- Most stops are regular kerbside stops.
- Many stops are unable to be lengthened; however we were unable to assess this for nearly half of all stops.
- The blade or sign is clear of the kerb at nearly all stops and the rear door would be clear at nearly three quarters of all stops.
- Nearly all stops allow buses to stop parallel to the kerb.
- Nearly one third of all stops had a hardstand area clear of obstruction for all doors, with 21% being obstructed. At 42% of stops only the front doors were clear of obstructions.
- Only one stop appears to be greater than 65 metres in length.

- Half of stops can be lengthened to 65 metres.
- Three quarters of stops have no road markings at front or rear.

All bus stops were assessed against a 65m benchmark which was developed from the following assumptions:

- 10.0m clearway in front of the platform for the bus to leave stop as per the on-street bus stop
- 40.0m platform which allows for rear bus to leave independently of bus at the front (Translink drawing shows 35.0m for 2 buses but this does not allow for the rear bus to leave there is also a note saying length may vary for articulated buses).
- 15.0m clearway at the rear to allow for buses to pull in, while the Translink on-street bus stop does not show a clearway in the rear the indented stop has a 21.0m taper to allow for bus entry.

We note that the ability (and the potential need) for the 444 stops along existing BUZ routes to accommodate HCVs without upgrades varies considerably and we were unable to determine some measurements for all stops. Route planning will need to be influenced by a ground-verified knowledge of the capacity of individual stops to accommodate HCVs that this technical note begins to deliver.

4.4 Inter Modal Services

The performance of HCVs for intermodal services can be assessed like any other interchange location. The key issue is the larger passenger volumes boarding or alighting from any one bus, compared to a standard bus.

For alighting passengers, this should not cause a problem as passengers exit the vehicle from one or more doors in a steady stream. This regulates the flow of passengers so that walkways, stairways, overbridges etc should be able to accommodate the demand.

It is passengers waiting to board that have the potential to cause congestion, if the waiting area hasn't been designed for the larger volume of passengers (up to 120 versus 75 on a standard bus). Accumulations of such high loadings are unusual for feeder bus services, but could occur if multiple services (e.g. rail) arrive at a station within a short period of time. Although the assessment of which routes should be selected for deployment of HCVs will not be undertaken until Stage 2 of this study, initial review of the network suggests it unlikely that a HCV would feed to rail.

No instances of HCV buses specifically for feeding to ferry services are likely to occur.

HCVs, by their nature, are less likely to feed into other bus services other than to low volume feeder buses at suburban locations. For example, to function effectively as a feeder system, two or more partially-loaded local services might arrive at a bus station for passengers to connect to a HCV based service. This would, by design, only occur at stations where there is the physical capacity available to accommodate HCVs which would include adequate passenger waiting areas.

4.5 Pavement Impacts

Pavement designs are based on the cumulative number of heavy vehicles in the design lane. In some cases the design lane may not be the most heavily trafficked lane, such as when designing inside widening of a multi-lane carriageway. Different types of vehicles cause different types of damage to pavements. Vehicle loading damage on highway pavement corresponds closely to axle weight and configuration.

Many studies have been done to reveal the relationship between trucks and pavement damage which can be used to inform the impacts of HCVs will have on pavements. Suspension type and characteristics, as well as tire type and configuration, are major contributors to pavement deterioration.

Buses typically have an even larger load impact than heavy trucks due to the limited number of axles and tires they employ to distribute their weight. The increase in damage level with load is not linearly proportional. It takes the shape of the exponential function with a power constant value range from 4 to 6. Under the fourth power rule one bus overloaded by 25% does as much damage to the road as two buses. The performance of HCV route pavements will be a function of load frequency and existing pavement design life. In order to combat the significant surface stresses of the setdown areas these should be constructed in concrete.

Pavement deterioration caused by HCVs will accelerate the need for greater pavement maintenance and a comprehensive Pavement Management program should be established to confirm whole of life costs for pavement rehabilitation or reconstruction.

4.6 Depots

A technical study was undertaken to assess the suitability and readiness of 16 existing bus depots in South East Queensland for future deployment of the 4 alternative high capacity vehicle types. The findings of this study can be found in Appendix C.

5. Operational Assessments

This section presents a summary of the Performance Evaluation report found in Appendix D.

5.1 Average Bus Stop Boarding and Alighting Times

5.1.1 Methodology

An assessment to determine the variation in boarding and alighting times was undertaken using data sourced from the *go card* electronic ticketing system. Data was gathered for the inbound and outbound directions during peak and off-peak operating periods between 1 March and 8 April 2012.

Source data was obtained from a netBi structured query of passenger *go card* tag on and tag off transaction times at all bus door card interface devices, then sorted from first to last by time, date and trip direction for each card interface device and bus stop. After extensive data cleansing and sequential logic testing, 507,500 boarding and 469,700 alighting transaction records were recovered from the 538,500 total *go card* transactions loaded from netBi, and from these, 184,500 boarding and alighting passenger counts derived per stop and used to compute the average boarding and alighting time measurements.

Approximately 13% of netBi source transaction records were deemed invalid and rejected. Source records were rejected in cases where more passenger alightings than boardings occurred during the stop sequence along the route, the service or route number remained unchanged either before or after a terminus stop (i.e. because drivers had forgotten to log off and back onto a new service at the *Driver's Control Unit (DCU)*), transaction time stamps were reversed in relation to the stop sequence or had stopped (i.e. due to drivers turning back without logging off and back on at the DCU and/or equipment breakdowns), unmatched boarding and alighting counts at end termini (i.e. sum of boardings not equal to sum of alightings for trip), etc.

Potential sources of error identified from using *go card* data for average bus top boarding, alighting and dwell time assessments resulted from:

- The ability of passengers to tag-off *go cards* before buses had pulled into stops, resulting in an overestimation of dwell time,
- The inability to determine instances where buses were delayed whilst passengers interacted with the driver (e.g. asking questions), which would increase the span of time between *go card* transactions being recorded, and
- Alighting passengers with paper tickets were not recorded, creating an underestimation of the number of alighting passengers (i.e. making average alighting times appear higher than actual times).

The bus types and routes covered in the operational survey were:

- Two Door 12.5m Rigid Bus (Study Reference Standard Vehicle)
  - Brisbane Transport Low Floor Buses 561 - 1055, Aspley Hypermarket to City Route 345
  - Brisbane Transport High Floor Buses 320 – 539, Aspley Hypermarket to City Route 345
  - Brisbane Transport Low Floor Buses 1030 - 1049, Teneriffe to West End Ferry Terminal CityGlider Route 60
- Two Door 12.5m Double Deck Bus

- Hornibrook Bus Lines Bus 343, Redcliffe to City Route 315

- Two Door 14.5m Rigid Bus
  - Brisbane Transport Buses 5003 – 5126, Browns Plains to City Route 150
- Two Door 18m Articulated Bus
  - Clarks Logan City Buses 116 – 117, Loganholme Bus Station to City Route 555
  - Brisbane Transport Buses 1601 – 1630, Eight Mile Plains to City Route 111
- Three Door 18m Articulated Superbus
  - Clarks Logan City Buses 555 – 556, Loganholme Bus Station to City Route 555.

5.1.2 Results

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Average Boarding Time Per Passenger	2.7s (LF) 3.0s (HF)	3.0s	3.1s	3.1s	3.5s (LC) 2.6s (BT)	3.7s
Average Alighting Time Per Passenger	2.0s (LF) 2.0s (HF)	2.2s	2.6s	2.0s	2.1s (LC) 1.7s (BT)	2.0s
Average Dwell Time Per Passenger with No Standees	2.5s (LF) 2.9s (HF)	2.7s	3.0s	2.5s	2.9s (LC) 2.4s (BT)	2.9s
Average Dwell Time Per Passenger at >20% Standing Capacity	3.0s (LF) 3.1s (HF)	2.9s	Not Reached	3.3s	3.1s (LC) 2.8s (BT)	3.1s

5.1.3 Conclusions

- The fastest average boarding, alighting and dwell times per passenger for the high capacity vehicles were measured on the Brisbane Transport two-door 18m articulated buses. Observations taken aboard all bus types surveyed suggest that this occurred on Brisbane Transport articulated buses primarily because alighting passengers positioned themselves at doors well in advance of busway station arrivals, then double streamed off at rear doors and in single file at front doors with minimal conflict to boarding passengers. The Brisbane Transport articulated bus Route 111 service surveyed had a very high incidence of concurrent passenger boarding and alighting and it was further noted that there was very little interaction on Brisbane Transport busway services between drivers and boarding passengers. Unlike either of the high capacity private bus operators, Brisbane Transport Route 111 drivers did not top up *go cards* and sold almost no paper tickets to boarding passengers.
- No significant differences in boarding, alighting and dwell time per passenger were measured between the Clarks Logan City two and three door articulated buses. Dwell time per passenger on the two Clarks articulated bus variants was found to be strongly dominated by their slow average boarding times rather than by faster average alighting times, which effectively negated the benefit of the Superbus double width middle alighting door.

  Observations aboard the Clarks Logan City articulated buses and at busway stations uncovered a very high incidence of passenger interaction with drivers primarily for paper ticket purchases and *go card* top ups. Driver-passenger interactions were observed to not only block off one stream of boarding passengers at the double width front doors, but to set off conflicts in the freely streaming channel between alighting and boarding passengers. Comparison of boarding times per passenger between the near identically configured Brisbane Transport and Clarks Logan City two door articulated buses has highlighted that a Translink policy to eliminate paper ticket sales and *go card* top ups on buses would cut up to 1 second per passenger off average boarding times and half a second per passenger off front door average alighting times on the high capacity buses.

- Significantly higher average boarding times than alighting times per passenger were measured on all bus types. This suggests that dwell time at stops would be improved with concurrent all door alighting and boarding.
- The longest alighting times per passenger were observed on the double deck buses where passengers from the upper deck often continued to alight through the double width rear door in single file well after passengers on the lower deck had fully disembarked. At the high AM peak offloading stops in Fortitude Valley and the CBD, passengers alighting from the upper deck continued to disembark for periods of up to 10s after passengers on the lower deck had fully cleared. Boarding times on the double deck bus were found to be largely unaffected by upper deck use, but it was noticed that alighting times could be significantly delayed by passengers not descending the narrow upper deck staircase until the double deck bus was stationary.
- Average alighting times per passenger were found to be similar between the older high floor 12.5m rigid buses with double width rear doors and two steps to the newer ultralow floor step-free 12.5m rigid buses with only single width rear doors. This indicates that the reduced rear door passenger alighting times afforded by an ultralow floor step free bus design have been effectively negated by the decision of bus operators to narrow rear doors on their standard rigid buses in an effort to regain two additional passenger seats.
- Marginally higher average boarding and alighting times per passenger were recorded on the all door boarding 12.5m low floor *CityGlider* buses than on the standard low floor 12.5m route buses. This was found to be due to the low concurrent utilisation of rear doors by boarding passengers, and the somewhat casual laid back nature of off-peak *CityGlider* bus users.

  Because this service has no fixed off-peak timetable and drivers can vary its pace by up to 5 minutes in each off-peak travel direction, it was found on 4 separate survey trips that the customer friendly *CityGlider* drivers repeatedly held over at bus stops for late arriving runner and hailer passengers, and most off-peak passengers made little or no effort to move to doors prior to bus stop arrivals. Further, because the *CityGlider* buses only had a single width rear door, those passengers who initially chose to board at the rear door had to wait until all onboard passengers had alighted, and in many cases relocated to the front door, or where they remained in the rear door queue, were still boarding well after passengers who boarded at the double width front door were already seated.

  In effect, the narrow single width rear door caused a longer average dwell time for all door boarding than for front door only boarding.

5.2 Passenger Alighting Preferences

5.2.1 Methodology

Passenger door alighting preferences have been summated and apportioned by percentage from netBi *go card* tag off records for all surveyed bus types and services, and have been observed from the data to be impacting on both average boarding and dwell times at bus stops. Surveys were also conducted at five busway stations and on 16 separate bus trips to determine passenger boarding and alighting patterns. In particular, the surveys were focussed on whether passengers chose to alight at front doors and thereby delay boarding passengers, or at rear doors which enabled concurrent conflict-free boarding and alighting. All door boarding and alighting preferences were also observed on 4 Brisbane Transport *CityGlider* peak and off-peak services.

5.2.2 Results

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Percent Who Alighted at Front Door	31% (LF) 36% (HF)	27%	47%	19%	55% (LC) 52% (BT)	14%
Percent Who Alighted at Middle Door						44%
Percent Who Alighted at Rear Door	69% (LF) 64% (HF)	73%	53%	81%	45% (LC) 48% (BT)	42%
Percent Who Boarded at Rear Door		26%				
Percent Who Boarded to Lower Deck			49%			
Percent Who Boarded to Upper Deck			51%			

5.2.3 Conclusions

While average boarding and alighting times per passenger are a valid measure of the efficiency of a given bus size and configuration to optimise concurrent passenger movements with minimal conflict, total bus stop dwell time was observed to be strongly impacted by passenger preferences to use specific bus doors when alighting. Minimum total dwell time at bus stops is achieved when combined passenger boarding and alighting movements occur concurrently at all doors without conflict in approximately equal time.

For AM peak inbound bus services to stops dominated by passenger boardings, average dwell time per passenger converges toward the average boarding time per passenger. Total stop dwell time for most of the trip therefore becomes proportional to the total number of passengers boarded, and incidental concurrent passenger alightings from the rear door have no material effect on the total dwell time accumulated at most stops. For AM peak inbound services, the lowest total dwell time will therefore occur when all or most alighting passengers prefer to use the rear door.

The opposite conditions prevail on PM peak outbound services to stops dominated by alightings where total bus stop dwell time becomes proportional to the total number of passengers disembarked. For PM peak outbound services, the lowest total dwell time will occur when alighting passengers prefer to alight equally at both doors, assuming both are double width doors.

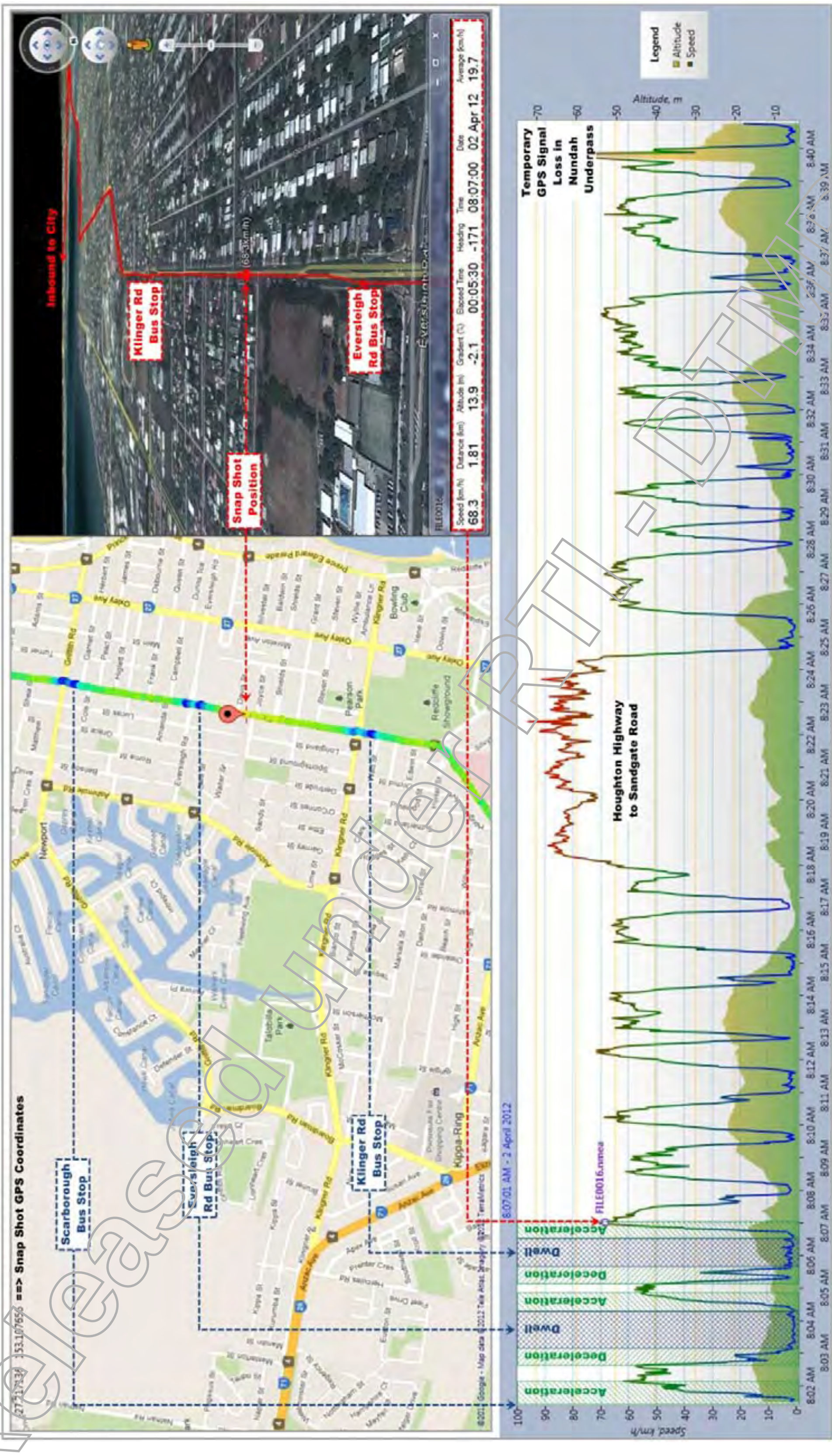
- Passenger door alighting preferences measured on all bus types very closely correlated with the positioning of the rear doors relative to available onboard passenger seated and standing spaces and were unaffected by rear and/or middle door width in the case of the articulated superbus. Based on this finding, boarding and alighting times on single deck low floor high capacity buses with two doors would benefit from a more aftward positioning of rear doors and increased aisle width and standing space opposite rear doors to store their higher alighting passenger numbers relative to the standard rigid buses.

- The current Bustech double deck seating configuration suits limited stop and express long haul services which can exploit its high seating capacity. Given the seating capacity on the double deck bus was underutilised on the Hornibrook 315 commuter service and never reached anywhere close to full seating capacity utilisation, the double deck configuration would benefit most from an additional staircase off the upper deck to improve alighting times on shorter regular stop city commuter services.
- Concurrent passenger alightings from the Clarks Logan City three door articulated superbuses provided the shortest total trip alighting time and least conflict between boarding and alighting passenger streams. The middle and rear doors on the Clarks 3 door superbus were almost equally preferred by alighting passengers and only 1 in 7 passengers using this vehicle type chose to exit from the front door.
- 69% to 73% (more than 2 to 1) passengers preferred to alight from the rear door on a standard low floor rigid bus, where 81% (over 4 to 1) passengers preferred to exit from the rear door on the 14.5m rigid high capacity bus. Disproportionate use of the rear door to exit from 14.5m rigid buses was found to occur because its longer bus cabin layout placed 90% of all passenger seats and standee areas closer to the rear door than the front door. Cabin layout and rear door position were identified as the key reasons why 14.5m buses took longer to offload passengers en mass than rigid and articulated buses at the AM peak inbound stops in the CBD and other similar highly congested bus stops such as those at the Cultural Centre and UQ Lakes Bus Stations.
- It has been found that regular Hornibrook commuters were near evenly split on their preference for sitting on the upper and lower levels of the Bustech double deck bus. Our onboard observations found that the young and able bodied passengers under 40 years of age preferred to use the upper deck, whilst older passengers and those for whom the upstairs ride was no longer a novelty preferred the lower deck. It is nonetheless plausible that the upper deck would be popular on the Gold Coast 700 series routes, given the high proportion of tourists and regional visitors using these Surfside services. Double deck bus alighting times were found to suffer from extended stop dwell times caused by slow single file alighting down the narrow stairway to the double width rear door, but as for the 14.5m rigid buses, highly extended stop dwells only occurred when a large number of passengers alighted en mass at high offloading stops and stations.
- Only 1 in 4 passengers on the *CityGlider* service chose to board at the rear door. It is considered this occurred because Brisbane bus passengers in the main have been conditioned over many decades only to board at the front door and because boarding passengers are reluctant to wait at the single width rear door for alighting passengers to fully disembark. It was noted on both peak and off-peak *CityGlider* trips that passengers who initially positioned themselves to board at the rear door frequently lost patience with alighting passengers from the narrow rear door and relocated to the front door boarding queue as it shortened. Single width rear doors appear to act as a strong deterrent to potential future all door boarding on standard low floor 12.5m rigid buses.

5.3 Average Deceleration, Acceleration and Speed

5.3.1 Methodology

Vehicle location and speed were measured on all bus types using a QStarz 66 channel, 5 acquisitions/second high resolution differential GPS logger accurate to within +/- 2.5m resolution. Measurements were taken while riding aboard each bus type for 2 or 3 trips while in live passenger service. GPS logs were later downloaded from the logger and analysed using *ActiveGPX*, *Google Maps* and *Google Earth* to plot route and stop locations, speed and gradient charts similar to those illustrated below were generated for the Hornibrook double deck bus on Route 315. *GPS Results* was also used to measure whole of trip average and best accelerations and decelerations to 50km/h and 90km/h.



5.3.2 Results

Measurement Description	Two Door 12.5m Standard	Two Door 12.5m Double	Two Door 14.5m Extended	Two Door 18m Articulated	Three Door 18m Articulated

	Rigid Bus	Deck Bus	Rigid Bus	Bus	Superbus
Typical Deceleration from 50km/h	-1.3 m/s²	-1.02 m/s²	-1.1 m/s²	-1.27 m/s²	-1.23 m/s²
Typical Deceleration from 90km/h	-0.86 m/s²	-0.64 m/s²	-0.72 m/s²	-0.64 m/s²	-0.8 m/s²
Average Trip Deceleration to Stop	-0.89m/s²	-1.04m/s²	-0.85m/s²	-0.6m/s²	-0.9m/s²
Typical Acceleration to 50km/h	1.1m/s²	0.76m/s²	0.96 m/s²	0.89m/s²	0.85 m/s²
Typical Acceleration to 90km/h	0.56m/s²	0.45 m/s²	0.54 m/s²	0.5 m/s²	0.48 m/s²
Average Trip Acceleration from Stop	0.9m/s²	0.7m/s²	0.76m/s²	0.67m/s²	0.8m/s²
Average Trip Speed	22km/h	41km/h	52km/h	43km/h	48km/h
Maximum Trip Speed	48km/h	92km/h	98km/h	92km/h	94km/h
Average/Maximum Speed	46%	45%	53%	47%	51%

5.3.3 Conclusions

- Average deceleration into bus stops and acceleration back to incident left lane traffic speed (peak) or regulated traffic speed (off-peak) fell inversely with increasing average traffic speed for all bus types, was found to have a low variance for each particular bus driver, but not for each bus type. Some drivers preferred to coast into stops and accelerate off slowly, while others were observed to be more aggressive on the vehicle's service brake and throttle. The lowest average stop acceleration and deceleration rates were measured on the *CityGlider* off-peak services and the results tabulated above reflect in-service driving habits more so than vehicle performance.
- Of the high capacity vehicles, the fastest 50/90km/h to 0km/h deceleration and standstill to 50/90km/h acceleration rates were recorded on the 14.5m rigid bus and were similar to those measured for 12.5m standard low floor buses. When fully loaded and driven hard by more aggressive drivers, the 14.5m rigid buses outperformed all other bus types, including all standard high and low floor 12.5m rigid buses, for both combined foot braked plus retarder deceleration and take-off acceleration from bus stops.
- At stations and bus stops that boarded or alighted less than 4 passengers, the time taken to decelerate into and accelerate out of the stop back to traffic speed typically exceeded the total bus stop dwell time.
- Average trip speeds were found to be around 48% of maximum service speed. In suburbs where bus stops were closely spaced within 450m, average speed fell to as little as 32% of the incident traffic speed, but on the busways where stations were spaced around 2.4km, average speed increased to 56% of the maximum busway speed (90km/h).
- Measured high capacity vehicle deceleration and acceleration results were found to be more closely related to stop spacing, driving performance and average traffic speed than to particular bus types or their manufacturer performance specifications.

5.4 Peak and Off-Peak Passenger Capacity Utilisation

5.4.1 Methodology

An assessment to determine the peak and off-peak passenger capacity utilisation on the different bus types was undertaken using data sourced from the Translink *go card* electronic ticketing system. Data was collated for both the inbound and outbound directions during peak and off-peak operating periods between 1 March and 8 April 2012. The source data used was obtained from a netBi structured query of passenger *go card* tag on and tag off transaction times at all door onboard card interface devices to determine the boarded passenger loads on each route and trip, and the measured results presented below therefore do not include passengers who boarded and purchased paper tickets.

Seated and total (seated plus standing) passenger capacities for each bus type were obtained from bus manufacturer drawings and bus operators. Low floor (LF) and high floor (HF) standard rigid buses were separately assessed for Route 345, and Clarks Logan City (LC) and Brisbane Transport (BT) 18m articulated buses separately assessed for Routes 555 and 111 respectively.

The terms “peak” and “off-peak” where used in the table of results below do not strictly correlate with *TransLink*’s defined AM/PM commuter peak and off-peak periods. It was found for instance that some bus loading peaks occurred on Route 345 during school runs, and before and after *TransLink* defined commuter peak periods on the longer 315, 150 and 555 routes.

When filtering the netBI ticket transaction data to assess the number of seated and standing passengers on each bus trip, it was assumed by our analysts that all seats were occupied before passengers began to stand and that the number of standees therefore equalled the difference between the boarded passenger load and bus type specific seating capacity. Observations made while travelling aboard bus services has indicated this assumption generally reflected how passengers distributed themselves between seated and standing areas, but it was noted that school and university students regularly chose to stand and socialise with friends, and passengers who boarded for short rides often chose to stand near rear exit doors when seats at the rear of the vehicle still remained unoccupied.

5.4.2 Results

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Seated Passenger Capacity	44 (LF) 47 (HF)	44	96	56	64 (LC) 63 (BT)	52
Maximum Passenger Capacity	75 (LF) 70 (HF)	69	116	92	90 (LC) 85 (BT)	95**
No of Services Operated Per Weekday	159 (LF) 159 (HF)	236	31	167	138 (LC) 199 (BT)	138
No of Peak Services Per Weekday with Standees	13 (LF) 21 (HF)	3	0	10	4 (LC) 4 (BT)	10
Percent of Services Per Weekday with Standees	8% (LF) 13% (HF)	1%	0%	6%	3% (LC) 2% (BT)	7%
Average Standees on Peak Services	10 (LF) 13 (HF)	8	0	10	9 (LC) 8 (BT)	10
Maximum Standees on Peak Services	34 (LF) 39 (HF)	38	0	44	39 (LC) 28 (BT)	40
Average Standing Time on Peak Services	13min (LF) 14min (HF)	8min	0min	18min	12min (LC) 9min (BT)	13min
Maximum Standing Time on Peak Services	27min (LF) 34min (HF)	25min	0min	37min	23min (LC) 19min (BT)	26min
Average No of Off-Peak Seats Occupied	17 (LF) 20 (HF)	11	26	23	24 (LC) 23 (BT)	23
Average Percent of Seat Capacity Used Off-Peak	39% (LF) 43% (HF)	25%	27%	41%	38% (LC) 37% (BT)	44%

Note: The Clarks Logan City 3 door *Superbus* was granted an exemption in its first year of operation to carry 112 passengers and is currently approved for 95 passengers. Future ultralow floor articulated superbuses with reduced seating are likely to have a capacity of around 112 – 115 passengers under proposed new *Heavy Vehicle National Regulation* axle load concessions.

5.4.3 Conclusions

- Only a very small percentage (2% to 7%) of high capacity vehicle weekday peak services carried standing loads as compared with the 12.5m standard rigid buses (typically 8% to 13%).
- For the high capacity vehicle peak weekday services on which passengers did stand, the average standing time varied between 9 and 18min, but for passengers who had to stand for most of the trip, the maximum standing time varied between 19 and 37 minutes. The worst case maximum standing time was very near to twice the average standing time for all high capacity buses.
- No double deck bus services were identified on which boarded passenger loads exceeded the bus seating capacity. It was presumed accordingly that no passengers ever stood on the double deck bus other than by personal choice.
- Only 27% - 44% of high capacity vehicle seats were occupied during off-peak services compared with 39% - 43% for the 12.5m standard rigid buses. Based on this and our preceding observations, all high capacity buses used on the services assessed could afford to reduce their seating capacity, increase their total (seated plus standing) capacity and improve their alighting, boarding and dwell times by widening of aisles and creation of standing areas opposite rear doors.

- Average and maximum standees and standing periods were found to be lowest on the high passenger turnover *CityGlider* and busway 111 routes. Our analysis methodology has demonstrated that driver overload reports and trip peak boarding counts do not provide accurate surrogates for the reliable determination of peak loading, overloading and overload duration, or for justifying replacement of standard 12.5m buses with high capacity buses based on such. Justification of high capacity bus deployment can only realistically be determined on high passenger turnover services by measuring cumulative tag ons and tag offs incrementally along trips measured after each bus stop and by measuring their whole-of-journey differences to calculate average and maximum standing loads and their standing durations.

5.5 Capacity Impact of Vehicle Type on Stops and Stations

5.5.1 Individual Stops

At individual stops, or bus stations that comprise a number of independent stops, the capacity of the stop can be measured either in terms of the number of passengers per hour, or number of buses per hour that can be served.

The assessment of this capacity can be undertaken using the methodology in the *Transit Capacity and Quality of Service Manual (TCQSM)*. A detailed summary of this methodology is contained in the relevant Technical Note.

The TCQSM methodology calculates the number of buses per hour that a stop can accommodate, by calculating the dwell time required for each bus, and the amount of time needed between one bus departing a stop and the next bus entering it. Dwell time includes components such as door opening and closing times and the time needed for passengers to board and/or alight. The time required between buses can either be very simple in segregated locations such as a busway, or more complex where access to a stop is affected by passing traffic.

A number of sensitivity tests were done to determine how the different vehicle types perform at an independent stop which has been designed to accommodate that size of vehicle:

- A full load of passengers boards each bus, no passengers alight, front door boarding only.
- A full load of passengers boards each bus, no passengers alight, all-door boarding available.
- Only 10 passengers board each bus, no passengers alight, front door boarding only.
- Only 10 passengers board each bus, no passengers alight, all-door boarding available.

These results are presented in the table below, where an average boarding time of 3.0s has been used for single door boarding (which is recommended as a default value in the TCQSM, and also matches the observed speed for TransLink services). For all door boarding, the recommended boarding rates are 2.0s for two door buses, and 1.6s for three door buses.

	Standard 12.5m Rigid	Double Deck 12.5m Rigid	Extended 14.5m Rigid	BT 2 door, 18m Articulated	LCBS 3 door, 18m Articulated
Bus length (m)	12.5	12.5	14.5	18	18
Capacity (pax)	75	116	92	88	112
Full Load Boarding, No Alighting, Front Boarding Only					
Buses per Hour	7.1	4.6	5.8	6.0	4.8
Pax Per Hour	528.9	536.7	532.9	532.1	536.2
Full Load Boarding, No Alighting, All Door Boarding					
Buses per Hour	10.4	6.8	8.5	9.2	8.8
Pax Per Hour	777.5	794.4	786.2	784.4	981.5
10 pax per bus Board, No Alighting, Front Boarding Only					
Buses per Hour	41.8	41.8	41.8	41.8	41.8
Pax Per Hour	417.8	417.8	417.8	417.8	417.8
10 pax per bus Board, No Alighting, All Door Boarding					
Buses per Hour	55.9	55.9	55.9	55.9	64.6
Pax Per Hour	559.0	559.0	559.0	559.0	646.4

- It can be seen that the number of passengers that can served per hour is roughly the same across all vehicles for single-door boarding, when loading either full or partial loads onto each bus.
- The number of buses per hour that can be served varies when full loading occurs, simply because more buses are required to serve a continuous stream of passengers.
- When all-door boarding is introduced, marked increases in capacity result. When loading partial loads (10 pax per bus), all-door boarding offers a 34% increase in capacity on all two door buses, and a 55% increase in capacity on three-door articulated buses.
- When using all-door boarding to load full bus loads, the increase in capacity is around 46-48% for all two door buses, and 83% for three door buses.

The conclusion from this is that the single greatest contributor to individual stop capacity is the number of doors available for boarding. The same is true if passengers are alighting.

It is worth noting that the use of wide (double) rear doors on a bus achieves the same result as using two rear doors (like a three door bus).

5.5.2 Station Platforms Including Busways

Bus stations, such as those provided on the busway, which are designed as a continuous length of kerb, are capable of accommodating a mix of bus types and sizes, as buses queue behind each other at the platform.

Each type of bus utilises a different length of platform loading space and we know that a 55m busway platform can accommodate more 12.5m standard buses at one time than 18m articulated buses. But each bus type has a defined number of passengers it can carry, and that can then be assessed per metre of bus length. Because each bus loses the same amount of space at the front for the driver area, and at the rear due to the engine, it seems logical that the longer the bus, the more efficient it becomes in terms of passengers per metre that it can carry. For example, a queue of 100m of articulated buses would be expected to hold more passengers than a queue of 100m of 12.5m buses.

However, some of the length of a busway platform is lost by the space required between stopped buses. This space needs to be long enough so that a bus can move independently away from the platform without colliding with the bus in front. Each bus type manoeuvres differently and has a different amount of clear space that it needs in front of it. 12.5m rigid (single or double deck) and 18m articulated buses require a 5m safety gap between buses.

In the case of the 14.5m extended rigid buses, the higher the gap spacing provided, the less pronounced is the rear tail swing in that occurs. With a 5m gap, the tail swing is around 700mm – large enough to conflict with street furniture and waiting passengers. If that gap is increased to 8m, the tail swing reduces to 300mm – the same as a 12.5m bus. This increased gap required between 14.5m buses begins to negate some of the benefit of using the larger rigid bus.

The table below presents the hypothetical performance of standard 55m busway platforms for each bus type, in accordance with the *TCQSM* methodology, for the same scenarios undertaken for single stops. The two options for 14.5m rigid buses are considered, using the minimum 5m gap between buses that generates the safety issue from the rear tail swing in, and the longer 8m gap which negates this issue.

	Standard 12.5m Rigid	Double Deck 12.5m Rigid	Extended 14.5m Rigid	Extended 14.5m Rigid	BT 2 door, 18m Articulated	LCBS 3 door, 18m Articulated
Bus length (m)	12.5	12.5	14.5	14.5	18	18
Gap between buses	5m	5m	5m	8m	5m	5m
Capacity (pax)	75	116	92	92	88	112
Passengers per metre of bus	6.00	9.28	6.34	6.34	4.89	6.22
Passengers per m of platform (inc gap)	4.29	6.63	4.72	4.09	3.83	4.87
Buses fitted into 55m platform	3	3	3	2	2	2
Full Load Boarding, No Alighting, Front Boarding Only						
Buses per Hour	18.7	12.3	15.4	10.7	11.2	8.9
Pax Per Hour	1401.6	1422.2	1412.3	985.9	984.4	991.9
Full Load Boarding, No Alighting, All Door Boarding						
Buses per Hour	27.5	18.1	22.6	15.8	16.5	16.2
Pax Per Hour	2060.3	2105.0	2083.4	1454.5	1451.2	1815.7
10 pax per bus Board, No Alighting, Front Boarding Only						
Buses per Hour	110.7	110.7	110.7	77.3	77.3	77.3
Pax Per Hour	1107.2	1107.2	1107.2	773.0	773.0	773.0
10 pax per bus Board, No Alighting, All Door Boarding						
Buses per Hour	55.9	55.9	55.9	55.9	55.9	64.6
Pax Per Hour	559.0	559.0	559.0	559.0	559.0	646.4

These results show how the different bus types perform for the standard design of a busway platform 55m in length. The longer articulated buses show a noticeable reduction in the number of buses and passengers per hour that can be served. This results from only being able to accommodate two 14.5m rigid buses on the platform at once, if the longer 8m gap between 14.5m extended rigid buses is enforced.

From this we can conclude that in order for 14.5m rigid buses to safely serve busway stations, one of two things must happen:

- The standard length of a busway platform must be increased from 55m to 60m; or
- A clear zone of 700mm from the kerb edge needs to be marked on busway platforms to warn passengers of the dangers of manoeuvring buses. This would be similar to how the platform edges at rail stations are presented.

The use of all-door boarding again yields notable increases in capacity of 47% for all two door buses, and 83% for three door buses. Even with all-door boarding, the increase in capacity for a three door articulated bus doesn't allow it to offer the capacity of a smaller rigid vehicle.

It is suggested that if all door boarding were to occur on a double deck bus, the benefit would be partially reduced as only one staircase is available, which would become a choke point for the two streams of boarding passengers.

Appendix A

Legislation and Policy Background Report

Document Information

Client	TransLink Transit Authority
Job Number	4746
Title	Research and Analysis of High Capacity Vehicle Use – Legislation and Policy Background Report
Prepared by	MRCagney Pty Ltd Brisbane, Queensland
Date	22 November 2012

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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by *TransLink Transit Authority (TransLink)* to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

Throughout the study, the 4 nominated high capacity vehicles will be compared to a reference vehicle operated by all *TransLink* bus service partners in South East Queensland, namely the:

- Two Door 12.5m Rigid Standard Route Bus.

The primary goal of this background report is to describe legislation, standards, land use and public transport plans and policies, and road and transport infrastructure programs which will impact on the future deployment and operation of the 4 high capacity vehicle types in South East Queensland. Some 54 documents have been reviewed by the authors to prepare this background report, broadly comprising of the following, and have been separately listed in the bibliography at Appendix B:

- Commonwealth and Queensland Transport Operations and Road Use Management Acts and Regulations,
- Commonwealth Disability and Commonwealth and Queensland Heavy Vehicle Standards,
- Queensland Dept of Transport and Main Roads Mass Concession, Restricted Access and Over-dimension Heavy Vehicle Schemes,
- The Edition 3 Australian Design Rules,
- Australian, Queensland DTMR and Austroads Road Design Standards,
- Queensland Land Use, Road Use Management, Transport Infrastructure Development and TransLink Infrastructure and Service Planning Policies,
- Queensland Regional, Integrated Regional Transport, Transport and Roads Investment, SEQ Infrastructure, TransLink Network and TransLink Strategic Plans,
- Queensland Transport Infrastructure, Busway and Road Planning and Design Manuals,
- TransLink Brisbane Transport and Private Operator Bus Contracts, and
- Bus Driver Awards.

1.2 Heavy Omnibus Legislation and Standards

Part 2 of this background report describes the plethora of Commonwealth and State Acts, Regulations, Vehicle Design Rules, Compliances and Standards which specify how high capacity omnibuses can be configured and constructed for safe conveyance of passengers, where, how and by whom they can be operated on public transport route and school services, and the dimensional, concessional, and axle mass limits which regulate how many passengers they can carry on Queensland roads. This Part also explores how Queensland road rules and road design standards impose restrictions on where routes and bus stops can be placed for high capacity omnibuses.

Part 2 summarises the mandatory legislative constraints with which high capacity vehicles must comply.

1.3 Planning and Policy Impacts on Future High Capacity Vehicle Deployment

Part 3 of this report explores contemporary State, Dept of Transport and Main Roads and TransLink regional land use, public transport and road plans, policies and funding programs to assess their support for and impacts on future deployment of high capacity vehicles. This Part also reviews other miscellaneous Acts and Regulations which define how, when, by whom and what constraints will apply to public transport planning and high capacity vehicle operations in South East Queensland over the coming 20 year horizon out to the year 2031.

The narratives provided in this Part attempt to present a broad overview of the vision, principles and objectives driving public transport development and reform in South East Queensland, and interpret the relevance of these to the future demand for high capacity vehicles.

Sections are included toward the end of Part 3 which assess high capacity vehicle opportunities and constraints under existing *TransLink* policies, operator contracts and driver awards. These sections serve as an introduction to later reports being prepared for the main body of the study.

1.4 Findings and Insights

The following is a brief preview of some of the more interesting findings and insights found during the document reviews undertaken for this report.

1. New axle mass limits proposed in the draft *Heavy Vehicle National Regulation* are highly favourable to future deployment of ultralow floor high capacity route buses, most notably the rear pusher type articulated buses. Provided axle mass limits are not exceeded, the Australian vehicle design rules and Queensland regulations provide considerable flexibility in the way high capacity route bus cabin layouts can be configured. Bus seating can be optionally maximised to reduce passenger standing on long trips or alternatively reduced to maximise mass transit total carrying capacity on short trips. The distance for which continuous passenger standing is permitted on urban route bus services has recently been extended to 20km.

2. 14.5m rigid high capacity route buses are 2m over length relative to contemporary *Australian Design Rules*, and as such, are not permitted under existing State or Territory road use management regulations to be registered and driven on public roads. They are however permitted to operate route bus services in some States and Territories under short term concessional access permits issued by the road authority in each jurisdiction.

   14.5m rigid buses have now been formally recognised in the new draft Heavy Vehicle National Regulation and classified as an over length special class of heavy vehicle, subject to the proposed new higher mass limit (HML) axle weight restrictions and HML area permits which effectively restrict the areas and roads on which these buses can be driven. HML area permits will replace the current Department of Transport and Main Roads (DTMR) gazetted concessional ccess permits expiring on 30 June 2012.

   By 2013, after the *Heavy Vehicle National Law* has been enacted across all Australian States and Territories, only the *National Heavy Vehicle Regulator*, in consultation with individual State and

Territory road authorities, will be empowered to declare HML areas and routes on which 14.5m rigid buses will be permitted to operate. National HML area permits will enable Gold Coast school and route bus services operated with 14.5m rigid buses to continue across the Queensland-NSW border.

3 Road authorities such as DTMR have previously had the power under State and Territory legislation to arbitrarily set different heavy vehicle dimension and axle mass limits for special heavy vehicle types that currently include 14.5m rigid buses. Consequently, 14.5m rigid bus concessional wheelbase and rear overhang length limits now vary considerably between the 3 Eastern States and ACT, and 14.5m rigid route buses built to meet these concessional length limits in each jurisdiction are also significantly different. The draft *Heavy Vehicle National Regulation* has not yet resolved the uniform wheelbase and rear overhang limits for 14.5m buses.

4 The draft *Heavy Vehicle National Regulation* has lifted the overall height limit on double deck buses to 4.4m to enable higher interior head clearances on both passenger decks, but has to date neither recognised ultralow floor double deck buses as an emerging new category of Australian heavy route omnibus, nor proposed higher general axle mass limits for PWD accessible ultralow floor double deck buses, similar to those already given to other PWD accessible bus sizes. There are 8 bridges in South East Queensland with clearances equal to or less than 4.4m.

5 Double deck buses are currently exempted from the stringent ADR59 structural rollover strength requirements applicable to all other heavy omnibus types. Consequently ADR59 exemptions for closed roof double deck urban route and school buses are anticipated to cease in future.

6 None of the 4 subject high capacity buses selected for the study was considered appropriate candidates for the 30 DTMR steep incline - no standing *Notified Roads* located in South East Queensland. School and route bus services on DTMR *Notifed Roads* should be operated using 12.5m rigid ADR68 *Complying Buses* fitted with structurally anchored seats, seat belts and child constraints.

7 High capacity hybrid diesel-electric buses are becoming increasingly more popular in European, SE Asian and USA capital cities because of their considerably faster take off acceleration from stops, lower fuel consumption and exhaust emissions in stop-start traffic conditions, and quieter operation relative to comparable high capacity diesel buses. Diesel-overhead electric and diesel-L-ion battery or supercap electric buses travelling through noise sensitive route sectors in these overseas cities must under local planning laws operate by electric motor only whilst located in CBD office districts, residential suburbs and public road tunnels. Environmental noise immission laws, rather than heavy vehicle noise emission rules, may restrict high capacity diesel buses from entering noise sensitive commercial, residential, health and education precincts under proposed future Queensland EPA environmental noise planning limits. Only traffic noise generated on State main roads are exempted from these limits.

8 The Queensland Road Planning and Design Manual and national Austroads Guide to Road Design Manual used by DTMR and SEQ Local Governments to design indented bus bays only have drawings suitable for 12m rigid and 18m articulated buses, but no drawings for 14.5m rigid buses. Other documents, including the *Code of IDAS* and *TransLink Infrastructure Manual* will need to be amended for high capacity buses.

9 In late 2011, DTMR published *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland* in response to desired regional outcomes 8, 10 and 12 of the *South East Queensland Regional Plan 2009 – 2031. Connecting SEQ 2031* describes sweeping changes to both the structure and operation of the rail and bus network in South East Queensland called *UrbanLink,* which is based on the mass transit trunk and feeder operating concept.

The proposed *UrbanLink* backbone is comprised of high speed long haul railway *ExpressLink*, busway and transitway spines radiating out from the Brisbane CBD to surrounding regional and sub-regional transport nodes called hubs, complemented by the new *GoldLinQ* light rail and *CoastConnect* coastal bus sub-spines on the Gold and Sunshine Coasts, with each sub-spine connected by high frequency cross-country connector and local bus services to the high-speed heavy rail corridors to the Brisbane CBD. A new form of bus service, similar to the railway *ExpressLink* is also envisaged in *Connecting SEQ 2031* that will provide 6am – 9pm express bus services between major outlying rail and bus station hubs in Greater Brisbane to other major transport nodes in adjoining SEQ regions, and from country railway stations to places of high employment.

High capacity buses are considered the optimum vehicle for carrying the high passenger loads expected on new *UrbanLink* cross-city, high frequency trunk and cross-country bus services proposed to be operated between regional activity centres.

10 *UrbanLink* implementation will involve conversion of hundreds of existing *TransLink* single seat bus journeys to split trunk and local feeder journeys, so that existing buses can be freed up to deliver higher frequency local district feeder services with greater area coverage. The effect of this structural reform to the way the SEQ bus network currently operates will be a transfer of multiple combined local district passenger loads to the proposed new high frequency trunk rail and bus spines.

A large number of early works planning, design and construct programs has been sighted in the State's current infrastructure funding programs to extend Brisbane busways and create multiple new bus priority transitways and corridors for the new *UrbanLink* bus network. *Connecting SEQ 2031* indicates that the development of these corridors will be packaged with the staged conversion of existing single seat bus services to trunk and feeder bus services, but there appears to be no planning or programs currently in place to deliver the additional fleet needed to operate the new trunk services along these priority bus corridors.

2. Heavy Omnibus Legislation and Standards

2.1 High Capacity Vehicle Types

Representative examples of the 4 high capacity vehicles and standard reference vehicle discussed in this report are illustrated below in Figure 1 and

Figure 2 respectively.

Figure 1: Representative Examples of the 4 High Capacity Vehicle Types

2 Door 12 - 12.5m Double Deck Bus		
2 Door 14.5m Rigid Bus		
2 Door 18m Articulated Bus		
3 Door 18m Articulated Superbus		

Figure 2: Representative Examples of the Standard Reference Vehicle

2 Door 12.5m Rigid Urban Route Bus		

2.2 Heavy Omnibus Passenger Carrying Capacity

All road vehicles illustrated in Figure 1 and

Figure 2 are similarly classified as both heavy vehicles and omnibuses in the relevant Commonwealth and Queensland legislation. Key determinants of how, when, where, who can be transported, who can operate, who can drive, and for what distance are closely linked by legislature to the vehicle type, length and height, axle configuration and permitted axle load masses. Every heavy vehicle omnibus axle configuration has an empty vehicle weight (the tare mass), a legislated maximum load limit and chassis manufacturer designed gross vehicle mass (GVM) limit. The passenger carrying capacity of the bus is essentially governed through legislation by the difference between the permitted axle mass limits and their respective axle tare masses. Maximisation of passenger carrying capacity on high capacity vehicles is achieved in practice by deliberate placement of passenger seats, luggage racks and standee areas to distribute the live passenger and luggage loads across all axles up to their permitted maximum load limits.

The 4 subject high capacity vehicles have a higher combined standing and seated passenger carrying capacity than the standard reference 12.5m rigid urban route bus and their typical passenger capacity ranges have been tabulated below in Table 1. Variations arise between identical bus configuration types fuelled by compressed natural gas and diesel, the former having a lower registered carrying capacity due to permitted axle loads less the combined weight of roof mounted gas cylinders and stored maximum natural gas charges. Seated capacities indicated in Table 1 are for modern ultralow floor *Disability Discrimination Act (DDA)* compliant urban route buses equipped with 2 rear facing wheelchair spaces, each fitted with 3 to 4 side or forward facing flip-up passenger seats used as both seated and standee floor areas when wheelchair spaces are unoccupied.

Table 1: Typical Passenger Carrying Capacity of Standard and High Capacity Vehicles

Typical Passenger Capacity	2 Door 12.5m Rigid Bus (Reference)	2 Door 12 - 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Wheelchair	2	2	2	2	2
Seated	44 - 47	82 - 96	56 - 58	63 - 65	46 - 52
Standing	18 - 22	20 - 27	34 - 42	20 - 37	58 - 66
Total	62 - 69	109 - 111	92 - 98	85 - 100	110 - 112
Equivalent Median Standard 12.5m Buses		1.69	1.46	1.42	1.71

2.3 Heavy Vehicle Occupant Load Limits

Australian legislation and the national vehicle standards which limit the maximum passenger carrying capacity of heavy omnibuses specify the:

- Heavy Vehicle Occupant Load Limits: to be adopted for legal determination of live occupant and luggage loads,
- Heavy Vehicle Axle Mass Limits: which define the maximum axle mass (or weight) permitted on each heavy vehicle axle or axle group, and the combined maximum gross mass (or weight) permitted on all axles and axle groups for different heavy vehicle types,
- Heavy Omnibus Standee Floor Area Restrictions: which define the floor areas on heavy omnibuses where luggage may be stowed and where passengers are permitted and not permitted to stand, and
- Heavy Omnibus Configuration and Dimensional Limits: which define the permitted configuration and dimensions of different heavy omnibus body types.

The Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* specifies that all vehicles must comply with the *Australian Vehicle National Standards Rules 1999 (Cth)*. Buses over 5 tonne G*ross Vehicle Mass (GVM)* registered in Australia are described by *Australian Vehicle National Standard Rules* and *Australian Design Rules (ADRs)* as *Category ME Heavy Omnibuses*. ADR58/00 defines the maximum occupant capacity applicable to *Category ME* heavy school and route service omnibuses without dedicated heavy luggage spaces as 65kg per driver, crew member and passenger.

Under these *Rules*, the passenger loading condition to be applied in the determination of live occupant load is taken to be the weight distribution of the seated driver and passengers in all available bus manufacturer nominated seat positions, plus the uniform distribution of standee passengers (including a conductor or ticket inspection crew member if applicable) to all aisle way and allocated standing areas, excluding those standing areas preserved by ADR58/00 and ADR44/02 for exterior passenger entry/exit doors, emergency exits and interior or rear open exterior upper deck staircases on double deck heavy omnibuses. Where a dedicated heavy luggage space is provided for carriage of other than personal hand luggage on a heavy omnibus, a mass of 15kg per passenger (seated and standing), distributed evenly throughout the luggage space, must also be added to the live axle load assessment.

Up to permitted axle mass limits, total passenger carrying capacity on school and route omnibuses can be increased through bus manufacturer design by reducing the number of available passenger seats and dedicating more floor space to standees as has been applied to maximise the carrying capacity on the 3 door 18m articulated superbuses, but other legislative instruments (described later) limit the road types, distance and duration of school and route services on which passengers are permitted to stand. (Refer to Table 1 for a comparison of a typical 2 door 18m articulated route bus with high seating capacity, and a typical 3 door 18m articulated superbus with reduced seating capacity).

2.4 Heavy Vehicle Axle Mass Limits

Permitted axle mass limits in Queensland for the reference standard 12.5m route omnibus and 4 subject high capacity omnibuses have been contrasted below in Table 2 to Table 5 inclusive.

A new *Heavy Vehicle National Law Bill 2011* was introduced into Queensland Parliament on 15 November 2011 and is anticipated to be enacted by late 2012, together with a new *Heavy Vehicle (Mass, Dimension and Loading) National Regulation* currently in its final draft review stage. Similar heavy vehicle bills and regulations are expected to be enacted in all Australian States and Territories by 2013, heralding a single uniform set of heavy vehicle dimension and axle mass limits throughout Australia. Regulated axle mass limits for heavy omnibuses are currently specified in the Queensland *Transport Operations (Road Use Management – Mass, Dimensions and Loading) Regulation 2005*, last revised in July 2011, and these substantially mirror the new national general mass limits proposed for uniform national regulation.

Subject to specified ADR compliances for newly built heavy vehicles defined by the national regulation, the new national general axle mass limits will afford automatic cross border national licensing of all heavy omnibuses in all Australian States and Territories. New national higher mass limits prescribe the upper axle mass limits that individual State and Territory road managers such as the *Queensland Department of Transport and Main Roads (DTMR)* and the newly created *National Heavy Vehicle Regulator* may approve for special class oversize and/or over mass heavy vehicle types such as 14.5m rigid route buses operating in road authority defined areas or roads, and replace State and Territory Government gazetted *Controlled Access Permit* systems presently operated by each independent road manager. The new national higher mass limit permits are similarly intended to operate across State and Territory borders and where higher mass limits have been proposed in the national regulation, equate to an increased heavy omnibus passenger carrying capacity of 15 passengers/axle tonne increase.

The current version draft *National Heavy Vehicle Regulation* broadly differentiates heavy route omnibuses into 5 categories:

- Complying Buses – are heavy omnibuses which comply with Australian passenger safety standards ADR44/02, ADR59/00 and ADR68/00 and are fitted with power-train retarders. All existing *TransLink* route buses other than double deck buses must comply with ADR44/02 and ADR59/00, and most existing route buses fitted with automatic transmissions invariably have inbuilt power-train retarders. ADR68/00 however strictly applies to heavy omnibuses specifically designed for and operated with all passengers seated on structurally anchored, strongly built, crash-resistant passenger seats equipped with individual occupant seat belts or infant child restraints.

  Some 30 roads within *TransLink*'s SEQ public transport network boundaries are currently classified by DTMR as *Notified Roads,* considered too steep for school and route buses to safely navigate with standing passengers. Complying 12.5m rigid buses and high floor coaches would be considered suitable for operating school and rural route services on DTMR *Notified Roads,* but the roads identified in DTMR published maps are considered unsuitable for any of the 4 subject high capacity buses,
- Ultra-low Floor Route Buses – must have 2 axles, places for standees and a stairless entry for passengers. This definition deliberately excludes 14.5m rigid and double deck route buses,
- Ultra-low Floor Articulated Buses – must have passenger access and rotary movement between their articulated sections, places for standees and a stairless entry for passengers. These include all new model 18m articulated buses and articulated superbuses,
- Class 2 Restricted Access Buses - cover oversize, over mass 14.5m rigid route buses which are to use the new national axle higher mass limits, and
- Other Buses – cover double deck buses and most existing 10 year and older high floor 12.5m rigid route buses, coaches and articulated buses presently operating *TransLink* scheduled school and route bus services in South East Queensland.

Notwithstanding the general mass limits prescribed in the draft *National Heavy Vehicle Regulation* or the higher mass limits permitted by the *National Heavy Vehicle Regulator* in concert with individual State and Territory road authorities, the *Gross Vehicle Mass (GVM)* specified by the bus chassis manufacturer for each heavy vehicle axle, its road wheels and tyres may not be exceeded.

Table 2: Permitted Axle Mass Limits for 2 Door 12.5m Standard Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Buses)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Buses)
Rear Drive Axle with Dual Tyres	10t (High Floor) 11t (Ultra-Low Floor)	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	15t (High Floor) 16t (Complying or Ultra-low Floor)	No Higher Mass Limit Permitted	15t (High Floor) 16t (Complying or Ultra-low Floor)

Table 3: Permitted Axle Mass Limits for 2 Door 14.5m Extended Rigid Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Upper Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	Non-Compliant	No Higher Mass Upper Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Tandem Axle Group with Dual Drive Tyres and Single Steer Axle with Single Tyres	Non-Compliant	14t **	13t ** (Standing Permitted) 14t ** (Complying Bus)
Gross Mass	Non-Compliant	20t	19t (Standing Permitted) 20t (Complying Bus)

Table 4: Permitted Axle Mass Limits for 2 Door 12 - 12.5m Double Deck Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
<<< Single Steer Front Axle >>>			
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Drive Dual Tandem Axle Group Fitted with Two Tyres	16.5t **	17t **	16.5t **
Gross Mass	22.5t	23t	22.5t
<<< Twin Steer Front Axle >>>			
Twin Steer Front Axle with Single Tyres	10t (Non-Load Sharing) 11t (Load Sharing)	No Higher Mass Limit Permitted	10t (Non-Load Sharing) 11t (Load Sharing)
Rear Drive Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t
Gross Mass	20t	No Higher Mass Limit Permitted	20t (Non-Load Sharing) 21t (Load Sharing)

**S55 of the Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* stipulates that heavy omnibus axles in an axle group other than a twin steer axle group must relate to each other through a load-sharing suspension system with effective damping characteristics on all axles of the group such that no axle carries over 10% more than the mass it would carry if the load was divided equally.

Table 5: Permitted Axle Mass Limits for 2 and 3 Door 18m Articulated Buses

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limits	Draft Heavy Vehicle National Regulation General Mass Limits
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Mid Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Rear Axle with Single Steer Tyres (High Floor)	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	22t	No Higher Mass Limit Permitted	22t (High Floor) 26t (Ultra-low Floor)

2.5 Heavy Omnibus Standee Floor Area Restrictions

Urban route buses used for both seated and standee passenger loads require a minimum longitudinal 380mm aisle width under ADR58/00, where complying buses designed for and operated exclusively with seated passengers are afforded a reduced aisle width concession of 300mm. A similar 300mm reduced aisle width concession applies to the longitudinal aisles on the upper deck of a double deck bus where no standing passengers are permitted by Queensland road rules whilst the double deck bus is in motion. Notwithstanding these restrictions, for modern high capacity heavy route omnibuses with minimum ADR58/00 compliant urban route bus moulded seats with 400mm wide cushions laid out in double forward facing rows along either side of the centre aisle, greater aisle widths of around 450mm are readily achieved.

The national *Disability Standards for Accessible Public Transport 2002* specifies a minimum of two separate or preferably consolidated 1,300mm x 800mm wheelchair parking spaces on all urban route buses and an increased aisle width of 850mm from the wheelchair loading door and driver operated or manually assisted wheelchair ramp (normally installed at the front entry door) to both wheelchair parking spaces, other than between heavy omnibus wheel arches where the aisle width may be reduced (but only if necessary) to 750mm.

Up to the permitted axle mass limits, longer omnibuses with proportionately greater floor areas can accommodate more standees, however low floor bus aisles with a rear of rear door gradient over 1 in 12, and aisle way or flat floor spaces with head room clearances below 1,800mm for single deck buses, and 1,650mm for double deck buses, may not be used as operator allocated standee areas. Other doorway, aisle and standing area requirements called for in the national vehicle and disability standards include anti-slip steps and flooring, and provision of a suitable number of hand straps, hand grips and hand rails in all standee areas. Queensland road rules, described later, strictly prohibit non-complying route buses not meeting these ADR58/00 prescribed standee safety requirements from being operated on school or urban routes with other than fully seated passengers.

Each additional entry/exit door added to the left hand side of an omnibus passenger cabin above the compulsory minimum front entry/exit door specified by ADR58/00 reduces its available passenger floor space by approximately 0.7m^2 (namely 2 seat or 4 standee spaces) for a minimum 850mm wide single entry/exit door, and approximately 1.15m^2 (4 seat or 7 standee spaces) for a 1,200mm wide double entry/exit door. ADR58/00 does not permit installation of any passenger entry/exit doors on the right hand side of an omnibus other than for passenger emergency exit doors, and high capacity vehicles may not be used in Australia for centre platform station loading similar to that permitted by regulations for tram, rail bus, light rail vehicles and trains.

Interior and rear exterior open upper deck staircases are permitted on double deck buses but similarly encroach on available wheelchair, seated and standee passenger floor spaces. To compensate, ADR58/00 permits non-DDA compliant narrow 400mm wide straight or spiral stairways to the upper deck on a double deck bus.

ADR59/00 rollover body structural strength requirements apply to all single deck omnibuses operated in Australia, but do not currently apply to double deck buses. Upper deck seating capacity on double deck buses is however limited under ADR58/00 to any passenger loading condition that would cause a double deck bus to become unstable and roll on a transverse incline of 28º or higher. Such a loading condition can occur with a fully seated load on the upper deck and no passengers on the lower deck to lower the heavy vehicle centre of mass. Current exemption from body structural rollover compliance with ADR59/00 afforded exclusively to double deck heavy omnibuses is highly likely to change in coming years if their deployment on capital city route bus operations becomes as widespread as it was in the mid-decades of the last century before ADR59/00 compliance was legislated.

Whilst ADR58/00 must be universally applied to the determination of legal maximum passenger loading throughout Australia, most Australian urban route bus designers and capital city bus operators adopt an empirical (but unlegislated) standee comfort space of 5 – 6.25 standees/m^2 of allocated standing floor space to prevent excessive passenger crushing and aisle blockage to boarding and alighting passenger movements.

2.6 Heavy Omnibus Configuration and Dimension Limits

ADR43/04 sets forth the permitted configuration and dimensions applicable to Australian registered heavy omnibuses. These are summarised overleaf in Table 6.

14.5m rigid heavy route omnibuses are currently classified as oversize, over mass heavy vehicles in all Australian jurisdictions, do not comply with the ADR43/04 maximum rigid vehicle length limit, have been registered to date under special provisions of the *National Transport Commission Performance Based Standards Scheme,* and are presently only permitted to operate in Queensland under gazetted *Controlled Access Bus Class Permit No 127-TH-11,* expiring 30 June 2012. Permit 127-TH-11 is intended as a stopgap authorisation to operate 14.5m route buses on Queensland roads, and only allows their controlled access route operations on:

- Major State and Local Government controlled roads, franchise toll roads and motorways classified as *Regional Significant Roads* or higher in the *State Road Network of Queensland* road hierarchy, but excluding permit nominated regionally significant roads in SEQ to Mount Tamborine and Lamington National Park and Samford – Mt Glorious Road,
- Declared busways, and
- Permit nominated arterial, sub-arterial and local roads within Brisbane City Council local government boundaries.

Controlled Access Permit No 127-TH-11 currently enables the rear overhang of a 14.5m rigid school or route bus to be extended 1m beyond that allowed under ADR43/00 to the lesser of 70% of the front axle to rear overhang line (namely the vehicle wheelbase at 1/3 of the rear tandem axle separation distance) or 4.7m. Where the rear tandem tag axle steers as on all modern 14.5m rigid buses (refer Figure 3), the rear overhang is measured from the rear drive axle (i.e. by treating the rear steer axle as if it were non-existent), resulting in rear steered 14.5m rigid buses exhibiting a high rear end swing when departing from a bus stop or turning on full lock.

Figure 3: ADR/Regulation Defined Rear Overhang for a 14.5m Rigid Bus with Rear Steering Tag Axle

Table 6: ADR43/04 Permitted Heavy Omnibus Configuration and Dimensional Limits

Configuration or Dimension	2 Door 12.5m Rigid Bus (Reference)	2 Door 12 - 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Maximum Length	12.5m	12.5m	Non-Compliant	18m	18m
Maximum Height	4.3m	4.3m	4.3m	4.3m	4.3m
Maximum Width	2.5m	2.5m	2.5m	2.5m	2.5m
Outer Turning Circle	25m	25m	25m	24m	24m
Inner Turning Circle	Not Applicable	Not Applicable	Not Applicable	5.3m	5.3m
Rear Overhang	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	3.7m	3.7m
Full Load Minimum Ground Clearance Midway between Axle Pairs on Flat Roads	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle	Lesser of 3.333% of Wheelbase or 100mm with 1m of An Axle
Full Load Minimum Load Ground Clearance Midway between Axle Pairs over Road Apexes	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients	Must Clear Apex of 2 Mirrored 1:15 Gradients

Controlled access 14.5m rigid heavy omnibuses built for New South Wales route operations have been permitted to date to extend their rear overhangs a further 200mm than in Queensland to the lesser of 70% of the front axle to rear overhang line or 4.9m. Consequently, a 14.5m rigid route bus built to Queensland controlled access permit limits can, with dual Queensland and New South Wales controlled access permits, operate school and route services crossing the border into NSW, but a 14.5m rigid bus built to NSW permit rules would not be permitted to hold dual permits and operate school and route services across the border into Queensland. Similarly, Victorian controlled access permit rules nominate a lower rear overhang than in Queensland or NSW of the lesser or 60% of the front axle to rear overhang line or 4.3m, similarly preventing NSW controlled access 14.5m rigid buses from entering Victoria. The draft *Heavy Vehicle National Regulation*, once enacted by all States and Territories, is intended to standardise all route bus length, height, width, front/rear overhang and axle mass limits throughout Australia.

The newly revised *Queensland Transport Operations (Mass, Dimension and Loading) Regulation 2005* and new draft *Heavy Vehicle National Regulation* adopt most of the earlier mentioned ADR43/04 permitted heavy omnibus configuration and dimension limits, but differ slightly in their treatment of high capacity buses:

- The Queensland regulation currently prohibits driving of any rigid heavy vehicle over 12.5m in length on Queensland roads, but the draft national regulation recognises heavy rigid omnibuses up to 14.5m long as Class 2 oversize rigid heavy omnibuses and specifies their permitted axle higher mass limits (HML), who is authorised, and the processes to be adopted to define future HML areas and routes in each road jurisdiction where 14.5m rigid omnibuses will be permitted to operate. The new draft regulation has to date not yet defined the permitted rear overhang for 14.5m rigid heavy omnibuses,
- The Queensland regulation does not permit higher gross mass limits for double deck buses with dual front load sharing steer axles and ultralow bottom deck floor heights capable of steplessly boarding passengers and wheelchairs. The national regulation recognises the former, but has not yet created a special heavy omnibus class for the emerging new types of ultralow floor double deck buses,
- The Queensland regulation does not differentiate between older high floor and modern ultralow floor “rear pusher” type 18m articulated buses, but the draft national regulation recognises older high floor and rear pusher ultralow floor articulated buses differently, and permits up to 4t higher gross axle mass limits on the latter,
- Both regulations now permit 100mm higher 4.4m high double deck buses, and
- Both regulations prevent the new *National Heavy Vehicle Regulator* and individual road authorities from granting arbitrary concessional mass and increased dimension limits to heavy omnibuses.

2.7 Performance Standards Affecting High Capacity Omnibuses

High capacity omnibuses need larger engines and transmissions to accelerate, maintain road speed and climb grades, and larger capacity compressed air braking systems and retarders to decelerate and descend inclines at a steady speed when fully loaded, than do their lower mass standard 12.5m rigid counterparts. This necessitates installation of larger and heavier onboard fuel storage tanks to power the vehicle and its various ancillary loads such as cabin ventilation, lighting and air conditioning, and to maintain vehicle operating range without twice daily refuelling. Increased relative mass and dimensions of HCVs also affect high capacity vehicle road performance relative to 12.5m standard buses and are discussed below.

2.7.1 Maximum Road Speed

ADR65/00 limits the maximum permitted road speed of a heavy omnibus to 100km/h, specifies that attainable road speed be automatically governed by a mechanical or electronic speed limiter, and stipulates that the power train design based on the bus chassis manufacturer’s maximum engine speed, overall transmission/differential gear reduction, tyre size and wheel revolutions per kilometre prevent a heavy omnibus from exceeding 100km/h.

These speed limiting conditions apply irrespective of whether a heavy omnibus is fully loaded or unloaded, and impact more significantly on the maximum road speed attainable by high capacity omnibuses than on smaller carrying capacity standard buses because of the relative change in live passenger and luggage weight between the unloaded and fully loaded conditions. In practice, the selection of engine size, automatic transmission and differential gear ratios needed for acceptable acceleration from urban bus stops, on hill starts and hill climbs limit the realisable maximum speed reached by a high capacity bus to 85 – 90km/h.

S140 of the Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* last revised in December 2011 now exempts Queensland high capacity omnibuses with a GVM over 14.5t (other than *Complying Buses*) that are fitted with hand grips or similar equipment for standing passengers from being fitted with ADR65/00 compliant speed limiting devices. It is unclear however whether this Queensland exemption will continue on after the national regulations take force.

2.7.2 Maximum External Vehicle Noise Emissions and EPA Permitted Environmental Noise Immissions

ADR83/00 limits the maximum permitted external noise emission within 7.5m of either side of a heavy omnibus passing at a speed of 50kph - 75% of its maximum road speed to 80dB(A) if fitted with an engine rated in the power range of 150 – 320kW. Engines in this rated power range are fitted on both the 12.5m route bus and the 4 subject high capacity route buses, but the latter have 30 – 45% larger and proportionately noisier engines. Consequently, 12.5m route buses can readily meet noise emission levels 5 to 10dB(A) below that set in ADR83/00, where high capacity omnibuses require elaborate engine noise encapsulation, exhaust muffling and radiator fan noise containment treatments to achieve noise emission levels below the ADR 80dB(A) threshold, the limit for which has been progressively falling over successive revisions of the standard.

Environmental nuisance noise imissions (namely nuisance noise levels reaching roadside property walls) are regulated in Queensland under Part 3 of the *Environmental Protection Act 1994* and the *Environmental Protection Regulation 2008*. The *Act* nominates the Queensland *Environmental Protection Agency (EPA)* and each *Local Government Authority* as responsible for the administration and enforcement of the noise immission regulations respectively, and the *Environmental Protection (Noise) Policy 2008* as setting the environmental noise acoustic quality objectives to be adopted throughout Queensland for new property development approvals and environmental noise planning levels. Traffic noise immissions from railways and main roads are exempted under the Act, but for non-main regional, arterial, sub-arterial and local roads passing through noise sensitive commercial and residential districts, the development approval planning noise levels are presently prescribed in the *Regulation* as:

- 63dB(A) at the $L_{10,18}$ level,
- 60dB(A) at the 1 hour continuous RMS A-weighted level ($L_{Aeq,1}$) between 10:00pm and 6:00am, and
- 80dB(A) for any single noise event maximum SPL.

The noise planning objectives of the Act, its Regulation and Policy aim to progressively ratchet down $L_{A1,1}$ hourly traffic noise immissions reaching private dwellings in future years to as low as 65dB(A) for all hours of the day, and $L_{Aeq,1}$ noise immission levels reaching prescribed noise sensitive public institutions such as schools, universities, childcare centres, hospitals and doctor surgeries to as low as 35dB(A).

Compliance with *EPA* regulated noise immission planning limits may in future prevent or limit the deployment of high capacity diesel omnibuses or enforce alternative use of low noise emission diesel-electric and hybrid buses in noise sensitive precincts. Noise immission compliances similar to those proposed by the *Environmental Protection (Noise) Policy* have already been implemented in many major European, South East Asian, Canadian and USA cities where high capacity overhead cable powered diesel-electric and hybrid omnibuses travelling through noise sensitive route sectors must operate by electric motor only whilst located in CBD office districts, residential suburbs and public road tunnels.

2.7.3 Upper Deck Level and Stairway Standee CCTV Monitoring on Double Deck Buses

Standing passengers are not permitted on the upper deck or stairways of a double deck bus when in motion. This will require double deck bus drivers to periodically observe regulated no standing areas on the vehicle before and after departing bus stops from a CCTV monitor mounted in the driver's cabin, and to use a pre-recorded or live voice *public address (PA)* announcement to direct passengers to sit. S31 of the *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010 and* ADR42/00 define the conditions under which a driver's visual display unit may be used on a heavy omnibus as a driving aid and where a permitted display unit may be mounted within the driver's visual field of view.

2.7.4 High Capacity Omnibus Standing and Overloading Restrictions

High capacity buses are traditionally designed and operated to minimise the number of standees or to reduce recurring incidents of overloading and missed passenger pick-ups. The *Transport Operations (Passenger Transport) Standard 2010* identifies any omnibus used for delivery of public passenger services as a *Relevant Vehicle* and prohibits a driver from operating a *Relevant Vehicle*:

- In an overloaded condition,
- Without an appropriate licence class and driver authorisation. An *MR (Medium Rigid)* class licence is needed to drive a standard 12.5m two axle rigid omnibus and a HR (heavy rigid) class licence to drive all 4 three axle high capacity omnibuses whose *gross vehicle masses (GVM)* exceed the prescribed 15t threshold. A HCV driver must continuously hold his/her open C class licence for 1 year before becoming eligible to hold an MR class licence, and must thereafter continuously hold both his/her C class licence and MR class licence for a period of 2 years and 1 year respectively before becoming eligible to hold a HR class licence. Driver licence requirements apply to all persons who drive a *Relevant Vehicle* (e.g. bus drivers, mechanics, cleaners, etc) on a road, but a driver authorisation is only mandated for a driver who actually operates a *Relevant Vehicle* on a public passenger service,
- With standing passengers in a bus fitted with seat belts, namely a *Complying Bus*, or *a Regional Classification Vehicle* with side facing seats (discussed later). The driver must additionally report any standing passenger allowed on a *Complying Bus* to his/her *Authorised Operator* at the end of each passenger service shift, or
- With standing passengers if not designed and constructed for such (to ADR58/00), on a long distance scheduled passenger service, a DTMR no standing passenger *Notified Road*, or if a scheduled school bus, for a distance of more than 20km**. The *Transport Operations (Passenger Transport) Standard* allows for 3 primary or pre-school children to occupy a single twin adult passenger seat for up to 90min, and an adult to nurse an infant on any scheduled school or route

omnibus not fitted with seat belts; but not on any *Complying Bus*, unless each child is individually restrained by a seat belt or in an approved infant child restraint.

(**The *Transport Operations (Passenger Transport) Standard* has only recently been amended to remove the no standee rule for school bus routes in excess of 20km. Prior to the amendment of this *Standard*, Brisbane Transport had to deploy articulated buses on its non-stop Route 142 to provide sufficient seating capacity for school children. Articulated buses were deployed on this route to provide additional seats, but the vehicle's total carrying capacity wasn't being fully utilised. With this restriction now removed, *TransLink* is free to allocate high capacity vehicles on any route other than a *Complying Bus* route operating on a DTMR *Notified Road*)

2.7.5 High Capacity Omnibus Scheduling for Mixed Bus Types

Because high capacity buses are permitted to board higher passenger loads, they may require bus type specific timetables if scheduled on mixed high capacity and standard 12.5m bus school or route services. The *Transport Operations (Passenger Transport) Standard 2010* stipulates that the driver of a scheduled school or route service must provide the passenger transport service in accordance with advertised schedules unless prevented from doing so by unforeseeable circumstances or schedules that are not realistically achievable. The *Authorised Operator* is obliged under the *Standard* to advertise timetables that are realistically achievable for the bus type and size allocated to a scheduled school or route service.

2.7.6 Prescribed Vehicle Regional Classification Requirements

The *Passenger Transport Standard* defines the prescribed vehicle classification of an omnibus as a *Local Classification Vehicle* if its operates a journey within a radius of 40km from the first passenger pick-up point, or if the journey is entirely within a single or contiguous urban area within a radius of 40km from the first passenger pick-up point. This classification applies to most existing heavy route omnibuses used for *TransLink* school and route bus services in SEQ.

If long haul trunk and spine express route services assigned to high capacity omnibuses as envisaged in *Connecting SEQ 2031* (discussed later) exceeded the 40km radius, but were less than 350km radius from the first passenger pick-up point, the prescribed vehicle classification of the high capacity bus would automatically revert to that of a *Regional Classification Vehicle* which must meet more stringent ADR safety compliances than a *Local Classification Vehicle*. The additional compliances specified for a *Regional Classification Vehicle* high capacity omnibus over those applicable to a *Local Classification* standard or high capacity route bus would include:

- Compliance with all non-route bus ADRs applicable to high and low back passenger seats,
- Installation of lap seat belts on side facing passenger seats complying with ADR4/00 and ADR5/00, and
- Provisions for light passenger luggage incapable of being held by hand, to be stored in overhead lockers or racks, but not in an aisle or any other floor space that would impede passenger egress to entry/exit doors or emergency exit doors. Where carriage of heavy passenger luggage was approved by *TransLink* or its *Authorised Operator*, it would either have to be placed in a passenger segregated luggage compartment or trailer, the latter of which would not be permitted under the draft *National Heavy Vehicle Regulation* on a 14.5m or 18m articulated route bus.

2.8 Queensland Road Rules Impacting High Capacity Bus Operations

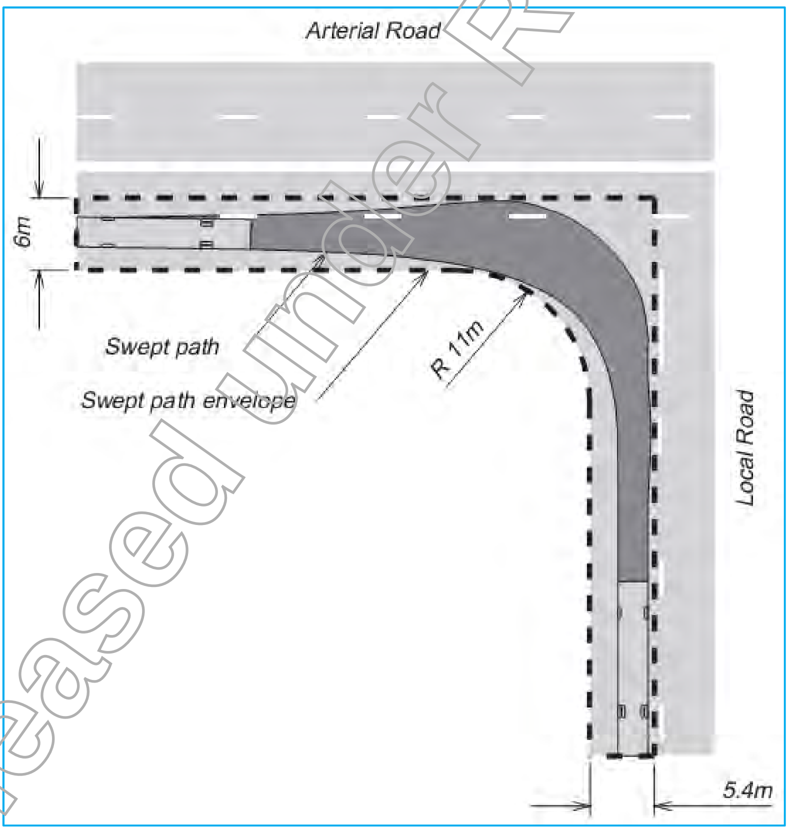
2.8.1 Heavy Omnibus Speed Limit

Notwithstanding the posted speed limit on any road or any exemption for fitment of speed limiting devices on high capacity omnibuses with a GVM over 14.5t, the Queensland *Transport Operations (Road Use Management – Road Rules) Regulation 2009* (hereinafter referred to as the *"Road Rules"*) prohibits the driver of a heavy omnibus with a GVM over 5t from travelling at a road speed greater than 100km/h.

2.8.2 Left and Right Turning Constraints on 14.5m Rigid Buses

Sections 27 through 34 inclusive of the *Road Rules* define how a long wheelbase heavy vehicle fitted with rear *Do Not Overtake Turning Vehicle Signs* may negotiate left and right hand turns from far side turning lanes at an intersection. The rules effectively limit left turns for a 14.5m over length bus to those from a two lane local road to a multilane major road where over length buses can safely and legally cross unidirectional traffic lanes as depicted in Figure 4, but similar left turn manoeuvres are not possible from a two lane local road into another two lane local road without either driving on the wrong side of the road or increasing the front steering locks to obtain a reduced swept path radius.

Figure 4: 14.5m Rigid Bus Left Turn from a Single Lane Local Road into a Two-Lane Arterial Road



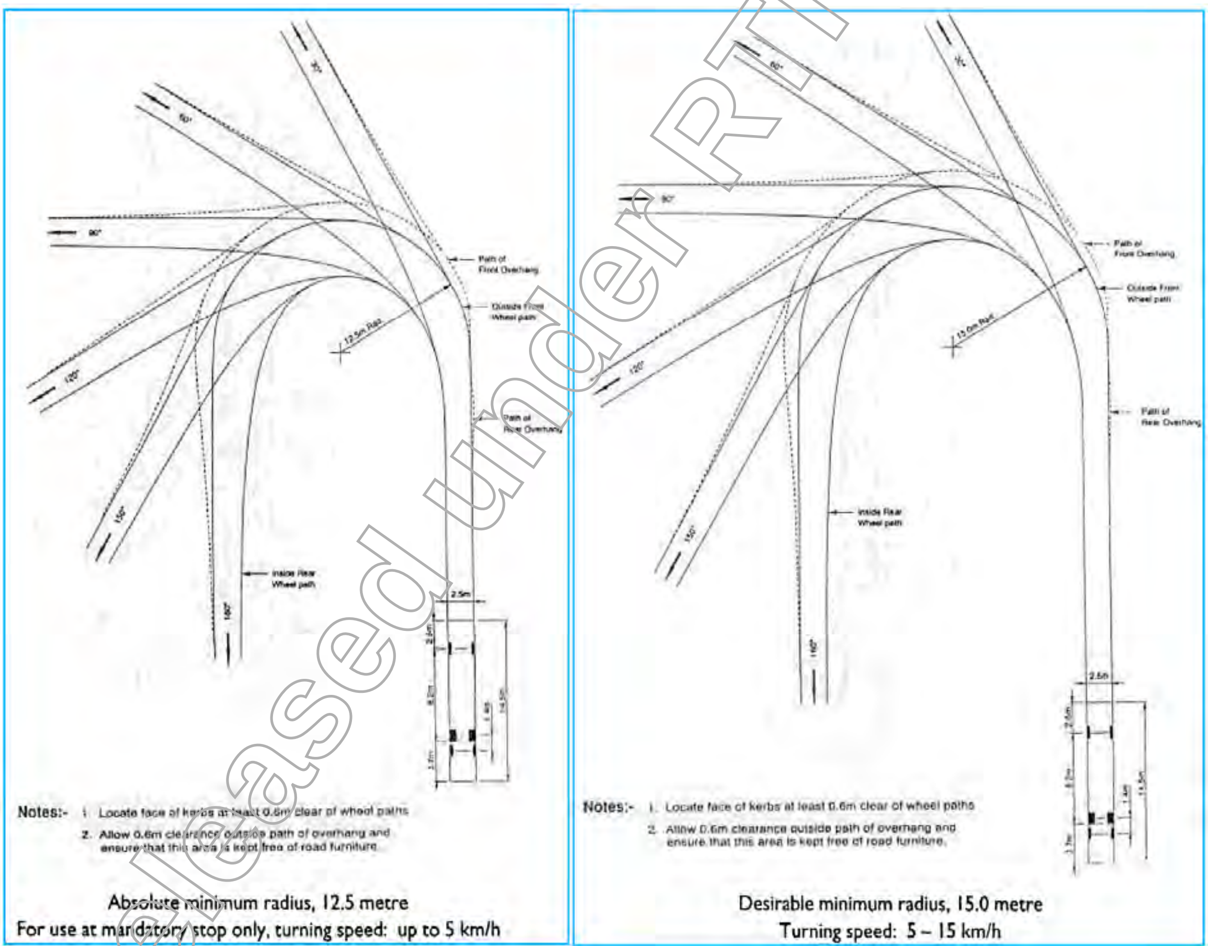
2.8.3 Turning Circle, Swept Path and Tail Swing on 14.5m Buses

ADR43/04 and the *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* specify that a heavy vehicle must be capable of turning left or right in a circle of not more than 25m diameter (12.5m radius) measured on the outer edge of its tyre track at ground level. This maximum regulated turning radius is applied by *Austroads* and all Australian road authorities to the design of minimum left turn kerb radii at intersections such as that depicted in Figure 4, which typically include an additional +R0.6m safety margin and range from R10m on local suburban road intersections up to R15m on major road intersections.

Neither vehicle standard specifies the vehicle road speed at which the regulated turning circle must be measured, but *Austroads* adopts a road design turning speed of 5km/h for 14.5m rigid bus turning circles of 12.5m radius (25m diameter) and recommends a greater turning circle of 15m radius (30m diameter) for road intersection design turning speeds up to 15km/h, as illustrated in Figure 5. At the latter 15km/h turning speed, the wall-to-wall swept path measured at the front right overhang of an over length 14.5m rigid bus is 32m (or R16m). These very large turning radii can be readily accomplished on a modern 14.5m rigid omnibus by setting the front steering wheel full lock stops to approximately 42°, but this effectively restricts operation to multilane main, arterial and sub-arterial roads, and in many cases, would prevent 14.5m rigid bus service routes from entering congested central business districts.

To enable tighter left turn and right turn cornering and full lock exiting from restricted length bus stops, 14.5m rigid bus operators increase their front steering full lock stop settings up to around 52° to achieve a greatly reduced wall-to-wall swept path radius of R12.5m, as illustrated in Figure 6.

Figure 5: Austroads 14.5m Long Rigid Bus Swept Paths Measured at 5km/h and 15km/h

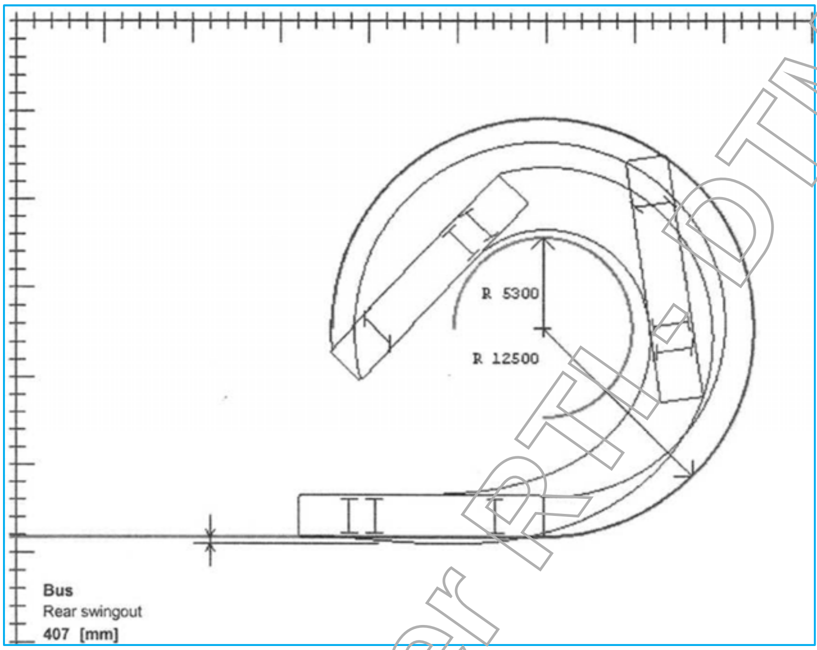


Whilst 14.5m rigid buses with increased front steering lock angles are fully compliant with the relevant ADR and Regulation, their reduced wall-to-wall turning radii may have the following unintended consequences if bus drivers do not exercise due care to prevent:

- Mid-body skirt kerb crossing or rear wheel kerb mounting during full lock left lane to left lane turns at intersections,

- Mid body skirt median crossing of median noses or rear wheel median nose mounting during full lock right lane turns at intersections,
- Rear tail swing in over kerbs on full lock right turn exiting from departure blocked left lane bus stops and zones, and
- Rear tail swing out into adjacent traffic lanes during full lock left and right turns.

Figure 6: 14.5m Rigid Bus Swept Path with Front Full Lock Stops Set for R12.5m Wall-to-Wall



These driving safety risks associated with setting increased front steering lock angles can be mitigated through appropriate management strategies for 14.5m rigid buses such as:

- Compulsory route assessments for all new 14.5m rigid bus services as currently enforced by the Road Traffic Authority of New South Wales,
- 14.5m rigid bus driver route orientation training,
- Positioning 14.5m rigid bus stops well clear of intersections where route left turns are scheduled,
- Preventing regulated parking zones immediately forward of straight left lane bus stop zones, and
- Constructing purpose built indented bus stops for 14.5m rigid buses with adequate run in and run out tapers.

2.8.4 Maximum Take Off Acceleration and Give Way to High Capacity Buses

S77 of the *Road Rules* states that all drivers must give way to a bus in the left lane or left line of traffic on a road in a built-up area where the speed limit is not more than 70km/h and the bus:

- Has stopped, is moving slowly or is stationary in a bus stop bay,
- Displays a rear *Give Way to Buses* sign and has activated its right direction turn indicator, or is
- About to re-enter or proceed ahead in the left lane or line of traffic in which the bus driver is already driving.

The give way to buses rule does not apply however to buses exiting bus stops and crossing lanes to right turn, buses pulling into traffic lanes on roads with posted speed limits above 70km/h, or relieve bus drivers from safely exiting bus stops without first checking in rear view mirrors that sufficient time has been given to oncoming traffic and sufficient gap length exists to safely re-enter the left line of traffic. The higher mass, slower acceleration and longer length of high capacity buses dictates that longer bus stop dwell times be allowed in high capacity bus service timetables for traffic lane re-entries during peak traffic periods.

2.8.5 Low Clearance Signs Affecting Double Deck High Capacity Buses

Notwithstanding the current 4.3m general heavy vehicle height limit or proposed new national extended 4.4m height limit permitted for double deck heavy omnibuses, s102 of the *Road Rules* prohibits the driver of a bus from driving past a *Low Clearance Sign* if the vehicle is higher than the height (in metres) indicated on the *Low Clearance Sign*.

The minimum clearance design height for all bridges constructed in Queensland is 4.6m. 14 low bridges with 4.8m or lower height clearance exist within *TransLink*'s SEQ route bus service boundaries and are listed in Table 7 below. Railway bridges Nos 1 and 2 in Table 7 would be considered impassable or marginal clearance heights respectively for single deck high floor route buses fitted with rooftop air conditioners and CNG cylinders, and bridge Nos 1 to 8 inclusive would be impassable to double deck buses.

Table 7: Low Clearance Bridges under 5m Height within TransLink Bus Route Service Boundaries

ID No	Bridge	Road	Suburb	Signed Clearance Height
1	Railway	Park Street	Milton	3.3m
2	Railway	Oxley Road	Corinda	3.6m
3	Railway	Annerley Road	Woolloongabba	3.8m
4	Railway	Muriel Avenue	Rocklea	3.8m
5	Railway	Cribb Street	Milton	3.9m
6	Pacific Motorway	Main Street	Beenleigh	4.0m
7	Railway	Countess Street	Petrie Terrace	4.4m
8	Hawthorne Street	Pacific Motorway Southbound Access On Ramp	Woolloongabba	4.4m
9	Linkfield Road	Gympie Arterial Road	Bald Hills	4.7m
10	Railway	Wynnum Road	Cannon Hill	4.7m
11	Pacific Motorway	Ipswich Road	Woolloongabba	4.7m
12	Anzac Avenue	Bruce Highway Exit to North Lakes	Murrumba Downs	4.8m
13	Kessels Road	Pacific Highway	Upper Mount Gravatt	4.8m
14	Watland Street	Old Pacific Highway Service Road	Slacks Creek	4.8m

2.8.6 No Buses Signs Affecting High Capacity Buses

S106 of the *Road Rules* prohibits the driver of a high capacity bus from driving past a *No Buses Sign* that has associated information on or with it indicating a mass or length, if the GVM or length of the bus exceeds the mass or length respectively indicated on the sign. *No Buses Signs* of this type normally only appear on unsealed or narrow rural roads and bridges or DTMR *Notified Roads* where 12.5m *Complying*

Buses would normally operate within *TransLink* network boundaries. These roads are considered unsuitable for the 4 subject high capacity vehicles.

2.8.7 Loading and Bus Zone Signs Affecting Long High Capacity Buses

Sections 179 and 183 of the *Road Rules* permit buses to stop in a signed loading zone for the sole purpose of dropping off and picking up passengers, and in a signed bus zone for any purpose whatsoever. Over length 14.5m and 18m articulated buses may not stop in these zones however if information displayed on zone signs preclude a bus of their specified type from stopping in the zone, or if the bus length exceeds the zone length and the driver cannot safely pull into the zone without double parking or blocking the left through lane of vehicular traffic, as prohibited by s189 of the *Road Rules*.

S195 of the *Road Rules* permits an over length high capacity bus to stop up to 20m behind and 10m ahead of a *Bus Stop Sign* if the driver can safely stop in a length of clear road or area to which a parking control sign applies or is approved by regulation, but is not occupied by a parked vehicle. S198 further permits an over length bus to obstruct bicycle paths, private vehicle and pedestrian accesses to footpath ramps whilst dropping off and picking up passengers.

2.9 Passenger Transport Regulations Affecting High Capacity Bus Operations

The *Transport Operations (Passenger Transport) Regulation 2005* governs public passenger transport operations on Queensland roads using buses, taxis, limousines, motorcycles and other vehicles. It deals primarily with operator and driver accreditation schemes and licensing of services. The following discusses where and how the passenger transport regulations would affect high capacity route buses differently to standard 12.5m rigid route buses. A *Relevant Vehicle,* as defined by the *Passenger Transport Regulation* and described herein, may be any of the 4 subject high capacity route bus types used to provide a public passenger service.

2.9.1 Driver Authorisations

S20B of the *Passenger Transport Regulation* requires the applicant for a *Relevant Vehicle* driver authorisation (new or 5 year renewal) to:

- Hold a prescribed licence of the appropriate class (HR) for the high capacity vehicle,
- Have continuously held an open C class or provisional licence for a car, truck or bus for at least 3 years, and
- Have passed a competency test approved by the chief executive (of DTMR) for the operation of the type of *Relevant Vehicle* the person intends to drive.

For a typical *TransLink* bus driver already possessing an MR class licence and driver authorisation to operate a standard 12.5m rigid route bus, attainment of the necessary prerequisites required for both a high capacity bus HR driver licence and driver authorisation would require a minimum 1 year lead time plus competency testing for each high capacity bus type in his/her authorised operator's bus fleet.

2.9.2 Driver Licence Suspension, Cancellation or Disqualification

S37 of the *Passenger Transport Regulation* states that if the driver licence of a person holding a driver authorisation is suspended, cancelled or disqualified from holding or obtaining a license, the person is automatically suspended, cancelled or disqualified from holding or obtaining a driver's authorisation for a corresponding period respectively. Depending on when in the 5 year renewal cycle of a high capacity vehicle driver authorisation a driver was to have his/her licence suspended, cancelled or disqualified, the prerequisite conditions for renewal would bar the bus driver from operating a high capacity bus for a period of up to 3 years, unless the driver was granted a provisional driver authorisation by the chief executive (of DTMR).

Where the continued livelihood of a bus driver was taken into account by the chief executive in the granting of a provisional driver authorisation and his/her authorised operator also had 12.5m rigid buses in its fleet, the conditions of the provisional driver authorisation may be limited to those applicable to an MR class licence only, still barring the affected driver from operating high capacity buses.

2.9.3 Market Entry Restrictions

Schedule 1 of the *Passenger Transport Regulation* limits provision of general route services other than those for dedicated school services to:

- Within cities and towns with a population of more than 7,500,
- On routes of not more than 40km between cities or towns, each having a population of more than 7,500, and
- Between villages with a population of 500 or more and a city or town with a population of greater than 7,500.

These market entry restrictions would conflict with the proposed new *UrbanLink* long haul trunk, cross-country and regional activity centre interconnect bus services described later in *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland*. These are service types best suited to future deployment of high capacity buses. Exceptions to market entry restrictions may be declared under the *Passenger Transport Act* by public notice or gazette issued by the chief executive (of DTMR).

2.10 Disability Standards Affecting High Capacity Buses

The *Disability Standards for Accessible Public Transport 2002* enforces the principle that *Equivalent Access* be provided for *Persons with Disabilities (PWD*s) to all public transport services. A public transport operator and provider (viz. *TransLink*) are mutually obligated to provide assistance to a *PWD* when requested and to vary the infrastructure, accesses to infrastructure and vehicle equipment and facilities that provide access to a public transport service such that an equivalent standard of amenity, availability, comfort, convenience, dignity, price and safety is maintained for *PWDs* to that afforded to other persons. The following disability standards may affect high capacity buses differently to standard 12.5m rigid buses.

2.10.1 Wheelchair Loading and Unloading

Non-slip, 800mm wide, 300kg rated wheelchair boarding devices are not called for under the *Disability Standards* for heavy buses operating dedicated school services, but are mandated on all other route buses and must be deployed if any passenger requests their use, whether a recognisable *PWD* or otherwise. Boarding ramps are normally installed at the front door of a route bus and may be of a type that is remotely powered and extended from the driver's seated position, or a type that needs to be manually pulled or flipped out onto the footpath kerb at the front door, necessitating that the driver leave his/her seat to assist the *PWD*.

Manually operated flip out ramps have become more prevalent on urban route service buses and are recognised by operators as more reliable, cheaper to install and easier to maintain. In addition to boarding device operations, a driver may be requested to assist a *PWD* with wheelchair pushing up boarding ramps and down bus aisles, and with stowage and retrieval of mobility appliances placed in luggage racks.

For a modern step-less entry ultralow floor bus, the vehicle will normally travel and stop with its compressed air front suspension raised to meet minimum ground clearance heights stipulated in ADR43/04 and the regulations, but must be lowered to near kerb height on the left hand side to board and alight persons with walking appliances, prams, wheelchairs, the visually impaired or blind. Inbuilt bus safety systems interlock the park or bus stop brakes whenever the wheelchair loading ramp is deployed, a door is opened or the bus suspension is not fully raised, and the bus cannot be moved off until all 3 safety conditions have been met.

The boarding ramp length and width necessitates both close spacing from and parallel alignment of the front door step to the kerb, and a near 90° wheelchair navigation path, which can be readily accommodated by 12.5m standard rigid buses at most bus stops constructed on left lane straight pull-in kerbs. Wheelchair loading and unloading challenges are however encountered with high capacity vehicles and include for:

- Double Deck Buses: 3.2 to 3.4m high double deck buses must be deliberately driven with a greater separation distance from kerbs than single deck buses to prevent accidental upper deck glazing, panel and roof strikes from shop awnings, traffic signs, posts, poles, tree branches and other high profile objects close to kerb lines. Double deck bus stop access is impacted by high profile obstructions in both the approach and departure paths, and these buses cannot be kneeled on the left side if high profile objects such as shop awnings and posts built to the kerb line exist within the bus stop zone.

  All wheel suspension kneeling may be necessary on a short wheelbase double deck bus to prevent excessive forward incline on wheelchair accessible bus aisles, and wheelchair kerb ramps similar to those provided for taxi and minibus wheelchair loading may prove necessary for double deck buses where wheelchairs have to boarded and unloaded to road because of high profile footpath furniture.

  Twin steer double deck buses such as Bus 343 under trial on the Gold Coast have narrower and longer aisle distances to reach wheelchair bays, and in combination with off-road wheelchair loading and/or all-wheel bus suspension kneeling, suffer longer dwell times at bus stops. Double deck buses may in some cases require larger onboard air storage tanks to speed up suspension raises and brake or auxiliary tank pressure recovery.

- 14.5m Rigid Buses: Over length 14.5m buses with increased steering lock settings suffer from excessive rear end swing into bus stops upon departure if full lock right turn outs are necessary to clear a vehicle (including another bus) parked in or immediately ahead of the bus stop. They are also impacted by non-parallel to kerb alignment in undersized straight and indented bus stops, and in indented bus stops with short turn-in or turn-out tapers designed to old road standards for short 12m rigid buses. Over length 14.5m rigid bus drivers, cognisant of rear end swing in due to forward path blockages, will deliberately space their buses up to 500mm out from the kerb to prevent swing in over the footpath, and kerb ramps may be needed at some existing short bus stops and indented bus bays to enable wheelchair loading off road.

- 18m Articulated Buses: Articulated buses are less susceptible to rear tail swing in, and with shorter front section wheelbases, can readily manoeuvre in close and parallel to kerbs in indented bus bays. However on existing short indented bus bays designed for 12m and 12.5m buses, articulated buses may be forced past the parallel section of kerb designated for front door passenger boarding into the turn out taper in order to clear the articulated trailer from the left through lane of traffic. This may result in wheelchair boarding over grassed, tiled or pebbled areas or from the road.

2.10.2 Hail and Ride PWD Pick Up/Set Down

Queensland *Road Rules* afford exclusive rights to urban route buses to park outside signed bus stop and bus zones across private driveways and pedestrian accesses, in front of fire hydrants, on bicycle lanes and in regulated clearway, loading, parking, taxi and other nominated vehicle zones if stopped solely and exclusively for the purpose of pick up or set down of passengers. The right to stop in these regulated zones does not apply if regulatory signs prohibit buses of a particular type from stopping.

A key purpose of this exclusive right of buses to stop virtually anywhere on an open kerb is to provide accessible public transport to the elderly, blind and persons with mobility disabilities where bus stops are separated by long distances or hilly terrain and where regulated bus zones have not been established close to aged people homes, hospitals, medical centres or similar facilities. Under the duty of customer care defined in the *Passenger Transport Regulations*, a route bus driver is arguably obligated and entitled by the *Road Rules* to pick up a *PWD* when hailed or to set down a *PWD* when requested to do so outside a designated bus stop when it is safe to do so, and such is understood to be common practice on *TransLink* route services operated in SEQ.

The opportunity to safely pick up and set down passengers outside regulated bus stops and zones is significantly curtailed by the availability of kerbside spaces available to 14.5m and 18m long high capacity buses in parking congested town centres and commercial business districts.

2.11 Transport Planning and Coordination Regulation

Part 2 of the Queensland *Transport Planning and Coordination Regulation 2005* defines IDAS local road standards to be applied on local government controlled roads that form part of a route used for a public transport service. Compliance with the *Code for IDAS* must be determined for all assessable developments granted under the Queensland *Sustainable Planning Regulation 2009*. The purpose of the *Code for IDAS* is to ensure that developer road works on local government roads do not have any significant adverse impact on the efficiency, safety and comfort of public passenger transport. The standards nominated by the *Code* override those published in the Queensland *Road Planning and Design Manual (RPDM)* and the national *Austroads Guide to Road Design (AGRD),* unless approved otherwise in Part 2 of the *Regulation*.

The following standards in Part 2 of the *Transport Planning and Coordination Regulation 2005* may restrict operation of high capacity buses vehicles on Local Government controlled roads approved under future *Controlled Access* or *HML Area Permits*:

- Lane Width on a Straight Undivided Two-Way Road: Lane widths of 3m on a straight undivided two-way local road would be unsuitable for operation of a 14.5m rigid and modern pusher type 18m ultra-low floor articulated bus if either the entry or egress intersection accessing the two-way local road had less than two lanes for left and right turns.
- Crossfall: Left lane crossfalls of 3 – 5% may not be suitable for 4.2 – 4.4m high double deck buses on narrow lane roads with trees, shop awnings, light poles, traffic signs and other high footpath furniture erected close to the kerb as can occur after a local government road widenings (for example in Milton Road, Auchenflower). Heavy loading on the upper deck of a double deck bus may cause a double deck bus to lean or oscillate leftward after crossing a side road intersection crown that has been elevated with successive layers of asphalt resurfacing.

- Indented Bus Bays: Indented bus bays prescribed by the *Regulation* for Local Government sub-arterial and higher order roads are required to comply with *RPDM* Chapter 20 and *AGRD* Parts 3 and 4 which provide indicative bay designs for either 12m rigid or 18m articulated buses, but no direction is given on which bus type and set down kerb length to design the bay for. For the proposed future high frequency *UrbanLink Bus Network* (discussed later), there will be an increased probability of closer running bus arrivals at indented bus bays, high capacity buses using indented bays and no overtaking lanes on congested road *TransitWays*. Unless *TransLink* and its service partners can positively verify that only low frequency standard rigid buses will use specific indented bays, it would be recommended that future indented bus bays be constructed for two 12.5m rigid buses with long run-out tapers to suit 14.5m rigid buses.
- Roundabouts: Whilst the general requirements for roundabouts on Local Government roads state that roundabout traffic islands must be designed in accordance with the *RPDM* and *AGRD* to clear the swept path of the design bus plus 0.6m clearance on each side, they do not specify for which design bus type. Modern steered tag axle 14.5m rigid and 18m pusher type ultralow floor articulated bus swept paths should be able to negotiate existing roundabouts at intersections on 4 lane two-way arterial and sub-arterial roads, but would experience difficulty negotiating non-flat top single lane two-way intersection roundabouts on most local roads.

3. Planning and Policy Impacts on Future Deployment of High Capacity Buses

This part reviews State, road and transport authority plans, policies and funding programs likely to impact on future demand for and deployment of high capacity buses in *South East Queensland (SEQ)* over the forthcoming 20 years out to 2031. Sweeping major changes are proposed to public transport delivery and related road and transport infrastructure during this period which tie in with State and Local Government regional planning for population growth, land use and redevelopment. Forthcoming changes affecting transport planning and funding priorities are broadly outlined in the following sections.

3.1 South East Queensland Regional Plan

The *South East Queensland Regional Plan 2009 – 2031* is the State's key long-term master plan for managing population growth, land use, new development and public infrastructure investment in SEQ over the forthcoming 20 year time horizon. The vision, strategic directions, principles and policies embodied in the *SEQ Regional Plan* prescribe the guidelines, strategic objectives and priorities to be adopted in all subordinate State and Local Authority road, transport and infrastructure plans and long-term infrastructure investment programs approved for the seven Local Government regions located in South East Queensland.

3.1.1 SEQ Regional Plan Vision and Strategic Directions

The overarching vision described in the *Regional Plan* for SEQ is for a region of interconnected communities with excellent accessibility to an extensive, integrated and efficient public transport system that contributes to reducing traffic congestion and greenhouse gas emissions.

Key strategic directions set out in the *SEQ Regional Plan* include restricting local planning schemes and development approvals to those that proactively reduce reliance on imported oil and private car dependency, with highest priority given to mixed-use (residential and employment precinct) transit oriented developments that support public transport through increased population density and close proximity to cities, major towns and defined activity centres with access to existing or proposed new public transport corridors. A core principle orchestrated in the strategic vision and principles is that reliable interconnected public transport services should be established prior to and lead development in regional activity centres to reinforce community travel habits that do not solely rely on private vehicle use.

3.1.2 Urban Footprint Development Concept

The *Regional Plan* envisages a new compact *Urban Footprint* land use for urban, rural, broadhectare, infill and remnant broadhectare areas located in SEQ, which incorporate a full range of urban uses, viz. residential housing, industry, business, infrastructure, community services, facilities and open spaces, underpinned by reliable, effective, high frequency public transportation. Priorities are assigned in the plan to those urban footprints which promote redevelopment in existing urban areas built around regional activity centres, established public transport nodes and corridors, and new public transport infrastructure which links regional activity centre transport nodes through a network of cross-city and inter-regional road, walking and cycling networks.

High capacity buses are well positioned to play a central role in providing cost-effective high frequency trunk and express services across the network of busways, cross-city and inter-regional roads with preserved bus corridors that will interconnect new activity centre transport nodes as they develop.

3.1.3 Regional Road, Public Transport and Infrastructure Priorities

Priorities have been ascribed to development in defined residential areas, regional activity centres, employment areas and identified population growth areas within each SEQ *Region.* The *Regional Plan* identifies specific future public transport nodes and corridors to be preserved and major public transport infrastructure projects to be included in all subordinate SEQ road, transport and infrastructure plans and funding programs, including but not limited to new busways, light rail track alignments, rail line duplications/extensions, bus/rail stations, tunnels, bridges, major road upgrades, pedestrian ways and cycle ways planned for identified high growth areas.

3.1.4 SEQ Regional Planning Principles and Policies

Future wide scale deployment of high capacity buses strongly supports the guiding principles and policies encompassed in the *SEQ Regional Plan* as follows:

- Sustainability Principle: High capacity buses offer the lowest cost per passenger-kilometre currently available for transporting heavy passenger loads at high frequency and reliability on mainline trunk corridors connecting distributed activity centre public transport nodes. They are also appropriately sized to deliver high capacity feeder and intermodal connecting services to and between major public transport nodes such as geographically disconnected light and heavy rail stations, regional airports and interstate transit centres,
- Reducing Greenhouse Gas Emission and Oil Supply Vulnerability Principles: High capacity buses consume the least imported fossil fuel and generate the lowest exhaust emission and greenhouse gas volumes per passenger-kilometre travelled. They also displace a greater number of private vehicles from public roads than any other currently known road based public transport mode, excepting the pushbike,
- Ecosystem Services Principle: *Ecosystem Services* are defined in the *SEQ Regional Plan* as public goods and services that benefit, sustain and support the human ecosystem. Provision of accessible public transport services and infrastructure to disconnected communities and social infrastructure is a linchpin element of the *Ecosystems Sustainability Framework for SEQ*.
- Rural Communities (Support) Principle: The *Regional Plan* attempts to redress the limited access, social and employment disadvantages of SEQ rural and small town communities to critical social infrastructure such as schools, hospitals, places of employment, shopping centres, etc. attributed to long separation distances from principal and major activity centres to places of residence, and a current general lack of existing available low cost public transport services. The *Regional Plan* identifies a number of key rural and public transport corridor mixed-use activity centres that are proposed to deliver higher order public infrastructure, community services, commercial activities, places of employment and improved public transport connectivity within SEQ. High capacity cross-country buses are anticipated to connect these key rural activity centres as they develop, and
- Social Planning and Addressing Disadvantage Principle: The *SEQ Regional Plan* forecasts an exponential growth of the aging population in SEQ over the next 2 decades and an urgent need for a broad choice of home, aged care and retirement accommodation options where aging persons can self commute to a hospital, medical centre, shopping centre or similar facility without needing to own and drive a private motor vehicle.

The plan identifies an emerging demand for highly interconnected public transport services that will encourage aged people, including those located in remote disadvantaged urban suburbs and rural communities, to continue living at home or in aged care facilities of their choice for the longest possible period, using a reliable public transport system that enables them to freely commute and "age in place". High capacity buses should play a primary role in providing cross-city and cross-country commuting services to social infrastructure including hospitals, medical centres and other professional services centres, enabling the elderly to "age in place".

3.1.5 Desired Regional Outcome 8 - Compact Settlement

Desired Regional Outcome 8 of the *Regional Plan* aims to prevent dispersed low-density population sprawl that has thus far dominated historical development in SEQ, to open up existing land parcels for redevelopment as new activity centres, and to only release new land parcels for compact high density mixed-use settlement where essential services and public infrastructure exists or can be provided at least cost to tax and ratepayers:

- Compact Development Principle: In addition to traditional utilities such as electricity, public lighting, telecommunications, water and sewerage reticulation; and essential public infrastructure such a roads, storm water drainage, footpaths, cycle ways, open spaces, etc, property developers will be required in future to focus their proposed developments within defined urban footprints and regional activity centres where public transport nodes and corridors already exist, or to suffer a high contribution penalty to the cost of creating new public transport services and infrastructure as a precondition of their development approvals.
- Containing Growth and Urban Character and Design Principles: These principles aim to constrain future growth by proactively discouraging new development outside defined urban footprints and in rural and broadhectare sites where public transport nodes, corridors and services do not already exist or are not already planned or committed to in published State or Local Government funding programs. Developers must either demonstrate current public transport programs exist and will be delivered prior to release of their new developments to market, or suffer the high cost penalty of having to contribute to any necessary new public transport infrastructure development. The latter option will be used as a strong disincentive to constrain unwanted sprawl, and developer agreement to payment of public transport infrastructure contributions will not guarantee unplanned development approvals.
- Activity Centres and Transit Corridors Principle: This principle commits State Government Departments, Statutory Authorities, Government Owned Corporations and Local Government Authorities (hereinafter called *State Government Entities*) to preparing detailed land use planning schemes and public infrastructure plans for defined *Principal, Major Regional, Specialist, Principal Rural and Major Rural* Activity *Centres* identified in the *SEQ Regional Plan* to guide land use, public transport and infrastructure delivery across SEQ. These defined regional activity centres are to be supported by quality public transport that will create compact, self-contained, diverse (mixed-use) communities interconnected by a network of public transport and active transport (walking and cycling) corridors.
- Integrated Land Use and Transport Planning Principle: This principle recognises the strong nexus that exists between land use and efficient public transport, and prescribes prerequisite conditions to be applied to future *Transit Oriented Development (TOD)* approvals in precincts located within close walking distance of a *High Frequency Priority (HFP)* or combined high frequency service transport node. *TOD Precincts* are to be built on a walking and cycling friendly core within 10 minutes walking distance of an existing or planned light or heavy rail station or bus station surrounded by high density residential, employment and other prescribed mixed land uses.

Under the *SEQ Regional Plan*, new *TOD Precincts* are to be geographically centred about existing or planned busway, bus and rail stations served by high frequency services on a dedicated transit corridor. Busway and bus station centric *TOD Precinct* nodes are proposed to be serviced by a combination of standard rigid local/feeder and high capacity trunk buses.

- Innovation and Technology (Support) Principle: This principle commits *State Government Entities* to providing reliable, high frequency public transport services to and infrastructure at activity centres dedicated by the State to research and development of science, health, education and training, innovation and technology which underpin the State's economy, future prosperity and international competitiveness.

3.1.6 Desired Regional Outcome 10 - Infrastructure

Desired Regional Outcome 10 of the *Regional Plan* addresses the need to plan, coordinate and deliver regional transport infrastructure and services in a timely manner commensurate with pace of predicted regional population growths, defined settlement patterns and desired community outcomes. Key principles relating to timely delivery of transport infrastructure include the:

- Demand Management Principle: This principle stipulates that all *State Government Entities* must strive to make best use of existing public infrastructure, and modify consumer behaviour rather than directing the State's limited resources toward development of other major new or upgraded infrastructure. In relation to public transport, the principle directs initiatives be taken to promote, intensify and encourage greater use of existing SEQ public transport infrastructure and increased public transport services to reduce public demand for imported oil and avoidable private motor vehicle journeys for both work and leisure.
- Protecting Key Sites and Corridors Principle: In relation to transport, this principle obligates all *State Government Entities* to identify, preserve, protect and manage key transport infrastructure sites and corridors located in SEQ. It further directs collocation where practicable of transport, energy, water, communications and other utilities in new generic infrastructure corridors and that preserved corridors be made available to the State emergency and police services.
- Social Infrastructure (Support) Principle: This principle states that new social infrastructure such as universities, hospitals, schools, aged care accommodation, etc. be located near safe, accessible, convenient public transport, pedestrian and cycle paths, and fully integrated with adjacent and compatible mixed land uses.

3.1.7 Desired Regional Outcome 12 – Integrated Transport

Desired Regional Outcome 12 of the *Regional Plan* describes the guiding principles and policies to be adopted by *Government Entity* road, transport and infrastructure planners and their funding programmers to realise highly connected accessible regions within SEQ based on an integrated transport system that is planned and managed to support compact urban growth and efficient travel; to connect people, places, goods and services; and promote public transport use, walking and cycling. *Outcome 12* sets the planning framework and guidelines for *Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland.* Key principles and policies outlined in *Outcome 12* of the *SEQ Regional Plan* include the:

- Integrated Transport Planning Principle: This principle states simply that land use and transport planning shall be integrated, provide regional interconnectivity and greater levels of trip self-containment within each SEQ sub-region. Specific policy objectives and programs encompassed by this principle stipulate:

- Construction of interconnected and coordinated rail and busway networks which provide high quality, dedicated passenger transport links across all SEQ urban areas,
- Planning and implementation of new public transport routes, facilities, high frequency services and priority transit corridors that will ensure safe and convenient passenger accessibility, and support the interrelationship between land use and transport as defined within the *SEQ Regional Plan,*
- Priority is to be afforded to public transport projects that support transit oriented communities and regional activity centres with interconnected public transport networks and services, safe cycling and walking routes,
- Priority planning and development approvals by all land use authorities in urban areas are to be directed toward those developments which support walking, cycling and public transport,
- Policy directions be developed to promote more compact forms of urban development, self-containment of passenger travel within SEQ sub-regions, continued development of new public transport spines for the Sunshine and Gold Coast Regions, and expanded use of the Brisbane rail and busway networks for *TOD Precincts*,
- Urgent consideration be given to the capacity of the existing public transport network to cope with projected population growth in identified high growth areas, and
- DTMR development of *Connecting SEQ 2031* and an *SEQ Infrastructure Plan and Program* in accordance with *Strategic Transport Network 2031* maps 22 to 24 inclusive for each region covered by the *SEQ Regional Plan*.

- Sustainable Travel and Improved Accessibility Principle: This principle asserts that sustainable travel choices must be provided in SEQ that support the accessibility needs of all community members, manage traffic congestion, and reduce private car dependency and transport generated pollution and greenhouse gas emissions. Specific policy objectives and programs encompassed by this principle include:
  - New infrastructure, improved public transport services and service information that will actively support walking, cycling and public transport,
  - Development and implementation of an *Urban Congestion Management Strategy* for SEQ,
  - A *10 year Network Plan* to be developed for all public transport services operated in the *TransLink* service area, and
  - Delivery of a high-quality public transport network in SEQ that supports increased urban densities around public transport nodes and along defined public transport corridors, community services and employment, reduces commuter travel time and loss of productive work time, and improves environmental outcomes and travel choices for people disadvantaged by their access to transport.
- Effective Transport Investment Principle: This principle states that investment in the public transport system shall be targeted to maximise use of existing infrastructure, minimise whole-of-life costs for new infrastructure, provide measurable community benefits, and reduce greenhouse gas emissions and vulnerability to future oil depletion. Specific policy objectives and programs encompassed by this principle target:
  - Integration of transport infrastructure, public transport services and land use planning by deliberate sequencing of defined *Development Areas* to align with State and Local authority transport investment programs,

- o Development of new bus-priority and high-occupancy vehicle transit lanes in the SEQ road network that support public transport, and
- o Timely implementation of State approved transport projects contained in the *SEQIPP*, *TransLink Network Plan* and the Australian Government *AusLink* program.

- Transport System Efficiency Principle: This principle asserts that an efficient and integrated public transport system shall be implemented in SEQ. Specific policy objectives and programs encompassed by this principle state:
  - o The use of existing public transport assets and services in SEQ are to be maximised by a combination of cost-effective transport investments and policies, demand management and application of new *intelligent transport system (ITS)* technologies,
  - o Key existing and future transport sites and corridors are to be identified, protected and managed, and
  - o Public transport networks and roads are to be designed to provide improved connectivity between *SEQ Regional Plan* defined *Activity Centres.*

3.2 South East Queensland Integrated Transport Plan

Connecting SEQ 2031 – An Integrated Regional Transport Plan for South East Queensland was published by DTMR in 2011 and sets out the 20 year forward plan for public transport network development across South East Queensland. It outlines when and where the SEQ public transport network will be augmented to address population growth and newly planned land uses and how it will achieve the desired outcomes prescribed by the *SEQ Regional Plan*. The plan repeats, but in significantly greater detail, the same vision, agenda and planning principles espoused in the *SEQ Regional Plan,* but with additional information pertinent to the future deployment of high capacity buses as follows.

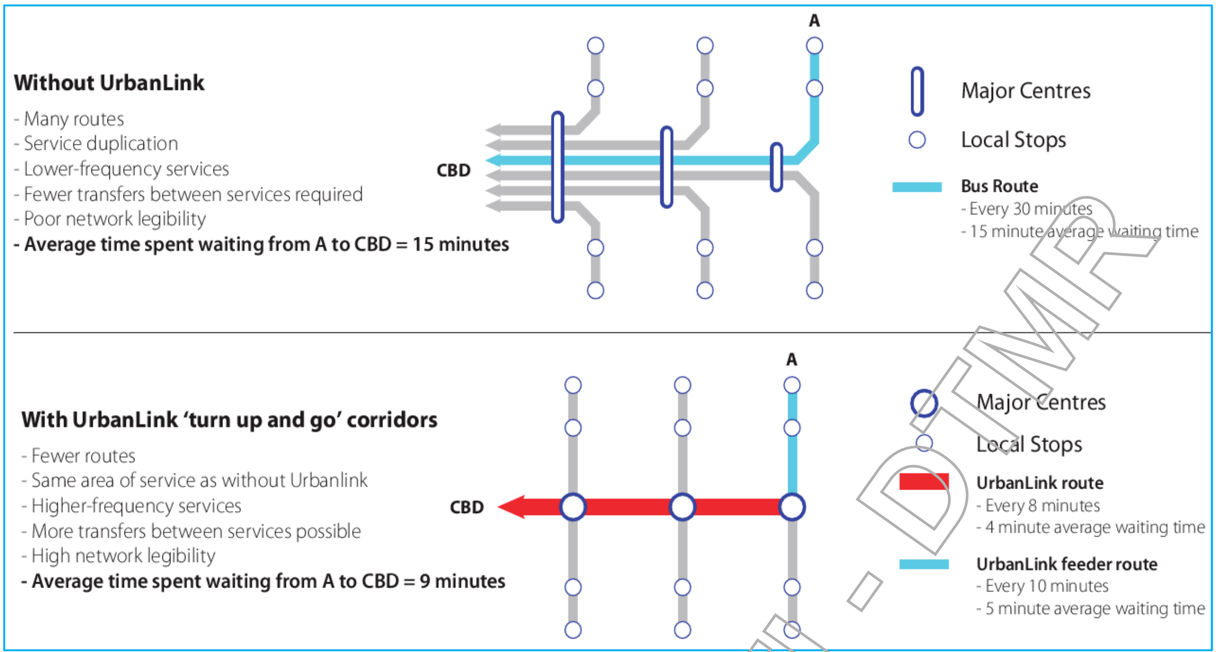
3.2.1 SEQ UrbanLink Network

Figure 8 presents a new *UrbanLink Network* envisaged to be rolled out across South East Queensland by 2031 under *Connecting SEQ 2031.* In close accord with the objectives of the *SEQ Regional Plan*, *UrbanLink* depicts a large number of geographically dispersed activity centre transport nodes interconnected by a network of existing and proposed new cross-city and cross-country high frequency bus services operating along priority busway and transitway corridors, the latter proposed for high density urban areas and known congested road corridors. The trunk and feeder concept proposed to underpin *UrbanLink* is illustrated overleaf in Figure 7.

The *UrbanLink* backbone comprises high speed priority railway, busway and transitway spines radiating out from the Brisbane CBD, the *Regional Plan* defined central principal activity centre transport node, to surrounding regional and sub-regional transport nodes, supported by the new *GoldLinQ* light rail and *CoastConnect* coastal bus sub-spines on the Gold and Sunshine Coasts, each connected by high frequency cross-country connector and local bus services to the long haul heavy rail corridors back to the Brisbane CBD.

UrbanLink is premised on all hours, 7 day, all stops, 10 to 15 minute (6am – 9pm) headway "turn up and go" trunk and feeder bus services operating to all major SEQ urban areas. It aspires to double the catchment of 15 minute walk and ride bus passengers by 2031, including those predicted to come from newly developed busway, bus and rail station centric *TOD Precinct* catchments. A new form of cross country bus service similar to the heavy railway *ExpressLink,* is also envisaged in *Connecting SEQ 2031* that will provide 6am – 9pm express bus services between major outlying rail and bus station hubs in Greater Brisbane to other major transport nodes in adjoining SEQ regions.

Figure 7: Trunk and Feeder Concept for 2031 UrbanLink Network



Connecting SEQ 2031 sets out ambitious public transport growth targets for *TransLink* heavy rail, light rail, bus and ferry services of 4.6% pa between 2006 and 2031, with 14% of all SEQ work and leisure trips targeted to be carried by the 4 modes in 2031. The trunk and feeder concept which underpins *UrbanLink* and achievement of the *Connecting SEQ 2031* passenger growth targets will invariably lead to:

- Increasing passenger loads and overloading on higher frequency local and spine feeder 12.5m standard bus services as the population and expected demand for public transport grows, and the supply of affordable car parking in major activity centres is constrained by local government parking regulations, increased parking charges and town centre planning schemes which reduce availability of both private under building and public car parking spaces,

- A progressive transfer of high passenger loads from local and spine feeder bus services (currently operating one seat terminus-to-terminus) to long haul trunk bus services travelling along the major bus spines from outlying transport hubs, sub-regional stations and park n' rides,

- Predicted high passenger boarding loads from intermodal transfer *UrbanLink* bus services not currently operating between the new coastal strip LRT and CoastConnect sub-spines and hinterland railway stations, and

- High passenger loads expected on the new *UrbanLink* cross-city and cross-country bus services proposed to be operated between regional activity centres as called for in the *Regional Plan* and planned for staged implementation under *Connecting SEQ 2031.*

In the past 7 years, Brisbane Transport has pressed some 30 new two door articulated buses and 128 two door 14.5m rigid buses into service, primarily to address growing passenger demand, long standing periods, overcrowding and passenger stranding at inner suburb bus stops by their lower capacity standard 12.5m rigid route buses. Other Australian capital city operators have witnessed similar gradual upward creep in passenger loads toward the maximum carrying capacity of their standard 12.5m route buses, and like Brisbane Transport have been confronted with the choice of either increasing service frequencies, drivers and standard route bus strengths deployed on high demand services, or to strategically retire off their older high floor 12.5m rigid buses and replace them with new ultralow floor high capacity buses before national disability compliances fall due.

If the new *UrbanLink Network* is implemented as envisaged by *Connecting SEQ 2031*, standard rigid 12.5m route buses are anticipated to be progressively relegated to operating shorter, higher frequency local, BUZ, spine feeder, one-seat terminus-to-terminus and low to moderate demand cross-city and cross-country bus services, and a growing demand will transpire for high capacity vehicles to take over the new coastal sub-spine to heavy rail intermodal transfers, high frequency priority and high capacity demand cross-city and cross-country interconnect services.

3.2.2 Predicted UrbanLink Bus Network and Services Demand

Connecting SEQ 2031 predicts that:

- By 2031, buses will need to carry half of all passenger journeys in SEQ to achieve its 2031 target; namely double the modal share of passenger trips currently being transported by bus,
- Between 2006 and 2031, daily bus passenger boardings will increase by 250%; namely 940,000 additional boardings per day above present daily boarded loads, and
- By 2031, kilometres travelled by combined regional operator bus fleets in the region will increase by nearly 200% over current total distance travelled.

Connecting SEQ 2031 highlights that the *UrbanLink Bus Network* will progressively transition in new cross-town connector bus routes as outer regional activity centres develop, and new cross-regional interconnector bus routes to deliver anywhere-to-anywhere travel between SEQ regions and sub-regions.

Connecting SEQ 2031 declares the rail network illustrated in Figure 8 as the preferred long haul mass transit spine for all SEQ regions and sub-regions lying outside greater Brisbane. It describes conceptual staging scenarios in which *UrbanLink* and cross-country bus services initially plug the discontinuities in the heavy and light rail long-haul spines, then transition to *UrbanLink* local and feeder bus services connecting dispersed activity centres to the rail backbone spines at the major railway station nodes depicted on Figure 9. The plan acknowledges that bus services similar to *ExpressLink* will be required in both the lead up to and beyond 2031 to transport commuters from outer town and city suburbs to major centres of employment, and will fill a similar role to *ExpressLink* rail services in those regional and sub-regional areas where rail services will not exist.

High capacity buses are considered the optimum future vehicle types to service these high peak demand bus services.

3.2.3 UrbanLink Activity Centres Access Hierarchy

Connecting SEQ 2031 defines a hierarchy of 3 new activity centre public transport nodes (called *Hubs*), all of which are to be provided with *UrbanLink* 7 day a week, 15 minute (6am – 9pm) or lower headway bus services and high quality transport infrastructure to deal with predicted peak passenger interchange demands:

- Regional Hubs: These first tier hubs will form the key termini and interchange points for most public transport trunk services operated in their respective regions. They are to be established in the *SEQ Regional Plan* defined principal activity centres of Brisbane CBD, Ipswich Central, Southport and Maroochydore,
- Sub-Regional Hubs: These second tier hubs are to be directly connected to first tier *Regional Hubs* by high speed, high frequency *UrbanLink* bus corridors and will be the secondary interchange points for multiple high frequency local and sub-regional feeder bus services. They are to be established at *SEQ Regional Plan* defined principal and major regional activity centres and will support hub-centric *TOD Precincts* and intensified mixed-use development, as well as direct bus access to adjoining areas of employment, education, health and services, and

- District Hubs: These third tier hubs will form transport interchange points in areas of significant employment and will be directly linked to the two higher tier transport hubs. They are to be established in *Regional Plan* defined specialist activity centres and enterprise opportunity areas.

Figure 8: 2031 Indicative UrbanLink Bus Network Map

Figure 9: 2031 Indicative Rail Network with UrbanLink, ExpressLink, CoastLink and Light Rail

3.2.4 UrbanLink Priority Transit Corridors

Connecting SEQ 2031 nominates and maps priority transit corridors predominantly comprising of motorway T2 and T3 lanes, new bus only *TransitWay* lanes and arterial and inner city road bus only left lanes.

Priority transit corridors are to be created for the new *UrbanLink Network* in each of the 7 SEQ Local Government jurisdictions where an immediate opportunity exists to increase mixed-use public transport supported development of at least 40 dwellings/hectare or 80 jobs/hectare in accordance with *SEQ Regional Plan Desired Outcome 8*.

Under the plan, construction of new priority *TransitWay* bus corridors is to be packaged up with *UrbanLink* bus service rollouts and will, in many cases, ultimately determine the staging and pace of new *UrbanLink* bus service implementations. *TransitWay* single lane bus corridors will incorporate indented bus stops to enable overtaking by non-stopping *UrbanLink* buses, and it is crucial therefore that new *TransitWay* indented bus stops be long enough for 18m articulated and 14.5m rigid buses, and their run out tapers extended to prevent excessive tail swing into bus stops.

3.2.5 Priority UrbanLink Network Reform and Infrastructure Projects

Connecting SEQ 2031 identifies timely completion of the following major network reforms and transport infrastructure projects as crucial to the roll out of the new *2031 UrbanLink Network:*

- Extension of the Northern Busway to Bracken Ridge with interim on-road priority treatments beyond Chermside,
- Extension of the Eastern Busway to Capalaba with interim on-road priority treatments beyond Carandale,
- Extension of the South Eastern Busway to Springwood,
- Two-way extension of the Gold Coast light rail northward to Helensvale Railway Station and southward to Coolangatta, the latter by 2031,
- Development of new strategic park n' rides in locations selected away from *TOD Precincts*, transit hubs and priority transit corridors, and sited at an average radial distance of 10km from the Brisbane CBD and 3km from other defined activity centres identified in the *SEQ Regional Plan*,
- Progressive transformation of the existing *TransLink* one seat terminus-to-terminus network to a trunk and feeder *UrbanLink* network,
- Progressive expansion in both coverage and frequency of all existing *TransLink* local bus services,
- Completion of the priority *Transitway* corridors shown on the indicative *UrbanLink* map in Figure 8, and
- Completion of the Sunshine Coast *CoastConnect* bus (and later heavy rail) corridor between Maroochydore and Caloundra via Mooloolaba and Kawana Town Centre.

3.3 Queensland Infrastructure Plan and SEQ Infrastructure Plan and Program

The annual *Queensland Infrastructure Plan 2011* and long term *South East Queensland Infrastructure Plan and Program 2010 - 2031* (*SEQIPP*) outline State Government investment priorities for regionally significant infrastructure. The *SEQIPP* details forward construction programs between 2010 and 2014, and future infrastructure development and upgrades planned over a 20 year time horizon out to 2031.

SEQIPP transport infrastructure investment priorities closely align with those directed by the *SEQ Regional Plan, Connecting SEQ 2031 Integrated Transport Plan* and *Queensland Infrastructure Plan,* but *SEQIPP* transport infrastructure priorities additionally take into account the interdependencies that exist between coordinated delivery of public transport and other regionally significant infrastructure projects such as new hospitals, schools and roads, and State Treasury budget constraints on the bottom line total cost of all SEQ infrastructure development programs.

Approved *SEQIPP* 2010 – 2014 bus transport programs include:

- Brisbane public transport corridor preservations (ongoing),
- *CoastLink* Creekside Boulevard to Kawana Town Centre corridor preservations (ongoing),
- Future stage investigation and planning for the Eastern Busway (2010/11 – 2013/14),
- Future stage investigation and planning for the Northern Busway from Kedron to Chermside Busway Station (2011/12),
- Future stage investigation and planning for the Northern Busway from Kedron to Carsedine and Fitzgibbon Busway Stations (2013/14), and
- Design of interim high occupancy vehicle lanes from Kedron to Bracken Ridge (2011/12).

Look ahead indicative *SEQIPP* 2015 – 2031 bus transport funding programs include:

- *CoastConnect* bus corridor design and construction (2014/15 – 2019/20),
- Nerang-Broadbeach Road upgrades incorporating priority *TransitWay* bus lanes (2014/15 – 2019/20),
- Gold Coast LRT – Gold Coast University Hospital to Broadbeach (2020/21 – 2025/26),
- Eastern Busway – Bennetts Road to Capalaba design and construction (2020/21 – 2025/26),
- Northern Busway – Kedron to Bracken Ridge design and construction (2020/21 – 2025/26),
- South East Busway – Eight Mile Plains to Rochedale and Rochedale to Springwood design and construction (2020/21 – 2025/26), and
- Redland Bus Priority Measures design and construction (2026/27 – 2030/31).

3.4 Queensland Transport and Roads Investment Program

The *Queensland Transport and Roads Investment Program 2011/12 to 2014/15* details the Queensland Department of Transport and Main Road's 4 year rolling maintenance and infrastructure investment program for the State's transport and road networks. The program is reviewed annually to take into account unforseen funding priorities such as urgent road, rail and bridge reconstruction following floods and other natural disasters which may cancel, suspend or delay less urgent planned capital transport infrastructure projects.

Currently approved major bus transport investment programs in South East Queensland include:

- *TransLink* Station Upgrades (2011/12 - $44M, 2012/13 - $35M),
- State-wide Public Transport Infrastructure Disability Compliance Upgrades (2011/12 - $1.935M, 2012/13 - $1.935M),
- Western Bus Priority Corridor and Northwest Transport Corridor Planning,
- Logan Central Station Upgrade,
- State Wide Bus Station and Stop Infrastructure Grants (2011/12 - $3M, 2012/13 - $3M),

- Transport Infrastructure Development Schemes (2011/12 - $8M),
- Construction of Carindale Station and new Eastern Busway Approaches (2012/13 - $50M),
- Northern Busway Planning and Land Acquisitions – Kedron to Bracken Ridge (2012/13 - $28.518M), and
- Brisbane CBD and Cultural Centre/Melbourne Street Tunnel 14.5m Rigid Bus Access Improvements (2011/12 - $5M, 2012/13 - $5M).

Look ahead indicative major SEQ bus transport investment programs in 2013/14 and 2014/15 include:

- TransLink Station Upgrades ($80.15M),
- State-wide Public Transport Infrastructure Disability Compliance Upgrades ($3.870M),
- State-wide Bus Station and Bus Stop Infrastructure Grants ($6M),
- Construction of Carindale Station and Eastern Busway Approaches ($60M),
- Construction of South East Busway - Eight Miles Plains to Rochedale ($23.32M),
- Construction of CoastConnect ($25.978M), and
- Northern Busway Planning and Land Acquisitions – Kedron to Bracken Ridge (2012/13 - $39.1M).

3.5 TransLink Public Transport Infrastructure Manual

The *TransLink Public Transport Infrastructure Manual* was last revised in June 2007 when standard 12.5m rigid and 18m high floor articulated route buses were in common use in SEQ, and as for the Queensland *Road Planning and Design Manual* and national *Austroads Guide to Road Design,* has not yet been updated for emerging new 14.5m rigid, rear pusher ultralow floor articulated and double deck high capacity buses.

The principles and key considerations applicable to bus stop zones, shelters, seating, furniture, landscaping, hardstand areas, boarding points, stop markers, accesses, walkways and national disability standard tactile ground surface indicators and wheelchair boarding areas are still considered relevant to high capacity vehicles. Premium and Signature bus stop dimensions suit all high capacity vehicles and incorporate 35m nominal or longer hard stand areas suitable for two standard 12.5m rigid or double deck buses with half bus length parking separations, two extended 14.5m rigid buses or a standard rigid or double deck bus parked nose to tail with a 14.5m or 18m articulated bus at adequate separation distances, and clear hardstand areas suitable for potential future all door passenger boarding and alighting.

Likely revisions required to the manual would include:

- New Shelter Type Definitions: for indented bus stops on future *Transitways*,
- Hard Stand Length: Intermediate stop hard stand lengths extended for 18m articulated and superbus stopping on proposed new *UrbanLink* cross city and cross country routes,
- Front Door Boarding Access Lighting Illuminance Level: Increase to 150 lux, as specified in the national disability standards for bus stops,
- Indented Bus Bay Length and Taper Redefinitions: Intermediate stop indented bus bay lengths and tapers increased for 14.5m rigid bus stopping on proposed new *UrbanLink* routes, including

departure paths clearances from regulated parking or other occupiable zones to prevent hard lock turn outs into left traffic lanes,

- Mandating High Capacity Bus Zone Separation Distances: from left lane route turns and right turn lane crossings approaching intersections, and
- Compulsory *TransLink* Route Assessment Guidelines: for proposed new double deck and 14.5m bus controlled access and HML routes. These guidelines are required to indentify whole of route operating constraints, not just those applicable to designated bus stops and zones.

3.6 Transport Operations (Passenger Transport) Act

The *Transport Operations (Passenger Transport) Act 1994 (TOPTA)*, last revised in January 2012, is intended to achieve the provision of best possible public passenger transport services at reasonable cost to the community and government.

3.6.1 Objectives

The overall objectives of this Act that potentially relate to the application of high capacity vehicles are to:

- Enable the effective planning and efficient management of public passenger transport in the State, and
- Provide a system of public passenger transport in the State that:
    - is responsive to community needs,
    - offers an attractive alternative to private motor vehicle transport in a way that reduces the overall environmental, economic and social costs of passenger transport,
    - addresses the challenges of future growth,
    - provides public passenger services at a reasonable cost to the community and government, and
    - promotes the personal safety of persons using public passenger transport.

3.6.2 Definition of a Vehicle

TOPTA defines a bus as a motor vehicle with a seating capacity for 9 or more passengers, excluding the driver. It defines public transport as a bus or ferry being used for a general route service.

3.6.3 Operator Accreditation

S14 (*Operator Accreditation Standards*) of *TOPTA* states that bus operators should:

- Have the capacity to ensure the appropriate operation and maintenance of public passenger vehicles; and
- Comply with all relevant vehicle design, safety and operational requirements.

In the context of future HCV deployment, not all *TransLink* operators have the capacity to operate or maintain high capacity buses.

3.6.4 Driver Authorisation

Chapter 4 of *TOPTA* refers to *Driver Authorisation*, which is a qualification a driver must obtain and continue to maintain whilst operating vehicles providing public passenger services. The purpose of the driver authorisation is to ensure that drivers of public passenger vehicles are responsible while in the act of driving, and capable of safely operating a public passenger vehicle of the relevant category. More detailed information about heavy vehicle licensing requirements is presented in Section 3.6.4.1 below.

Bus drivers are required to obtain a driver authorisation for scheduled route bus services, as opposed to other categories of driver authorisation such as those for taxi and limousine drivers. In addition to having the correct licence for the vehicle type, driver authorisation also obliges drivers to submit to a medical assessment and prove their eligibility to work in Australia. There are no additional requirements for high capacity vehicle drivers other than those relating to licence class.

3.6.4.1 Heavy Vehicle Licences

According to the DTMR website, bus drivers must pass a practical driving test if they want to upgrade their existing licence to a heavy vehicle (class MR, HR or HC) licence and may also be required to pass a heavy vehicle road rules test. Table 8 shows the licence classes applicable to all bus types presently operated on the *TransLink* network. In general, licence classes broadly align with bus gross vehicle masses.

Table 8: Queensland Licence Classes

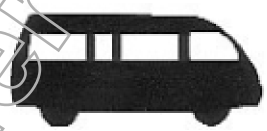
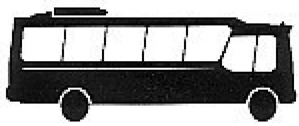
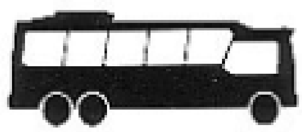
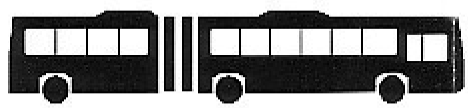
Licence Class	Vehicle Description	Example *TransLink* Bus Currently in Operation
LR (Light Rigid)	A **light rigid** bus more than 4.5 tonne GVM, but not more than 8 tonne GVM, built to carry more than 12 adults including the driver	 Minibus
MR (Medium Rigid)	A **medium rigid** bus more than 8 tonne GVM, with not more than two axles.	 12.5m Rigid
HR (Heavy Rigid)	A **heavy rigid or articulated** bus more than 15 tonne GVM, with at least three axles.	 14.5m Rigid 12 – 12.5m Double Deck  18m Articulated 18m Superbus

Table 9 sets out the minimum periods that a driver is required to hold a particular class of licence before becoming eligible to progress to the next higher class of licence. Each particular class of licence must have been held for a minimum holding period within the last five years when applying for the next higher class. The holding period may be a single continuous period or made up of a number of individual periods, however times when a licence is suspended or expired cannot be included when calculating minimum holding periods.

Table 9: Queensland Licence Class Holding Periods

Class of Licence Held	Minimum Holding Period	Next Eligible Class of Licence
C (car)	At least 1 year	LR or MR
C (car)	At least 2 years	HR
LR or MR	At least 1 year	HR

A *TransLink* bus operator cannot assign a 12.5m standard rigid bus driver with an MR class licence to operate a high capacity vehicle. The bus driver must either already hold the relevant HR license or wait for the minimum MR licence holding period to expire before he/she can upgrade an MR licence to a HR licence before progressing to operate a high capacity vehicle.

Section 41 of *TOPTA* states that a service contract may establish performance levels for the quality and type of public passenger vehicles and current version *TransLink* 3G contracts contain similar provisions. Bus operator 3G contracts are discussed later in Section 3.17.

3.6.5 Special Events

Section 67B of *TOPTA* asserts that a special event declaration may be made only if *TransLink* considers, amongst other criteria, that the provision of transport services to or from the special event is likely to rely on an increased use of vehicles by *TransLink*. If *TransLink* had more high capacity vehicles operating in its network, the impact of a special event on existing network capacity could arguably be reduced and/or might, in some cases, negate the need to declare the special event or provide additional bus services. The assignment of high capacity buses to special event services would also reduce the cost to special event organisers and patrons of providing any additional services.

3.6.6 Fare Evasion

Chapter 11 of *TOPTA* covers fare evasion offenses and responsibilities, and specifically states that a person must not evade payment of a fare lawfully required for the person's use or hire of a public passenger vehicle. This is important in the context of considering various measures to reduce bus stop dwell times on high capacity vehicles, such as through all door boarding. There is nothing in the legislation that prevents all door boarding on any *TransLink* bus and the responsibility to pay the correct fare falls upon the passenger. A bus driver or other authorised person such as a Transit Officer, is only authorised under *TOPTA* to enforce payment of fares.

A driver is authorised to check tickets under the legislation, and therefore has a role to play in managing fare evasion. However it is not known in practice how a bus driver would validate fare payment using go cards. This will be explored further in later reports.

3.6.7 Prevention of Boarding on Full Buses

Section 143AH of *TOPTA* empowers a bus driver or an authorised officer to direct a person to leave or not enter a public passenger vehicle, or compartment of the vehicle, if:

- the person is about to enter, or has just entered the vehicle, or a compartment of the vehicle, that already appears to have its full complement of passengers, and
- the driver or authorised person tells the person in a general way, that the vehicle or compartment is full and that the person cannot board the vehicle, or compartment, or remain on the vehicle, or in the compartment, and
- the person then fails to leave, or not to enter the vehicle or compartment.

The deployment of high capacity vehicles will reduce the probability of drivers having to give such directions which occasionally lead to serious conflicts or altercations between drivers and passengers. More information about management of full buses is discussed later in Section 3.16.

3.6.8 Demand Management

Section 147 of *TOPTA* states that the Minister for Transport and Main Roads may authorise a local government to carry out, under a local law, demand management measures to encourage the use of public passenger transport. The Act defines demand management strategies such as pricing on parking, bus priority and high occupancy vehicle measures. While the *Act* does not clearly define high occupancy vehicle measures, it is assumed these measures apply to bus only, T2 and T3 high occupancy vehicle lanes, but could be interpreted as any other measures to facilitate the introduction of high occupancy buses, such as larger bus stop bays or alternative kerbside allocations.

3.7 TMR Information Bulletins – Vehicle

Vehicle information bulletins issued by DTMR on its website are designed to provide plain English explanations of the *TOPTA* standards and regulations. These have no specific requirements applicable to high capacity buses that differ from those applicable to standard 12.5m buses used for general route or school services.

3.8 Transport Operations (TransLink Transit Authority) Act

The main purpose of the *Transport Operations (TransLink Transit Authority) Act 2008* is to deliver best possible mass transit services at reasonable cost to the community and government in *TransLink's* South East Queensland network area, while keeping government regulation to a minimum. The *TTA Act* does not quantify the definition of mass transit services in terms of bus passenger carrying capacity, but defines it simply as general route services for the carriage of large numbers of passengers.

The objectives of the *TTA Act* are not dissimilar to those expressed in *TOPTA* (see Section 3.6.1), but enable the effective operational planning and efficient management of mass transit services, as opposed to public passenger transport services for *TOPTA*. The *TTA Act* has an additional objective beyond those stated in *TOPTA*, namely to help the government achieve its congestion management priorities relating to road transport.

Most of the provisions in the *TTA Act* focus on the establishment and statutory responsibilities of the TTA, its Board, CEO and employment office. Other than referencing the *Special Event* provisions already discussed for *TOPTA* in Section 3.6.5 and the State Government's congestion management agenda, the *TTA Act* makes no direct mention of high capacity vehicles.

Chapter 5A of the *TTA Act* clarifies that the chief executive officer of *TransLink* may give a direction with the Transport Minister's approval, to second essential public transport infrastructure to allow any operator of a relevant service for the infrastructure to use the infrastructure on stated conditions fixed by the chief executive, but not to change the infrastructure in any way that would restrict its future use. Before giving the direction, the chief executive must undertake consultation with the infrastructure asset owner and be satisfied there is no other reasonable and practicable alternative to the direction that will secure its use. The asset owner may claim compensation from the State for costs incurred by the asset owner in complying with the direction, but failure to comply with the direction attracts a penalty of up to 1,665 penalty units.

Under the provisions of Chapter 5A, the CEO of *TransLink* may declare a road as an essential piece of public transport infrastructure and direct the road asset owner, such as DTMR or an SEQ local government authority to provide bus priority and/or upgrade bus stops to enable the deployment of high capacity vehicles.

3.9 Transport Operations (TransLink Transit Authority) Regulation

There are no references to or implications for high capacity buses in the current version of the *Transport Operations (TransLink Transit Authority) Regulation 2008.*

3.10 Disability Discrimination Act

The federal *Disability Discrimination Act 1992 (DDA)* provides protection for anyone in Australia against discrimination based on a disability. It encourages everyone to be involved in implementing the *DDA* and to share in the overall benefits to the community and economy that flow from participation by the widest range of people. Discrimination occurs when a person with a disability is treated less favourably than a person without a disability. The *Act* makes is unlawful to discriminate in the provision of access to transport premises, vehicles, services and facilities.

The compliance requirements of the *DDA* for bus stops and heavy vehicles are the same, regardless of vehicle size and carrying capacity. However there are some indirect *DDA* considerations for high capacity vehicles if they are to be deployed on future school bus services. These are set out in the *Disability Standards for Accessible Public Transport (Transport Standards)* and discussed below.

3.10.1 Disability Standards for Accessible Public Transport (Transport Standards)

The Australian Government released the *Disability Standards for Accessible Public Transport* in October 2002. The disability *Transport Standards* establish minimum accessibility requirements for the providers and operators of public transport conveyances (DDA terminology for vehicles), infrastructure and premises. They encompass a wide range of compliance specifications for public transport facilities, bus stops and buses including:

- Wheelchair access paths, manoeuvring areas, ramps and vehicle boarding devices,
- Allocated spaces, doorways, controls, symbols, signs, waiting areas, boarding points, surfaces, hand and grab rails,
- Doorways and doors, lifts, stairs, toilets and tactile ground surface indicators (*TGSIs*),
- Alarms, lighting, controls, furniture and fittings,
- Street furniture, gateways, payment of fares and hearing augmentation systems, and
- Information provision, booked services, food and drink services, stowage of belongings and priority access arrangements.

The *Transport Standards* further specify levels of service, measures and actions that public transport operators and providers must take to discharge their obligations under the *DDA* and how public transport by bus, taxi, tram, train, ferry and commercial aircraft is to be made 'accessible'. The *Standards* apply to all new transport conveyances (vehicles) and infrastructure introduced into service after 23 October 2002. A progressively staged timetable for compliance over a 20 to 30 year period applies to conveyances (vehicles) and infrastructure built before this date.

Both vehicles and bus stops need to meet the DDA compliance targets shown in Table 10 but an operator or provider may apply to the *Australian Human Rights Commission (AHRC)* for an exemption from compliance with the *Standards*. Exemptions may be subject to conditions that are set by the *AHRC* but are often only temporary or limited to a short term of not more than five years. Exemptions have primarily been granted to small regional bus service operators and members of the *Australasian Railway Association*.

A dedicated school bus service is defined in the *Transport Standards* as a service operated to transport primary or secondary students to or from school or for other school activity purposes. These services are excluded from 26 physical access parts of the *Transport Standards* and have been summarised at Appendix A.

Table 10: DDA Compliance Targets

Compliance Year	Compliance Target
2007	25%
2012	50%
2017	75%
2022	100%

The exclusions set out in Appendix A effectively mean that dedicated *TransLink* school buses and coaches are excluded from most physical access requirements in the *Transport Standards* and are not required to provide:

- A boarding device for persons using mobility aids,
- Handrails or grab rails,
- Allocated spaces for people with mobility aids,
- Wide step and aisle wheelchair manoeuvring areas,
- Automatic or power-assisted doors, and
- Doorways of a minimum width necessary to assist people with mobility impairments.

These exemptions now look destined to cease within the 20 – 25 year life cycle of a *TransLink* operator school bus or coach. Historically, the exclusion of dedicated school buses from the physical access parts of the *Transport Standards* was in response to identified high costs of retrofit to existing school buses and coaches. Parts of the *Standards* not excluded only provided a small degree of accessibility, primarily to students with a visual impairment and covered by the low cost signage, illumination and information specifications in the *Standards*.

Part 34 of the *Transport Standards* however obliges the Federal Minister for Infrastructure and Transport, in consultation with the Attorney-General, to review the efficiency and effectiveness of the *Standards* every five years after coming into effect. The first review was undertaken in 2007, and the final report on the review was released by the Australian Government on 3 June 2011. The consultant who conducted the review for the relevant Ministries was tasked to undertake an analysis for one of the key recommendations in the final report, namely a '*RIS Analysis of Dedicated School Bus Exclusion Options*'.

The RIS analysis estimated that the cost of enforcing dedicated school buses to comply with the *Standards* would be $1.265 billion over 20 years (at 1998 prices, Attorney-General's Department, 1999), which would in the main be incurred by a large number of small bus operators. These costs were deemed to be extremely high, and it was further argued by disaffected school bus service operators that:

- They were small business people, generally operating older and often second-hand vehicles, which were turned over infrequently,
- There was little or no demand for accessible services, and the cost could not be justified by the limited demand,
- It was unlikely that there would be accessible pathways between bus stops and PWD residences so accessible transport improvements to buses would not be utilised, and
- Existing bus stops were generally unformed, sometimes comprising merely a space for the school bus to pull over on the roadside (Attorney General's Department, 1999).

It was also noted on the Attorney-General's Department website that another reason for excluding dedicated school buses was in response to issues associated with operating ultralow floor buses on 'difficult terrain' (Attorney-General's Department, 2006).

The *RIS* analysis concluded that paratransit solutions would be more cost effective than upgrading school buses and recommended that school buses be considered in State and Territory Action Plans, with a view to further considering options for making school bus services fully accessible in the future. In spite of this suggestion, recent Action Plans released by most State and Territory Governments have not progressed the issue, and it appears that the majority of stakeholders consider the current exclusions for dedicated school buses to be an ongoing full exclusion from the *Standards*.

Exclusions for dedicated school bus services raise concerns about the operator practice of allowing other passengers to board school services. In rural and regional areas, it is common practice for non-school students to also use dedicated school services to get into town. It is currently not clear if, by allowing other adult passengers on a school bus service, the service remains a dedicated school service or reverts to a general access service. If dedicated school bus services that provide a service to other patrons are considered to be providing a general access service, operators may be forced in future to cease the practice to avoid being subject to the numerous accessibility requirements defined in the *Transport Standards*.

Arguments about a lack of suitable bus stop infrastructure ignore the fact that bus stop infrastructure in most SEQ regions needs to be upgraded for general route services operating side-by-side with school services. The underlying reasoning behind the current exclusions was not that they provide ongoing relief to bus operators from compliance with the *Transport Standards*, but rather that further assessment and consideration be given by States and Territories to making dedicated school bus services fully accessible in the future. The final *RIS* report considered two options:

- Option 1: status quo, maintaining the current school bus exclusions in the *Standards,* or
- Option 2: removing the exclusions from the *Transport Standards* that currently applied only to dedicated school bus services over an extended time period.

The final recommendation of the analysis was that Option 2 should be adopted on the basis that it was the best cost minimisation approach. The Option 2 approach presented the best way forward in terms of allowing the *Standards* to fulfil their purpose, while minimising compliance costs for government and the bus industry.

Following close consideration of the final review report and its recommendations, the Australian Government announced its response on 3 June 2011. The response contained 15 recommendations, the most relevant being...

Recommendation 14: *"Phased application of dedicated school bus services to physical access requirements in the Transport Standards, commencing in 2029 and being fully required by 2044.*

The Government supports this recommendation in principle.

The Review found that the current exclusions to the physical access provisions of dedicated school buses limit the current and future provision of services for students with a disability. The Government recognises the importance of providing students with a disability every opportunity to participate in community life, including being able to travel alongside students without disability on dedicated school bus services. The Government also considers there is merit in examining the potential consequences of this recommendation on existing complaints-based mechanisms of compliance.

The Government proposes that the Australian Transport Council considers the most appropriate mechanism to progress this recommendation, noting that the Review concludes that a full RIS would be required in light of the potential cost impact on school bus operators and providers. As part of the further analysis, there would be merit in examining the number of second-hand accessible buses that may currently be available for purchase by dedicated school bus operators given accessible buses have been in service since 1995 and, if possible, the scope to commence earlier or to shorten the phase-in requirements".

3.10.2 Disability (Access to Premises Buildings) Standards

The *Disability (Access to Premises Buildings) Standards 2010* commenced on 1 May 2011. Part H2 of the *Premises Standards* specifically relates to buildings associated with public transport services. This component has been transferred from the *Transport Standards*. Part H2 covers all public transport buildings including railway stations, bus interchanges and ferry terminals and would also apply to underground bus stations such as King George Square, Lutwyche and Queen Street Bus Stations. These standards will be reviewed in future reports being delivered under this study.

3.11 TransLink Strategic Plan

The *TransLink Strategic Plan 2011-2015* contains 5 pillars (or strategic priorities) with a underlying theme of providing 'value for money'. Of the 17 measures and targets established under the 5 pillars, those listed in Table 11 overleaf relate directly or indirectly to the future deployment of high capacity vehicles on *TransLink* school and route bus services.

3.12 TransLink Network Plans

TransLink Network Plans (*TNPs)* are developed annually as a strategic platform to articulate *TransLink*'s vision for making travel easy. The overarching goal of network planning is to simplify the network; making public transport easier for customers to use and to understand for their entire journeys. Each *TNP* reflects on *TransLink*'s achievements over the past year, identifies public transport trends and challenges, and sets out a plan for shaping the network for the future.

Table 11: TransLink Strategic Pillars, Measures and Targets

Pillar	Measure	2010/11 Actual	2014/15 Target
Quality Customer Experience	1.1 - Customer Satisfaction	70/100	75/100
Manage the Network	4.1 - Cost Recovery	22.5%	30.2%
	4.2 - Mode Share	7% (2006)	8.7%
	4.3 - Patronage	178.6 Million	193.1 Million
	4.4 - Capacity Enhancement	308,000 weekly seats	TBA
Financial Sustainability	5.2 - Subsidy per Passenger Trip	$6.06	$6.10
	5.3 - Average Revenue per Passenger Trip	$1.76	$2.64
	5.4 - Revenue Leakage (via Fare Evasion)	NA	TBA
	5.5 - Cost per Seat Capacity	$8,636 (Target)	$9,567 (Target)

3.12.1 TransLink Network Plan 2011

3.12.1.1 Strategic Objectives

Key challenges outlined in *TNP 2011* included:

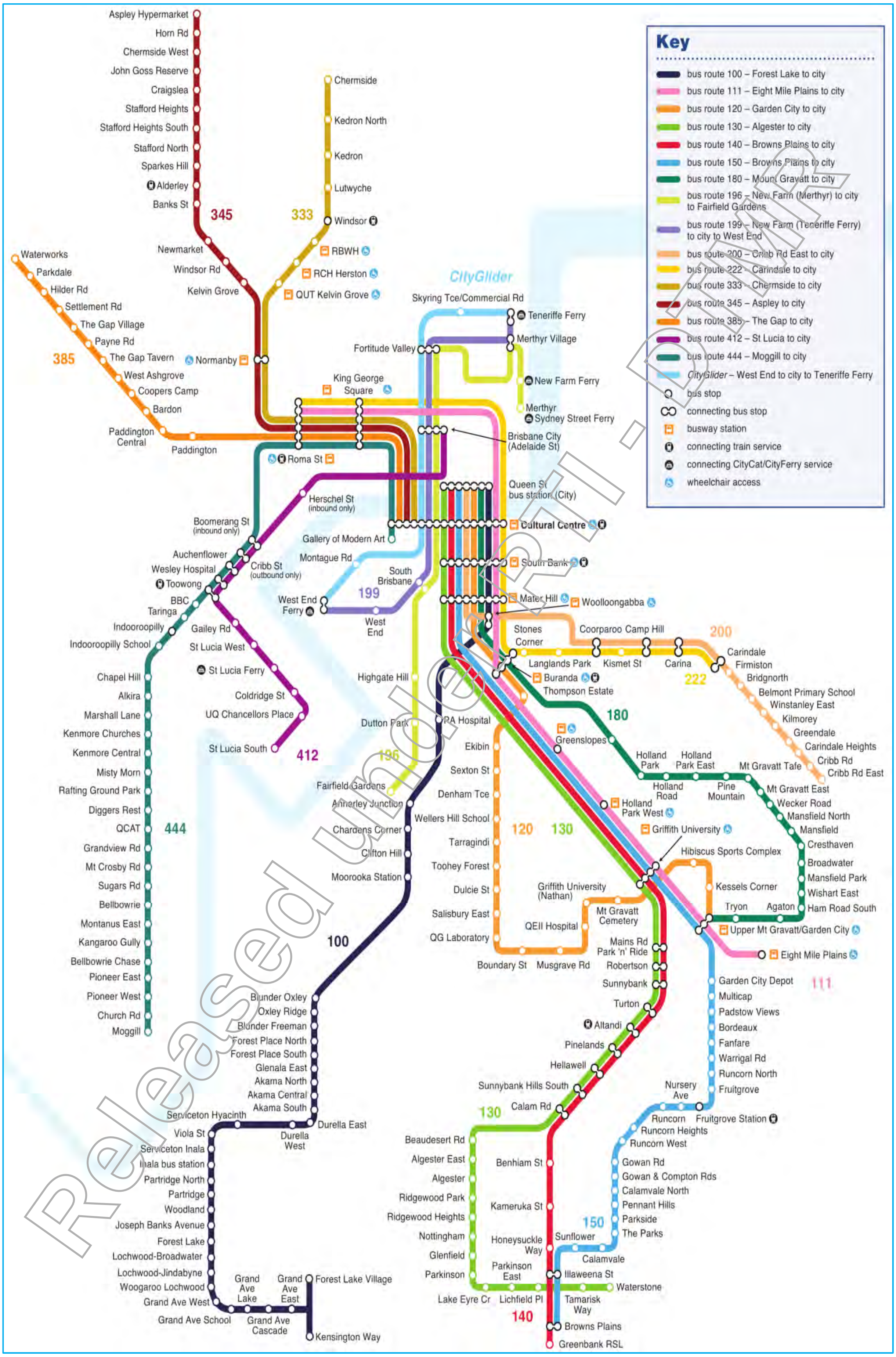
- Congestion: A key issue for the State and Local Governments in South East Queensland is the growing traffic congestion on SEQ roads. Traffic congestion poses significant threats to the SEQ region and impacts on its overall productivity due to increased freight costs and lost productive work time. Congestion also poses a considerable threat to the region's air shed and living environment from engine exhaust emissions and noise pollution generated by vehicles driving slowly and idling in traffic for long periods. *TransLink* aims to lead, plan, develop and promote public transport services to alleviate growing traffic congestion on SEQ roads.
- Value for Money: As the lead public transport agency in South East Queensland, *TransLink* has a responsibility to ensure public transport is an affordable and viable alternative to private motor vehicle travel. Whilst tasked to offer affordable transport options to its customers, *TransLink* must also secure the long-term financial sustainability of the SEQ public transport system and facilitate future growth of the public transport network.
- Maintaining the Transport Fleet: To ensure it can continue to meet the growing capacity demand on its network, *TransLink* invests annually in new railway rolling stock and bus fleet capacity. Its current capacity is 201 three-car heavy rail train sets and a fleet of 2,312 buses servicing the entire network, however in order to meet future projected capacities, *TransLink* will be adding 6 additional new three-car train sets to its network by December 2011, and working with its service providers to identify and replace buses in accordance with its ongoing *Bus Replacement Schedule*.

3.12.1.2 Capacity Enhancement

A notable focus of *TNP 2011* has been network capacity enhancement and *TransLink* set a target of 305,000 additional weekly bus seats in 2011. By close of year, *TransLink* had exceeded its target, delivering an extra 308,000 weekly seats in the year, distributed across its SEQ bus network as follows:

- 110,000 additional weekly seats on Brisbane buses,
- 11,000 additional weekly seats on Sunshine Coast buses,

Figure 10: TransLink High Frequency Bus Network in Brisbane



- 10,000 additional weekly seats on Gold Coast buses, and
- 17,000 additional weekly seats on Redcliffe, North Lakes, Caboolture, Logan and Ipswich buses.

It is understood the capacity growth target set for 2012 is 318,000 additional weekly seats.

3.12.1.3 High Frequency Priority Bus Routes

TransLink currently operates 18 high frequency priority bus routes in the SEQ Region, most of which are illustrated on the schematic route maps for greater Brisbane in Figure 10 below, which excludes the Logan City to Brisbane CBD high frequency superbus Route 555.

TNP 2011 also references the expanding busway network, with new busway extensions to Langlands Park and Kedron being completed in FY2011/12. DTMR bus corridor planning is currently underway to further expand the greater Brisbane busway network northward, southward and eastward where indicated on Figure 11.

Figure 11: Existing and Proposed Busway Network in Brisbane

3.12.2 TransLink Network Plan 2009

A review has been conducted on unpublished *TransLink Network Plan 2009*. *TNP 2009* is a more comprehensive planning document than the later version *TNP 2010* and *TNP 2011* summary plans and contains detailed *TransLink* policies and network strategies not included in later editions. *TNP 2009* makes the following specific references relevant to high capacity vehicles.

3.12.2.1 Passenger Comfort

TNP 2009 discusses *TransLink*'s commitment to passenger comfort and defines it as providing sufficient capacity to cater for growing demand using modern, air-conditioned, clean vehicles and continuing to work towards access compliance with the *Disability Discrimination Act 1992.*

3.12.2.2 Strategic Objectives

TNP 2009 addresses the top seven challenges for *TransLink* in South East Queensland and cites increased public transport capacity as a key response to meeting growing passenger demand and managing overcrowding. Capacity has become a prominent issue for SEQ public transport, especially in the greater Brisbane region. This has been partly due to a rapid increase in public transport take up since *TransLink* began managing public transport throughout SEQ in 2004. Some overcrowding can be reasonably expected in the capital city region and it will never be practicable to provide all peak hour passengers with a bus seat.

Service capacity needs to be continuously expanded so passengers can be assured of a comfortable ride, particularly on long service trips. To boost services along existing high-demand transport corridors, *TransLink* has established improved forward planning and procurement processes to allow early ordering of additional new buses and trains. With inner city Brisbane continuing as the major employment centre and transport hub for passenger transfers between buses, trains and ferries in the SEQ Region, meeting service capacity in the capital city has become a top priority. Planning is currently underway to investigate more capacity for both rail and bus services travelling to inner city Brisbane.

TNP 2009 further references the need to provide environmentally sustainable travel through more efficient use of resources. Public transport is considered at least 10 times more efficient in terms of fuel and energy consumption per passenger-kilometre and a considerably more efficient use of road space than single occupant motor vehicles.

3.12.2.3 Bus Priority

TNP 2009 acknowledges the role of local and State road authorities in delivering the "priority" for its *High Frequency Priority* (HFP) services, and strongly encourages both SEQ Local Governments and DTMR to invest in bus priority and high occupancy vehicle lane projects for new *TransLink* nominated HFP bus service corridors. To maximise the people-carrying capacity of roads, buses must be given priority access to busy activity centres through congested sections of the road network. This can be achieved by way of bus priority at signalised road intersections, bus only lanes and shared motorway high occupancy vehicle (T2 and T3) transit lanes, where buses can share lanes with other vehicles carrying two or more persons. The benefits of bus priority road treatments by these various road authorities include:

- Faster bus travel times which reduce bus fuel consumption, air pollution and greenhouse gas emissions,
- Improved reliability by reducing daily variations in service running times, allowing buses to meet their timetables more consistently, and
- More people carried in far fewer vehicles.

DTMR has prepared a *HOV Network Strategy* for South East Queensland and coordinated development of the *TransLink* HFP network has been a key input to the HOV strategic planning and funding prioritisation processes.

3.12.2.4 Service Categories

TNP 2009 defined future services on the *TransLink* network under the following 4 categories:

- High Frequency Priority (HFP): covering high frequency services provided by both bus and rail,
- Local: covering local and district bus services,
- Peak Only: covering extra bus and rail services needed to boost peak capacity and to provide direct trips for commuters during peaks, and
- Regional Links: covering inter-city rail services on the Ipswich, Gold Coast and Sunshine Coast railway lines.

3.12.2.5 High Frequency Priority Network

TNP 2009 focussed on rollout of *TransLink*'s then new high frequency priority (HFP) network, a 'turn up and go' service network for which passengers would not need timetables. *TransLink*'s 2009/10 strategy was to develop the new network of high frequency priority services that would form the backbone of South East Queensland's future trunk and feeder public transport system, (namely, the new *UrbanLink* network described in *Connecting SEQ 2031)*.

The initial high frequency network concept developed in *TNP 2009* operated at a headway of 15 minutes or better between 6am and 9pm each day of the week. Based on the trunk and feeder operating concept, the high frequency priority network used a combination of fast, very frequent, high capacity trunk bus services connecting with less frequent local feeder bus services that essentially provided transport only to local district destinations. A feature of the high frequency network was its capability for trunk bus services to operate as limited-stop and express services, leading to shorter overall journey times for customers. Converting existing bus routes to limited stop and express trunk routes created an ideal niche for high capacity buses, eliminating their perceived weakness of excessive dwell times at interchange and intermediate bus stops along the route.

While HCVs have been identified as prime candidates for deployment to HFP trunk routes, they could equally well be deployed on many existing peak-only and school bus routes, most of which have limited passenger turnover en route and operate for short periods of very high load demand. *TNP 2009* presented a schematic HFP map for each of TransLink's seven sub-regions, showing indicative routes targeted for implementation out to 2020. The HFP map developed for the greater Brisbane HFP network appears overleaf in Figure 12, and since 2010, the skeleton of the future HFP network envisaged in *TNP 2009* and shown on the map has already begun to take shape.

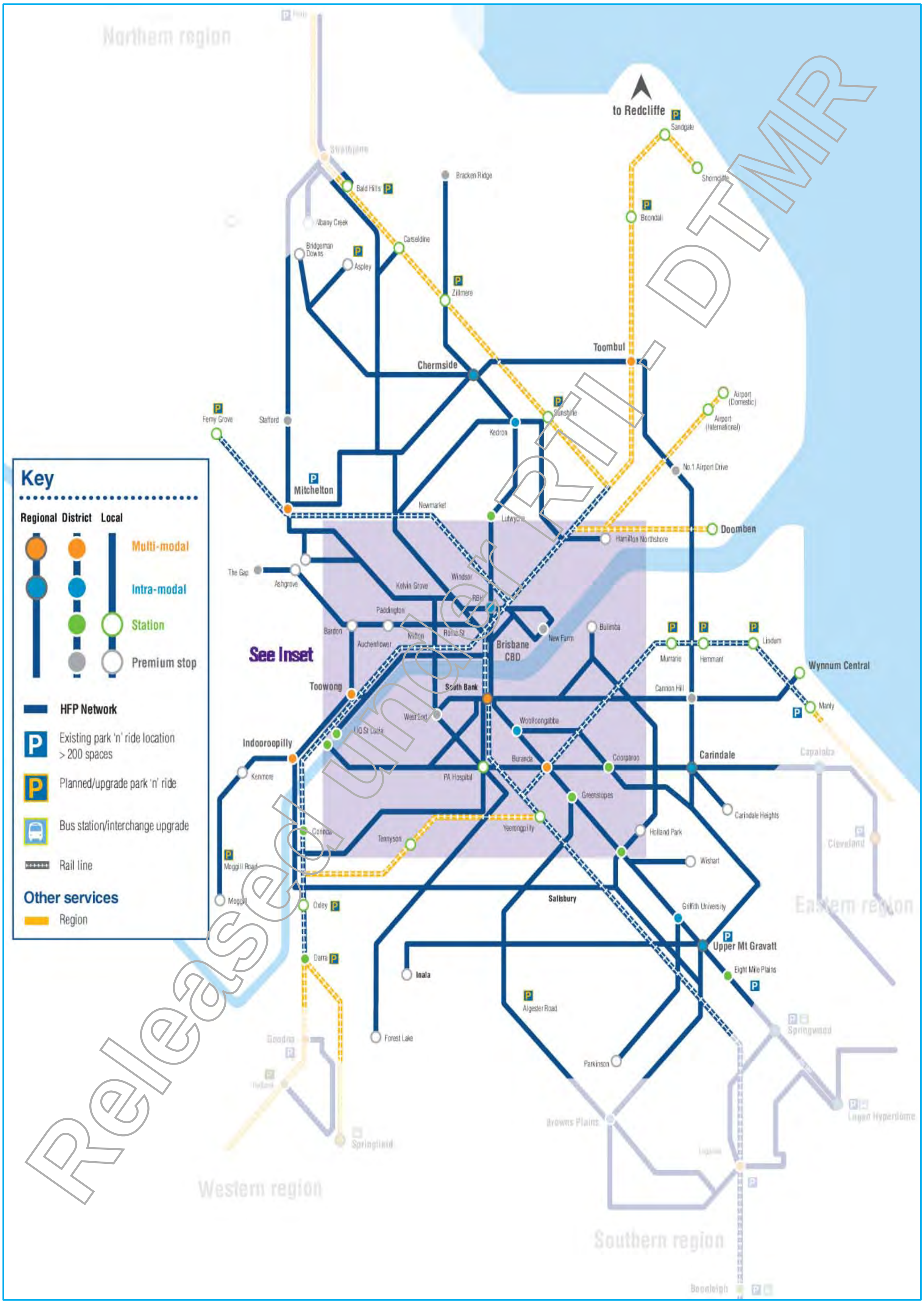
3.12.2.6 Bus Fleet Vehicle Mix and Specifications

TNP 2009 discussed expanding and enhancing the bus fleet, and developing standard bus specifications that allowed greater portability of the fleet across the network. This included refining the bus fleet vehicle mix to ensure it better met operational requirements by:

- Increasing the provision of higher capacity buses on high demand corridors such as busway and HFP routes, through targeted deployment of 14.5m rigid and 18m articulated buses,
- Development of *TransLink* standard bus specifications to provide consistent high-quality vehicles across the network, and

- Use of midibuses in areas of weak demand, provided only that such satisfied the national *DDA* accessibility standards.

Figure 12: Indicative HFP Network for Brisbane Envisaged in TNP 2009



Fleet improvement initiatives highlighted in *TNP 2009* included:

- Trial of hybrid diesel-electric buses,
- Trial of high capacity buses,
- Phase out of minibuses, and
- Development of a fleet strategy to promote innovation in development of clean, modern vehicle types.

TNP 2009 committed *TransLink* to make the bus fleet more environmentally sustainable through continued support for use of compressed natural gas on Brisbane Transport buses and trial of other alternative fuel technologies which burned less fuel and produced lower carbon equivalent emissions per passenger kilometre, favouring high capacity buses.

3.12.2.7 Bus Depots

TNP 2009 made reference to bus depots, citing new depots would be needed for the bus fleet to expand and meet expected future growth demand. Ill considered siting of bus depots can significantly affect the level of wasted bus dead running time to and from depots and termini whilst not carrying passengers. *TransLink* proposed in *TNP 2009* to become more proactive in locating, developing and managing bus depot rollouts as availability of land suitable for new depots became increasingly scarce. *TransLink* proposed in the plan to partner with bus operators and Local Governments in SEQ to investigate opportunities to strategically manage new depot rollouts with the aim of:

- Reducing overall network operating costs,
- Improving resource use, including depot sharing between operators,
- Responding to land use intents in local areas, including provision of adjoining park 'n ride and kiss 'n ride facilities for local residents,
- Ensuring long-term stability of the network, and
- Ensuring future growth could be accommodated as efficiently as possible.

3.13 TransLink Service Planning Policy

The *TransLink Service Planning Policy,* endorsed by *TransLink* senior management in 2011, does not specifically mention the bus fleet or high capacity vehicles, but contained the policy statement, extracted below, linking supply (of services) to demand (from land use) which favoured future high capacity bus deployment on HFP trunk services.

Policy Statement

Deliver an effective match between public transport services and land uses in the *TransLink* area.

Policy Narrative

The viability of TransLink Public Transport Services is determined by the demand generated by urban land uses from within the catchment of stops and stations. To improve the ability of Public Transport to compete with car based transportation, TransLink will utilise the following tools to assess the provision of Public Transport Services in the TransLink area:

- *The link between land use and the type and frequency of public transport that can be reasonably provided is to be as detailed in the TransLink Standards of Service relative to Land Use Density* (refer Table 12 below), and

- *Lower-density urban development (below 10 dwellings per hectare) is difficult to serve with mass transit. The minimum residential densities for Public Transport Services in new and existing urban areas are to be as detailed in the TransLink Level of Service relative to Land Use Density* (refer Table 13 below).

The policy links dwelling and job density to service frequency and not to a specific vehicle type or capacity, however the planning policy clarifies that the *TransLink* network shall provide a mix of service types to cater for the type of trip, time of day, day of week, frequency and origin/destination needs of communities across the *TransLink* service area. In effect, this aligns services generally with the typical service characteristics summarised in Table 14.

Table 12: TransLink Standards of Service Relative to Land Use Density

	Density	Typical Development Type	Public Transport Service Type
TransLink Mass Transit Services	High-density 40 dwellings/ha or more 100 residents or jobs/ha	City Centre, Activity Centre, Specialist Activity Centre or Urban (as per TOD Guide prepared by DIP)	HFP services
TransLink Mass Transit Services	Medium-density 30 dwellings/ha or more 50 residents or jobs/ha	Suburban and Neighbourhood (as per TOD Guide prepared by DIP)	HFP services on major corridors Infill by feeder services
TransLink Mass Transit Services	Low-density 15 to 29 dwellings/ha 20 residents/ha or 10 jobs/ha	New urban development areas* Business parks	Feeder services on hourly frequencies Some access to HFP and peak only services
TransLink Mass Transit Services	Low-density 10 to 14 dwellings/ha	Existing urban areas*	Feeder services on hourly frequencies Some access to HFP and peak services
	Low-density and Non-urban Fewer than 10 dwellings/ha in existing urban areas and 15 dwellings/ha in new urban development areas	Older subdivisions Hectare subdivisions Rural towns Isolated villages	Does not generally support mass transit services Park 'n ride to facilitate access to the public transport network Flexible transport (provided by Local Government or DTMR) may be appropriate Inter-regional service may connect centres

It is generally considered that lower demand would not warrant assignment of high capacity vehicles to local feeder services. There may however be some potential in the future to deploy HCVs on selected *NightLink* services, notably the more popular 3am *NightLink* services departing city entertainment districts just after lock-out.

Table 13: TransLink Level of Service Relative to Land Use Density

Net Residential Density	Approximate Lot Size (m²)	Minimum Public Transport Level of Service
0 to 9 dwellings/ha	900m² or greater	Flexible transport (not provided by TransLink)
10 to 14 dwelling/ha	600 to 700m²	Local or feeder services (in existing urban areas only)*
15 to 19 dwellings/ha	400 to 500m²	Local or feeder services
20 dwellings/ha or more	300m² or less	HFP and feeder services

The *TransLink Service Planning Policy* does not reference school services as a specific service type and these are covered by a separate policy.

Table 14: TransLink Typical Service Characteristics

	High Frequency Priority (HFP)	High Frequency Priority Express	Peak Express	Regional	Local Feeder	NightLink After Hours
Public Transport Type	Bus, rail and ferry	Bus and rail	Bus and rail	Rail	Bus	Bus and rail
Key Function	Increase patronage	Increase patronage	Provide extra capacity to cater for peak-period commuter travel	Increase patronage and provide high speed links between regional areas	Provide coverage across the entire urban area and meet minimum service standards (2)	Supplement taxi services and provide safe late-night travel
Core Attribute	'Turn up and go' high frequency all day	'Turn up and go' high frequency all day with limited stops	Peak period express services Monday to Friday	Inter-region link	Provides access to HFP routes and local attractors	Secure late night services
Frequency	15 minutes or better all day	15 minutes or better all day	30 minutes or better peak only and where required	10 to 60 minutes all day	60 or better minutes all day	60 minutes or better Friday and Saturday nights
Minimum Hours of Operation	6.00am – 9.00pm 7 days	As required	Peak only	9.00am – 5.00pm weekdays / Saturdays; 9.00am – 4.00pm Sundays	9.00am – 5.00pm weekdays / Saturdays; 9.00am – 4.00pm Sundays	Set down on demand 1.00am – 5.00am Saturday and Sunday mornings
Stop Spacing	400m to 1.6 km	800m to 1.6km	400m to 2km with a section of the route running express	3 to 20km	400 to 800m	400m to 2km (note: set down on demand)

3.14 TransLink Infrastructure Planning Policy

The *TransLink Infrastructure Planning Policy,* endorsed by *TransLink* senior management in 2011, makes no specific mention of the bus fleet or high capacity vehicles, but addresses the future network capacity.

TransLink's priority in this regard has been to optimise existing capacity by implementing better network designs and alternative servicing strategies to yield improved efficiencies, before resorting to design and construction of additional new infrastructure capacity. Where it has been identified that new infrastructure is both warranted and justifiable, *TransLink* endeavours to match the type of public transport infrastructure to the long-term capacity requirements of the network, based on the following 4 assessment criteria:

- Support for Land Use Development: modal selection must be based on the desired role of the public transport network in supporting the overall development of an urban area, not simply as an bolt-on extension to the existing transport system,
- Right Mode for the Task: consideration must be given to current and future origins and destinations of trips using the nearest transport corridor and nodes, so that the mode of transport selected best meets the maximum number of passenger needs at an affordable cost,
- Minimisation of Overall Journey Time: public transport travel times must be competitive with private car travel times in peak periods, and
- Business Case Justification: must ensure cost-benefit realisation and contribution to delivery on *TransLink's* long term strategic objectives.

Modal Selection

Table 15 summarises current *TransLink* guidelines for planning different public transport delivery modes. Ranges shown reflect different assumptions for dwell time and in the case of trains, the number of cars per train set. Peak-hour factor and passenger loading assumptions used to derive this table reflect *Transit Capacity* and *Quality of Service Manual* recommendations. Highest observed values only have been listed.

Table 15: Modal Selection Thresholds

	Passenger Capacity in Peak Directions (passengers/hr)		Average Travel Speed (km/hr)	
	Low	High	Low	High
Bus in Mixed Traffic	500	1,000	6	10
CBD Bus Lane	1,500	4,000	6	14
On Street Light Rail with Signal Priority	2,600	5,000	13	24
Light Rail with Exclusive Right of Way	6,000	16,000	42	55
Bus on High Occupancy Vehicle (HOV) Lane	500	1,500	55	87
Busway with Passing, including Stations	2,000	12,000	56	72
Suburban Rail	7,000	24,000	32	81
Long Distance Commuter Rail	2,000	7,000	56	89
Metro Rail	10,000	60,000		

3.14.1 Bus Station and Stop Hierarchy

Policy Statement 2 of the *TransLink Infrastructure Planning Policy* indicates generally that stations and stops in the *TransLink* area will provide for easy and safe circulation of passengers and vehicles. Table 16 outlines the current *TransLink Station and Stop Hierarchy*.

TransLink defines different categories of functionality for its station and stop facilities as follows:

- Local Facility: is a local facility sited and designed primarily to cater for the transport needs of the immediate surrounding community. The primary means of access to a local station or stop is walking via local footpaths and roads,
- District Facility: is a station located at a significant attractor in the network. These stations have a good standard of passenger facilities. Services to district facilities are primarily a mix of express and all-stops HFP trunk services, but some feeder services also operate from the station, and
- Regional Facility: is a major station or interchange with a very high standard of passenger facilities located at a major attractor such as a regional shopping centre, or where two or more HFP services converge in the network.

Table 16: TransLink Stop and Station Hierarchy

Functionality	Category	Typical location criteria*	PT Mode
Local	Regular Stop	low patronage no interchanging between services outer suburban or low density areas low frequency services	Bus
Local	Intermediate Stop	moderate patronage no interchanging between services often located within suburban areas low to moderate frequency services	Bus
Local / District	Premium Stop	moderate to high patronage limited interchanging between services often located along major corridors moderate to high frequency services	Bus Busway Light Rail Ferry
Local / District	Standard Station	moderate to high patronage limited interchanging between services key point of transfer between services of the same mode often located along public transport corridors such as rail lines or busways moderate to high frequency services	Bus Busway Light Rail Heavy Rail Metro Rail Ferry
District / Regional	Intra-modal Station	high to very high patronage high level of interchanging key point of transfer between services of the same mode often located at major district or regional attractions, or at strategic places within the network high frequency services	Bus Busway Light Rail Heavy Rail Metro Rail
District / Regional	Multi-modal Station	high to very high patronage high level of interchanging key point of transfer between services of both the same and different modes often located at major district or regional attractions, or at strategic places within the network high frequency services	Bus Busway Light Rail Suburban Rail Long-distance commuter Rail Metro Rail

In future, high capacity buses are more likely to use *District* and *Regional* facilities. Under the *TransLink Infrastructure Planning Policy,* bus stations and stops are classified according to the service frequency and patronage hierarchy presented in Table 17.

Table 17: Service Frequency and Patronage Hierarchy

Frequency Levels	For the purpose of this policy, frequency of services (in the peak) at stops or stations will typically be as follows: • Low: Local Services - greater than 60 minutes • Moderate: Local Services - 15 to 30 minutes • High: High Frequency Priority (HFP) Services - 10 to 15 minutes • Very High: High Frequency Priority (HFP) Services - greater than 10 minutes
Patronage Levels	For the purpose of this policy, patronage levels (in the peak) at stops or stations will typically be as follows: • Low: 0 to 250 passengers per hour • Moderate: 250 to 2,500 passengers per hour • High: 2,500 to 20,000 passengers per hour • Very High: greater than 20,000 passengers per hour

There is no existing capacity requirement that marries specific vehicle sizes to bus station and stop service frequencies and patronage demand.

3.14.2 Bus Depots

Policy Statement 4 of the *TransLink Infrastructure Planning Policy* states simply that bus depots and train stabling shall contribute to an efficient network. The location and capacity of bus depots have significant influence over the operating efficiency of the *TransLink* mass transit bus network. The following criteria are applied when planning new, or upgrading existing bus depots:

- Efficiency: Depot location selection to minimise vehicle dead running time and distance and maximise network operating efficiencies. This normally translates to siting depots close to where the majority of bus routes originate in the morning and terminate in the evening,
- Capacity: Sufficient depot capacity to be provided to accommodate future growth as efficiently as possible and to ensure the long term stability of the bus network,
- Utilisation: Adequate space to be provided to ensure efficient and effective bus operations and maintenance. Depot infrastructure is to be readily accessible to bus drivers and other depot staff and provide an appropriate level of amenity, and
- Impacts: Depot locations should minimise operational and maintenance impacts on surrounding communities.

The current policy acknowledges that more detailed bus depot strategies will be necessary to inform future planning for new or upgraded existing bus depot infrastructure.

3.14.3 Mass Transit Definition

Under the *Transport Operations (TransLink Transit Authority) Act 2008, TransLink* is responsible for delivery of mass transit services in South East Queensland. *TransLink*'s service and infrastructure planning policies define mass transit as follows...

"For the purpose of this policy, mass transit is an urban public transport system which provides regular scheduled bus, light rail, rail or ferry services. Mass transit only operates where the carrying capacity of

the transport mode is 24 seats or greater. Mass transit is generally provided to areas that have a density of 10 dwellings per hectare or greater".

This definition distinguishes the service capacity to be provided by *TransLink* from the service capacity to be provided by DTMR under their respective public transport charters within SEQ, and defines the minimum carrying capacity of their respective passenger transport vehicles.

3.15 Draft Service Augmentation Policy

The 2004 *TransLink Network Plan* proposed that services carrying more than 30 passengers per in-service hour be considered for augmentation. Since public release of this document, the policy has never been formally amended.

While not yet officially endorsed by *TransLink* senior management, informal agreement has been reached on a new draft policy position defining when services should be augmented going forward into the future. The draft policy is set to replace the former policy contained in the 2004 *TransLink Network Plan,* and is likely to be incorporated into the *Service Planning Policy*. Its position is summarised as follows...

"A service may be considered for a capacity upgrade if the maximum passenger load equals or exceeds 90% of the legal passenger carrying capacity of the vehicle for a continuous period of 20 minutes or longer. When considering capacity upgrades, the service must consistently meet or exceed the above thresholds to warrant a permanent capacity upgrade, taking into account seasonal fluctuations in demand".

The new draft policy does not imply that service augmentation necessarily means plugging additional services into a persistently loaded route, but allows for the qualifying service to be augmented by a vehicle capacity upgrade where such would more cost-effectively resolve overcrowding and missed passenger boardings without adding additional services. It is understood that the *TransLink* Strategy and Planning Team is keen to upgrade netBi functionality that would enable load profiles to be generated for individual services against their scheduled times, so that thresholds could be set to detect extended periods of overloading and thereby target services for which high capacity buses or additional services would be needed.

The earlier *TNP 2004* policy made no reference to either vehicle capacity or passenger turnover. The latter determines the magnitude and duration of transient passenger load peaks along the route, and is affected by the service type and distribution of surrounding land uses at scheduled bus stops. By way of example, the current Route 199 BUZ has the highest passenger boardings of any *TransLink* bus route. But because the 199 route services numerous mixed land uses on its high density corridor in both the peak and contra-peak travel directions, the service experiences a very high passenger turnover.

In contrast to the Route 199 BUZ, most school, university and peak express rocket services have only one or a few high passenger offloading stops and therefore experience only limited passenger turnover en route. Consequently, whilst the total number of passenger boardings on the 199 BUZ greatly exceeds the carrying capacity of HCVs along its entire route length, these vehicles would not reach full capacity for any significant period of time as a consequence of high passenger churn.

3.16 Driver Full Bus Reports

In the absence of having load profile functionality in its current version of netBi, Brisbane Transport has chosen to prioritise its service crowding mitigation initiatives by requesting bus drivers to report when buses appear full. Historically, full buses were reported when drivers finished their shifts at home depots and this necessitated drivers being diligent in both recalling and recording the affected service(s) and where on their routes overloading was encountered.

More recently, Brisbane Transport has resorted to using its bus two-way radio system which enables instant driver reporting at the push of a button on the in-vehicle mobile radio when the driver observes the bus is full. Electronic bus full data captured by mobile radio not only reports the full bus and service number, but additionally records the GPS coordinates of the vehicle to show where along the route the bus first became full. It is unknown whether drivers also manually record where, further along the route, the bus was no longer full, taking into consideration that the boarded passenger status on high turnover routes may fluctuate repeatedly between fully and partially loaded.

A recognised problem with full bus reports, be they manual or electronic, is they rely on the subjective judgement of the bus driver. A bus driver is authorised and obligated under *TOPTA* to prevent passengers boarding a bus that is considered full, and while the driver might know the legal carrying capacity stamped on the compliance plate of the vehicle being driven, he/she would not know how many passengers were actually boarded without conducting a head count. Accurate touch on and touch off electronic ticketing data could be used to calculate boarded load in real time, but is not currently provided to the bus driver and is only passed to *TransLink* for post-service evaluation and planning purposes.

It is understood that the popular high frequency BUZ route buses are amongst those most frequently reported full by bus drivers, but their assessments fail to consider high passenger turnover and service frequency (i.e. passenger waiting time between services), or whether preceding or following services along common corridor route segments may have had surplus boarding capacity. It is considered therefore that reliance solely on driver subjective assessment of passenger loads in deciding which services should be augmented with higher capacity buses or additional services is not a sustainable long term proposition for prioritising future *TransLink* service augmentations.

3.17 TransLink 3G Bus Contracts

3.17.1 Private Operator 3G Contracts

14 private bus operators presently hold *3G (Third Generation)* operating contracts with *TransLink*. The following sections review the current 3G contract and discuss selected clauses and schedules of the contract with direct or indirect implications for the future deployment of high capacity vehicles.

3.17.1.1 Vehicle Standards

3G contracts define a vehicle as a bus used, or which may be used by or for the operator to perform the services under the contract. This definition is the same as that found in *TOPTA*. 3G contracts further state the operator will comply with all State and Commonwealth Government laws in relation to vehicle accessibility and emission standards, and in particular, with the *Disability Standards for Accessible Public Transport 2002* and accompanying guidelines implemented under the *Disability Discrimination Act 2002 (Cth)*.

Schedule 7 of the private bus operator 3G contract provides a list of vehicle standards but most of the standards relate only to vehicle cleanliness and safety. There is no mention in the contract standards that vehicles should, for instance, be fitted with:

- Air conditioning,
- Two entry/exit doors, or

- Changeable electronic destination and route numeral signs, save that one destination sign must be fitted on the front of the bus.

No mention appears in the 3G contract about vehicle passenger carrying capacity, except in respect of reference to the *TOPTA* bus definition which basically defines a bus as having 9 or more passenger seats.

Under the 3G contract, *TransLink* must approve the purchase of new buses required by an operator to provide the services. If the operator chooses to purchase a bus that is considered to exceed *TransLink*'s minimum specifications, the operator must self-fund the difference between the cost of a vehicle that would have met the minimum specifications to provide the services and the vehicle that the operator has elected to purchase. For example, where a standard 12.5m route bus would be sufficient to provide route and school services in the operator's contract area, but the operator elects to purchase a coach to operate its own private tours, *TransLink* will only pay the cost of a standard route bus. In a similar vein, *TransLink* will not compensate the operator for any additional depreciation and running costs associated with a vehicle it elects to procure which exceeds the minimum specifications needed to deliver the contract services.

3.17.1.2 Livery

The 3G contract outlines *TransLink*'s branding requirements in relation to bus livery. An operator must ensure that its vehicles exhibit *TransLink*'s trademark and name in accordance with *TransLink* standards and guidelines for their proper use, and *TransLink* may direct an operator to change the livery of its vehicles to accord with the standards and guidelines. *TransLink* will pay to an operator the actual and reasonable cost incurred by it for any changes made to the livery of existing vehicles, but not for livery changes to vehicles made during their normal refurbishment or maintenance, or on a new vehicle.

If *TransLink* chooses to assign existing high capacity vehicles to routes that have a unique service brand necessitating an update of service branding elements in the fleet livery (such as say for new HFP routes), the cost of livery changes would be claimable back from *TransLink* by operators under current 3G contract conditions.

3.17.1.3 Fuel Costs

Schedule 8 - Indexation of the 3G contract states vehicle fuel costs will be paid to operators by *TransLink,* based on the actual cost of fuel and using *FuelTrack* to determine the indexation factor.

TransLink does not presently specify the bus fuel type or propulsion system to be used by the operator, nor the manufacturer, model or size of vehicle to be used, however as the receiver of all passenger ticket revenue generated by the services, high capacity buses placed on heavily loaded routes would realise the lowest fuel consumption and highest revenue generation per passenger-kilometre travelled.

3.17.1.4 Contract Payments

3G contract clauses indicate that there will be no change to the contract payments made to an operator by reason of a reduction in the level of service provided in accordance with the base kilometres specified in the contract, unless otherwise mutually agreed. These clauses exist to assure operators that they would not be financially disadvantaged as a consequence of any *TransLink* decision during the life of the contract to reduce the base kilometres below those which existed when operators first joined the *TransLink* network in 2004.

These clauses place potential constraints on the future deployment of high capacity vehicles. For instance, two articulated buses may be considered equivalent to three standard rigid buses in terms of total carrying capacity. If *TransLink* chose to substitute two articulated buses in place of three standard rigid buses on a route to improve the economic performance of particular services, the operator's base kilometres would be reduced by one third, but at no realisable saving to *TransLink*.

In the 8 year period that has elapsed since 2004, total operator base kilometres have increased by an average of 64.53% and the opportunity exists to reduce or contain further growth in travelled kilometres through greater high capacity bus utilisation, provided that new base kilometres are not locked in at their increased levels in the next round 4G contracts. In practice, *TransLink* will be more likely in future to selectively deploy high capacity vehicles on high demand routes in lieu of increasing services and kilometres. This approach would be expected to help constrain growth in base kilometres, rather than reduce existing kilometres.

3.17.1.5 Performance Management Framework

Schedule 10 of the 3G contract outlines the performance management framework for delivery of services and includes penalties for the following items of relevance to high capacity buses:

- On-time Running: The number of buses departing from agreed scheduled locations no more than 1 minute earlier than scheduled, and no more than 5 minutes later than scheduled, must be less than 5% of the total agreed scheduled departures for a day. (It is understood that these thresholds may have subsequently been revised by *TransLink*), and
- Missed Trips: The number of trips removed from the daily schedule must be no greater than 0.5% of the total trips scheduled for the day.

It could be argued by operators that they should be exempted from the above performance management framework penalties if the deployment of higher capacity vehicles failed to account for additional running time in the schedule to cover longer dwell times and generally slower acceleration from stops due to the higher mass of HCVs.

Another performance measure nominated in the schedule sets a target of 1 accident per 100,000km. A high capacity vehicle longer or higher than a standard 12.5m rigid bus may be expected to have a higher rate of accidents per 100,000km, based simply on the fact that it takes up more road and air space than its 12.5m counterpart, calling for greater driver diligence, concentration and care to manoeuvre and avoid accidents.

3.17.1.6 Private Charters and Tours

Some SEQ bus operators run private charter and tour services outside their standing 3G route and school service contracts with *TransLink*. In these instances, *TransLink* pays that proportion of the vehicle running cost associated with operating its own scheduled services, and the operator picks up the remaining cost expended on its own private charter and tour operations. Operators in the private charter business generally prefer to buy high floor coaches with more seats than low floor standard 12.5m route buses and with luggage stowage compartments below the main passenger deck. They predominantly operate their private charter services in *TransLink* scheduled service off-peak periods.

This arrangement has proven to be cost effective for both the private charter operators and *TransLink*, as the operators can utilise their high floor coaches on school routes during the peaks which often demand higher seating capacity, and coaches do not currently need to be *DDA* compliant. In effect, *TransLink* only pays for the vehicle to be operated on school routes, and the vehicle's initial procurement and ongoing running costs are cross-subsidised by private charter operations in circumstances where operating school bus services alone would be financially unviable.

For ultralow floor buses used on urban routes, *TransLink* arguably pays for a portion of its mass transit fleet to sit idle and underutilised in depots during off-peak periods, as most operators with ultralow floor bus fleets do not operate private charter businesses. The current exemption from DDA compliance for new buses used exclusively on school services looks set to expire after 2029, presenting *TransLink* with a dilemma of deciding to continue authorising purchase of coaches by operators in the tour business, or directing they purchase ultralow floor buses, given the typical 20 to 25 year life cycle of buses and coaches in SEQ.

It is unlikely a high capacity 14.5m rigid or 18m low-floor articulated bus could be used by an operator for charter services, but some operators might consider using low floor double deck buses for their charter services, where the lower deck could be partially partitioned off for luggage storage. Where this option was unacceptable to charter operators, this might mean that *TransLink* would need to pay up to 100% of the cost of a new high capacity vehicle and to shore up its return on investment by operating high capacity vehicles on other services where high demand warranted such. The cross-city and cross-country route services envisioned in *Connecting SEQ 2031* could be one future avenue to absorb this excess network capacity.

3.17.1.7 New Vehicle Funding

3G contracts state that an operator may be eligible for financial assistance under a guideline such as the *Accessible Bus Program Guideline.* These guidelines are now considered to be out-of-date as they only strictly relate to urban regional bus operators who hold a service contract with the Department of Transport and Main Roads. The guidelines do not apply to *TransLink* school and route service bus operators.

TransLink does however indirectly fund its operator new vehicle purchases through an operating lease arrangement. Under this lease arrangement, *TransLink* pays the annual lease instalments for each newly procured bus over a number of years, and the mutually agreed residual value is paid out by the operator upon termination of the lease period. The lease agreement is sufficient to enable operators to source finance for their ongoing fleet renewal programs with *TransLink* assurance provided both as initial lessee and financial guarantor.

It is understood that *TransLink* pays 125% of the lease cost of a standard 12.5m rigid bus for a 14.5m rigid bus and 150% for an articulated bus, and the lease cost ratios are based on the relative seating capacities of the 3 vehicle types. Notwithstanding this financial agreement, Brisbane Transport planners argue that their 14.5m rigid buses are equivalent to articulated buses in terms of their total carrying capacity.

3.17.1.8 Replacement Vehicles

Schedule 7 of the 3G contract stipulates that the maximum age of an operator's vehicles must not exceed 25 years and the average age of an operator's fleet must be no greater than 13 years. Schedules 4 and 5 of the operating contract specify vehicle register details that operators are to provide to *TransLink* annually for their existing fleets, proposed vehicle acquisitions and replacements. Any existing buses or coaches proposed to be removed from service and/or replaced must be negotiated annually with *TransLink*.

Current 3G contracts do not require private operators to advise *TransLink* of the each vehicle's total carrying capacity, only their seated capacity. The compliance plate installed in each bus details the vehicle's designed (legal) carrying capacity and whilst this information may be recorded by private operators, it is not currently collected through their respective fleet registers by *TransLink*. The Brisbane

Transport fleet register is the only register that records both seated and total carrying capacity for each vehicle and bus subgroup.

3.17.1.9 Spare Vehicles

While the 3G private operator contract is silent on the percentage of the bus fleet to be held as spares, *TransLink* adopts bus industry best practice of around 10%, namely one spare vehicle for every 10 vehicles demanded during the highest weekday peak.

3.17.2 Brisbane Transport 3G Contract

It is understood that the conditions contained in the Brisbane Transport 3G contract are broadly similar to those in private operator 3G contracts, but the former includes the following additional provisions in regard to the Brisbane Transport bus fleet:

- *TransLink,* Brisbane City Council and Brisbane Transport are to agree each year on new fleet orders and the fleet mix of 12.5m rigid, 14.5m rigid and 18m articulated buses before orders are placed with the Council's bus chassis and body manufacturers, and
- *TransLink,* Brisbane City Council and Brisbane Transport are to agree each year on the planned fleet growth and replacement program.

It is further understood that *TransLink* has agreed to fund 125 equivalent rigid bus purchases per annum up until the end of FY2011/12, subject to annual agreement upon the fleet composition and bus replacement program. All vehicles procured under this arrangement have to date been CNG or diesel engine, air conditioned, ultralow floor, PWD accessible, two door route buses. A total of 128 new 14.5m rigid buses and 30 new 18m articulated high capacity buses have been procured under the agreed replacement program to date.

3.17.3 Brisbane City Council - Volgren Joint Venture

The current Brisbane City Council administration announced commitments to procure 400 and later 500 new buses during their last two terms in office. These commitments were made without *TransLink*'s prior agreement to fund either the new bus procurements or their deployment on scheduled school and route services. In recognition of this, it is understood the current Brisbane Transport 3G contract held with Brisbane City Council contains new provisions to ensure similar forward commitments cannot be made by Council without *TransLink*'s prior consultation and approval.

In 2008, Brisbane City Council announced it had entered into a 10 year joint venture with Australian aluminium bus body manufacturer Volgren Australia, to construct a new $19 million bus build factory at Trade Coast Central, Eagle Farm. It is understood Council donated a 2.54 hectare site valued at $6.7 million to Volgren to establish the new factory, which later opened in December 2009. Brisbane Transport bus body fabrication staff from the Council's Brisbane Transport Bus Workshops at Toowong were transferred to the new enterprise under the joint venture agreement, resulting in the closure of the Toowong bus body construction line previously used to fabricate and assemble new Council buses. It is understood the Volgren factory has the capacity to produce up to 200 buses per annum and the joint venture, executed in 2008, has a further 6 years to run.

Volgren has publically confirmed its Brisbane facility could build GM-Allison based hybrid diesel/electric rigid buses similar to those presently being trialled in Melbourne, and had the capability to also manufacture hybrid articulated buses. Brisbane City Council is however currently only placing orders for new diesel rigid buses to replace its older high floor diesel route buses located in depots which have no close proximity to existing high pressure natural gas pipelines. It is further understood that Brisbane City Council is reluctant to make further acquisitions of 18m articulated buses and considers the 14.5m rigid bus to be the equivalent of an articulated bus in terms of total carrying capacity and considerable cheaper to build, maintain and operate.

3.18 High Capacity Vehicle Scheduling Constraints

3.18.1 Depot Related Scheduling Constraints

Practical scheduling constraints prevent assignment of high capacity vehicle types to particular bus routes. These relate to:

- Intra-depot Constraints: Not all existing bus depots have the facilities, or would through appropriate modifications, be suitable candidates to park, maintain, wash and refuel high capacity vehicles. There may also exist road access or bus stop infrastructure limitations on bus routes operated from particular depots that prevent service delivery using high capacity buses. (Examples of typical depot related high capacity vehicle constraints are later described in the SIP business case study found at Section 3.18.5), and
- Inter-depot Constraints: Large operators with multiple depot sites attempt to limit assignment of bus routes to one or the two best depots which minimise their resident fleet average dead running time. This practice provides a bonus advantage in that drivers stationed at multiple depots do not need to be fully acquainted with every route on the operator's network. This is particularly important in the case of *TransLink*'s largest bus operator, Brisbane Transport, which has over 200 bus routes in the greater Brisbane area serviced by 1,250 buses from 9 separate depots.

With the advent of the *TransLink* go card, when a driver logs onto his/her vehicle DCU, stops are listed in sequential order for the route about to be driven, so driver reliance on prior knowledge of routes has arguably become less critical and the current Brisbane Transport Award pays its drivers more for operating services from multiple depots.

Notwithstanding this apparent flexibility, the inability to globally optimise scheduling between depots obviates potential interlining of services that would maximise operating efficiencies and further reduce dead running. The HASTUS and AUSTRICS scheduling systems used by most *TransLink* operators apply business rules established by each operator which effectively thwart opportunities for *TransLink* to further improve network efficiency. Example A below illustrates how depot siloing business rules can affect efficient interlining of two hypothetical services operated from different depots.

> Example A: Say Brisbane Transport Route 111, operated out of Garden City Bus Depot, shared a common terminus with Route 222 at Roma Street Busway Station. Because Route 222 is only operated out of Carina Bus Depot, it cannot be interlined with Route 111 under HASTUS business rules, because drivers stationed at Garden City Bus Depot are not expected to be familiar with routes operated exclusively by Carina Bus Depot bus drivers. Because these services can't be interlined under HASTUS business rules, the hypothetical Route 111 bus must leave the busway to start at another origin stop in the CBD which can be interlined with a route operated out of Garden City Bus Depot.

A cost effective method known to reduce dead running cost is to assign designated vehicle types to turn back high frequency routes. This practice allows, for instance, an inbound HFP high capacity bus to arrive at its CBD terminus, take a short recovery period without repositioning, then return back along the same route in the outbound direction. In a more complicated but equally cost effective interlining scenario, two converging high frequency routes operated from the same home depot and sharing a common terminus can facilitate interlining of both services for a minimum layover period. This is illustrated by Example B below.

Example B: Say BUZ Routes 345 and 385 share the same terminus at the Gallery of Modern Arts and operate out of the same bus depot so HASTUS business rules permit their interlining. The buses can be scheduled to operate every 10 minutes (5 minutes combined) during the peaks and every 15 minutes during the off-peak (every 7.5 minutes combined). By interlining these two separate routes, the interlined recovery time becomes 5 minutes in the peaks and 7.5 minutes in the off-peak without incurring any bus dead running distance or driver paid time for repositioning of either bus.

Under the two hypothetical scenarios presented above, the opportunities to interline are constrained to those which can be accommodated by drivers and buses operating out of the same home depot.

3.18.2 Livery Constraints

Creation of special fleet subgroups with their own distinctive livery reduces bus interchangeability between depots, prevents substitution of similar bus sizes between services, increases the whole-of-fleet spare bus ratio and essentially de-optimises fleet utilisation and route scheduling. Utilisation can however be optimised for fleet sub-groups with a distinctive livery if operated all day on high frequency routes with a minimum of spare buses held in depot as in the case of, for example, the Brisbane *CityGlider.* Unlike other similar size buses without a distinct livery, a scheduler could not interline a *CityGlider* bus with say a peak hour *Rocket* service, as the redeployment of the *CityGlider* vehicle on another route would erode the service brand and only serve to confuse customers, but the continuous all day demand for the *CityGlider* service renders the need for interlining unnecessary.

Unlike standard rigid 12.5m buses, high capacity buses are further constrained by their relatively smaller sub-group strengths, standby spare bus reserves and the limited number of routes to which they can be scheduled. If further sub-grouped by a distinct livery for other than all day, high priority, high frequency services, high capacity buses may be found sidelined in depots for long off-peak periods each day.

3.18.3 Meeting Minimum Depot Fuel Quotas

Many operators have diesel (or natural gas) supply contracts in place with bulk fuel delivery vendors which specify minimum fuel storage top up thresholds for tanker deliveries and/or minimum weekly, fortnightly or monthly accounting period consumption thresholds which will attract bulk fuel discounts. These fuel supply arrangements, while intended to achieve economies of scale for best fuel price, indirectly result in buses with high kilometre routes being deliberately stationed at particular depots so minimum depot fuel order thresholds are reached, albeit that the selection of the vehicles' home depot may be considered suboptimal from both a scheduling and dead running perspective than other available depots. High capacity buses operating high frequency limited stop and express routes for long periods of the day consume fuel at considerably higher rates per day than smaller capacity 12.5m buses, and are tempting targets for operators to selectively place at depots where attainment of minimum fuel quotas is a priority consideration.

3.18.4 Assessing Load Profile and Turnover for HCV Deployment

If selection of high capacity bus routes is based solely on driver reported or netBi measured load profiles, such may result in high capacity vehicles being inefficiently deployed to infrequent, low passenger turnover routes with resulting network de-optimisation if such routes don't share common termini with other routes, limiting interlining opportunities to reduce layover time and dead running needed to reposition trip origins. The challenge when selecting target routes for high capacity vehicles will be to contrast the cost per passenger-kilometre of augmenting low frequency crowded routes with low passenger turnover against the cost of augmenting high frequency routes with high passenger turnover along the route.

The latter routes are generally considered better candidates for cost-effective deployment of a dedicated high capacity vehicle fleet, however due to their high frequency, turn back contra-peak operation and servicing of multiple destinations, these routes may have the desired high patronage turnover but demand may not necessarily justify use of high capacity vehicles throughout the day.

3.18.5 Service Improvement Program Business Case – High Capacity Vehicle Deployment (Gateway 2)

This section describes a recent *TransLink* business case to reallocate high capacity vehicles to specific bus routes that consistently delivered full standing loads. The business case highlights the issues that were considered and constraints encountered when allocating high capacity vehicles to other bus routes.

As part of its 20 February 2012 *Service Improvement Program*, *TransLink* reallocated high capacity vehicles to operate on specific Brisbane bus routes for the first time. The objective of this project was to achieve a more functional and efficient utilisation of the Brisbane Transport high capacity bus fleet. By reallocating 14.5m rigid and 18m articulated high capacity vehicles to known congested routes, *TransLink* sought to proactively manage increased passenger demand without increasing peak bus service numbers.

Specific routes were selected largely on the basis of driver full bus reports and the project proposed an increase in weekly capacity on the network of 2,640 seats to address the growth in passenger demand. The Brisbane bus routes selected by the project team have been summarised below in Table 18.

Table 18: Proposed Deployment of High Capacity Vehicles on Brisbane Bus Routes

Route	To/From	Operations Proposal
66	Woolloongabba to Royal Brisbane Womens Hospital via Busway	Operate using articulated (18 metre) buses, 5 days a week (inbound and outbound)
109	UQ Lakes to CBD via Inner Busway	Operate using 18 metre articulated buses, 5 days a week (inbound and outbound), and 14.5 metre vehicles on Saturday and Sunday.
111	Eight Miles Plains to CBD via South East Busway	Operate using 18 metre articulated buses, 7 days a week (inbound and outbound)
130	Calamvale to CBD via Mains Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
139	Sunnybank to University of Queensland via South East Busway	Operate using 14.5 metre vehicles, 5 days a week (inbound and outbound)
140	Brown Plains to CBD via Mains Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
150	Browns Plains to CBD via Warrigal Road	Operate using 14.5 metre vehicles, 7 days a week (inbound and outbound)
P137 and P142	Sunnybank and Browns Plains to CBD	Additionally routes 137 and 142 to be allocated exclusively to 14.5 metre vehicles
160	Garden City to Queen Street Bus Station	Operate using 18 metre articulated buses, 5 days a week (inbound and outbound)
169	Eight Mile Plains to University of Queensland via Busway	Operate using 14.5 metre vehicles 7 days a week (inbound and outbound)

Most the routes listed in Table 18 are considered to be all hour high frequency priority weekday routes, with the exception of Routes P137 and P142 which are limited stop, peak only routes. Some of the above listed routes incurred additional running time allocations, but it is unclear from the business case if this was justified by increased traffic congestion or in anticipation of future higher passenger loads and longer dwell times at bus stops. Full implementation required some operational platform adjustments at Queen Street and Browns Plains Bus Stations to accommodate the longer high capacity vehicle reallocations.

The business case supported withdrawal of high capacity vehicles from selected routes and their reallocation to specific HFP routes with known consistently high or full standing loads. This resulted in the need to augment some of the services on the routes from which the high capacity vehicles were drawn to ensure their commuters received a level of service commensurate with that which existed before the higher capacity vehicles were redeployed. The following routes were identified by the project for supplementary augmentation:

- Route 135: Two additional trips at 7:30 and 8:00 am to compensate passengers who previously had access to articulated vehicles on Route 135 trips commencing at 7:17am and 7:46am,
- Route 136: One additional trip at 7:13am to compensate passengers who previously had access to articulated vehicles on the 6:58am trip, and
- Route 155: One additional trip at 7:25am to compensate passengers who previously had access to articulated vehicles on the 7:35am trip.

It is understood at present that there is no documented *TransLink* policy which explicitly states that redeployment of higher capacity vehicles to better match supply to passenger demand should result in maintenance of the current level of capacity, and the HFP routes listed in Table 19 were excluded from the reallocation of higher capacity vehicles for the reasons indicated.

Table 19: Routes Excluded from Redeployment of High Capacity Vehicles

Route	Reason for being Excluded from HCV Project
412	Route 412 cannot be allocated as a Higher Capacity Route as it originates from the Toowong Bus Depot which currently does not accommodate high capacity vehicles. Additionally Brisbane Transport has advised that Stop 16 Adelaide Street cannot accommodate 14.5 metre vehicles (a shared stop with Route 109)
385	Route 385 is unsuitable as a Higher Capacity Route as the alignment it operates on cannot facilitate 14.5 metre vehicles, in particular along Coopers Camp Road. Additionally the bus stops at Bardon and Paddington are not set up to handle 14.5 metre vehicles
333 345	Both these bus services operate from the Virginia Bus Depot which currently does not accommodate higher capacity vehicles. KGS stop cannot accommodate 14.5 metre or articulated vehicles. Would result in excessive dead running associated with repositioning vehicles
196	Considering the current level of service and the alternative bus routes in the corridor (199 and CityGlider), Rroute 196 is not being considered as a Higher Capacity Route at this time
120	Route 120 was transitioned to a HFP route in June 2011. Currently there is insufficient demand for higher capacity vehicles on this route
200 and 222	Route 222 was upgraded to a full HFP route in June 2011. It has provided additional capacity throughout the Old Cleveland Road corridor resulting in a reduction in overcrowding on route 200. Currently there is no need to introduce Higher Capacity Vehicles on Routes 200 or 222 as both are not at capacity
180 and 100	These routes will be transitioned to HFP status on 31st October. TTA will monitor their performance and consider allocating higher capacity vehicles if demand warrants

3.19 Passenger Vehicle Transportation Award 2010

Fair Work Australia introduced the Commonwealth *Passenger Vehicle Transportation Award* on 1 January 2010. Subsequent amendments to the *Award* took effect on 21 June 2011. This modern national award replaced previous State specific awards (referred to as *Division 2B State Awards*) and has transitional arrangements in place effective up till 1 July 2014. The Commonwealth award applies throughout Australia to employees in the passenger transportation industry, defined by the *Award* as the transport of passengers by motor vehicle, limousine, hire car, bus, coach, electric tram, monorail or light rail vehicle. The *Award* does not apply to employees who are already covered by a modern enterprise award or an enterprise instrument commonly known as an *Enterprise Bargaining Agreement*.

Neither the making of this award nor the operation of its transitional arrangements was intended to result in a reduction in the net take-home pay of employees. The *Award* contains the minimum conditions of employment for employees and the monetary obligations imposed on their employers, but discharge of monetary obligations does not preclude any voluntary or employee negotiated over-award payments. Bus operators, for instance, may freely choose to provide monetary benefits above the minimum employee entitlements specified by the *Award*.

An employer and individual employee may agree to vary the application of certain provisions of the *Award* to meet the genuine needs of the employer and individual employee. The terms the employer and the individual employee may agree to vary are confined to:

- Arrangements for when work is to be performed,
- Overtime rates,
- Penalty rates,
- Allowances, and
- Leave loading.

It is understood that several *TransLink* bus operators have chosen to adopt the modern federal award, while most others have chosen to retain *Enterprise Bargaining Agreements* with their employees that were already in operation before the new federal award replaced existing State awards.

3.19.1 High Capacity Vehicle Allowance

Clause 15.1(b) of the *Passenger Vehicle Transportation Award 2010* stipulates that an employee required to drive an articulated bus during a shift will be paid an additional $10.00 allowance for that shift. This amounts to a 1.56% loading on the standard weekly rate defined in the *Award* for a Grade 3 employee earning $640/week. The award does not provide a precise definition of an articulated bus, but is reasonably assumed to exclude 14.5m rigid and double deck buses. It is understood that Brisbane Transport currently pays its bus drivers a 15% loading on shifts that include the driving of articulated buses, but it is unknown if this loading also currently applies to 14.5m rigid buses.

It is also uncertain whether bus drivers on the federal *Award* are paid the additional 1.56% for all shifts, regardless of whether an articulated or other high capacity vehicle was actually deployed on their respective shifts. Given allowances may be varied above the minimum set by the federal *Award*, some operators may choose for instance to pay all drivers who hold a HR class licence (refer Section 3.6.4.1) a high capacity bus shift allowance, as this would be an easier method of calculating the allowance payment when vehicle allocations are regularly changed on the day of operation.

We are also uncertain if other *TransLink* operators such as Thompson Bus Services, Surfside Bus Lines and Logan City Bus Service pay their high capacity vehicle drivers a HCV allowance or a pay loading, and forthcoming stakeholder interviews will attempt to ascertain this information.

3.19.2 Minimum Wage Rates for Drivers

The minimum wage rates for full-time adult drivers and other employees are prescribed in the federal *Award* for Grade 2 to Grade 6 employees inclusive. The *Award* also covers pay and conditions for part-time and casual employees and both are assumed to work less than 38 hours per week. Casual drivers attract an additional 25% loading over rates prescribed for full-time drivers of a similar grade.

The federal *Award* provides definitions for each grade of employee as summarised in Table 20 below. Grade 3 and higher drivers may operate heavy omnibuses and there is no distinction in these 4 *Award* classifications specifically given to drivers of high capacity buses.

Table 20: Driver Grades Defined in Passenger Vehicle Transportation Award

Grade	Description
Grade 2	A driver of a passenger vehicle with a carrying capacity of less than 25 school children to and/or from a school
Grade 3	An employee engaged in driving a passenger vehicle with a carrying capacity of 25 or more school children to and/or from school, or employee engaged in driving a passenger vehicle with a carrying capacity of less than 25 passengers on a specified route service which operates regularly between fixed terminals
Grade 4	Employees who efficiently operate passenger vehicles and issue tickets, balance and account for tickets and revenue, practice basic customer relations when providing information to passengers and the general public, inspect and monitor general conditions of the passenger vehicle, perform basic mechanical support duties and report and record information
Grade 5	An employee who - performs the duties of a driver with a sound understanding of operational work practices and procedures, performs activities of increasing complexity with some scope to exercise initiative in the application of established work procedures, may instruct other employees including on-the-job training, operates special services with a sound knowledge of the routes of other depots, instructs new drivers in route and passenger vehicle operations, inducts new drivers to aspects of depot operations and information, communicates with all types of customers with an advanced degree of courtesy and accuracy of information, and carries out duties associated with passenger surveys and service monitoring
Grade 6	Employees who are classified as supervisors and/or trainers and who perform more complex activities, which may require the exercise of knowledge and initiative in the application and establishment of work procedures. An employee at this level performs the duties of driver, plus as required, provides training, supervision, inducting and monitoring of trainee drivers, drives routes in other depots to cover vehicle schedules and assists in preparing rosters and amendments. This employee is required to have a customer service focus and is also required to provide support to operations officers at special events including supervision and coordination of transport movements, and is responsible for routine probationary service monitoring and assessment of new drivers

Most bus drivers operating *TransLink* urban routes would fall within the definition of Grade 4 employees or higher, given they already collect fares and issue tickets. Additional allowances are paid to drivers who supervise trainee drivers, but it is not known at this stage if this includes trainees on high capacity vehicles.

It would appear that minimum wage rates for junior bus drivers (aged 20 and under) are not applicable to bus drivers in Queensland, as the new Queensland driver licensing regime requires persons under 23 years of age to hold a learner's permit for 1 year, then a P1 licence for 1 year, a P2 licence for 2 years, and an open C or similar class license for another year before becoming eligible for a heavy vehicle licence.

3.19.3 Vehicle Allowance

The federal *Award* provides for employers to pay a vehicle allowance of $0.74/km however it does not provide a definition for the vehicle allowance and it is not clear if this applies to urban bus drivers or long distance coach drivers. This matter will also be clarified during stakeholder interviews.

3.19.4 Medical Examination Allowance

Bus drivers are expected to cover their own costs of obtaining a heavy vehicle licence and this expense is not normally covered by the operator but the federal *Award* provides for drivers to claim a *Medical Examination Allowance*. A medical examination is required by any employee applying for or renewing a heavy omnibus *Driver Authorisation* in Queensland and it is likely the *Medical Examination Allowance* would only apply to existing licence holders who need to apply for or renew their authorisations during work hours.

3.19.5 Fatigue Management

The *Award* sets out various rules on maximum hours of work which have presumably been aligned with those in the national heavy vehicle fatigue management regulations which will take precedence under future law. While there are no known fatigue management rules that would apply specifically to high capacity route bus drivers, HCV deployment in lieu of standard buses could reduce maximum HCV driver hours if considered necessary to contribute to improved driver fatigue management by bus operators.

Appendix A

Current DDA Exemptions for School Buses

Transport Standards Part	Comments
3.2 Access for passengers in wheelchairs	Requires that passengers with mobility aids must be able to enter and exit a conveyance (vehicle) and position their aids in allocated spaces, with or without the requested assistance of the bus driver
6.2 Boarding ramps	Specifies that a boarding ramp must comply with the relevant Australian Standard
6.3 Minimum allowable width (ramps)	-
6.4 Slope of external boarding ramps	Specifies the slope of boarding ramps, for both assisted and unassisted wheelchair access
8.2 When boarding devices must be provided	-
8.3 Use of boarding devices	Specifies that a boarding device must be provided at all designated bus stops
8.4 Hail-and-ride services	Specifies the use of boarding devices for Hail-and-ride services
8.5 Width and surface of boarding devices	-
8.6 Maximum load to be supported by boarding device	-
8.7 Signals requesting use of boarding device	-
8.8 Notification by passenger of need for boarding device	-
9.1 Minimum size for allocated space	-
9.4 Number of allocated spaces to be provided in buses	-
9.7 Consolidation of allocated parking spaces on vehicles	Suggests that allocated spaces should be consolidated
9.9 Use of allocated space for other purposes	Specifies that allocated spaces can be used for other purposes when not occupied
9.11 Movement of mobility aid in allocated space	Specifies that an allocated space must constrain movement of a mobility aid towards the front and sides of a conveyance (vehicle)
10.1 Compliance with Australian Standard (surfaces)	Specifies the ground and floor surface properties on conveyances (vehicles)
11.3 Handrails on steps	-
11.4 Handrails above access paths	-
11.5 Compliance with Australian Standards (grab rails)	Specifies that grab rails must comply with the relevant Australian Standard
11.6 Grab rails to be provided where fares are to be paid	-
11.7 Grab rails to be provided in allocated spaces	-
12.1 Doors on access paths	Requires that any doors along an access path not present a barrier to independent travel
12.4 Clear opening of doorways	-
12.6 Automatic or power-assisted doors	-
14.1 Stairs not to be sole means of access	-

Appendix B

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51 *Vehicle Standard (Australian Design Rule 65/00 – Maximum Road Speed Limiting for Heavy Goods Vehicles and Heavy Omnibuses) 2006*

52 *Vehicle Standard (Australian Design Rule 68/00 – Occupant Protection in Buses) 2006*

53 *Vehicle Standard (Australian Design Rule 80/03 – Emission Control for Heavy Vehicles) 2006*

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Appendix B

Compilation of Technical Notes of Infrastructure Assessments

Technical Note

Subject:	Assessment of Bus Station Infrastructure
Project:	Research and Analysis of High Capacity Vehicles
Our file:	4749 Date: 25 November 2012
Status:	Final Prepared by: RB, JV

Table of Contents

1. Introduction

1.1 Background

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

1.2 Purpose of this Technical Note

The main purpose of this technical not is to provide a high-level assessment of the suitability of existing bus station infrastructure to accommodate HCVs within the next five years (ie. by 2017). This assessment was developed using a sample of bus stations as discussed in the following section.

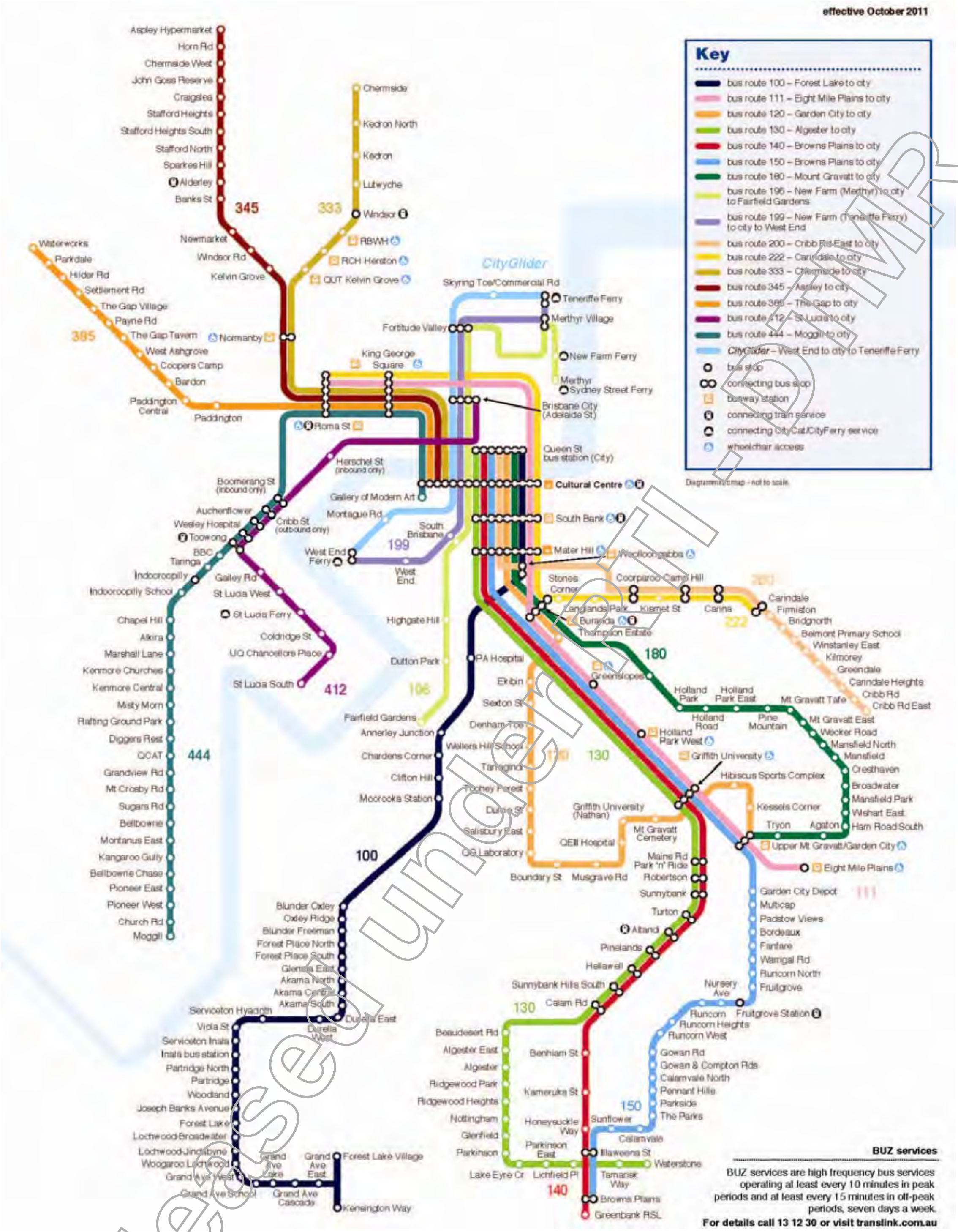
2. Station Infrastructure Assessment Methodology

To assess the impact HCVs might have on existing bus station infrastructure, the following assessment methodology was undertaken once bus stations along selected routes in the BUZ network were identified:

1. Assess manoeuvring at entry and exit point to the bus station from the external road network.
2. Assess manoeuvring around and through station.
3. Assess manoeuvring for entry and exit of each individual stop.
4. Determine if stops are adequate and if not can they be extended/reconstructed to accommodate buses.
5. Assess clearances and obstructions
6. Assess existing station infrastructure is clear of bus boarding areas

The assessments were conducted using aerial photography as station plans and design drawings were unavailable. The bus station infrastructure which was assessed was selected from the TransLink BUZ network as shown in the following figure.

Figure 1: TransLink BUZ Network



The following bus stations were assessed as a sample of SEQ's bus station infrastructure:

- Chermside
- Carindale
- Garden City
- Toombul
- Indooroopilly
- Aspley Hypermarket
- UQ Chancellors Place
- Inala Bus Station
- Capalaba
- Springwood
- Loganholme

3. Bus Station Infrastructure Assessment

3.1 Consolidated Summary of Findings

As part of this assessment, 69 bus stops were surveyed at eleven stations with the aggregated results presented in the following tables. For ease of reference the survey queries are grouped by general topic: shape, obstructions, turning, double-decker bus. The results are discussed below and presented in the following tables.

The majority of stops are either sawtooth 33% (or sawtooth island 12%), or island platform 22%. 62% of stops cannot be lengthened to accommodate 14.5 metre buses. A similar number, 64%, cannot be lengthened to accommodate 18m buses. However, for those stops at a station or park and ride with reserved bus standing or holdover bays 88% of bays are long enough and accessible for longer buses.

Nearly all stops do not have obstructions to the rear door, have a stop blade or sign that is clear of the kerb, and have a clear approach. Most stops allow a bus to stop parallel to a kerb, however 14% do not. Departure obstruction is a problem at 3% of stops, and a further 20% of stops would require an exit on full lock to clear obstructions. Of all stops 77% are clear of obstructions on exit. On entry or exit to the station there may be problems at 45% (five out of eleven) of the stations. A bus can enter and exit a stop safely at 55% of stops, with problems at 39%. Most kerbside areas have a hardstand area that is free of obstructions.

At 18% of stops the tail of a 14.5m bus would swing over the kerb or collide with street furniture. At 90% of stops a 14.5m rigid or 18m arctic bus would fit within the swept path turning template around a station for all road entries and exits. Only 7% of stops have hard left turns near an intersection, roundabout or island platform that would create difficulties when turning. Of all stops, 18% are underground or under a building and 4% pose a problem for entry by a double decker bus. At only 6% of stops are there double decker height clearance obstructions on arrival or departure sides of the stops

Stop Shapes and Lengths

Query	Item	#	Item	#	Item	#
Stop Shape	Central Platform	1.5%	Indented	2.5%	Indented in-line	8.5%
	In-line	8.5%	Island Platform	22%	Kerbside	12%
	saw tooth	33%	Sawtooth island	12%	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	38%	No	62%	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	36%	No	64%	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	88%	N/A	12%	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	98.5%	No	1.5%	---	---
Is Stop Blade or Sign clear of Kerb	Yes	98.5%	No	1.5%	---	---
Approach clear of obstructions	Yes	100%	No	0%	---	---
Departure clear of obstructions	Yes	77%	Problems on exit	3%	Only on full lock	20%
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	55%	No	39%	N/A	6%
Are there any obstructions for Buses entering or exiting Bus station	No	42%	Yes	46%	N/A	12%
Can bus stop parallel to kerb	Yes	86%	No	5.5%	N/A	8.5%
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	90%	No	10%	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	23%	No	65%	N/A	12%

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	18%	No	66%	N/A	16%
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	90%	No	10%	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	7%	No	93%	---	---

Double decker buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	14%	No	4%	N/A	82%
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	6%	No	94%	---	---

3.2 Summary of Findings by Station

The following is a review of bus stops by station.

3.2.1 Chermside Station

Chermside Station has 5 stops; all are island platforms. Three stops can be lengthened to accommodate 14.5m buses and 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter and exit the stop safely at 3 stops. Road works are required at Hamilton Rd intersection and internal road for buses to enter and exit safely at the other stops. The buses can stop parallel to the kerb at 3 stops.

At two stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. The left turn from Hamilton Rd requires a hard left turn that would cause the body skirt of a turning 14.5m bus to cross the island platform. There are no obstructions at the third rear door on the 18m arctic superbus.

There are no height clearance obstructions on arrival or departure sides of the stop.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Island Platform	5	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	2	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	2	No	3	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	5	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	5	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	5	No	0	Empty	0
Approach clear of obstructions	Yes	5	No	0	Empty	0
Departure clear of obstructions	Yes	5	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	3	No	2	N/A	0

Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	5	N/A	0
Can bus stop parallel to kerb	Yes	3	No	2	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	2	No	3	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	5	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	5	No	0	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	5	No	0		
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	5	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	5
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	5	---	---

3.2.2 Carindale Station

Carindale Station has 10 stops; all of which are sawtooth. Six stops can be lengthened to accommodate 14.5m buses and 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter the stops safely at 10 stops, but full lock is required for safe exit. If there is a bus in stop E, it is possible that the entrance to the station could be blocked. The buses can stop parallel to the kerb at 9 stops.

At 6 stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There is a column in the hardstand area at 4 stops that may obstruct passengers boarding. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. There are no obstructions at the third rear door on the 18m arctic superbus for the 5 stops where this applies.

A double decker bus is able to enter all stops. There are no height clearance obstructions on arrival or departure sides of the stop.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Sawtooth	10	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	6	No	4	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	6	No	4	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	10	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	10	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	10	No	0	Empty	0
Approach clear of obstructions	Yes	10	No	0	Empty	0
Departure clear of obstructions	Yes	0	Problems on exit	0	Only on full lock	10
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	6	No	0	N/A	4

Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	10	N/A	0
Can bus stop parallel to kerb	Yes	9	No	1	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	6	No	0	N/A	4
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	10	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	10	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	4	No	6	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	5	N/A	5

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	10	No	0	N/A	0
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	10	---	---

3.2.3 Garden City Station

Garden City Station has 15 stops; 5 are sawtooth, 4 are island platform and 6 are indented inline. 12 stops can be lengthened to accommodate 14.5m buses and 18m buses. Of all stops, 14 reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter the stops safely at 10 stops, and safely exit at 9. The exit taper at one stop is not long enough. From 6 stops buses can safely enter and exit the station. At 9 stops the manoeuvring room is tight if there is a bus in stop A. The buses can stop parallel to the kerb at all stops.

At 2 stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Inline	5	Island Platform	4	Indented Inline	6
Can stop be lengthened accommodate 14.5m Buses	Yes	12	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	12	No	3	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	14	N/A	1	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	15	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	15	No	0	Empty	0
Approach clear of obstructions	Yes	15	No	0	Empty	0
Departure clear of obstructions	Yes	13	Problems on exit	2	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	11	No	4	N/A	0

Are there any obstructions for Buses entering or exiting Bus station	No	6	Yes	9	N/A	0
Can bus stop parallel to kerb	Yes	15	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	2	No	13	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	15	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	15	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	15	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	15	N/A	

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	15
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	15	---	---

3.2.4 Toombul Station

Toombul Station has 6 stops; all are island platform. No stops can be lengthened to accommodate 14.5m buses and 18m buses. Reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses at all stops.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The 14.5m and 18m buses cannot manoeuvre into stops.

A 14.5 or 18m arctic bus will not fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are obstructions at no stops for the third rear door on the 18m arctic superbus.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Island Platform	6	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	0	No	6	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	0	No	6	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	6	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	6	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	6	No	0	Empty	0
Approach clear of obstructions	Yes	6	No	0	Empty	0
Departure clear of obstructions	Yes	6	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	0	No	6	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	0	N/A	6
Can bus stop parallel to kerb	Yes	0	No	0	N/A	6

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	0	N/A	6
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	0	No	6	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	6	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	6	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	6	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	6
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	6	---	---

3.2.5 Indooroopilly Station

Indooroopilly Station has 1 central platform and 2 kerbside stops. 2 stops can be lengthened to accommodate 14.5m buses and 18m buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter the stops safely at all stops, and safely exit at all stops. From 3 stops buses can safely enter and exit the station. The buses can stop parallel to the kerb at all stops.

At no stops will the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are obstructions at no stops for the third rear door on the 18m arctic superbus.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Central Platform	1	Kerbside	2	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	2	No	1	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	2	No	1	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	0	N/A	3	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	3	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	3	No	0	Empty	0
Approach clear of obstructions	Yes	3	No	0	Empty	0
Departure clear of obstructions	Yes	3	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	3	No	0	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	3	Yes	0	N/A	0

Can bus stop parallel to kerb	Yes	3	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	3	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	3	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	3	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	3	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	3	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	3	N/A	0
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	3	---	---

3.2.6 Aspley Hypermarket Station

Aspley Hypermarket Station has 4 sawtooth stops. 1 stop can be lengthened to accommodate 14.5m buses and 18m buses. At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. If there is a 14.5m or articulated bus in the front stop buses cannot leave. Buses in stop D can block the entrance to the station. The buses can stop parallel to the kerb at all stops.

At no stops will the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There one stop there is an obstruction for the third rear door on the 18m arctic superbus.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Saw Tooth	4	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	1	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	1	No	3	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	0	N/A	4	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	4	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	4	No	0	Empty	0
Approach clear of obstructions	Yes	4	No	0	Empty	0
Departure clear of obstructions	Yes	4	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	0	No	4	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	4	N/A	0
Can bus stop parallel to kerb	Yes	4	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	4	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	4	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	4	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	4	No		---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	1	N/A	3

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	4
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	4	---	---

3.2.7 UQ Chancellors Place Station

UQ Chancellors Place Station has 5 sawtooth stops. No stops can be lengthened to accommodate 14.5m buses or 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions, the blade or sign is clear of the kerb, and the approach and departure are clear of obstruction. The bus can enter the stops safely at all stops, and safely exit. From all stops buses can safely enter and exit the station. The buses can stop parallel to the kerb at all stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are no obstructions for the third rear door on the 18m arctic superbus.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Sawtooth	5	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	0	No	5	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	0	No	5	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	5	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	5	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	5	No	0	Empty	0
Approach clear of obstructions	Yes	5	No	0	Empty	0
Departure clear of obstructions	Yes	5	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	5	No	0	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	5	Yes	0	N/A	0

Can bus stop parallel to kerb	Yes	5	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	5	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	5	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	5	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	5	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	5	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	5
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	5	---	---

3.2.8 Inala Station

Inala Station has 1 inline and 4 sawtooth stops. Two stops can be lengthened to accommodate 14.5m buses and 1 stop can be lengthened to accommodate 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions and the blade or sign is clear of the kerb at 4 stops. The approach and departure are clear of obstruction at 5 stops. At two stops buses can enter and exit safely. At 3 stops buses cannot exit if a 14.5 metre or arctic bus is in the front stop. If there is a 14.5m bus or an arctic bus in stops B or C buses cannot pass on entry and exit to the station. The buses can stop parallel to the kerb at all stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At 4 stops there is clear hardstand area for passenger boardings, while the hardstand area is very narrow at one stop. There are no obstructions for the third rear door on the 18m arctic superbus at 4 stops, while there is a garden bed obstructing at one stop.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Inline	1	Sawtooth	4	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	2	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	1	No	4	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	5	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	4	No	1	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	4	No	1	Empty	0
Approach clear of obstructions	Yes	5	No	0	Empty	0
Departure clear of obstructions	Yes	5	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	2	No	3	N/A	0

Are there any obstructions for Buses entering or exiting Bus station	No	0	Yes	4	N/A	1
Can bus stop parallel to kerb	Yes	5	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	5	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	5	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	5	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	4	No	1	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	1	No	4	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	5
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	5	---	---

3.2.9 Capalaba Station

Capabala Station has 5 kerbside stops. 1 stop can be lengthened to accommodate 14.5m buses and 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions and the blade or sign is clear of the kerb. The approach and departure are clear of obstruction at all stops. At all stops buses can enter and exit safely. There are no obstructions to buses entering and exiting the station. Buses can stop parallel to the kerb at all stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. A 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are no obstructions for the third rear door on the 18m arctic superbus.

There are restrictions for double decker buses in relation to height clearance at 4 stops where the awning is close to the kerb.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Kerbside	5	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	1	No	4	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	1	No	4	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	5	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	5	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	5	No	0	Empty	0
Approach clear of obstructions	Yes	5	No	0	Empty	0
Departure clear of obstructions	Yes	5	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	5	No	0	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	5	Yes	0	N/A	0

Can bus stop parallel to kerb	Yes	5	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	5	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	5	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	5	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	5	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	5	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	5
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	4	No	1	---	---

3.2.10 Springwood Station

Springwood Station has 2 indented and 1 kerbside stops. No stops can be lengthened to accommodate 14.5m buses or 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions and the blade or sign is clear of the kerb. The approach and departure are clear of obstruction at all stops. At two stops buses can enter and exit safely. The remaining stop is not long enough. There are no obstructions to buses entering and exiting the station. Buses can stop parallel to the kerb at 2 stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. At 2 stops a 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits, while at the remaining stop the rear of a bus would stick out. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are no obstructions for the third rear door on the 18m arctic superbus at any stop.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Indented	2	Kerbside	1	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	0	No	3	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	0	No	3	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	3	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	3	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	3	No	0	Empty	0
Approach clear of obstructions	Yes	3	No	0	Empty	0
Departure clear of obstructions	Yes	3	Problems on exit	0	Only on full lock	0
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	2	No	1	N/A	0
Are there any obstructions for Buses entering or exiting Bus station	No	3	Yes	0	N/A	0

Can bus stop parallel to kerb	Yes	2	No	1	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	2	No	0	N/A	1
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	2	No	1	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	3	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	3	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	3	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	0	N/A	3
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	3	---	---

3.2.11 Loganholme Station

Loganholme Station has 8 sawtooth island platform stops. No stops can be lengthened to accommodate 14.5m buses or 18m buses. All reserved bus standing or holdover bays are long enough and accessible for 14.5m rigid, 18m arctic and 12.5m double decker buses.

At all stops the rear door is clear of obstructions and the blade or sign is clear of the kerb. The approach and departure are clear of obstruction at all stops, though departure requires full lock at 4 stops. At 1 stop buses can enter and exit safely. At 4 stops full lock is required to depart and if an articulated bus or a 14.5m bus is in the stop in front then the departure is blocked. 3 stops are too short for the arctic bus. There are no obstructions to buses entering and exiting the station. Buses can stop parallel to the kerb at all stops.

At no stops the tail of a 14.5m bus will swing out over the kerb unsafely or collide with street furniture on full lock. At 8 stops a 14.5 or 18m arctic bus will fit within the swept path turning template around the station from all road entries and exits. There are no hard turns, roundabouts or island platforms that would cause the body skirt of a turning 14.5 m bus to cross the island or platform kerb. At all stops there is clear hardstand area for passenger boardings. There are no obstructions for the third rear door on the 18m arctic superbus at any stop.

There are no restrictions for double decker buses in relation to height clearance.

Stops

Query	Item	#	Item	#	Item	#
Stop Shape	Sawtooth island platform	8	---	---	---	---
Can stop be lengthened accommodate 14.5m Buses	Yes	0	No	8	---	---
Can stop be lengthened accommodate 18.0m Buses	Yes	0	No	8	---	---
If a station or park 'n ride with reserved bus standing or holdover bays, are the bays long enough and accessible for 14.5m rigid, 18.0m artic and 12.5m double deck buses	Yes	8	N/A	0	---	---

Obstructions

Query	Item	#	Item	#	Item	#
Is rear door clear of obstructions	Yes	8	No	0	Empty	0
Is Stop Blade or Sign clear of Kerb	Yes	8	No	0	Empty	0
Approach clear of obstructions	Yes	8	No	0	Empty	0
Departure clear of obstructions	Yes	4	Problems on exit	0	Only on full lock	4
Can bus enter and exit stop safely. (14.5m & 18.0m)	Yes	1	No	7	N/A	0

Are there any obstructions for Buses entering or exiting Bus station	No	7	Yes	0	N/A	1
Can bus stop parallel to kerb	Yes	8	No	0	N/A	0

Turning

Query	Item	#	Item	#	Item	#
Would the tail of a 14.5m bus swing out over the kerb unsafely or collide with street furniture on full lock	Yes	0	No	8	N/A	0
Will a 14.5m rigid or 18.0m artic bus fit within the swept path turning template around station from all road entries to all road exits	Yes	8	No	0	---	---
Are there any hard left turns at a near intersection, roundabout or island platform of a station that would cause the body skirt of a turning 14.5m bus to cross the island or platform kerb	Yes	0	No	8	---	---
Is the kerbside area used by passengers to board and exit all doors a hardstand and free of obstructions	Yes	8	No	0	---	---
Are there third rear door obstructions on the 18.0m artic superbus	Yes	0	No	8	N/A	0

Double Decker Buses

Query	Item	#	Item	#	Item	#
If an underground or under building station, will a double decker bus be able to enter	Yes	0	No	8	N/A	0
Are there any other double decker bus height clearance obstructions on the arrival or departure sides of the stop	Yes	0	No	8	---	---

4. Summary and Conclusions

This technical note reviews a sample of bus stations to represent SEQs infrastructure. This analysis included a total of 69 stops and was for the following stations:

- Chermside
- Carindale
- Garden City
- Toombul
- Indooroopilly
- Aspley Hypermarket
- UQ Chancellors Place
- Inala Bus Station
- Capalaba
- Springwood
- Loganholme

Our analysis of stations was based on a desktop analysis of aerial photos and plans where available. While suitable for a high level analysis of a network, an on-site review of each station is recommended to verify our results on the ground prior to confirming any routes or operations for HCVs.

Key aggregate findings are outlined here:

- About two thirds of stops cannot be lengthened to accommodate 14.2 or 18 metre buses.
- Nearly all reserved bus standing or holdover bays are long enough and accessible for HCVs.
- Nearly all stops do not have obstructions at the rear door, a stop blade/sign that is obscured.
- Nearly all stops offer a clear approach, however 20% of stops require exit on full lock and a further 3% present obstruction on exit.
- Slightly over half of stops are located in stations where there are no obstacles to entry and exit of the station.
- Buses can enter and exit 55% of stops safely.
- At 18% of stops, the tail of a 14.5m bus would swing over the kerb or collide with street furniture.
- At 90% of stops a 14.5m or 18m arctic bus would fit within the swept path turning template around a station for all road entries and exits.
- Double decker buses do not have problems for height clearance at most stops.

The ability for the stations along existing BUZ routes to accommodate HCVs without upgrades varies considerably. Route planning will need to be influenced by a ground-verified knowledge of the capacity of individual stops to accommodate HCVs that this technical note begins to deliver.

Attachment 1: Audit Results

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Technical Note

Subject:	Impact of HCV Loadings on Pavement Performance
Project:	Research and Analysis of High Capacity Vehicles
Our file:	4749 Date: 26 November 2012
Status:	Final Prepared by: BP

Table of Contents

1. Introduction

1.1 Background

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

1.2 Purpose of this Technical Note

The main purpose of this technical note is to provide a high-level discussion of the impacts that HCVs would have on pavements.

2. Impacts of HCVs on the Pavement Deterioration

Pavement designs are based on the cumulative number of heavy vehicles in the design lane. In some cases the design lane may not be the most heavily trafficked lane, such as when designing inside widening of a multi-lane carriageway.

Different types of vehicles cause different types of damage to pavements. Vehicle loading damage on highway pavement corresponds closely to axle weight and configuration.

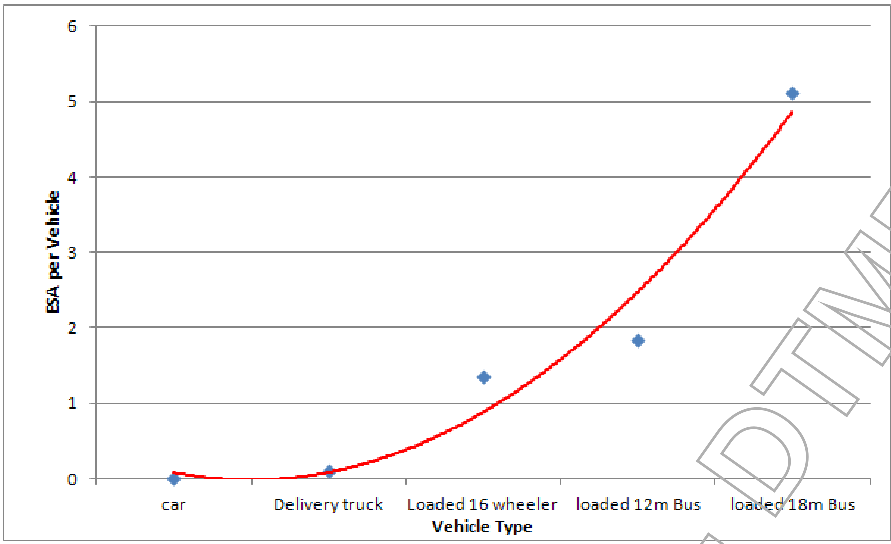
Many studies have been done to reveal the relationship between trucks and pavement damage which can be used to inform the impacts of HCVs will have on pavements. Suspension type and characteristics, as well as tire type and configuration, are major contributors to pavement deterioration.

2.1.1 HCV Pavement Failure

The factors that contribute to failure for flexible pavements can generally be categorized in two groups; vehicle factors and pavement factor. Most arterial and collector pavement deterioration is associated with vehicle use or loads. Loads are the vehicle forces exerted on the pavement by automobiles, trucks and buses. These forces create stress and deformation within the pavement structure. Repeated loading creates fatigue and resulting distress in the pavement. Excessive loading can lead to rapid deterioration of the pavement structure evidenced by cracking and distortion of the pavement surface. Damage caused by vehicles goes up exponentially with weight. A single large truck can cause as much damage as several thousand automobiles.

Buses typically have an even larger load impact than heavy trucks due to the limited number of axles and tires they employ to distribute their weight. The increase in damage level with load is not linearly proportional. It takes the shape of the exponential function with a power constant value range from 4 to 6. Under the fourth power rule one bus overloaded by 25% does as much damage to the road as two buses. This is shown in the following figure which presents the number of equivalent standard axles (ESAs) for different vehicle types.

Figure 1: Equivalent Standard Axle Loadings for Different Vehicle Types



2.1.2 Increased Loads Accelerate Pavement Failure

The loads imposed by vehicles on Brisbane streets have increased historically both in magnitude and frequency. Industry efficiencies have led to an increase in the size of trucks and their loads. Truck demand has increased rapidly. Arterial streets that serve Brisbane's industrial areas have the highest volume of medium and heavy truck trips today and in the future. Brisbane surface streets carry much of the truck freight that access Port facilities and truck freight terminals.

With anticipated increasing demand for public transport the frequency of bus movements is expected to increase. The sum result of these factors is an increased load demand on key freight routes and transit corridors and accelerated pavement failure.

2.1.3 Growth rate and cumulative traffic volumes

In accordance with recent growth and the predicted doubling of the road freight task from 2000 to 2020 (DOTARS, 2002), all motorways (including ramps), highways and arterial roads are required to be designed with a minimum heavy vehicle growth rate of 4% per annum, unless detailed traffic modelling is undertaken which specifically considers the future freight task for the pavement being designed.

Buses are also classified as heavy vehicles, and research has shown that heavy vehicles are mainly responsible for pavement damage and costs incurred to rectify the damage. Buses differ from trucks in load distribution, suspension, and travel characteristics. Buses do cause significant damage on pavements, which based on the estimated bus ESA's is often comparable to the damage caused by trucks.

Buses have a unique travel characteristic: they frequently stop at bus stops. Research has shown that this action causes great damage to the pavement at bus stops.

The number of ESA's that a pavement can carry decreases with a decrease in speed. Thus, at sections where HCV buses stop, the pavement will deteriorate faster compared with other sections of the road.

AUSTROADS (2004a) defines a standard axle as a Single Axle with Dual Tyres (SADT) applying a load of 80 kN to the pavement. This load is applied over four tyres so each tyre is providing a downward force of 20 kN. Huang (2004) provides a calculation to determine the contact area of each tyre. Following AUSTROADS in assuming a tyre pressure of 750 kPa the equation determines a contact area of 0.0267 m2, or an equivalent rectangle of 136 mm by 197 mm, Pavement design is directly influenced by the expected number of heavy axle loadings, as opposed to the gross vehicle weight, as multiple axles help spread the load on the pavement and reduce the impact. However, loading is not even across axles, and typically the rear axle on a two-axle vehicle will carry 70 to 75 percent of the gross vehicle weight. Note that even small increases in weight on an axle can cause disproportionately large amounts of damage to the pavement structure.

For the purposes of design, the traffic volume is represented by the number of equivalent standard axles (ESAs) typically using a design period of 20 years for flexible pavements and 40 years for concrete pavements. When comparing different pavement structures, a whole-life analysis of the alternatives is required to produce an equitable comparison.

Because it has been well established that light vehicles contribute very little to structural deterioration, only heavy vehicles are considered in pavement design. Traditionally, the term 'commercial vehicle' has been used to denote these vehicles. In conformance with Austroads terminology, the term 'heavy vehicle' is now adopted. The damage caused to a pavement by the passage of a heavy vehicle depends not only on its gross weight but also on how this weight is distributed to the pavement. In particular, it depends on:

- the number of axles on the vehicle
- the manner in which these axles are grouped together – into axle groups
- the loading applied to the pavement through each of these axle groups – the axle group load.

For pavement design purposes, the following (heavy vehicle) axle group types are identified:

- single axle with single tyres (SAST)
- single axle with dual tyres (SADT)
- tandem axle with single tyres (TAST)
- tandem axle with dual tyres (TADT)
- tri-axle with dual tyres (TRDT)
- quad-axle with dual tyres (QADT).

2.2 Assumed Pavement Types

Pavement materials can be classified into essentially four categories according to their fundamental behaviour under the effects of applied loadings:

- Unbound granular materials, including modified granular materials
- Bound (cemented) granular materials
- Asphaltic Concrete
- Cement Concrete

The surfacing materials can also be classified into essentially three categories or types:

- Sprayed bituminous seals
- Asphaltic concrete and bituminous micro-surfacing
- Cement Concrete

However the granular pavement comprises the majority of the Brisbane Council road network as it is considered to provide the lowest whole of life costs and enables ready access for installation and maintenance of utilities. The design life for flexible pavements is 20 years while the design life for rigid pavements is 40 years. Arterial routes which serve as bus routes must be designed for the estimated traffic loads derived from approved traffic studies with a minimum traffic loading of 3.7×10^6 equivalent standard axles for road type F and 1.0 x 10^7 equivalent standard axles for road type G. Similarly, suburban routes serving as bus routes must have a minimum traffic loading of 7.5 x 10^5 equivalent standard axles.

2.3 Impacts of HCV's on the Design Life

When the axle mass limits as outlined above are applied to the Standard Axle Repetition formula as outlined in the *Pavement Design Guide (Austroads, 2004a)* it becomes quite clear that the equivalent design axles for the proposed HCV buses increase significantly and could prematurely decrease (by up to 5 years) the design life of the pavement resulting in increased maintenance. In particular where chosen HCV routes are 75% of their design life they should undergo specific pavement evaluation to determine their current condition status.

3. Summary and Conclusions

The performance of HCV route pavements will be a function of load frequency and existing pavement design life. In order to combat the significant surface stresses of the setdown areas these should be constructed in concrete.

Pavement deterioration caused by HCVs will accelerate the need for greater pavement maintenance and a comprehensive Pavement Management program should be established to confirm whole of life costs for pavement rehabilitation or reconstruction.

Attachment 1: Legislated Axle Mass Limits

The following tables provide the axle mass limits proposed for the various bus configurations (as identified in the Legislation and Policy Background Report completed as part of this study).

Table 2: Permitted Axle Mass Limits for 2 Door 12.5m Standard Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Buses)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Buses)
Rear Drive Axle with Dual Tyres	10t (High Floor) 11t (Ultra-Low Floor)	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	15t (High Floor) 16t (Complying or Ultra-low Floor)	No Higher Mass Limit Permitted	15t (High Floor) 16t (Complying or Ultra-low Floor)

Table 3: Permitted Axle Mass Limits for 2 Door 14.5m Extended Rigid Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Upper Limit	Draft Heavy Vehicle National Regulation General Mass Limit
Front Steer Axle with Single Tyres	Non-Compliant	No Higher Mass Upper Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Tandem Axle Group with Dual Drive Tyres and Single Steer Axle with Single Tyres	Non-Compliant	14t **	13t ** (Standing Permitted) 14t ** (Complying Bus)
Gross Mass	Non-Compliant	20t	19t (Standing Permitted) 20t (Complying Bus)

Table 4: Permitted Axle Mass Limits for 2 Door 12 - 12.5m Double Deck Route Bus

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limit	Draft Heavy Vehicle National Regulation General Mass Limit
<<< Single Steer Front Axle >>>			
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Drive Dual Tandem Axle Group Fitted with Two Tyres	16.5t **	17t **	16.5t **
Gross Mass	22.5t	23t	22.5t
<<< Twin Steer Front Axle >>>			
Twin Steer Front Axle with Single Tyres	10t (Non-Load Sharing) 11t (Load Sharing)	No Higher Mass Limit Permitted	10t (Non-Load Sharing) 11t (Load Sharing)

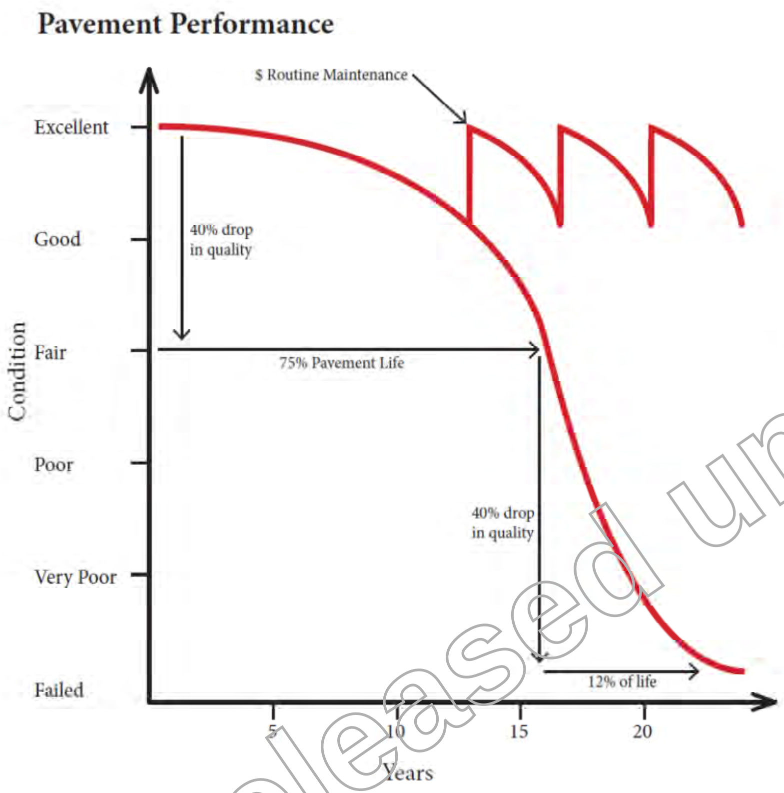
Rear Drive Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t
Gross Mass	20t	No Higher Mass Limit Permitted	20t (Non-Load Sharing) 21t (Load Sharing)

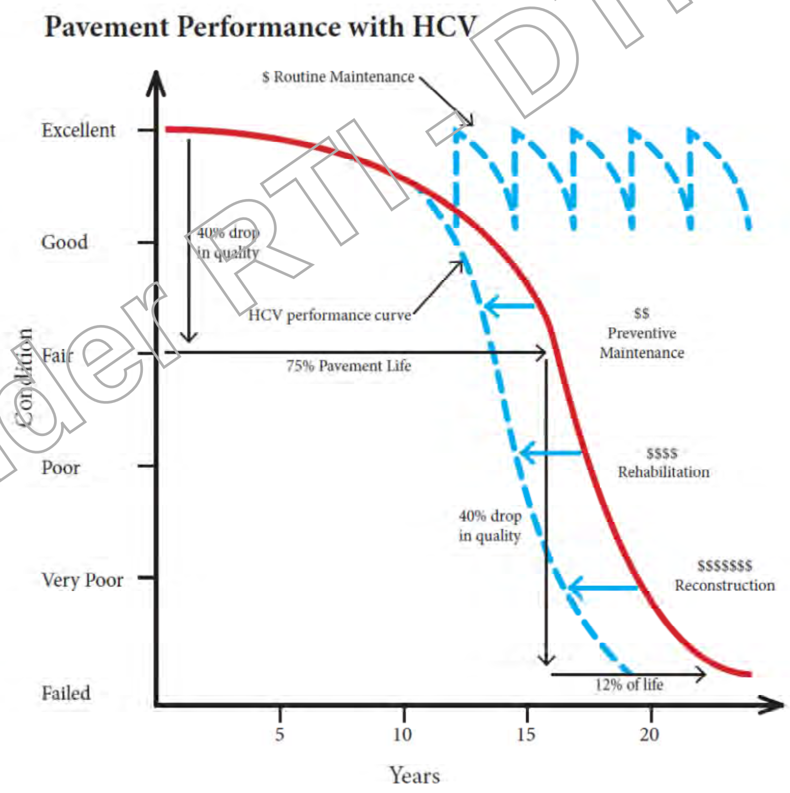
**S55 of the Queensland Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010 stipulates that heavy omnibus axles in an axle group other than a twin steer axle group must relate to each other through a load-sharing suspension system with effective damping characteristics on all axles of the group such that no axle carries over 10% more than the mass it would carry if the load was divided equally.

Table 5: Permitted Axle Mass Limits for 2 and 3 Door 18m Articulated Buses

Axle or Axle Group	Current Transport Operations (Mass, Dimensions and Loading) Regulation Mass Limit	Draft Heavy Vehicle National Regulation Higher Mass Limits	Draft Heavy Vehicle National Regulation General Mass Limits
Front Steer Axle with Single Tyres	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Mid Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Rear Axle with Single Steer Tyres (High Floor)	6t (Standing Permitted) 6.5t (Complying Bus)	No Higher Mass Limit Permitted	6t (Standing Permitted) 6.5t (Complying Bus)
Rear Axle with Dual Tyres	10t	No Higher Mass Limit Permitted	10t (High Floor) 11t (Ultra-Low Floor)
Gross Mass	22t	No Higher Mass Limit Permitted	22t (High Floor) 26t (Ultra-low Floor)

Attachment 2: Example Illustration of the Impact of HCVs on Pavements and Maintenance





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Technical Note

Subject:	Assessment of Bus Stop Infrastructure		
Project:	Research and Analysis of High Capacity Vehicles		
Our file:	4749	Date:	26 November 2012
Status:	Final	Prepared by:	RB, JV

Table of Contents

1. Introduction

1.1 Background

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis of high capacity vehicle *(HCV)* use within the *TransLink* network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in use or on trial in its network and include:

- Two Door 12m - 12.5m Double Deck Buses,
- Two Door 14.5m Rigid Buses,
- Two Door 18m Articulated Buses, and
- Three Door 18m Articulated *Superbuses*.

1.2 Purpose of this Technical Note

The main purpose of this technical note is to provide a high-level assessment of the suitability of existing bus stop infrastructure to accommodate HCVs within the next five years (i.e. by 2017). This estimate was developed using a sample of bus routes as is discussed in the following section.

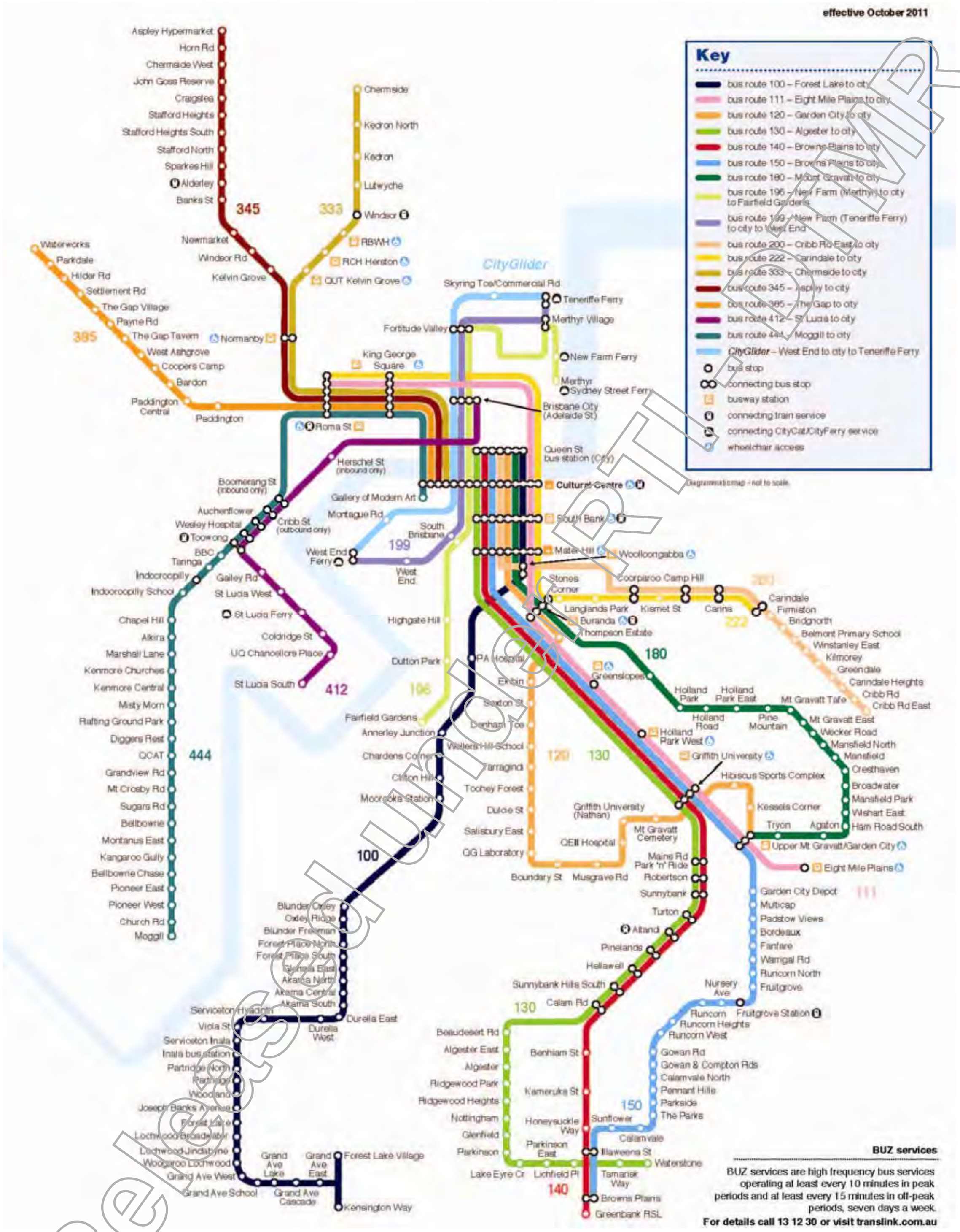
2. Infrastructure Assessment Methodology

To assess the impact HCVs might have on existing bus stop infrastructure, the following assessment methodology was undertaken.

1. All bus stops along selected routes in the BUZ network were identified
2. The type of bus stop was identified using Chapter 2 of the Public Transport Infrastructure Manual (June 2007)
3. The ability for HCVs to enter and exit stops was assessed using AutoTURN software with a TransLink 14.5m Rigid Bus Tag Steer as the design vehicle.
4. Using available aerial imagery, the following attributes of each bus stop were assessed:
    a. The stop shape, length, length of any tapers using available aerial imagery
    b. Pavement line marking
    c. Whether the stop could be lengthened. If it was possible, to what length could it be extended? Could it be lengthened to 65m to allow a 14.5m rigid and an 18m articulated bus to park together and easily manoeuvre out of the stop?
    d. Whether the rear door of the bus was clear of obstructions
    e. If the Stop Blade or Sign was clear of the kerb
    f. If the rubbish bin was clear of the kerb
    g. Were the approaches and departures clear of obstructions
    h. Could the bus stop allow a 14.5m rigid enter and exit the stop safely? (Where bus stops were not clearly marked out, it was assessed whether bus stops could be lengthened to allow the design vehicle to exit safely.
    i. Could the bus stop allow
    j. Were there Regulatory signs before and after the bus stop
    k. Could the bus stop parallel to the kerb
    l. Did the bus stop have a hardstand area clear of obstructions for all doors
    m. Any general observations made.

The bus stop infrastructure which was assessed was selected from the TransLink BUZ network as shown in the following figure. The routes within the BUZ network were considered to provide a reasonable sample of routes which are likely to run HCVs within the next five years.

Figure 1: TransLink BUZ Network



The bus stops on the following BUS routes were assessed as a sample of SEQ's bus stop infrastructure:

- Bus route 100 – Forest Lake to city
- Bus route 140 – Brown Plains to city
- Bus route 150 – Brown Plains to city
- Bus route 130 – Algester to city

- Bus route 120 – Garden City to city
- Bus route 180 – Mount Gravatt to city
- Bus route 385 – The Gap to City

3. Bus Stop Infrastructure Assessment

3.1 Summary of findings

As part of this assessment, 444 bus stops were surveys and the aggregated results are as follows:

Aggregated Survey Results

Stop Type	Regular	91%	Premium	8%	No image	0%
Stop Shape	Kerbside	88%	Indented	9%	Indented(other)	3%
Can the stop be lengthened?	Yes	19%	No	31%	N/A	50%
Is rear door clear of obstructions?	Yes	76%	No	15%	No image	9%
Is Stop Blade or Sign clear of Kerb?	Yes	95%	N/A	2%	No image	3%
Is approach clear of obstructions?	Yes	99%	No	1%	N/A	0%
Is departure clear of obstructions?	Yes	99%	No	1%	N/A	0%
Can the bus stop allow buses to enter and exit safely?	Yes	99%	No	1%	N/A	0%
Can bus stop parallel to kerb?	Yes	99%	No	1%	N/A	0%
Does the stop have a hardstand area clear of obstructions for all doors?	Yes	31%	No	21%	N/A	0%
	Front only	42%	No hardstand	1%		
Is the bus stop >=65m length?	Yes	0%	No	37%	N/A	63%
If the bus stop can be extended, can the stop be extended to 65m?	Yes	49%	No	46%	N/A	5%
Are there road markings at the stop?	No	77%	Rear only	4%	No image	4%
	Both front and rear	12%	Front only	3%		

Of the 444 stops, 8% are premium and the rest are regular stop types. The stop shape most common is kerbside, with only 12% being indented. We were only able to determine that 19% of stops can be lengthened.

The rear door was identified as being clear of obstructions in 76% of stops, while it was obstructed in 15%. The air photos did not reliably show the balance of stops. Nearly all stops were clear of obstructions on approach and departure and allowed a bus to enter and exit the stop safely. Also at nearly every stop, the bus could stop parallel to the kerb.

Nearly one third of all stops had a hardstand area clear of obstruction for all doors, with 21% being obstructed. At 42% of stops only the front doors were clear of obstructions.

No stops were identified as being longer than 65 metres which would make them capable of use by HCV. However half of stops could be extended to 65m. At 77% of stops there were no road markings, while 12% had markings at both rear and front.

3.2 Bus route 100 – Forest Lake to City

Route 100 travels from Forest Lake to the City and has 68 total stops. Most of the stops are regular, while three of them are premium stops. Most stops are kerbside stops, while only 11 are indented. There are no turnaround stops. For only 16 stops was it able to be determined that they could be lengthened. For 51 stops we were unable to determine this.

For 66 stops it was determined that the rear door was clear of obstructions. For all stops it was determined that the stop blade or sign is clear of the kerb. Also for all stops it was determined that the approach and departure are clear of obstacles. Only one stop presented difficulties for a bus safely entering or exiting the stop. Only one stop presented difficulties for a bus stopping parallel to a kerb.

Only 16 stops have a hardstand area clear of obstruction for all doors, while 34 had a front only hardstand. There are 15 stops without a hardstand clear of obstruction for all doors.

Of all stops 21 are less than 65 metres in length. It appears 38 stops can be extended to 65 metres, while 28 cannot. There are no road markings at 53 stops, both front and rear markings at 11 and rear only at 2.

Route 100

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	65	Premium	3	Park&Ride	0	No image	0
Stop Shape	Kerbside	57	Indented	11	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	16	No	1	N/A	51	No image	0
Is rear door clear of obstructions	Yes	66	No	2	N/A	0	No image	0
Is Stop Blade or Sign clear of Kerb	Yes	68	No	0	N/A	0	No image	0
Approach clear of obstructions	Yes	68	No	0	N/A	0	No image	0
Departure clear of obstructions	Yes	68	No	0	N/A	0	No image	0
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	67	No	1	N/A	0	No image	0
Can bus stop parallel to kerb	Yes	67	No	1	N/A	0	No image	0
Does the stop have a hardstand area clear of obstructions for all doors	Yes	16	No	15	N/A	0	No image	0
	Front Only	34	No Hardstand	0	None	3	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	21	N/A	47		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	38	No	28	N/A	2		
Are there road markings at the stop?	No	53	Rear only	2	N/A	2		
	Both front and rear	11	Front only	0				

3.3 Bus route 140 – Brown Plains to City

Bus route 140 travels from Brown Plains to the City, with 32 stops. Of all stops 29 are regular, 1 is premium and 2 are park and rides. Of these 30 are kerbside stops, while 2 are indented.

Only 15 stops were determined to be able to be lengthened, while 6 were not. There were 11 stops where we could not determine this. All stops had a rear door clear of obstructions, an approach and departure clear of obstructions. For all stops a bus was determined to be able to safely enter and exit the stop safely and the bus could stop parallel to the kerb.

Of all stops 21 had a hardstand area clear of obstructions for all doors, while 2 did not. There were 9 stops that had a clear hardstand area for front doors only. 17 stops could not be lengthened while we could not determine this for the remainder.

Of all stops 17 are less than 65 metres in length. It appears 15 stops can be extended to 65 metres, while 13 cannot. There are no road markings at 16 stops, both front and rear markings at 12.

Route 140

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	29	Premium	1	Park&Ride	2	No image	0
Stop Shape	Kerbside	30	Indented	2	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	15	No	6	N/A	11	No image	0
Is rear door clear of obstructions	Yes	32	No	0	N/A	0	No image	0
Is Stop Blade or Sign clear of Kerb	Yes	32	No	0	N/A	0	No image	0
Approach clear of obstructions	Yes	32	No	0	N/A	0	No image	0
Departure clear of obstructions	Yes	32	No	0	N/A	0	No image	0
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	32	No	0	N/A	0	No image	0
Can bus stop parallel to kerb	Yes	32	No	0	N/A	0	No image	0
Does the stop have a hardstand area clear of obstructions for all doors	Yes	21	No	2	N/A	0	No image	0
	Front Only	9	No Hardstand	0	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	17	N/A	15		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	15	No	13	N/A	4		
Are there road markings at the stop?	No	16	Rear only	0	N/A	4		
	Both front and rear	12	Front only	0				

3.4 Bus route 150 – Brown Plains to City

Bus route 150 also travels from Brown Plains to the City with 45 stops. There are 4 indented stops while the balance is kerbside stops. We determined that 6 stops could be lengthened and that 7 could not. We were not able to determine whether the remaining 33 could be altered for length.

For 4 stops the rear door was clear of obstructions while 2 were not. We could not determine whether 10 stops were clear of obstructions. For 41 stops the stop blade or sign is clear of the kerb, but for 5 we were unable to determine this.

All stops were clear of obstructions for approach and departure, the bus was able to enter and exit the stop safely and the bus could stop parallel to the kerb. In terms of a hardstand area clear of obstructions for all doors 22 stops had this for the front only, 15 for all doors and 7 did not have this. We were unable to determine this for one stop.

Of all stops 14 are not greater than 65m. There are 29 stops which may be lengthened and 12 which cannot. There are 43 stops with no road markings and we could not determine this for the balance.

Route 150

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	44	Premium	1	Park&Ride	0	No image	1
Stop Shape	Kerbside	42	Indented	4	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	6	No	7	N/A	33	No image	0
Is rear door clear of obstructions	Yes	34	No	2	N/A	0	No image	10
Is Stop Blade or Sign clear of Kerb	Yes	41	No	0	N/A	2	No image	3
Approach clear of obstructions	Yes	45	No	0	N/A	0	No image	1
Departure clear of obstructions	Yes	45	No	0	N/A	0	No image	1
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	45	No	0	N/A	0	No image	1
Can bus stop parallel to kerb	Yes	45	No	0	N/A	0	No image	1
Does the stop have a hardstand area clear of obstructions for all doors	Yes	15	No	7	N/A	0	No image	1
	Front Only	22	No Hardstand	0	None	0	Unknown	1
Is the bus stop >=65m length?	Yes	0	No	14	N/A	32		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	29	No	12	N/A	5		
Are there road markings at the stop?	No	43	Rear only	0	N/A	46		
	Both front and rear	0	Front only	0				

3.5 Bus route 130 – Algester to City

Bus route 130 travels from Algester to the City with 74 stops. There are 66 regular stops, 6 premium stops and 2 park and ride stops. Of these stops 66 are kerbside while 8 are indented. We were able to determine that 7 stops could be lengthened, 19 could not and were unable to determine whether the remaining 48 could be lengthened or not.

Nearly all stops have a blade or sign clear of the kerb, while 1 does not and we were unable to determine this for 7 stops. For 71 stops the departure is clear of obstructions, while 72 stops the approach is also clear. We could not determine this for 2 stop in each category. We determined that the bus can stop parallel to the kerb at 73 stops, but could not tell for 1 stop.

At 23 stops the hardstand area is clear of obstructions for all doors, but this is not the case for 10 stops. The front doors were clear for 37 stops. We could not determine this for 4 stops.

14 bus stops were less than 65 metres in length. We could not determine the length of 60 stops. 46 stops could be lengthened, while 26 could not. 64 stops had no road markings, 7 had both front and rear markings and 1 stop had rear and another front only.

Route 130

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	66	Premium	6	Park&Ride	2	No image	0
Stop Shape	Kerbside	66	Indented	8	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	7	No	19	N/A	48	No image	0
Is rear door clear of obstructions	Yes	54	No	10	N/A	0	No image	10
Is Stop Blade or Sign clear of Kerb	Yes	66	No	1	N/A	4	No image	3
Approach clear of obstructions	Yes	72	No	0	N/A	0	No image	2
Departure clear of obstructions	Yes	71	No	1	N/A	0	No image	2
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	72	No	0	N/A	0	No image	2
Can bus stop parallel to kerb	Yes	73	No	0	N/A	0	No image	1
Does the stop have a hardstand area clear of obstructions for all doors	Yes	23	No	10	N/A	0	No image	4
	Front Only	37	No Hardstand	0	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	14	N/A	60		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	46	No	26	N/A	2		
Are there road markings at the stop?	No	64	Rear only	1	N/A	1		
	Both front and rear	7	Front only	1				

3.6 Bus route 120 – Garden City to City

Bus Route 120 travels from Garden City to the City with 61 stops. Of all stops 59 are regular and 2 are premium. There are 57 kerbside stops and 4 indented. Only 5 stops were able to be lengthened, while 23 were not able to be and we could not determine this for 33 stops.

At 39 stops the rear door is clear of obstructions, while it is obstructed at 23 stops. We could not determine this for 33 stops. At 57 stops the blade or sign is clear of the kerb, but we could not determine this at 4 stops.

At 58 stops the approach is clear of obstructions, while 1 approach is impeded and we could not determine this either way for 2 stops. At 59 stops the departure is clear of obstructions, while we could not determine this for 2 stops. For 58 stops the bus was able to stop parallel to the kerb, but not at one stop and we could not determine this at 2 stops.

The hardstand area is clear of obstructions at 15 stops, not clear at 18 stops and is clear for the front only at 24 stops. We could not determine this for 4 stops.

10 stops are less than 65 metres in length and we could not determine this for the balance. 31 stops can be lengthened to 65 metres, while 23 cannot. There are road markings on both front and rear at 2 stops, no markings at 51 stops and one stop has rear markings and another front markings.

Route 120

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	59	Premium	2	Park&Ride	0	No image	0
Stop Shape	Kerbside	57	Indented	4	Turnaround	0	Indented(other)	0
Can stop be lengthened	Yes	5	No	23	N/A	32	No image	1
Is rear door clear of obstructions	Yes	39	No	16	N/A	0	No image	6
Is Stop Blade or Sign clear of Kerb	Yes	57	No	0	N/A	1	No image	3
Approach clear of obstructions	Yes	58	No	1	N/A	0	No image	2
Departure clear of obstructions	Yes	59	No	0	N/A	0	No image	2
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	57	No	2	N/A	0	No image	2
Can bus stop parallel to kerb	Yes	58	No	1	N/A	0	No image	2
Does the stop have a hardstand area clear of obstructions for all doors	Yes	15	No	18	N/A	0	No image	4
	Front Only	24	No Hardstand	0	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	10	N/A	51		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	31	No	23	N/A	7		
Are there road markings at the stop?	No	51	Rear only	1	N/A	6		
	Both front and rear	2	Front only	1				

3.7 Bus route 180 – Mount Gravatt to City

Bus Route 180 travels from Mount Gravatt to the City with 98 stops. Of all stops 87 are regular and 11 are premium. Most stops are kerbside while only 5 are indented. We determined that 30 stops could be lengthened, 46 could. We were not able to determine this for 22 stops.

At 70 stops the rear door is clear of obstructions, while it is impeded at 18. We could not determine this at 10 stops. At 95 stops the blade or sign was clear of the kerb, and we could not determine this for 3 stops.

Only 1 stop had an approach that was not clear of obstructions and all stops had a departure that was clear of obstructions. At all stops the bus was able to enter and safely exit the stop safely. For 96 stops the bus could stop parallel to the kerb, but not at 1 stop and we could not determine this for another 1 stop. The hardstand area was clear of obstructions for all doors at 29 stops, not clear at 15 stops and clear for the front only at 44 stops. One stop did not have a hardstand. We were not able to determine this for 9 stops.

60 stops are less than 65 metres while we could not determine this measurement for 37 stops. Of all stops 39 might be lengthened to 65 metres while 52 cannot be. There are 74 stops without road markings, 4 with front and rear markings, 4 with rear only and 5 with front only markings.

Route 180

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	87	Premium	11	Park&Ride	0	No image	0
Stop Shape	Kerbside	83	Indented	5	Turnaround	0	Indented(other)	10
Can stop be lengthened	Yes	30	No	46	N/A	22	No image	0
Is rear door clear of obstructions	Yes	70	No	18	N/A	0	No image	10
Is Stop Blade or Sign clear of Kerb	Yes	95	No	0	N/A	0	No image	3
Approach clear of obstructions	Yes	97	No	1	N/A	0	No image	0
Departure clear of obstructions	Yes	98	No	0	N/A	0	No image	0
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	98	No	0	N/A	0	No image	0
Can bus stop parallel to kerb	Yes	96	No	1	N/A	0	No image	1
Does the stop have a hardstand area clear of obstructions for all doors	Yes	29	No	15	N/A	0	No image	9
	Front Only	44	No Hardstand	1	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	0	No	60	N/A	37		
If the bus stop can be extended, can the stop be extended to 65m?	Yes	39	No	52	N/A	6		
Are there road markings at the stop?	No	74	Rear only	4	N/A			
	Both front and rear	4	Front only	5				

3.8 Bus route 385 – The Gap to City

Bus Route 385 travels from the Gap to the City with 65 stops. Of all stops 54 are regular and 11 are premium stops. There were 54 kerbside stops, 8 indented, 1 turnaround and 2 indented (other). We determined that 7 stops could be lengthened, 34 could not and we could not determine this for 24 stops.

At 43 stops the rear door was clear of obstruction, while it was not clear at 19 and we could not determine this for 3 stops. At all stops the blade or sign was clear of the kerb. At 64 stops the bus had an approach and departure clear of obstructions, but we could not determine this at 1 stop. The bus could enter and exit safely at 64 stops but not at 1 stop. At 64 stops the bus could stop parallel to the kerb, but not at 1 stop.

The hardstand area was clear of all obstructions for all doors at 20 stops, not clear at 27, the front door was clear only at 15 stops and we were not able to determine this for 3 stops.

26 stops are less than 65 metres in length while 1 is greater than 65 metres. 16 stops can be extended to 65 metres, while 48 cannot. There are 11 stops with markings at the front and rear, 5 with front only and 10 with rear only. We could not determine this for 38 stops.

Route 385

Category	Item	#	Item	#	Item	#	Item	#
Stop Type	Regular	54	Premium	11	Park&Ride	0	No image	0
Stop Shape	Kerbside	54	Indented	8	Turnaround	1	Indented(other)	2
Can stop be lengthened	Yes	7	No	34	N/A	24	No image	0
Is rear door clear of obstructions	Yes	43	No	19	N/A	0	No image	3
Is Stop Blade or Sign clear of Kerb	Yes	65	No	0	N/A	0	No image	0
Approach clear of obstructions	Yes	65	No	0	N/A	0	No image	0
Departure clear of obstructions	Yes	64	No	0	N/A	0	No image	1
Can bus stop be modified to allow buses to enter and exit stop safely?	Yes	64	No	0	N/A	0	No image	1
Can bus stop parallel to kerb	Yes	64	No	1	N/A	0	No image	0
Does the stop have a hardstand area clear of obstructions for all doors	Yes	20	No	27	N/A	0	No image	3
	Front Only	15	No Hardstand	0	None	0	Unknown	0
Is the bus stop >=65m length?	Yes	1	No	26	N/A	38		
Can the stop be extended to 65m?	Yes	16	No	48	N/A	1		
Are there road markings at the stop?	No	0	Rear only	10	N/A	38		
	Both front and rear	11	Front only	5				

4. Summary and Conclusions

This technical note reviews bus routes 100, 140, 150, 130, 120, 180 and 385 to assess the capacity of existing stop infrastructure along these routes to accommodate HCVs. These routes were selected as representative of the overall network.

Our analysis of stops is based on a desktop review of aerial photos. While suitable for a high level analysis of a network, an on-site review of each stop is recommended to verify our results on the ground prior to confirming any routes for HCVs. We were unable to perform an aerial photo analysis on a proportion of stops for key categories (i.e. ability to lengthen a stop) because of photo quality or obscured stop images.

Our overall findings are summarised as follows:

- Overall results indicate that stops are nearly all clear of obstructions on approach and on departure of buses.
- Most stops are regular kerbside stops.
- Many stops are unable to be lengthened; however we were unable to assess this for nearly half of all stops.
- The blade or sign is clear of the kerb at nearly all stops and the rear door would be clear at nearly three quarters of all stops.
- Nearly all stops allow buses to stop parallel to the kerb.
- Nearly one third of all stops had a hardstand area clear of obstruction for all doors, with 21% being obstructed. At 42% of stops only the front doors were clear of obstructions.
- Only one stop appears to be greater than 65 metres in length.
- Half of stops can be lengthened to 65 metres.
- Three quarters of stops have no road markings at front or rear.

The ability for the 444 stops along existing BUZ routes to accommodate HCVs without upgrades varies considerably and we were unable to determine some measurements for all stops. Route planning will need to be influenced by a ground-verified knowledge of the capacity of individual stops to accommodate HCVs that this technical note begins to deliver.

Attachment 1: Audit Results

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
	Route 100																			
	Forest Lake Bvd	300555	5	Premium	South-North	Indented	Yellow Line Marking	55	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	20	No	Yes	Yes
	Forest Lake Bvd	300425	5	Regular	North-South	Indented	Yellow Line Marking	40	Yes	Yes	yes	yes	Yes	Yes	Yes	25	20	No	yes	Yes
	Kensington Way	303041	5	Regular	West-East	Indented	None	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	20	No	Yes	Front Only
	Kensington Way	303042	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Grand Ave East	303043	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Grand Ave East	303053	5	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave Cascade	303044	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave Cascade	303052	5	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave Lake	303045	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Grand Ave Lake	303051	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave School	303046	5	Regular	East-West	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Grand Ave School	303050	5	Regular	West-East	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Grand Ave West	303047	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Grand Ave West	303049	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Woogaroo - Lochwood	303048	5	Regular	North-South	Indented	None	45	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	20	No	Yes	Yes
	Woogaroo - Lochwood	300599	5	Regular	West-East	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Lochwood Jindabyne	300603	5	Regular	East-West	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Lochwood - Jindadyne	300600	5	Regular	West-East	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Lochwood Broadwater	300602	5	Regular	East-West	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Lochwood Broadwater	300601	5	Regular	West-East	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Forest Lake A	300556	5	Regular	South-North	Indented	None	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	30	No	Yes	Yes
	Forest Lake B	300423	5	Regular	North-South	Indented	None	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	30	No	Yes	Yes
	Forest Lake B	300597	5	Regular	South-North	Indented	None	37	Yes	Yes	Yes	Yes	Yes	Yes	Yes	15	15	No	Yes	Yes
	Joseph Banks Ave	300557	5	Regular	West-East	Indented	Lane Marking	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	15	No	Yes	Front Only
	Joseph Banks Ave	300422	5	Regular	East-West	Indented	Yellow Line Marking	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	15	No	Yes	No
	Woodland	300558	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Woodland	300552	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Partridge	300559	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Partridge	300551	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Partridge North	300529	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Partridge North	300544	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Serviceston Inala	300680	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Serviceston Inala	300679	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	None
	Viola Street	300681	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Viola Street	300678	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	None
	Serviceston Hyacinth	300682	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Serviceston Hyacinth	300682	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Kev Hoopwer Park	300683	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Kev Hoopwer Park	300676	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Durella West	300684	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Durella West	300693	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Durella East	300692	5	Regular	SW-NE	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Durella East	300685	5	Regular	NE-SW	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Akama South	300686	5	Regular	SE-NW	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Akama South	300691	5	Regular	NE-SW	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Akama Central	300690	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Akama Central	300687	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Akama North	300689	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Akama North	300688	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Glenala East	300666	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Glenala East	300695	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Blunder - Glenala	300655	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Forest Place Sth	300665	5	Regular	North-South	Kerbside	None	15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	12	No	Yes	Yes
	Forest Place Sth	300656	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Blunder - Freeman	300663	5	Regular	North-South	Indented	Yellow Line Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	15	Yes	Yes	Yes
	Blunder - Freeman	300658	5	Regular	South-North	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Oxley Ridge	300662	4	Regular	North-South	Kerbside	Lane Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Oxley Ridge	300659	4	Regular	South-North	Kerbside	Lane Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Blunder Oxley	300660	4	Regular	South-North	Kerbside	Yellow Line Marking	15	Yes	Yes	Yes	Yes	Yes	Yes	No	17	24	No	No	Front Only
	Blunder Oxley	300661	4	Regular	North-South	Kerbside	Lane Marking	15	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	None
	Moorooka Station	304027	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Moorooka Station	304028	3	Regular	South-North	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Clifton Hill	304034	2	Regular	North-South	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Clifton Hill	306281	2	Regular	North-South	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Annerley Junction	306289	2	Premium	South-North	Kerbside	Yellow Line Marking	50	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Annerley Junction	306279	2	Premium	North-South	Kerbside	Yellow Line Marking	50	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	PA Hospital	306271	2	Regular	North-South	Indented	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	10	10	Yes	Yes	Yes
	PA Hospital	306294	2	Regular	South-North	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
	Route 140																			
	Greenbank RSL Stop B	201053	6	Park&Ride	West-East	Kerbside	Yellow Line parking	20	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
	Greenbank RSL Stop A	201054	6	Park&Ride	West-East	Kerbside	Yellow Line parking	20	Yes	Yes	yes	yes	yes	yes	yes	n/a	n/a	Yes	Yes	No
	Illaweena St	305475	5	Regular	North-South	Kerbside	Lane Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	35	No	Yes	Yes
	Illaweena St	305440	5	Regular	South-North	Kerbside	Lane Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	35	No	Yes	Yes
	Honeysuckle Way	305474	5	Regular	North-South	Kerbside	Lane Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	30	No	Yes	Yes
	Honeysuckle Way	305441	5	Regular	South-North	Kerbside	Lane Marking	15	Yes	Yes	Yes	Yes	Yes	Yes	Yes	30	25	No	Yes	Yes
	Kameruka St	305443	5	Regular	South-North	Kerbside	Lane Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	25	No	Yes	Yes
	Kameruka St	305472	5	Regular	North-South	Kerbside	Lane Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	18	No	Yes	Yes
	Benham St	305471	5	Regular	North-South	Kerbside	Lane Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	15	35	No	Yes	Yes
	Benham St	305444	5	Regular	South-North	Kerbside	Lane Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	25	No	Yes	Yes
	Calam Rd	305489	5	Regular	South-North	Indented	Lane Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	20	Yes	Yes	Yes
	Calam rd	305476	5	Regular	North-South	Kerbside	Yellow Line parking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	15	30	Yes	Yes	Yes
	Sunnybank Hills South	305490	5	Regular	South-North	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Sunnybank Hills South	305521	5	Regular	Noth-South	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
	Hellawell	305520	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Hellawell	305491	5	Regular	South-North	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Pinelands	305517	4	Regular	North-South	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Pinelands	305493	4	Regular	South-North	Kerbside	Lane Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Altandi	306070	4	Premium	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
	Altandi	306356	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Pristina Street	306075	4	Regular	South-North	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Pristina Street	306069	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Turton Street	306179	4	Regular	South-North	Kerbside	None	N/a	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	yes	Yes	Yes
	Turton Street	306068	4	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	yes	Yes	Yes
	Elva Street	306076	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Elva Street	306067	4	Regular	North-South	Kerbside	None	N/a	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Sunnybank	306355	4	Regular	South-North	Kerbside	Yellow Line Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Sunnybank	306066	4	Regular	North-South	Kerbside	Yellow Line Marking	35	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Robertson	306078	4	Regular	South-North	Kerbside	None	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Robertson	306064	4	Regular	North-South	Kerbside	None	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
	Mains Rd Park & Ride	300502	4	Regular	South-North	Indented	None	40	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	20	Yes	Yes	Yes
	Mains Rd Park & Ride	307092	4	Regular	Norh-South	kerbside	Lane Marking	55	No	Yes	Yes	Yes	Yes	Yes	Yes	25	N/A	Yes	Yes	Yes
	Route 150																			
Honeysuckle Wy	Sunflower	305386	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Honeysuckle Wy	Sunflower	305387	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Honeysuckle Wy	Calamvale	305385	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Honeysuckle Wy	Calamvale	305388	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Honeysuckle Wy	The Parks	305384	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Gowan Rd	The Parks	305390	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Gowan Rd	Parkside	305392	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Gowan Rd	Parkside	305411	5	Regular	North-South	Indented	None	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	18	No	Yes	Yes
Gowan Rd	Pennant Hills	305393	5	Regular	South-North	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Pennant Hills	305410	5	Regular	North-South	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Calam North	305395	5	Regular	South-North	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Calam North	305408	5	Regular	North-South	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Gowan - Compton	305407	5	Regular	North-South	Kerbside	Yellow Line Marking	30	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Gowan - Compton	305396	5	Regular	South-North	Kerbside	Yellow Line Marking	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Gowan Rd	Gowan Rd	305439	5	Regular	South-North	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Gowan Rd	Gowan Rd	305397	5	Regular	North-South	Kerbside	Yellow Line Marking	25	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Gowan Rd		305438	5	Regular	South-North	Kerbside	Yellow Line Marking	20	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Nemies Rd	Runcorn East	305436	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nemies Rd	Runcorn West	305398	5	No Image	No Image	Kerbside	None	N/A	N/A	No Image	No Image	No Image	No Image	No Image	No Image	N/A	N/A	No Image	No Image	No Image
Nemies Rd		305431	5	Regular	West-East	Kerbside	None	N/A	No	No image	N/A	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Nemies Rd	Runcorn Heights	305399	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nemies Rd	Runcorn Heights	305430	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nursery Ave	Runcorn	305432	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nursery Ave	Runcorn	305435	5	Regular	South-North	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nursery Ave	Nursery Avenue	305433	5	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Nursery Ave	Nursery Avenue	305434	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Beenleigh Rd	Fruitgrove Station	306187	4 and 5	Regular	West-East	Indented	Yellow Line Marking	45	No	Yes	No image	*	Yes	Yes	Yes	10	5.5	No Image	Yes	Yes
Beenleigh Rd	Fruitgrove Station	306216	5 and 4	Regular	East-West	Indented	Yellow Line Marking	50	No	Yes	No image	*	Yes	Yes	Yes	10	8	No Image	Yes	Yes
Warrigal Rd	Fruitgrove	306186	4	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Fruitgrove	306217	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Runcorn North	306185	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Warrigal Rd	Runcorn North	306218	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Warrigal Rd	Warrigal Road	306184	4	Regular	North-South	Kerbside	None	N/A	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Unknown
Warrigal Rd	Warrigal Road	306219	4	Premium	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Warrigal Rd		306183	4	Regular	South-North	Kerbside	Yellow Line Marking	20	Yes	No image	N/A	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Fanfare	306182	4	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Fanfare	306220	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Warrigal Rd	Bordeaux	306181	4	Regular	North-South	Kerbside	Yellow Line Marking	20	Yes	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Bordeaux	306221	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Padstow Views	306222	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Warrigal Rd	Padstow Views	306180	4	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Padstow Rd	Multicap	306259	4	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Padstow Rd	Multicap	306242	4	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Logan Rd	81	306243	4	Regular	South-North	Indented	White Line Marking	25	Yes	No image	Yes	N/A	Yes	Yes	Yes	15	18	No	Yes	No
Macgregor St	Garden City Depot	305979	4 and 3	Regular	East-West	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Macgregor St	Garden City Depot	305981	4 and 3	Regular	West-East	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
	Route 130																			
Illaweena St	Waterstone	305382	5	Regular	West-East	Kerbside	None	N/A	N/A	No image	No	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Illaweena St	Waterstone	305380	5	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Illaweena St	Tamarisk Way	307080	5	Regular	East-West	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Illaweena St	Tamarisk Way	307081	5	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Lichfield Place	307096	5	Regular	West-East	Kerbside	None		N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Lichfield Place	307097	5	Regular	East-West	Indented	Yellow Line Marking	36	Yes	Yes	Yes	N/A	Yes	Yes	Yes	15	16	No	Yes	Yes
Algester Rd	Parkinson East -92	303079	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Parkinson East -92	303078	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Algester Rd	Lake Eyre Crescent - 91	303077	5	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	*Yes
Algester Rd	Lake Eyre Crescent - 91	303080	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Parkinson East -90	303076	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Algester Rd	Parkinson	303081	5	Regular	South-North	Indented	None	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	25	12	No	Yes	Yes
Algester Rd	Glenfield	303082	5	Regular	North-South	Kerbside	Yellow Line Marking	22	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Glenfield	303075	5	Regular	South-North	Kerbside	Yellow Line Marking	22	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Algester Rd	Nottingham	303074	5	Regular	North-South	Kerbside	Yellow Line Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Algester Rd	Nottingham	303083	5	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*Yes
Ridgewood Rd		303092	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	N/A	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Ridgewood Heights	303112	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Ridgewood Rd	Ridgewood Heights	303093	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Helica Street - 85a	303094	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Ridgewood Park	303111	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Ridgewood Park	303095	5	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Ridgewood Rd	Wollybutt Street - 84	303104	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Ridgewood Rd	Wollybutt Street - 84	303096	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Algester - 83	303097	5	Regular	West-East	Indented	White Line Marking	29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	7	9	No	Yes	Front Only
Ridgewood Rd	Algester - 83	303103	5	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Ridgewood Rd	Rapanea Street - 82	303102	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
Ridgewood Rd	Rapanea Street - 82	303098	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Limewood Place - 81	303101	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Ridgewood Rd	81	303099	5	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Ridgewood Rd	Satinwood Street - 80	303100	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Algester East - 79	303116	5	Regular	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Algester East - 79	303069	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	*Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Algester Central - 78a	303117	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Algestor Central - 78a	303068	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Algester Rd	Delforest Drive - 78	303118	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Algester Rd	Beaudesert Road - 76	303067	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Algester Rd	Beaudesert Road - 76	303119	5	Regular	South-North	Kerbside	None	N/A	N/A	No image	No image	*	No Image	No image	No image	N/A	N/A	*	Yes	No Image
Beaudersert Rd		305470	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	N/A	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Beaudersert Rd		305445	5	Regular	South-North	Kerbside	None	N/A	N/A	Yes	N/A	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Compton Rd		305488	5	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Compton Rd		305487	5	Regular	East-West	Indented	Yellow Line Marking	25	Yes	Yes	N/A	N/A	Yes	Yes	Yes	18	14	No	Yes	Front Only
Calam Rd	Calam Rd	305489	5	Premium	South-North	Indented	None	40	No	Yes	Yes	Yes	Yes	Yes	Yes	18	15	Yes	Yes	Yes
Calam Rd	Calam Rd	305476	5	Premium	North-South	Indented	Yellow Line Marking	30	No	No image	No image	Yes	Yes	*No	Yes	17	N/A	Yes	Yes	Yes
Calam Rd		305522	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Calam Rd	Sunnybanks Hill South	305490	5	Regular	South-North	Kerbside	None	N/A	No	No image	No image	*	No Image	No image	No image	N/A	N/A	No image	No image	No Image
Calam Rd	Sunnybanks Hill South	305521	5	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Calam Rd	Hellawell	305520	4 and 5	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Calam Rd	Hellawell	305491	5 and 4	Regular	South-North	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Pinelands Rd		305119	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Pinelands Rd	Barney Street 71-70	305492	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Pinelands Rd	Barney Street 71-70	305518	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Pinelands Rd	Pinelands	305517	4	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Pinelands Rd	Pinelands	305493	4	Regular	South-North	Indented	White Line Marking	42	No	Yes	Yes	Yes	Yes	Yes	Yes	6	0	No	Yes	Front Only
Mains Rd		306074	4	Regular	South-North	Kerbside	White Line Marking	16	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Mains Rd		306073	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Mains Rd	Runcorn School-68b	306072	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Mains Rd	Runcorn School-68b	306071	4	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Mains Rd	Altandi - 68	306070	4	Premium	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Mains Rd	Altandi - 68	306356	4	Premium	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Mains Rd	Pristina Street - 67	306075	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Mains Rd	Pristina Street - 67	306069	4	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Mains Rd	Turton Street - 80	306179	4	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Mains Rd	Turton Street - 80	306068	4	Regular	North-South	Kerbside	None	N/A	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Mains Rd	Elva Street - 65	306076	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Mains Rd	Elva Street - 65	306067	4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Mains Rd	Sunnybank	306066	4	Premium	North-South	Kerbside	White Line Marking	27	Yes	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Mains Rd	Sunnybank	306355	4	Premium	South-North	Kerbside	Yellow Line Marking	34	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Mains Rd	Musgrave Road - 63	306077	4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Mains Rd	Musgrave Road - 63	306065	4	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Mains Rd	Robertson - 4	306064	4	Regular	North-South	Kerbside	None	N/A	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Mains Rd	Robertson	306078	4	Regular	South-North	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*No
Mains Rd	Mains Rd. Park & Ride	300502	4 and 3	Park&Ride	South-North	Indented	White Line Marking	38	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	16	Yes	Yes	Yes
Mains Rd	Mains Rd. Park & Ride	307092	3 and 4	Park&Ride	North-South	Kerbside	Yellow Line Marking	*	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Route120																			
Kessels Rd	Cremin Street 45/60	300426	4	Regular	West-East	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Kessels Rd	Cremin Street 45/60	305727	4	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Kessels Corner - 44	306079	3	Regular	South-North	Kerbside	Yellow Line Marking	18	Yes	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Logan Rd	Mt Gravatt Corner - 44	305923	3	Regular	North-South	Kerbside	Yellow Line Marking	29	Yes	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Logan Rd	Kessels Corner - 43	305922	3	Regular	North-South	Kerbside	Yellow Line Marking	30	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Logan Rd	Upper Mt Gravatt School - 43	305984	3	Regular	South-North	Kerbside	Yellow Line Marking	60	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	St Bernards - 42	305921	3	Regular	North-South	Kerbside	Yellow Line Marking	18	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	St Bernards - 42	306080	3	Regular	South-North	Indented	Yellow Line Marking	29	No	Yes	Yes	Yes	Yes	Yes	Yes	8	11	No	Yes	Yes
Klumpp Rd		305677	3	Regular	East-West	Indented	Yellow Line Marking	31	No	Yes	N/A	N/A	Yes	Yes	Yes	9	11	Yes	Yes	Yes
Klumpp Rd	Klump-Dawson - 42	305676	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Klumpp Rd	Hibiscus	305678	3	Premium	East-West	Indented	Yellow Line Marking	50	No	Yes	Yes	Yes	Yes	Yes	Yes	21	13	Yes	Yes	Yes
Klumpp Rd	Hibiscus	305675	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Klumpp Rd	Mt Gravatt Cemetry	305143	3	Regular	West-East	Kerbside	Yellow Line Marking	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Klumpp Rd	Mt Gravatt Cemetry	305144	3	Regular	East-West	Kerbside	Yellow Line Marking	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Griffith Rd	Recreation Road - 55a	305142	3	Regular		Indented	Yellow Line Marking	No image	No	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image
Troughton Rd	QEII Hospital	300498	4 and 3	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	*No	N/A	N/A	No	Yes	Front Only
Troughton Rd	QEII Hospital	300434	3 and 4	Regular	North-South	Kerbside	Yellow Line Marking	25	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Troughton Rd	QEII Hospital - 37	300497	4 and 3	Premium	South-North	Kerbside	Yellow Line Marking	24	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*No
Troughton Rd	Musgrave Rd	300435	3 and 4	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Troughton Rd	Musgrave Rd - 39	300496	4 and 3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Musgrave Rd	Musgrave Rd	300436	3	Regular	East-West	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Musgrave Rd	Mandarin Street - 54	300495	3	Regular	West-East	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Musgrave Rd	Mossop Street - 54	300437	4 and 3	Regular	East-West	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Musgrave Rd	Boundary	300438	3	Regular	East-West	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Musgrave Rd	Boundary	300494	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Musgrave Rd	Orange Grove Rd - 54b	300439	4 and 3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Musgrave Rd	Orange Grove Rd - 54b	300493	3	Regular	West-East	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Q G Laboratory	305139	3 and 4	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Q G Laboratory	305140	4 and 3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Orange Grove Rd	Aldi - 52	305138	3 and 4	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Aldi - 52	305141	4 and 3	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Salisbury East - 51	305137	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Orange Grove Rd	Salisbury East - 51	305146	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Orange Grove Rd	52A	305147	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Orange Grove Rd	52A	305136	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Orange Grove Rd	Dulcie Street - 52	305135	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Orange Grove Rd	Dulcie Street - 52	305148	3	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Orange Grove Rd	Toohey Forest - 53	305134	3	Regular	North-South	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Toohey Rd	Toohey Forest - 53	305133	3	Regular	South-North	Kerbside	None	N/A	No	No	Yes	N/A	No	Yes	No	N/A	N/A	No	No	No
Toohey Rd	53	307082	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	No image	N/A	Yes	Yes	Yes	N/A	N/A	No image	Yes	No image
Toohey Rd	Tarragindi - 44/48	305099	3 and 2	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
Toohey Rd	Tarragindi - 44/48	305156	2 and 3	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No image
Toohey Rd	Bramston Street - 47	305157	2	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Toohey Rd	Bramston Street - 47	305155	2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Toohey Rd	Chamberlain Street -46a	305158	2	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Toohey Rd	Chamberlain Street -46a	305154	2	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Toohey Rd	Wellers Hill School - 47a	305159	2	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Toohey Rd	Wellers Hill School - 47a	305153	2	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Toohey Rd	Weller Road - 45	305152	2	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Toohey Rd	Weller Road - 45	305160	2	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Toohey Rd	Denham Terrace - 44/41	305106	2	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Toohey Rd	Denham Terrace - 44/41	305105	2	Regular	South-North	Kerbside	None	N/A	N/A	No	Yes	No	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Sexton St	Sexton Street	305187	2	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Sexton St	Sexton Street	305185	2	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Sexton St		305188	2	Regular	East-West	Kerbside	None	N/A	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image	No image
Sexton St		305184	2	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Ekibin Rd	Ekibin - 30	306342	2	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Ekibin Rd	Ekibin - 30	306340	2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Earl St	18	305241	2	Regular	South-North	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Earl St	Thompson Estate 17	305222	2	Regular	South-North	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Earl St	Thompson Estate 17	305221	2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
	Route 180																			
Kessels Rd	Cremin Street 45/60	300426	4	Regular	West-East	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Kessels Rd	Cremin Street 45/60	305727	4	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Mt Gravatt-Capalaba Rd	Tryon - 61	305726	3	Regular	East-West	Indented(other)	White Line Marking	34	Yes	Yes	Yes	N/A	Yes	Yes	Yes	11	10	No	Yes	Yes
Mt Gravatt-Capalaba Rd	Tryon - 61	305734	3	Premium	West-East	Indented(other)	White Line Marking	32	Yes	Yes	Yes	Yes	Yes	Yes	Yes	20	N/A	Yes	Yes	Yes
Mt Gravatt-Capalaba Rd		305735	3	Regular	West-East	Kerbside	None	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Mt Gravatt-Capalaba Rd	62/78	305725	3	Regular	East-West	Indented(other)	White Line Marking	28	No	Yes	Yes	N/A	Yes	Yes	Yes	16	18	No	Yes	No
Mt Gravatt-Capalaba Rd		305724	3	Regular	East-West	Indented	White Line Marking	28	Yes	No image	No image	N/A	Yes	Yes	Yes	10	0	No image	No image	No Image
Mt Gravatt-Capalaba Rd		305176	3	Regular	West-East	Kerbside	None	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Mt Gravatt-Capalaba Rd	Agaton	305717	3	Regular	West-East	Indented(other)	White Line Marking	26	Yes	No	Yes	Yes	Yes	Yes	Yes	22	22	No	Yes	Front Only
Mt Gravatt-Capalaba Rd	Agaton	305723	3	Regular	East-West	Indented(other)	White Line Marking	44	No	No image	Yes	Yes	Yes	Yes	Yes	9	22	N/A	Yes	No
Mt Gravatt-Capalaba Rd		305718	3	Regular	West-East	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Mt Gravatt-Capalaba Rd	Ham Road South	305719	3	Regular	West-East	Indented(other)	White Line Marking	25	Yes	No	Yes	Yes	Yes	Yes	Yes	15	13	No	Yes	Front Only
Mt Gravatt-Capalaba Rd	Ham Road South	305722	3	Regular	East-West	Indented(other)	White Line Marking	32	Yes	No	Yes	Yes	Yes	Yes	Yes	7	16	No	Yes	Front Only
Mt Gravatt-Capalaba Rd	Wishart East	305720	3	Regular	West-East	Indented(other)	White Line Marking	23	No	Yes	Yes	Yes	Yes	Yes	Yes	16	14	Yes	Yes	Yes
Mt Gravatt-Capalaba Rd	Wishart East	305721	3	Regular	East-West	Indented(other)	White Line Marking	31	No	Yes	Yes	Yes	Yes	Yes	*Yes	11	0	No	Yes	Yes
Broadwater Rd	Mansfield Park	305682	3	Regular	West-East	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Broadwater Rd	Mansfield Park	305681	3	Regular	East-West	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Broadwater Rd		305680	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Broadwater Rd	Broadwater	305698	3	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Broadwater Rd	Broadwater	305697	4	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Broadwater Rd	Broadwater Creek - 75	305696	3	Regular	West-East	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Broadwater Rd	Broadwater Creek - 75	305683	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cresthaven Drive	Cresthaven - 74	305617	3	Regular	North-South	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	*Yes	*Yes	N/A	N/A	No	Yes	Yes
Cresthaven Drive	Cresthaven - 74	305618	3	Regular	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cresthaven Drive	Salandra Street - 6c/73	305615	3	Regular	North-South	Kerbside	Yellow Line Marking	25	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No Hardstand
Cresthaven Drive	Salandra Street - 6c/73	305619	3	Regular	South-North	Kerbside	Yellow Line Marking	28	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Aminya St	Mansfield - 67a	305612	3	Regular	East-West	Kerbside	Yellow Line Marking	22	No	No image	No image	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No Image
Aminya St	Mansfield - 67a	305620	3	Regular	West-East	Kerbside	Yellow Line Marking	23	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Balamara St	Balamara Street - 67	305611	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Olivella St	Olivella Street - 66	305621	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Olivella St	Olivella Street - 66	305610	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Luprena Street	Arura Street - 65	305609	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Luprena Street	Arura Street - 65	305622	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Luprena Street	Mansfield North	305606	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Luprena Street	Mansfield North	305623	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Wecker Rd	Wecker Rd Business Centre-63	305700	3	Regular	East-West	Kerbside	None	33	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Wecker Rd	Wecker Rd Business Centre-63	305605	3	Premium	West-East	Kerbside	Yellow Line Marking	20	Yes	No	Yes	N/A	*No	Yes	Yes	N/A	N/A	Yes	*No	No
Wecker Rd	Wecker Rd - 6	305604	3	Regular	West-East	Kerbside	Yellow Line Marking	22	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Wecker Rd	Wecker Rd - 6	305701	3	Regular	East-West	Kerbside	Yellow Line Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Wecker Rd	Grevillea Oval - 61	305702	3	Regular	West-East	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Wecker Rd	Grevillea Oval - 61	305063	3	Premium	East-West	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cavendish Rd	Mt Gravatt East - 60	305281	3	Regular	South-North	Kerbside	Yellow Line Marking	22	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cavendish Rd	Mt Gravatt East - 60	305280	3	Regular	North-South	Indented	Yellow Line Marking	23	No	Yes	Yes	Yes	Yes	Yes	Yes	7	7	Yes	Yes	Yes
Cavendish Rd	Seton College - 56/59	305279	3	Regular	North-South	Indented(other)	Yellow Line Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	17	0	Yes	Yes	Yes
Cavendish Rd	Seton College - 56/59	305278	3	Regular	South-North	Kerbside	Yellow Line Marking	26	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cavendish Rd	Mt Gravatt TAFE - 55	304974	3	Regular	North-South	Kerbside	Yellow Line Marking	*	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Cavendish Rd	Mt Gravatt TAFE - 55	305323	3	Regular	South-North	Kerbside	Yellow Line Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No Image
Cavendish Rd	Coolibah Street - 54	304975	3	Regular	South-North	Kerbside	Yellow Line Marking	23	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Cavendish Rd	Coolibah Street - 54	304973	3	Regular	North-South	Kerbside	*	*	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cavendish Rd	Coolong Street - 53	304976	3	Regular	South-North	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No Image
Cavendish Rd	Coolong Street - 53	304972	3	Regular	North-South	Kerbside	None	N/A	N/A	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No Image
Cavendish Rd	Pine Mountain - 52	304971	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cavendish Rd	Pine Mountain - 52	304977	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cavendish Rd	Oates Avenue - 51	304978	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*No
Cavendish Rd	Oates Avenue - 51	304970	3	Regular	North-South	Kerbside	Yellow Line Marking	30	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cavendish Rd	Crystal Street - 50	305282	2	Regular	East-West	Kerbside	Yellow Line Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Cavendish Rd	Crystal Street - 50	304969	3	Regular	West-East	Kerbside	Yellow Line Marking	*20	Yes	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cavendish Rd	Turquoise Street - 49/63	305283	3	Regular	East-West	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Cavendish Rd	Turquoise Street - 49/63	304968	3	Regular	West-East	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Cavendish Rd	Holland Park East - 42	304964	2 and 3	Regular	West-East	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cavendish Rd	Holland Park East - 42	304965	3 and 2	Regular	East-West	Kerbside	Yellow Line Marking	25	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cavendish Rd	Cavendish Rd High School 41	304963	2 and 3	Regular	North-South	Kerbside	Yellow Line Marking	27	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Cavendish Rd	Cavendish Rd High School 41	304966	3 and 2	Regular	South-North	Kerbside	Yellow Line Marking	25	Yes	Yes	Yes	Yes	Yes	*Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cavendish Rd	Cavendish Rd Reservoir - 40	304962	2 and 3	Regular	North-South	Kerbside	White Line Marking		No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Holland Rd	Bus Stop - 45	305253	3 and 2	Regular	North-South	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Holland Rd	Bus Stop - 45	305252	2 and 3	Regular	South-North	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Holland Rd	Holland Road - 44	305251	2 and 3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Holland Rd	Holland Road - 44	305254	3 and 2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
Holland Rd	Bus Stop - 43	305255	3 and 2	Regular	North-South	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Holland Rd	Bus Stop - 43	305250	2 and 3	Regular	South-North	Kerbside	Yellow Line Marking	14	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Holland Rd	Bus Stop - 43A	305256	3 and 2	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Logan Rd	Barter Avenue - 30	305994	3 and 2	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Logan Rd	Barter Avenue - 30	305907	2 and 3	Regular	North-South	Kerbside	Yellow Line Marking	24	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Logan Rd	Holland Park - 29	305995	3 and 2	Premium	South-North	Indented	Yellow Line Marking	29	Yes	No	Yes	Yes	Yes	Yes	Yes	11	0	Yes	Yes	No
Logan Rd	Holland Park - 29	305906	2 and 3	Premium	North-South	Indented	Yellow Line Marking	24	No	No	Yes	Yes	Yes	Yes	Yes	5	0	Yes	Yes	No
Logan Rd	Harold Street - 28	306084	2	Regular	South-North	Kerbside	Yellow Line Marking	30	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Harold Street - 28	305905	2	Regular	North-South	Kerbside	Yellow Line Marking	29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Logan Rd	Swain Street - 27	305904	2	Regular	North-South	Kerbside	Yellow Line Marking	22	No	Yes	Yes	Yes	Yes	*Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Swain Street - 27	306085	2	Regular	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	C B Mott Park - 26	305903	2	Regular	North-South	Kerbside	Yellow Line Marking	24	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	C B Mott Park - 26	306086	2	Regular	South-North	Kerbside	Yellow Line Marking	28	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Raff Ave - 25	305902	2	Regular	North-South	Kerbside	Yellow Line Marking	25	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Greenslopes Mall - 25/24	306087	2	Premium	South-North	Kerbside	Yellow Line Marking	29	No	No image	No image	N/A	Yes	Yes	Yes	N/A	N/A	No image	Yes	No Image
Logan Rd	Greenslopes Mall - 25/24	305901	2	Premium	North-South	Kerbside	Yellow Line Marking	29	No	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Logan Rd	Donaldson Street - 23	306088	2	Regular	South-North	Kerbside	Yellow Line Marking	22	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Donaldson Street - 23	305900	2	Regular	North-South	Kerbside	Yellow Line Marking	10	Yes	No image	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Greenslopes - 22	305899	2	Premium	North-South	Indented	Yellow Line Marking	26	No	Yes	Yes	Yes	Yes	Yes	Yes	7	12	Yes	Yes	Yes
Logan Rd	Greenslopes - 22	306089	2	Premium	South-North	Kerbside	Yellow Line Marking	33	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	*Yes
Logan Rd	Greenslopes School - 21	306090	2	Regular	South-North	Kerbside	Yellow Line Marking	43	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Logan Rd	Greenslopes School - 21	306336	2	Regular	North-South	Kerbside	Yellow Line Marking	25	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Bradsley Ave - 20	306335	2	Regular	North-South	Kerbside	Yellow Line Marking	29	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Bradsley Ave - 20	306091	2	Regular	South-North	Kerbside	Yellow Line Marking	27	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Logan Rd	Logan Road North - 19	306092	2	Premium	South-North	Kerbside	Yellow Line Marking	24	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Logan Rd	Logan Road North - 19	306334	2	Premium	North-South	Kerbside	Yellow Line Marking	12.5	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Cornwall St	Cleveland Street 18a	305223	2	Regular	West-East	Kerbside	Yellow Line Marking	21	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Cornwall St	Baron Street 18	305242	2	Regular	West-East	Kerbside	Yellow Line Marking	28	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Juliette St	Beatrice Street - 19	305219	2	Regular	East-West	Kerbside	Yellow Line Marking	15	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Juliette St	Baron Street 18	305220	2	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
	Route 385																			
	Waterworks	302658	3	Regular	0	Turnaround	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	N/A	Yes	Yes
Waterworks Rd	Parkdale	302657	3	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Parkdale	302656	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Waterworks Rd	Petmar-Waterworks	302837	3	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	*No
Waterworks Rd	Petmar-Waterworks	302826	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Waterworks Rd	Hilder Road - 46	302835	3	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Waterworks Rd	Hilder Road - 46	302838	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	Settlements Rd - 36	302834	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Settlements Rd - 36	302839	3	Regular	West-East	Indented	Yellow Line Marking	37	No	Yes	Yes	Yes	Yes	Yes	Yes	9	11	Yes	Yes	No
Waterworks Rd	Gap Uniting Church - 35	302840	3	Regular	West-East	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	Gap Uniting Church - 35	302833	3	Regular	East-West	Kerbside	None	N/A	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	Gap High School - 34	302841	3	Regular	West-East	Kerbside	Yellow Line Marking	19	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	*Yes
Waterworks Rd	Gap High School - 34	302832	3	Premium	East-West	Indented	Yellow Line Marking	73	No	Yes	Yes	Yes	Yes	Yes	Yes	20	17	Yes	Yes	Yes
Waterworks Rd	The Gap Village - 33	302842	3	Premium	West-East	Kerbside	Yellow Line Marking	37	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	The Gap Village - 33	302993	3	Premium	East-West	Kerbside	Yellow Line Marking	29	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Waterworks Rd	Jevons Street - 32	302843	3	Regular	West-East	Kerbside	None	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Yes
Waterworks Rd	Jevons Street - 32	302831	3	Regular	East-West	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Waterworks Rd	Payne Road - 31	302825	3	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Waterworks Rd	Payne Road - 31	302830	3	Regular	East-West	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Waterworks Rd	Cooinda Street - 30	302829	3	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Waterworks Rd	Cooinda Street - 30	302826	3	Regular	West-East	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Waterworks Rd	Kilmaine Street - 29	302827	3	Regular	North-South	Kerbside	None	N/A	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Waterworks Rd	Glenquarie Place - 29	302828	3	Regular	East-West	Indented	Yellow Line Marking	23	No	Yes	Yes	Yes	Yes	Yes	Yes	16	12	No	Yes	Front Only
Waterworks Rd	Greenlanes Road - 28/27	302994	3	Regular	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Acton Street - 27	302790	3	Regular	East-West	Kerbside	Yellow Line Marking	31	Yes	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Firhill Street - 26	302789	3	Regular	East-West	Kerbside	Yellow Line Marking	29	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Front Only
Waterworks Rd	Firhill Street - 26	302844	3	Regular	West-East	Kerbside	Yellow Line Marking	*	Yes	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Waterworks Rd	Monoplane Street - 25	302788	3	Regular	East-West	Indented	None	21	No	Yes	Yes	N/A	Yes	Yes	Yes	0	15	No	Yes	Yes
Waterworks Rd	West Ashgrove - 24	302737	3	Regular	North-South	Kerbside	Yellow Line Marking	15	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Coopers Camp Rd	West Ashgrove	302736	3	Regular	South-North	Kerbside	Yellow Line Marking	21	Yes	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	36a	302738	3	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Coopers Camp Rd	Coopers Camp - 29	302723	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	Coopers Camp - 29	302740	3	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	28	302741	3	Regular	North-South	Kerbside	None	N/A	N/A	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	28	302722	3	Regular	South-North	Kerbside	None	N/A	N/A	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	27	302742	2	Regular	North-South	Kerbside	Yellow Line Marking	20	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Coopers Camp Rd	27	302721	2	Regular	North-South	Kerbside	Yellow Line Marking	17	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Coopers Camp Rd	26	302720	2	Regular	East-West	Kerbside	Yellow Line Marking	33	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	No	Yes	Front Only
Jubilee Tce	Bardon - 15	302878	2	Regular	East-West	Kerbside	None	N/A	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Jubilee Tce	Bardon - 15	302859	2	Regular	West-East	Kerbside	Yellow Line Marking	*	No	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Macgregor Tce	Macgregor Tce-Tooth-14	302860	2	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Macgregor Tce	Macgregor Tce-Tooth-14	302877	2	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Perrott Avenue - 13	302876	2	Regular	East-West	Kerbside	Yellow Line Marking	23	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Perrott Avenue - 13	302861	2	Regular	West-East	Indented(other)	Yellow Line Marking	17	No	Yes	Yes	N/A	Yes	*Yes	*Yes	17	0	Yes	Yes	Yes
Latrobe Tce	Gilday Street - 12	302875	2	Regular	East-West	Kerbside	Yellow Line Marking	30	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Gilday Street - 12	302862	2	Regular	West-East	Kerbside	Yellow Line Marking	20	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Trammie's Corner - 11	302874	2	Premium	East-West	Indented	Yellow Line Marking	15	No	No image	Yes	Yes	Yes	Yes	Yes	6	8	Yes	Yes	No Image
Latrobe Tce	Trammie's Corner - 11	302863	2	Premium	West-East	Kerbside	Yellow Line Marking	24	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Paddington Central	302873	2	Premium	East-West	Indented	Yellow Line Marking	20	Yes	Yes	Yes	Yes	Yes	Yes	Yes	0	8	Yes	Yes	No
Latrobe Tce	Paddington Central	302864	2	Premium	West-East	Indented	Yellow Line Marking	*	No	No	Yes	Yes	Yes	Yes	Yes	*	*	Yes	*No	No
Latrobe Tce	Old Ithaca Fire Station - 9	302872	2	Regular	East-West	Indented	Yellow Line Marking	30	No	Yes	Yes	N/A	Yes	Yes	Yes	11	0	Yes	Yes	No
Latrobe Tce	Old Ithaca Fire Station - 9	302865	2	Regular	West-East	Kerbside	Yellow Line Marking		No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Latrobe Tce	Old Paddo Post Office - 8	302871	2	Regular	South-North	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Given Tce	Old Paddo Post Office - 8	302866	2	Regular	West-East	Kerbside	Yellow Line Marking	17	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Given Tce	Great George - 7	302870	2	Regular	East-West	Kerbside	None	N/A	N/A	No image	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No Image
Given Tce	Great George - 7	302867	2	Regular	West-East	Kerbside	Yellow Line Marking	18	No	No	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Given Tce	Paddo Tavern - 6	302869	2	Regular	East-West	Kerbside	Yellow Line Marking	13	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Given Tce	Paddo Tavern - 6	302868	2	Regular	West-East	Kerbside	Yellow Line Marking	20	Yes	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes

Street Name	Stop Name	Stop Number	Zone Number	Stop Type	Direction of Tracvel	Stop Shape	Pavement line marking	Length Parallel to Kerb(m)	Can stop be lengthened	Is rear door clear of obstructions	Is Stop Blade or Sign clear of Kerb	Is bin clear of kerb	Approach clear of obstructions	Departure clear of obstructions	Can bus enter and exit stop safely	Run in taper length(m)	Run out taper length (m)	Are there regulatory signs before and after bus stop	Can bus stop parrallel to kerb	Does the stop have a hardstand area clear of obstructions for all doors
Given Tce	Paddington - 5	302996	2	Regular	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Given Tce	Paddington - 5	302995	2	Premium	West-East	Kerbside	None	N/A	N/A	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	No	Yes	No
Caxton St	Caxton Street - 4	306487	1	Premium	South-North	Kerbside	None	N/A	No	No	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	No
Caxton St	Caxton Street - 4	306488	1	Regular	North-South	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Petrie Tce	Windmill Café - 3	306486	1	Regular	South-North	Kerbside	None	N/A	No	Yes	Yes	N/A	Yes	Yes	Yes	N/A	N/A	Yes	Yes	Yes
Upper Roma St	Upper Roma Street - 3	307127	1	Premium	West-East	Indented(other)	None	42	No	Yes	Yes	*	Yes	No image	No image	5	0	N/A	Yes	No
Upper Roma St	Upper Roma Street - 2	306483	1	Premium	East-West	Kerbside	None	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	N/A	N/A	N/A	Yes	Yes

Appendix C

Depot Evaluation Report

Document Information

Client	TransLink Transit Authority
Job Number	4746
Title	Research and Analysis of High Capacity Vehicle Use - Depot Evaluation for High Capacity Vehicles
Prepared by	MRCagney Pty Ltd Brisbane, Queensland
Date	24 September 2012

Quality Assurance Register

Issue	Description	Prepared by	Reviewed by	Authorised by	Date
1	Initial Issue for Review	MF, JH	BW, JV	LC	31/07/2012
2	Author Review and Edit	MF	BW, JV	LC	21/08/2012
3	Final Edit	MF	LC, JV	LC	24/09/2012

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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by *TransLink Transit Authority (TransLink*) to undertake research and analysis of high capacity vehicle *(HCV)* use within its South East Queensland network. The subject high capacity vehicle types nominated by *TransLink* for the study are already in service on its network and include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

This technical study assesses the suitability and readiness of 16 existing bus depots in South East Queensland for future deployment of the 4 alternative high capacity vehicle types. The bus operators and depots selected for evaluation in consultation with *TransLink* were:

- Clarks Logan City Bus Service
  - Loganlea Bus Depot, 42 Jutland Street, Loganlea
- Hornibrook Bus Lines
  - Clontarf Bus Depot, 19 Grice Street, Clontarf
  - North Lakes (Satellite) Bus Depot, Wills Street, North Lakes
- Park Ridge Transit
  - Park Ridge Bus Depot, 3830 Mount Lindsay Highway, Park Ridge
- Surfside Buslines
  - Coomera Bus Depot, Old Coach Road, Upper Coomera
  - Molendinar Bus Depot, 10 Mercantile Court, Molendinar
  - Tweed Heads Bus Depot, Ourimbah Road, Tweed Heads
- Veolia Transdev Queensland
  - Capalaba Bus Depot, 10 Smith Street, Capalaba
- Brisbane Transport
  - Bowen Hills Bus Depot, Abbotsford Road, Bowen Hills
  - Carina Bus Depot, Creek Road, Carina
  - Garden City Bus Depot, MacGregor Street, Upper Mount Gravatt
  - Richlands (Satellite) Bus Depot, Government Road, Richlands
  - Sherwood Bus Depot, Sherwood Road, Sherwood
  - Toowong Bus Depot, Dean Street, Toowong
  - Virginia Bus Depot, Ferric Street, Virginia
  - Willawong Bus Depot, Sherbrooke Road, Willawong
  - Trade Coast Bus Depot, Schneider Road, Eagle Farm (currently under construction).

1.2 Depot High Capacity Vehicle Suitability Evaluation Criteria

In this study, each depot has been evaluated for its suitability and readiness to maintain, service and accommodate the 4 high capacity vehicle types. Depots were inspected and assessed for:

- Existence and suitability of existing facilities, plant and equipment necessary to maintain and service each high capacity vehicle type,
- Adequate height, width and clearance of garage work bay roller access doors for manoeuvring and entry of each high capacity vehicle into existing covered mechanical, electrical and body maintenance work bays,
- Sufficient garage roof truss, pendant fixture and suspended service heights for worker safe hoisted undercarriage and bus roof-top maintenance of each high capacity vehicle,
- Adequate covered garage pit and/or work bay depth, inclusive of internal circulation passageways, or adequate garage building width between opposing drive-through access doors for floor level and hoisted chassis maintenance on the longer 14.5m rigid and 18m articulated buses, either under full cover, or partial cover to a level exterior concrete hardstand apron,
- Minimum clear approach length and width of existing garage hardstand aprons to safely manoeuvre, turn in and reverse out each high capacity bus type from existing garage maintenance work bays,
- Sufficient height and width of existing bus washing, refuelling, high pressure cleaning, tyre repair, and other bus servicing sheds and annexes for manoeuvring and entry of each high capacity vehicle type,
- Minimum clear approach and departure length and turning path width to drive each high capacity bus type into or through servicing sheds and annexes,
- Existing refuelling capability for each high capacity bus type, including where applicable, CNG and/or diesel refuelling bowsers and Adblue urea dispensers for new high capacity diesel buses fitted with Euro 5 (or later) environmentally rated SCA engines,
- Swept path template overlaying on all depot circulation and parking yard access corridors to ensure each high capacity bus type could be safely driven around and manoeuvred within all existing depot confines without accidental collisions or side swipes,
- Determination of maximum depot parking capacities for each high capacity bus type, based on existing depot yard layouts with appropriate modifications where necessary, for future high capacity vehicle parking and depot circulation. This has included development of concept designs for new yard parking schemes to accommodate high capacity vehicles in depots currently configured only to accommodate standard length 12.5m rigid buses,
- Impacts of each high capacity bus type on the depot standard bus parking capacity and depot fleet passenger carrying capacity, and
- Identification of the high capacity bus type(s) best suited for deployment at each depot.

1.3 Summary of Findings

Depot High Capacity Vehicle Maintenance, Servicing and Accommodation Assessments

In the context of this study, *Bus Maintenance* encapsulates all scheduled, preventative and reactive mechanical, electrical and body repair activities undertaken in each depot to maintain the roadworthiness, amenity and safety of its resident bus fleet. Maintenance activities were characterised by fault diagnostics, dismantling, repair or replacement of vehicle components and performed by qualified tradespersons or contractors with specialised knowledge and skills.

Bus maintenance tasks were typically performed under cover over garage pits or in work bays fitted out with external roller or folding doors, work benches, parts storage shelving, parts cleaning troughs, overhead lighting, single and 3 phase appliance power sockets, reticulated water and compressed air outlets. Specialised hand and power tools, inspection lights, test instruments, drum trolleys, mobile pump out and welding equipment, cleaning consumables, spare component assemblies and parts were invariably required at hand in garage work bays for tradespersons or contractors to undertake their maintenance tasks.

Where vehicles had to be raised for undercarriage maintenance in mechanical work bays; 6 mobile multi-post wheel hoists or adjustable height axle stands were additionally required. Where maintenance work had to be undertaken above the vehicle's roofline; mobile trestles, elevated work platforms or catwalks and roof truss tethered anti-fall safety harnesses were additionally required. Dedicated pits or work bays fitted with in-ground suspension shakers, brake testers and wheel aligners were needed for heavy vehicle safety testing, and a general workshop equipped with a spare parts and materials store, welding bay, essential machine tools such as a lathe, band saw, pedestal grinding wheel and press drill, an overhead radial or monorail chain hoist and fixed work stands were also needed for major vehicle assembly repairs such as engine and differential overhauls.

With the exception of spare components and parts unique to each vehicle type, the necessary human resources and maintenance facilities for future high capacity vehicle maintenance already existed at most depots assessed during the study and were already used to maintain existing buses. Where such didn't exist, maintenance was either being transferred offsite to a mother depot in the case of satellite bus depots, or outsourced to specialist contractors. Major accident repairs, full body repaints, structural rebuilds, transmission overhauls and electronic equipment repairs were commonly outsourced to specialist contractors by most bus operators.

Minor new maintenance equipment purchases such as additional pairs of multi-post hoists for high capacity vehicles, energy guidance system cylinder pressurisation and bellows removal tools for articulated buses, and higher work trestles and tethered harness cables for double deck buses were not considered in the study to be significant impediments to future high capacity vehicle deployment. Significant garage rebuilds, upgrades or modifications needed for future high capacity vehicle maintenance were however considered to be major impediments to future high capacity vehicle deployment and have included:

- Garage work bay roller doors incapable of being easily raised under existing wall or roof structures found too low to permit double deck bus entry,
- Garage roof trusses, overhead pendant fixtures and reticulated service pipes found too low for double deck bus hoisting and/or roof top repairs,
- Garage work bays too short for covered floor level or partially covered hoisted 14.5m rigid and articulated bus undercarriage maintenance, and

- Existing garage concrete aprons too narrow or short to turn and/or manoeuvre high capacity vehicles into maintenance work bays between existing door slides and wall or roof structural members.

In the context of this study, *Bus Servicing* encompassed routine vehicle upkeep tasks which did not involve dismantling or replacement of vehicle components. Bus servicing was performed by unskilled personnel such as drivers, cleaners and labourers, and completed either on an exterior hardstand, in an ancillary garage bay, or under a covered building lean-to, annexe or shed separated from and not requiring vehicle entry into the primary bus maintenance garage. Routine bus servicing tasks included:

- Bus exterior washing, interior cleaning, Adblue urea tank top-up and refuelling,
- High pressure chassis, engine compartment, wheel and undercarriage cleaning,
- Tyre storage, wear inspection, replacement, rotation and rim balancing,
- Alternator, water pump, air conditioner and radiator fan belt tightening or replacement,
- Chassis, suspension, axle, drive train, wheelchair loader and door mechanism greasing,
- Engine, transmission, differential and steering box oil replacement or top-up, and
- Water, water additive, pneumatic and hydraulic oil replacement or top-up.

At large bus depots, bus exterior washing, interior cleaning, Adblue top-up and refuelling were semi-automated on a two stop process line, and performed daily or bi-daily by bus drivers returning to depot, some with and others without the assistance of a rostered duty cleaner (or refueller in the case of compressed natural gas buses). All other abovementioned bus servicing tasks, including bus exterior washing in the case of small depot operators, were performed by full-time semi-skilled staff such as cleaners and labourers, or by contractors in the case of high pressure chassis cleaning.

Major facility rebuilds, upgrades or modifications needed for routine high capacity bus servicing considered to be significant impediments to future high capacity vehicle deployment included:

- Non-existent compressed natural gas (CNG) refuelling capability at Brisbane Transport depots for existing articulated buses. It has been noted from interviews with Brisbane Transport that it was no longer intended to procure more CNG articulated buses, and depot assessments assumed that any future new Brisbane Transport articulated buses, if procured, would be powered by diesel,
- Service building, annexe and shed roof trusses, overhead pendant fixtures and/or reticulated service pipes too low to permit double deck bus entry,
- Existing bus washing machine flail/brush spindles, water harvesting pipes and crossover frame heights too low for double deck buses, and
- Existing concrete aprons too narrow or short to manoeuvre high capacity vehicles into tyre repair bays between existing roller door frames and wall or roof structural members.

High capacity vehicle *Depot Accommodation and Circulation* constraints have been identified at 12 of the 16 assessed depots, but in every case, appropriate low cost modifications to existing depot yard circulation and parking schemes (described in Section 3.6) have enabled all high capacity vehicle types to be accommodated in all depots. None of the existing circulation constraints or yard modifications proposed was considered to be a significant impediment to potential future deployment of high capacity buses.

Tables appearing overleaf on the following 2 pages summarise the high capacity vehicle suitability assessments for the 8 Brisbane Transport and 8 private operator bus depots surveyed during the study.

Bus Depot	Mechanical Maintenance			Body/Electrical Maintenance			Bus Refuelling			Bus Exterior Washing			Bus Chassis Cleaning			Accommodation & Circulation		
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses
Brisbane Transport																		
Bowen Hills	No. Shed Roof Too Low	Yes	Yes. But Only Future Diesel Artics	No. Shed Roof Too Low	Yes	Yes	Yes	Yes	Yes. But Only Future Diesel Artics	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	No. Shed Roof Too Low	Yes	Yes	No. Will Need Resumption of Car Parking Spaces and Added High Capacity Bus Circulation and Exit on Gebbie Street		
Garden City	Yes	Yes	Yes	Yes. Will Need Elevated Catwalks	Yes	Yes	Yes	Yes	Yes	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	Yes	Yes	Yes	Yes. But Raise Water Harvest Pipe on Logan Rd Boundary	Yes	Yes
Carina	No. Won't Fit Under Roller Doors But Bus Can be Hoisted in North Building	Yes	Yes. Has Existing CNG Articulated Bus Maintenance Facilities	No. South Building Roof Too Low	Yes	Yes	No. South Building Roof Too Low	Yes	Yes. But Only 10 Max CNG Artic Buses or Future Diesel Artic Buses	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	Yes	Yes	Yes	Yes. But Would Need Bus Parking Lanes Along Eastern Boundary Kept Clear for Late Night High Capacity Bus Entry to Rear of Yard Lanes		
Virginia	No. Door Heights OK But Only Body Shed Roof High Enough	Yes	No. Shed Widths Too Short and Doors too Low to Hoist	Yes. Door Heights OK But Only Body Shed Roof High Enough	Yes	Yes. With Partial Cover	Yes	Yes	Yes	Yes. But Wash Roller Frame and Down Pipe Need To be Raised	Yes	Yes	Yes	Yes	Yes	Yes. But Existing Yard Lanes Would Need to be Shortened One 12.5m Rigid Bus Length to Enable High Capacity Bus Depot Circulation		
Willawong	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. Shed OK. Wash Roller Frame too Short	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Richlands	No. All Maintenance Required at Toowong Bus Depot	Yes. Partial Cover But All Hoisted Major Repair & Maintenance Required at Toowong Bus Depot		No. All Maintenance Required at Toowong Bus Depot	Yes	Yes	No. Roof Trusses & Braces Too Low	Yes	Yes. But Only Future Diesel Artics	No. Roof Too Low. Could Wash on Hard Stand	Yes	Yes	No. All Chassis Cleaning Would Need to be Completed at Toowong Bus Depot			Yes	Yes	Yes
Toowong	Yes	Yes	Yes	Yes	Yes	Yes	No. Service Shed Roof Trusses Too Low	Yes	Yes	No. Service Shed Roof Trusses Too Low	Yes	Yes	Yes	Yes	Yes	Yes. But Existing Yard Lanes Would Need to be Shortened One to Three 12.5m Rigid Bus Lengths in Sections to Enable High Capacity Bus Circulation		
Sherwood	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But Only Future Diesel Artics	Yes. Shed OK. Wash Roller Frame Too Short	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Bus Depot	Mech & Elect Maintenance			Body Maintenance			Bus Refuelling			Bus Exterior Washing			Bus Chassis Cleaning			Accommodation & Circulation		
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses
Clarks Logan City Bus Service																		
Loganlea	Yes	Yes	Yes	Yes. But With Minimal Height Clearance	Yes. With Partial Cover	Yes. With Partial Cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. Existing Yard Layout Could be Easily Modified Using Lanes for Improved High Capacity Bus Circulation		
Hornibrook Bus Lines																		
Clontarf	Yes	Yes	Yes. But Only In 3 Drive-Through Bays. Partial Cover Only in 16m Short Bays	Yes. Some Lights Would Need to be Raised in Drive-Through Bay	Yes	Yes. Partial Cover in Short Bays	Yes	Yes	Yes	Yes	Yes	Yes	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes	Yes	Yes
North Lakes	Yes. Basic Maintenance Only with All Hoisted Major Repairs and Maintenance Required at Clontarf Bus Depot			Yes. Basic Maintenance Only with All Major Maintenance and Repairs Required at Clontarf Bus Depot			Yes	Yes	Yes	Yes	Yes	Yes	Yes. With Chassis Cleaning at Clontarf Bus Depot			Yes. 6 Bus Bays at Rear and 1 Lane Bay on Eastern Side of Yard Would Need to be Kept Clear at All Times for High Capacity Bus Circulation		
Park Ridge Transit																		
Park Ridge	Yes. But 12 Bus Parking Bays in Front of Shed to be Kept Clear for Manoeuvring. Downpipe on Front of Shed to be Lifted			Yes	Yes	Yes	Yes. Would Need Adblue Dispenser for New High Capacity Buses			Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. But 12 Bus Parking Bays in Front of Maintenance Shed to be Kept Clear for High Capacity Bus Manoeuvring		
Surfside Buslines																		
Molendinar	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tweed Heads	No. All Repairs and Maintenance Only on Hard Stand Area	No. Covered or Partially Covered, But Can Only be Hoisted for Major Repairs and Maintenance on Garage Hard Stand		No. All Repairs and Maintenance Only on Hard Stand Area	Yes. Covered	Yes. Partially Covered	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But 31 (Currently Unused) Standard Bus Parking Bays Would Need to be Given Up for High Capacity Bus Circulation in Parking Yard		
Coomera	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Veolia Transdev Queensland																		
Capalaba	No. Door Height Too Low. All Maintenance & Repairs Only on Hard Stand	Yes	Yes	No. Door Height Too Low. All Maintenance & Repairs Only on Hard Stand	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But This Depot Uses Highly Packed First In-Last Out Yard Parking. High Capacity Bus Parking Would Require 7 Bus Parking Spaces in Access Corridor be Kept Clear Till Late Evening		

Depots Found Suitable for All High Capacity Vehicle Types

6 of the 16 assessed bus depots have been identified as universally suitable, with minimal or no major upgrades for maintenance, servicing and accommodation, of a large high capacity bus fleet comprising of

any high capacity bus type or combination of high capacity bus types. The universal high capacity bus depots identified were:

- Loganlea Bus Depot,
- Molendinar Bus Depot,
- Coomera Bus Depot,
- Garden City Bus Depot,
- Willawong Bus Depot, and
- Sherwood Bus Depot.

Double Deck Buses Not Recommended for any Brisbane Transport Bus Depot

5 old generation Brisbane Transport bus depots originally designed for maintenance of single deck buses have existing garage roller doors, building roof trusses, or service critical building heights too low for double deck bus entry. Old Brisbane Transport depots found unsuitable for double deck bus maintenance and/or servicing were the:

- Bowen Hills Bus Depot,
- Carina Bus Depot,
- Virginia Bus Depot,
- Toowong Bus Depot, and
- Richlands Satellite Bus Depot.

Earlier high capacity bus studies further identified a large number of existing low clearance railway bridges on the Ipswich Railway Line which present a formidable physical barrier to double deck bus operations at numerous locations from Darra inbound to the city, and with two other flood prone low railway bridges over Oxley Road at Corinda and Muriel Avenue at Rocklea, effectively block double deck bus road movements along the western, southern and eastern public road approaches to the Sherwood Bus Depot. Double deck buses could only be operated currently without low bridge avoiding route diversions on Brisbane Transport suburban bus services out of the Garden City and Willawong Bus Depots.

The inability to freely accommodate, maintain, service or operate double deck buses from 6 out of 8 existing bus depots makes this high capacity bus type a less flexible and viable option than single deck high capacity buses for future Brisbane Transport suburban bus operations. Deployment of double deck vehicles has therefore not been recommended for any Brisbane Transport bus depot.

Maximum Depot High Capacity Vehicle Parking Capacity Assessments

The majority of depots currently accommodated only standard 12.5m length rigid buses and utilised either nose-to-tail yard parking lanes or yard perimeter parking bays with narrow turning and circulation corridors designed to maximise standard bus parking densities. Whilst 12 of the 16 depots assessed required yard parking scheme modifications to enable high capacity bus entry and accommodation, major yard parking scheme changes were essentially confined to providing new forward in-out parking lanes for articulated buses in yards with perimeter parking bays only.

To determine which high capacity vehicle type made best use of the existing depot property within its boundary length, width and circulation constraints, maximum parking capacities were evaluated for every high capacity vehicle type and compared to the depot's standard bus parking capacity. These evaluations were performed for all high capacity vehicle types irrespective of whether their operators had adverse opinions about, or existing maintenance and servicing facilities were considered unsuitable for particular high capacity vehicle types, and the results of the evaluation appear in the table overleaf.

Bus Depot	Suitable (with Minor Upgrades)			Depot Refuelling Capability	TransLink Advised Depot Safe Working Capacity	Total TransLink Buses Currently Garaged	Assessed Maximum Depot Parking Capacity			
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses				12.5m Standard Rigid Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses
Brisbane Transport										
Bowen Hills	No	Yes	Yes (Note 9)	Diesel	112	111	112	54 (Note 6)	44	28
Garden City	Yes	Yes	Yes	CNG + Diesel	200	183	184	184	153	118
Carina	No	Yes	Yes (Note 10)	Diesel	160	174	185	183 (Note 6)	156	119
Virginia	No	Yes	Yes	CNG + Diesel	160	179	179	108 (Note 6)	80	58
Willawong	Yes	Yes	Yes	CNG + Diesel	200	193	222	222	185	148
Richlands	No	Yes	Yes (Note 9)	Diesel	45	32	56	49 (Note 6)	44	75
Toowong	No	Yes	Yes	CNG + Diesel	165	182	183	155 (Note 6)	132	108
Sherwood	Yes	Yes	Yes (Note 9)	Diesel	200	142	215 (Note 3)	215 (Note 6)	172	129
Trade Coast (Note 1)	Likely	Yes	Yes	Diesel (Note 2)	200	0	200 (Note 4)	200 (Note 4)	160 (Note 4)	120 (Note 4)
Clarks Logan City Bus Service										
Loganlea	Yes	Yes	Yes	Diesel	135	125	138 (Note 7)	136 (Note 7)	124 (Note 7)	51 (Note 7)
Hornibrook Bus Lines										
Clontarf	Yes	Yes	No	Diesel	60	48	52	25	21	9
North Lakes	Yes	Yes	Yes	Diesel	60	13	57	28	28	28
Park Ridge Transit										
Park Ridge	Yes	Yes	Yes	Diesel	120	80	121	119	74	19
Surfside Buslines										
Molendinar	Yes	Yes	Yes	Diesel	160	247	170	142	110	46
Tweed Heads	No	Yes	Yes	Diesel	150	61	150	113 (Note 6)	113	79 (Note 7)
Coomera	Yes	Yes	Yes	Diesel	125	0	190	186	144	126
Veolia Transdev Queensland										
Capalaba	No	Yes	Yes	Diesel	95	119	105 (Note 5)	50 (Note 8)	45 (Note 8)	12 (Note 8)

Note 1: As at 31 August 2012, the new Trade Coast (Eagle Farm) Bus Depot was still under development.
Note 2: Trade Coast is located close to a high pressure gas pipeline and could be developed as a new CNG + Diesel bus depot.
Note 3: Sherwood Bus Depot has sufficient reserve yard parking space to accommodate up to 258 standard 12.5m rigid buses.
Note 4: Based on TransLink advised depot parking capacity and similar yard lane layout to Willawong and Sherwood Bus Depots.
Note 5: Based on 105 first in-last out high density bus yard parking plus 26 standard 12.5m buses parked in on-site building.
Note 6: These depots are considered unsuitable for double deck buses because of building height or road access restrictions.
Note 7: Parking layout and access/circulation corridors to be modified at this depot for high capacity buses and numbers listed.
Note 8: Additional parking of high capacity vehicles in two on-site building through-running lanes would increase these capacities.
Note 9: BT articulated buses are currently CNG only. These depots would only be suitable for future diesel articulated buses.
Note 10: Carina Depot has an existing low pressure natural gas pipeline suitable for refuelling 10 CNG articulated buses/day.

Recommended High Capacity Vehicle Types Based on Depot Equivalent Standard Bus Capacity Reduction Impacts

The relative impacts of accommodating each high capacity vehicle type in each depot have been quantified in terms of the net decrease caused to the depot's existing standard bus parking capacity and the change in its standard bus fleet passenger carrying capacity with high capacity buses deployed to the maximum parking capacities indicated in the table above. Whilst accommodation of any particular high capacity bus type to its maximum depot parking capacity was considered unlikely in the near future, relative changes to equivalent standard bus capacities provided a useful comparison for recommending and ranking those high capacity bus types best suited to each depot site.

All depots have been determined to be suitable for maintenance and servicing of at least two alternative high capacity vehicle types, but the introduction of high capacity buses onto standard bus depot sites has generally incurred a high reduction in the depot's equivalent standard bus parking capacity. Loss of equivalent standard bus parking capacity was typically highest for 14.5m and 18m articulated buses and lowest for 12.5m double deck buses, the latter of which could be readily accommodated in the greatest number of existing standard bus parking spaces at all depots other than Tweed Heads. Further, no material loss of equivalent standard bus parking capacity was attributable to double deck buses accommodated at the Clontarf, Molendinar and Capalaba Bus Depots, and although not recommended for Brisbane Transport, incurred no loss of standard bus parking space at its 4 largest depots.

Across all depots, 14.5m rigid and articulated buses incurred an average 9% net reduction in standard bus parking capacity, where 12.5m double deck buses incurred only an average 4% net reduction.

Bus Depot	Suitable for This Depot (with Minor Upgrades)			Recommended for This Depot (as Ranked by Capacity)				Std Bus Capacity	Equiv Std Bus Parking Capacity Decrease			Equivalent Std Bus Passenger Capacity Increase/Decrease			
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses	12.5m Double Deck Buses	14.5m Rigid Buses	2 Door 18m Artic Buses	3 Door 18m Artic Buses	12.5m Standard Rigid Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	2 Door 18m Artic Buses	3 Door 18m Artic Buses
Brisbane Transport															
Bowen Hills	No	Yes	Yes (Note 1)	No	1	3	2	112	-6	-11	-9	31	-5	-24	-19
Garden City	Yes	Yes	Yes	No	1	3	2	184	0	-12	-18	127	6	-37	-15
Carina	No	Yes	Yes (Note 1)	No	1	3	2	185	0	-7	-3	126	8	-18	3
Virginia	No	Yes	Yes	No	1	3	2	179	-13	-24	-25	62	-9	-35	-25
Willawong	Yes	Yes	Yes	No	1	3	2	222	0	-10	-14	153	7	-38	-12
Richlands	No	Yes	Yes (Note 1)	No	1	3	2	56	-7	-11	-10	27	-1	-15	-13
Toowong	No	Yes	Yes	No	1	3	2	183	-21	-25	-22	86	-12	-40	-21
Sherwood	Yes	Yes	Yes (Note 1)	No	1	3	2	215	0	-18	-35	148	-2	-55	-32
Clarks Logan City Bus Service															
Loganlea	Yes	Yes	Yes	1	4	3	2	138	-2	-15	-6	92	16	-11	-2
Hornibrook Bus Lines															
Clontarf	Yes	Yes	No	1	2	No	No	52	0	-1	-4	17	4	-6	-4
North Lakes	Yes	Yes	Yes	1	2	No	No	57	-17	-17	-17	5	-7	-7	-2
Park Ridge Transit															
Park Ridge	Yes	Yes	Yes	1	2	3	3	121	-2	-12	-9	80	9	-5	-2
Surfside Buslines															
Molendinar	Yes	Yes	Yes	1	4	3	2	170	0	-15	-2	98	-5	-14	-6
Tweed Heads	No	Yes	Yes	No	1	3	2	150	-31	-16	-16	59	8	-39	-25
Coomera	Yes	Yes	Yes	1	2	4	3	190	-4	-11	-22	124	-11	-34	-11
Veolia Transdev Queensland															
Capalaba	No	Yes	Yes	No	1	2	2	105	0	0	0	35	14	-3	-1
					Equiv Std Bus Totals			2319	-103	-205	-212	1271	19	-383	-186
					Percent of Std Bus Capacity				**-4%**	**-9%**	**-9%**	**55%**	**1%**	**-17%**	**-8%**

High capacity vehicle impacts on the depot's standard bus fleet passenger carrying capacities were also compared and quite significant differences emerged between the alternative vehicles.

When compared at fully seated plus 50% standing loads, double deck buses increased fleet carrying capacity at every depot, averaging a substantial 55% net increase across all depots. 14.5m rigid buses increased the fleet passenger carrying capacity in half the depots assessed, but decreased it in half the other depots, averaging a 1% net increase across all depots. Articulated buses substantially decreased fleet passenger carrying capacity in every depot, averaging a 17% reduction across all depots for the 2 door articulated buses, and 8% reduction for the 3 door articulated superbuses.

The sensitivity of equivalent standard bus passenger carrying capacity assessments to standing loads was tested over the range of 25% to 100% standing, and while a 3% improvement was observed for the 3 door articulated bus, relative assessments remained virtually unchanged between the 4 high capacity vehicle types.

Recommendations and rankings for the 4 high capacity types have been listed in the assessment table above and summarised as follows:

- Double Deck Buses have been recommended as the best high capacity vehicle choice for private operator depots where they can be accommodated, maintained and operated,
- 14.5m Rigid Buses have been recommended as the best high capacity bus choice for all Brisbane Transport depots and for private operator depots where double deck buses cannot be accommodated, maintained or operated, but excluding Loganlea and Molendinar where a high parking capacity loss would be incurred for the 14.5m rigid bus,
- 3 Door Articulated Buses have been only been recommended at Loganlea and Molendinar Bus Depots, based on loss of parking capacity with 14.5m buses, and
- 2 Door Articulated Buses have not been recommended for deployment to any depot.

Alternately Extended Depot Bus Parking Lanes

Review of all the assessed depot layouts has indicated that bus yards with nose-to-tail parking lanes achieve 5 to 15% higher equivalent standard bus parking densities (i.e. buses per unit area of yard parking space) than yards configured with perimeter parking bays. All existing Brisbane Transport and 3 new private operator depots had implemented nose-to-tail bus parking lanes, but when the lanes were converted, and their circulation accesses widened for parking high capacity vehicles, equivalent standard bus parking space was reduced generally in accordance with the colour coded table and legend below.

12.5m Standard Rigid Bus	12.5m Double Deck Bus	14.5m Rigid Bus	18m Articulated Bus
2	2	1	1
3	3	2	2
4	4	3	2
5	5	4	3
6	6	5	4
7	7	6	5
8	8	7	5
9	9	7	6
10	10	8	7

Green	<6% Equivalent Standard Bus Parking Capacity Loss
Yellow	6% - 15% Equivalent Standard Bus Parking Capacity Loss
Red	>15% Equivalent Standard Bus Parking Capacity Loss

It has been however been demonstrated by the Sherwood Bus Depot example appearing in Section 3.7.2 of the report that lost high capacity vehicle parking capacity could potentially be recovered in most depots by alternately extending lanes into yard circulation corridors widened for high capacity bus turning.

2. High Capacity Bus Depot Facilities

2.1 Study Background

This technical study investigates the suitability of 16 existing bus depots in South East Queensland for future deployment of 4 alternative high capacity vehicle (*HCV*) types, namely the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

Criteria used to evaluate the suitability and compatibility of each depot for future high capacity vehicle deployment have included detailed assessments and checks for:

- Adequate height, width and clearance of garage work bay roller access doors for manoeuvring and entry of each high capacity bus type into existing covered mechanical, electrical and body maintenance work bays,
- Existence of sufficient garage roof truss, pendant fixture and suspended service heights for worker safe hoisted undercarriage and standing bus roof-top maintenance on each high capacity vehicle type,
- Adequate work bay depth, inclusive of internal circulation passageways, or garage building width between opposing drive-through garage access doors for both floor level and hoisted chassis maintenance on 14.5m rigid and 18m articulated buses, under full or partial cover to levelled concrete hardstands,
- Minimum approach length and width of existing garage hardstand aprons to manoeuvre, turn in and reverse out each high capacity bus type from existing garage maintenance work bays,
- Sufficient height and width of existing bus washing, refuelling, high pressure cleaning, tyre repair, and other onsite servicing sheds or annexes for entry of each high capacity vehicle type,
- Existence of sufficient approach and departure length and swept turning path width to drive each high capacity bus type into or through onsite servicing sheds and annexes,
- Existing depot refuelling capability for each high capacity bus type, including where applicable, CNG or diesel refuelling bowsers and Adblue urea dispensers for new high capacity diesel buses likely to be fitted with Euro 5 or higher environmentally rated SCA engines,
- Swept path template overlaying on all existing depot bus circulation and parking yard access corridors to ensure each high capacity bus type can be safely driven around and manoeuvred within all existing depot confines,
- Development of concept designs for new yard parking layouts and circulation accesses to accommodate high capacity vehicles in depots currently configured only to accommodate standard 12.5m length rigid buses,
- Determination of maximum depot parking capacities for each high capacity bus type, based on existing depot layouts with appropriate modifications for future high capacity vehicle parking and circulation,
- Quantification of the impacts of each high capacity bus type on the depot equivalent standard bus parking capacity and its equivalent standard bus fleet passenger carrying capacity, and
- Identification of the high capacity bus type(s) best suited for deployment at each depot.

2.2 High Capacity Vehicle Maintenance and Servicing Facilities

2.2.1 Portable Hand Tools and Test Equipment

Portable hand tools and test equipment needed to maintain high capacity buses in existing bus garages will, in the main, be identical to those already procured and in use for maintenance of standard 12.5m rigid buses. Different facilities, mobile and fixed plant will however be required to maintain the longer chassis and bodies of single deck high capacity buses, and the higher body of the double deck bus.

2.2.2 Exterior Hardstand Bus Maintenance Work Areas

Uncovered exterior concrete hardstands similar to that shown below in Figure 1 can be used to maintain a small fleet of buses on most days of the year in South East Queensland sunny climatic conditions, and can accommodate both standard 12.5m rigid buses and all high capacity vehicle types. However exterior hardstand work areas cannot generally be used for underfloor chassis maintenance at night or during wet weather and when protracted periods of rainy weather set in, reliance on exterior hardstand work areas may lead to a number of stopped buses with little or no prior warning.

Figure 1: Uncovered Exterior Hardstand Work Area (*Photo: Surfside Buslines and Endurequip*)

Undercarriage mechanical and electrical bus maintenance is typically expedited on exterior hardstand areas using 4 or 6 mobile multi-post hoists similar to those depicted above in Figure 1, but there are recognised health and safety risks to tradespersons working on exterior hardstands continuously exposed to solar radiation, extremes of hot and cold weather, unpredictable wind gusts and sudden rain showers. Wet electrical power appliances, mobile hoist plugs and leads laid across an exterior hardstand work area may become live or randomly drop out electrical safety protection devices, create trip, slip and fall hazards to maintenance personnel, can be accidentally driven over when trying to relocate buses off the hardstand in a hurry, and hoisted buses can become trapped aloft on wet hoists.

Latest generation battery powered mobile multi-post hoists manufactured by companies such as MAHA and illustrated overleaf in Figure 2 are cable free and eliminate many of these recognised electrical safety hazards, but only one bus depot (viz. the Brisbane Transport Sherwood Bus Depot) visited during this study owned and operated cable free battery powered multi-post hoists and deployed them only within their covered garage work spaces.

Figure 2: Cable Free Battery Powered Mobile Multi-Post Hoist (*Photo: MAHA GmbH & Co*)

Portable undercarriage inspection lamps and power tools, test instruments and toolboxes, mobile welding and pumping equipment, parts storage shelving, work stands and benches needed to be readily at hand to tradespersons completing underfloor maintenance work on buses cannot be left unsecured and exposed to the weather on exterior hardstands, and when used for such, suffer faster deterioration. Further, mechanical and body maintenance requiring tradespersons or contractors to climb on top of bus roofs cannot generally be undertaken with safely on uncovered exterior hardstand work areas.

2.2.3 Covered Garage Maintenance Pits and Work Bays

Weather protected, roller or folding door accessible, well lit, well ventilated and naturally exhausted interior pit or floor level work bays fitted with reticulated town water, single and 3 phase power and compressed air tool outlets, parts storage shelving and work benches are considered to be healthier, safer, faster, more reliable and more efficient for high turnaround bus maintenance than exterior hardstand areas. Fully covered bus maintenance work bays enable implementation of 24 hour x 7 day and night work shifts, and when also fitted with roller or folding doors, can be closed at any time to secure and protect personnel, equipment and vehicles from the elements.

Figure 3: Bus Underfloor Maintenance Pit (*Photo: Clarks Logan City Bus Service*)

Bus chassis mechanical and electrical maintenance frequently requires work to be completed underfloor. Some (generally older) garages incorporate maintenance bays with longitudinal drive-on pits for underfloor maintenance similar to that shown above in Figure 3, but because pits need to be accessed by steep internal ladders covered over by a parked vehicle, are narrow, difficult to keep clean and drained, and are themselves recognised as potential fall and back strain hazards, modern garages now tend to only utilise mobile multi-post hoists augmented with adjustable height wheel stands to hoist vehicles above head height, where personnel can safely work on level floors. Buses need to be hoisted on both exterior hardstand and interior work bays to a height of approximately 1750mm above floor level (*AFL*) for tall tradespersons to continuously work below without excessive crouching or risk of back strain.

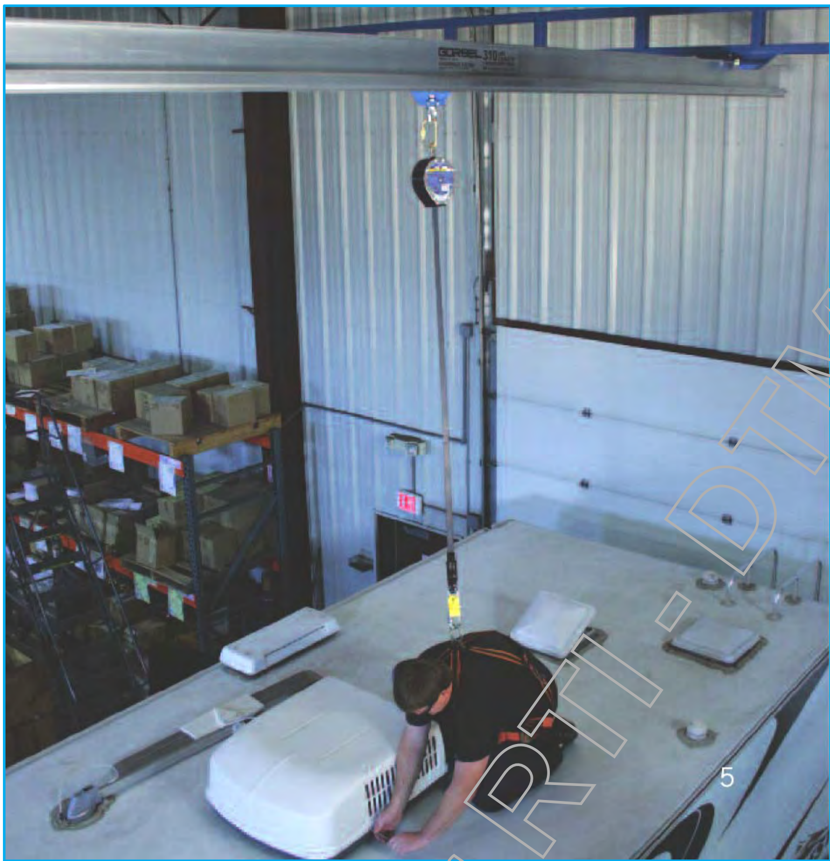
Modern garage work bays also address personnel safety, adopting high bay pendant luminaires for shadow-free high luminance artificial lighting, suspended multi-post hoist cables, power outlets, compressed air and water hoses to deliver services both above and off-floor as illustrated below in Figure 4.

Figure 4: Modern Garage Maintenance Work Bays (*Photo: Brisbane Transport and Endurequip*)

The clear height and bus turn-in manoeuvring width of covered maintenance work bay roller or folding door openings, work bay length, and below roof truss or suspended service fitting height clearance ultimately determine which high capacity vehicle types can be maintained within existing covered garage buildings. For existing garage covered work bays with adequate door height and width clearances, it is possible to reverse a longer length high capacity vehicle into a standard 12.5m rigid bus bay, work on the rear sections of the vehicle under cover, turn around and forward drive the vehicle back into the bay and complete work on its forward sections under cover. If garage work bays or pits have opposing high roller door openings suitable for drive-through, or a single high roller door opening onto a level exterior concrete hardstand apron as found at many existing old garages, longer 14.5m rigid and 18m articulated buses can alternatively be hoisted partly over the work bay and partly on the hardstand, thereby providing partial, but acceptable, weather protected work cover.

A maintenance need also exists in garages for tradespersons or contractors to occasionally stand on bus roofs to repair/replace leaking or damaged roof moulds, engine air intakes, air conditioners, ventilation or emergency escape hatches and radio or GPS equipment antennas. Increased demand for roof top work applies particularly to compressed natural gas (CNG) buses where high pressure shut-off valves need to be regularly closed for welding, gas cylinder replacements or engine fuel component repairs, and CNG cylinders installed in lift off carry frames need to be hoisted off and onto buses for compulsory annual and 5 yearly inspection and static pressure testing.

Figure 5: Tethered Anti-fall Safety Harness for Bus Roof Top Work



To carry out bus maintenance above the vehicle roofline, tradespersons or contractors must access the vehicle roof off a mobile trestle or scissor lift elevated platform brought alongside the vehicle, or from a drive-in fixed height catwalk erected level with the vehicle rooftop. While working on the vehicle roof, repairers must be safely tethered to a recoiling anti-fall safety harness underslung by rollers off an overhead beam or taut wire cable running the length of the vehicle similar to that depicted above in Figure 5. When tethered by harness, the repairer must be able to stand fully erect on the bus roof below roof trusses, luminaires, air ducts, hoists and other suspended objects likely to cause an accidental head injury or fall.

Where pits are not incorporated in covered work bays for routine bus maintenance, the need to either hoist the bus and stand under its chassis, or to stand on the vehicle's roof adds an extra above floor level *(AFL)* clearance imposition to the underside of roof trusses and roof suspended fixtures or services of approximately 2.4m to 2.8m to the overall vehicle height.

The additional 1.1 - 1.2m height of a double deck bus over that of single deck high capacity buses has been identified as a significant barrier to its maintenance in many existing SEQ covered garage buildings originally designed for single deck 3.1m to 3.4m high buses. By way of example, the new Brisbane Transport Willawong garage work bays shown above in Figure 4 have a raised folding door height of around 4.4m, close to the height of the Bustech double deck bus, and their interior service pipe and roof truss tie clearances were found to be precariously close to the raised AFL height needed to stand fully erect under, and taut harness wire height needed to stand fully erect on the double deck bus.

Only 3 SEQ bus operators and 6 of their new depots have industrial height garage maintenance buildings similar to the Clarks Logan City Bus Service garage illustrated below in Figure 6 with the necessary minimum door height and width clearances for turn-in bus manoeuvring, 19m or longer covered work bays, adequate side, front and rear clear working spaces, and rear of work bay walking and mobile plant accesses to readily accommodate the entire range of high capacity bus dimensions.

Figure 6: Industrial Standard High Bay Garage Building (*Photo: Clarkes Logan City Bus Service*)

2.2.4 Covered Bus Servicing Annexes and Sheds

Bus servicing covers a range of routine bus maintenance activities which do not involve substantial fault diagnosis, dismantling or replacement of vehicle components by qualified tradespersons or contractors. Servicing tasks are typically undertaken by unqualified personnel such as bus drivers, cleaners and labourers and completed on an exterior hardstand, in an ancillary garage bay, or under a covered building lean-to annexe or shed separated from the primary maintenance garage.

Common routine bus servicing activities include:

- Bus washing, bus interior cleaning, tyre pressure checking, Adblue top-up and refuelling,
- High pressure chassis, engine compartment, wheel and undercarriage cleaning,
- Tyre storage, wear inspection, replacement, rotation and balancing,
- Alternator, water pump, air conditioner and radiator fan belt tightening or replacement,
- Chassis, suspension, axle, drive train, wheelchair loader and door mechanism greasing,
- Engine, transmission, differential and steering box oil replacement or top-up, and
- Water, water additive and hydraulic oil replacement or top-up.

Most South East Queensland bus operators have covered drive-through bus servicing annexes or sheds for daily refuelling, Adblue dispensing, interior cleaning, tyre pressure checking and periodic wash down of their vehicles.

Large bus operators utilise automatic drive-through flail or stiff roller brush washing machines similar to that illustrated below in Figure 7 to wash their bus exteriors on a daily, bi-daily or twice-weekly exterior wash down cycle, while small bus operators prefer to manually wash their bus exteriors less frequently using low pressure water and detergent wash down brooms. Automatic drive-through washing machines can wash large fleet bus exteriors at a typical maximum rate of 30 - 40 vehicles per hour, where manual hand broom washing is typically limited to 4 – 5 standard 12.5m standard size buses per hour down to 3 - 4 high capacity single or double deck buses per hour.

Figure 7: Automatic Drive-Through Roller Brush Bus Washing Machine

Daily bus refuelling is typically undertaken by drivers on their return to depot, either after the first morning or last evening work shift, and refuelling operations typically include other ancillary tasks such as cabin debris removal and sweep out (or vacuuming), tyre pressure checking and re-pressurisation, engine and windscreen washer water level checking and top-up; and on new model Euro 5 diesel buses, Adblue urea tank top-up. These ancillary refuelling tasks are, more often than not, split between drivers and a rostered duty cleaner or full time bus refueller in the case of CNG buses.

Depot bus refuelling and washing annexes or sheds are invariably open-sided structures similar to those shown below in Figure 8. In practice, daily bus refuelling operations need to be physically separated from bus washing machine or manual broom wash down operations to prevent refuelling bays becoming contaminated with wash-down water or wind carried overspray, and to prevent chemically treated recycled wash down water being contaminated with diesel, oil, Adblue and engine anti-freeze spills.

Figure 8: Covered Drive-Through Bus Refuelling Sheds (*Photos: Hornibrook Buslines*)

Where automatic bus washing machines have been installed by large depot bus operators in older service sheds but only designed to wash up to a nominal single deck bus height of around 3m, these older machines will not wash the upper deck windows, body panels and exterior roof covings above the lower level of a double deck bus and such would have to be cleaned manually by broom or by a mobile drive around high capacity bus washing machine such as the unit shown below in Figure 9. These mobile bus washing units can fully wash the exteriors of 4 to 8 single or double deck high capacity buses per hour.

Figure 9: Mobile Drive Around High Capacity Bus Washing Machine

2.2.5 High Pressure Chassis Cleaning Aprons, Annexes and Sheds

Bus chassis and floor frames, wheels, engine compartments and undercarriages gradually build up dry hard thick crusts of wheel thrown small stones and gravel, and moist layers of diesel, exhaust and oil soaked dust, the latter of which poses a potential underfloor fire hazard if left untreated. Depending on the condition and sealing of road surfaces in the vehicle's service areas, these residues must be periodically scoured off at around 3 to 6 monthly intervals using either automatic or manually operated steam or detergent-boiled water high pressure jet nozzles.

Figure 10: Embedded Drive-Over High Pressure Jet Nozzle Chassis Cleaner

The water and thick road grime sludge removed during steam or high pressure jet chassis cleaning must be captured within a bunded or funnel-sectioned concrete apron, its water and condensate filtered and separated out to sewer, and the sludge piped to an underground holding tank for periodic removal by an industrial waste mini-tanker. High pressure chassis cleaning is normally carried out as both a separate operation to, and in a separate location from, bus exterior washing.

Covered pits or grates with embedded drive-over automatic chassis high pressure cleaning nozzles similar to those shown above in Figure 10 have been installed in some large operator bus garages, but most SEQ bus operators, including Brisbane Transport, use an exterior covered shed or open concrete apron equipped with an in-ground hydraulic bus hoist or drive-on ramp to clean their bus chassis using manual high pressure steam or high pressure detergent-boiled water lances. Manual chassis cleaning does a superior job to automatic pressure nozzle cleaning, but must be performed by cleaners suited up from head to toe in personal protective apparel including full cover industrial rain coats and hats, rubber boots and gloves, goggles and face masks. Manual chassis cleaning is an extremely hot, dirty and labour intensive task, and cleaners required to perform this type of work need regular breathers and can only reasonably be expected to clean from 10 - 13 standard size bus chassis per week. This throughput drops to around 8 – 9 larger size articulated or 14.5m rigid buses per week.

Queensland Department of Transport and Main Roads machinery inspectors will either refuse to inspect or stop buses found with excessive build-ups of undercarriage road grime and oil or diesel soaked residues, and chassis cleaning cycles are usually intensified in the lead-up to compulsory TMR 6 monthly bus machinery inspections. Because of the continuously wet, hot and greasy conditions which permeate bus chassis cleaning areas, underfloor pits and powered multi-post hoists cannot generally be used for manual chassis cleaning, but multi-post hoists can be used to place buses onto fixed height stands. This adds additional labour to the overall task, because high pressure cleaning aprons also have to be steam or high-pressure cleaned after each chassis clean to continually eliminate slippery work surfaces.

Similar problems arise to those described for exterior refuelling and bus washing sheds where over height or over length high capacity vehicles can't be easily hoisted, driven into or physically accommodated within existing covered chassis annexes and cleaning sheds originally designed for standard length 12.5m rigid buses.

2.3 High Capacity Vehicle Depot Circulation and Yard Parking

2.3.1 Garage Maintenance Bay and Service Shed Bus Manoeuvring

Australian Design Rule ADR43/04, Queensland *Transport Operations (Road Use Management – Vehicle Standards and Safety) Regulation 2010* and the proposed new national *Heavy Vehicle Regulation 2012* stipulate the dimensional limits appearing overleaf in Table 1 for standard and high capacity heavy omnibuses registered for use on Queensland roads. The inner and outer turning circles listed in Table 1 are not specified at any particular travel speed in the design rule or either regulation, and are assumed to apply at a maximum bus turning speed of 5km/h.

In addition to legislated dimensional limits, *Austroads* has published a set of inner/outer wheel track turning circle and body wall-to-wall swept path templates for each high capacity vehicle type which it recommends for design of public road lanes, kerbs and roundabouts and for off-road building access manoeuvres, circulation paths and vehicle parking yards. Modified *Austroads* swept path templates have been regenerated in Figure 11 through Figure 15 using *AutoTurn Version 8.1* for the specific axle groups, wheelbases, front and rear overhangs and steering lock angles applicable to the high capacity bus types currently operating in South East Queensland.

Table 1: ADR43/04 and Heavy Vehicle Regulation Omnibus Permitted Dimensional Limits

Configuration or Dimension	2 Door 12.5m Rigid Bus (Reference)	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Maximum Length	12.5m	12.5m	14.5m	18m	18m
Maximum Height	4.3m	4.4m	4.3m	4.3m	4.3m
Maximum Width	2.5m	2.5m	2.5m	2.5m	2.5m
Outer Turning Circle	25m	25m	25m	24m	24m
Inner Turning Circle	Not Applicable	Not Applicable	Not Applicable	5.3m	5.3m
Rear Overhang	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	Lesser of 60% of Wheelbase or 3.7m	3.7m	3.7m

5km/h swept path templates illustrated in Figure 11 through Figure 15 have been used to assess slow vehicle manoeuvring and turns into garage exterior hard stand bays, covered work bays and pits, refuelling sheds, body wash down sheds and chassis cleaning sheds. Coloured 5km/h swept path templates appearing in Figure 11 through Figure 15 have been used to identify high capacity bus turns on all depot aerial views appearing in Section 3.6.

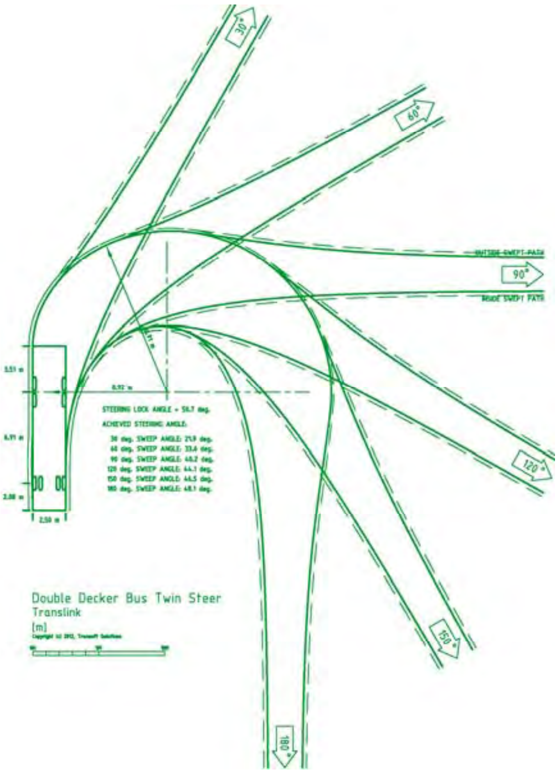
Austroads recommends a minimum 600mm side clearance be allowed to curbs, walls, door openings, poles and other solid vertical objects either side of its published vehicle paths when driven at 5km/h. These clearance envelopes have been illustrated in broken outline on the 5km/h swept path templates and used in all high capacity vehicle slow speed manoeuvring evaluations.

2.3.2 Depot and Parking Yard Bus Circulation

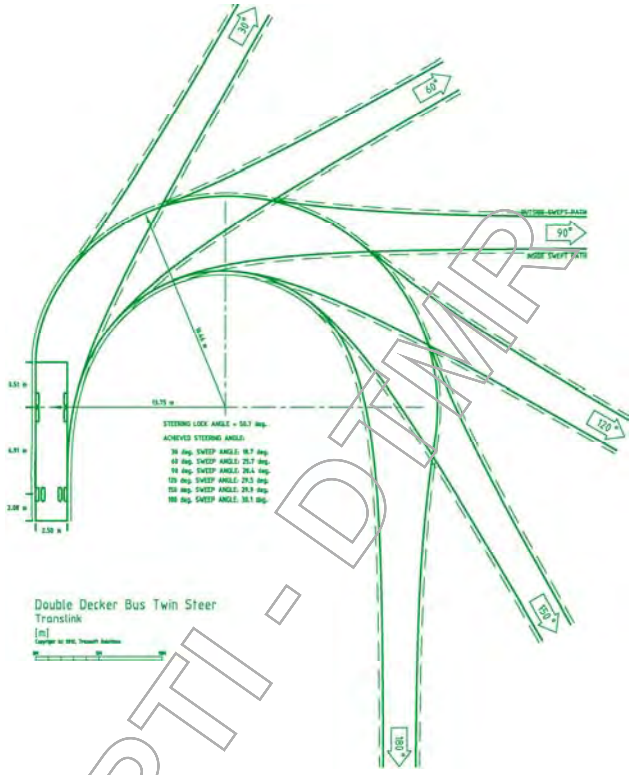
The 15km/h swept path templates shown in Figure 11 through Figure 15 have been adopted to assess most depot and parking yard circulation and access corridors between buildings to garage work bays and service sheds. Coloured 5km/h swept path templates appearing in Figure 11 through Figure 15 have been used to identify high capacity bus turns on all depot aerial views appearing in Section 3.6.

Austroads recommends a minimum 600mm side clearance to curbs, walls, poles and other solid objects either side of vehicle paths when driven at speeds of 5 to 15km/h. These clearance envelopes are shown in broken outline on the 15km/h swept path templates and have been used in most high capacity bus depot circulation evaluations. Circulation assessments have also included identification of existing low aerial cable crossings, building awning and soffit overhangs and tree branches likely to impact double deck bus circulation between existing depot and garage buildings.

Figure 11: 12.5m Twin Steer Double Deck Bus Swept Path Templates at 5km/h and 15km/h

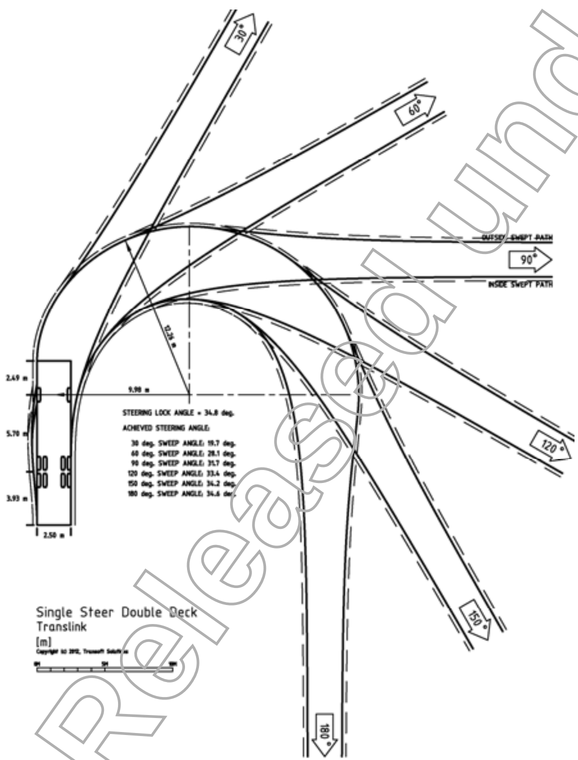


12.5m Twin Steer Double Deck Bus at 5km/h

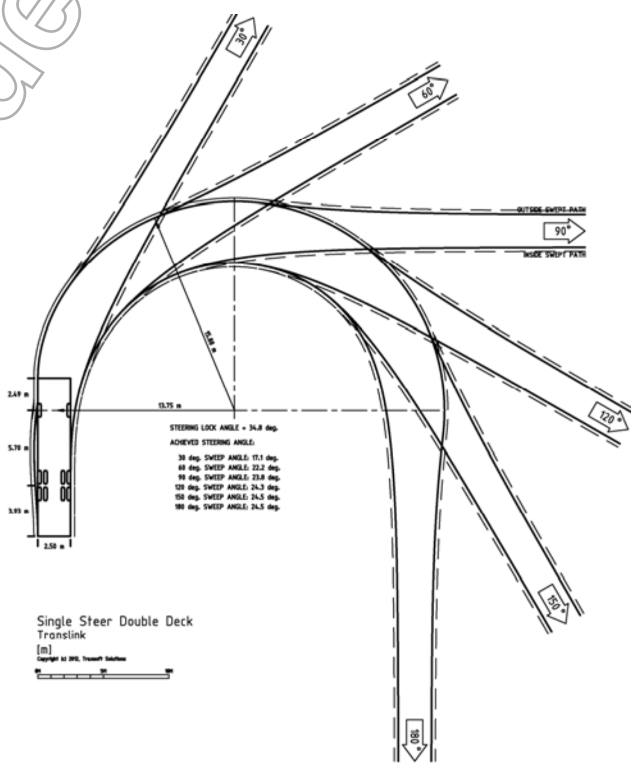


12.5m Twin Steer Double Deck Bus at 15km/h

Figure 12: 12.5m Single Steer Double Deck Bus Swept Path Templates at 5km/h and 15km/h

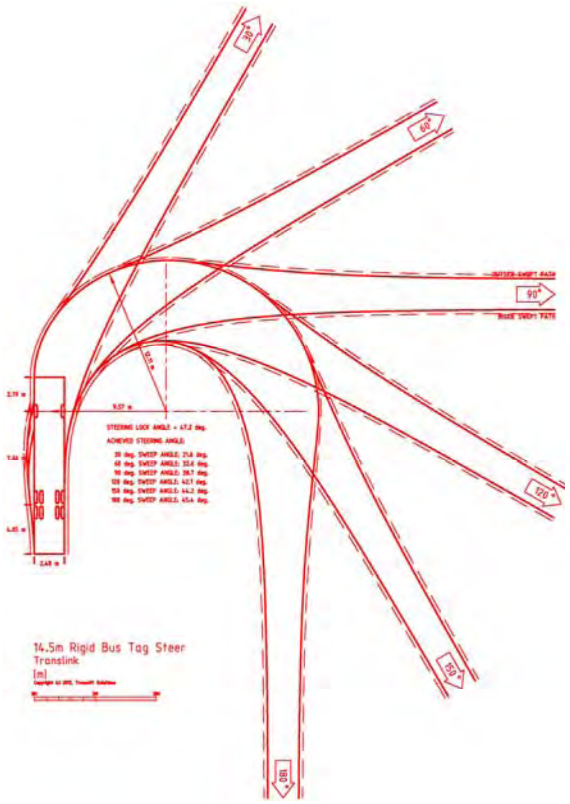


12.5m Single Steer Double Deck Bus at 5km/h

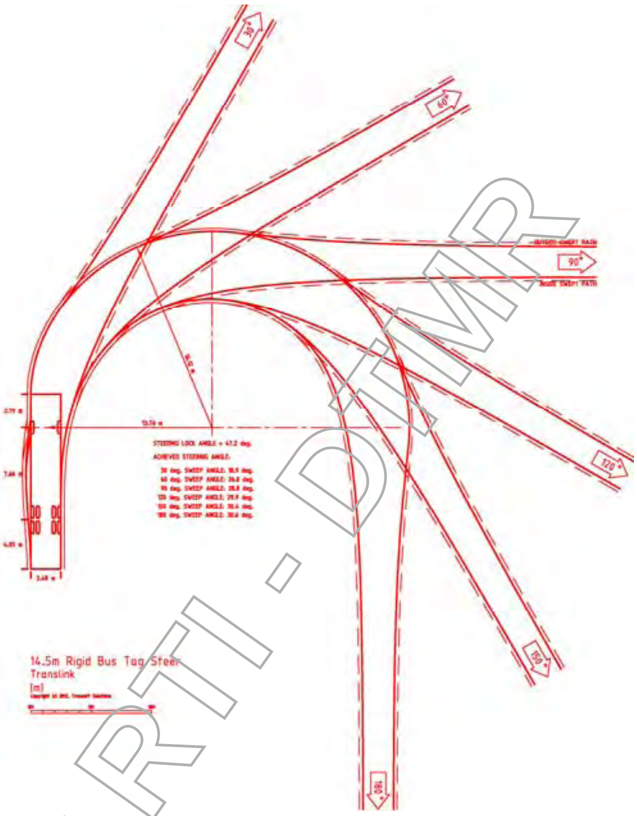


12.5m Single Steer Double Deck Bus at 15km/h

Figure 13: 14.5m Steered Tag Axle Rigid Bus Swept Path Templates at 5km/h and 15km/h

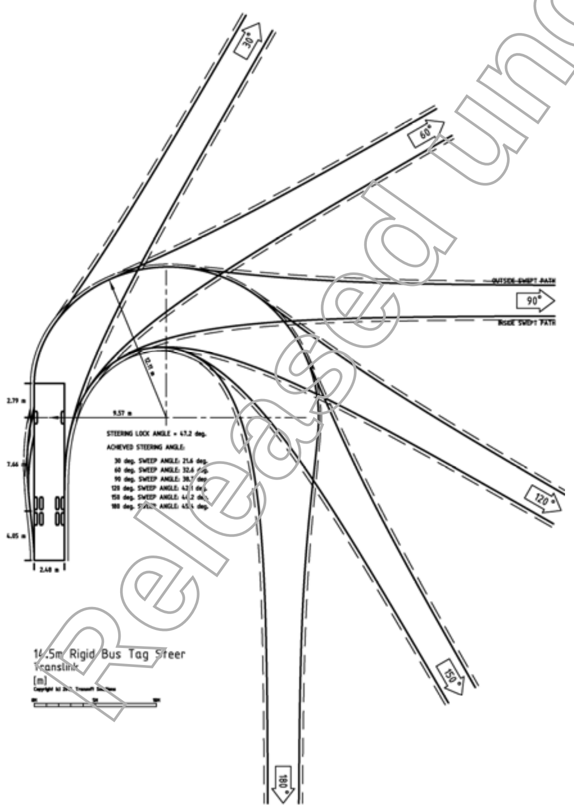


14.5m Steered Tag Axle Rigid Bus at 5km/h

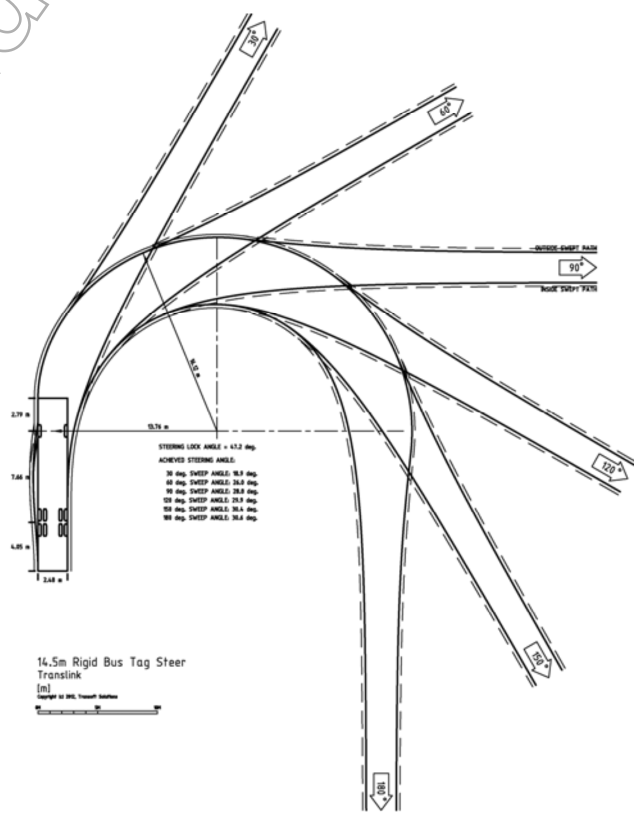


14.5m Steered Tag Axle Rigid Bus at 15km/h

Figure 14: 14.5m Fixed Tag Axle Rigid Bus Swept Path Templates at 5km/h and 15km/h

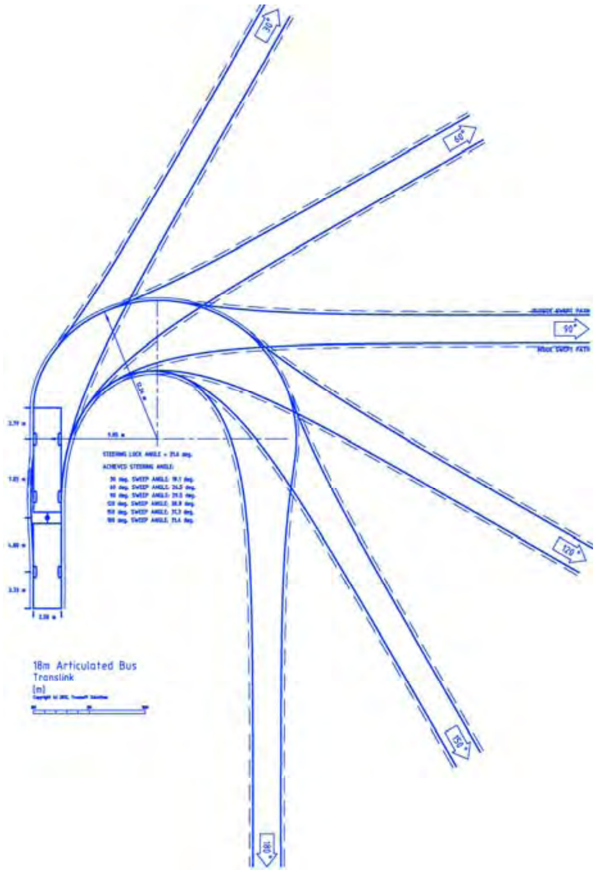


14.5m Fixed Tag Axle Rigid Bus at 5km/h

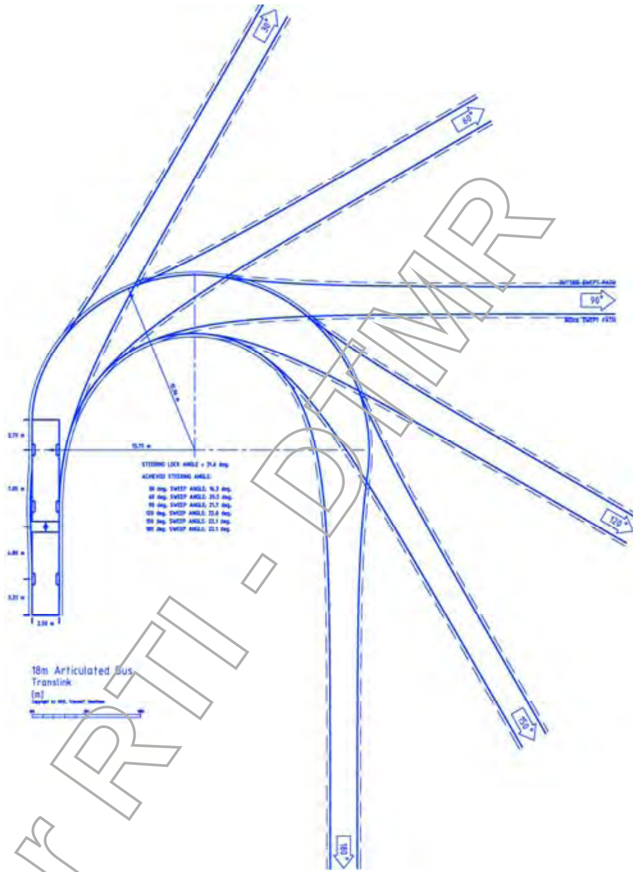


14.5m Fixed Tag Axle Rigid Bus at 15km/h

Figure 15: 18m Fixed Rear Axle Articulated Bus Swept Path Templates at 5km/h and 15km/h



18m Fixed Rear Axle Pusher Articulated Bus at 5km/h



18m Fixed Rear Axle Pusher Articulated Bus at 15km/h

2.3.3 Maximum Depot High Capacity Bus Parking Capacity

Maximum depot yard parking capacities have been evaluated for every high capacity vehicle type at the 16 bus depots nominated in Section 3.1 and have been estimated only for existing yard lanes and perimeter bus parking spaces located in depots adjacent to existing buildings and fences. Maximum parking capacities exclude buses parked in high usage garage exterior hard stand work areas and work bays, on service aprons and in service sheds, unless otherwise already accommodated in such at densely packed bus depots described later in the layout assessments appearing at Section 3.6.

The bus depot parking capacity study has identified 3 different bus parking schemes common use at the 16 assessed bus depots:

- Nose-to-Tail Bus Parking Lanes: This parking scheme was employed at all Brisbane Transport bus depots and at 3 new private operator bus depots. (Refer to Figure 16),
- Perimeter Parking Bays: This parking scheme was identified at most private operator bus depots. Under this arrangement, buses are parked around yard perimeters and alongside depot and garage buildings. Most private operators used line marked angled rows of perimeter bus parking bays, but one operator, Surfside Buslines, used unmarked 90º perimeter parking bays with buses parked in rows one or two deep. (Refer to Figure 17), and
- Densely Packed (First In-Last Out) Parking: This parking scheme was adopted at 2 highly congested private operator bus depots. Under this parking scheme, all perimeter bus parking bays were initially occupied by buses returning to depot following the afternoon peak, then the yard access and depot circulation corridors were back filled from the rear of the yard by buses returning in the early evening, and finally garage maintenance parking bays and service sheds

occupied by buses returning in the late evening. With this parking arrangement, buses can only be dispatched on the following day from the road frontage to the rear of the depot yard in the reverse order (i.e. first in-last out) to the previous day's bus returns.

Depot yards employing nose-to-tail bus parking lanes with perimeter access and circulation corridors as depicted in Figure 16 achieved considerably higher parking densities than depot yards which only utilised perimeter bus parking bays and inter-bay access corridors illustrated by Figure 17. Nose-to-tail parking lanes must generally be dedicated to each particular bus type stationed onsite or as reserved non-dispatchable mixed bus maintenance lanes. They have the advantage of one-way forward in-out bus parking but can cause bus entrapment and mis-dispatch if buses scheduled for maintenance are accidentally placed amongst other buses on dispatchable lanes. In large depots, nose-to-tail lane parking necessitates employment of a full-time dispatcher to continually manage the yard, and rigorous adherence by all bus drivers and garage personnel to parking buses on their prescribed "bus type" and "maintenance" lanes when returned to the yard.

Figure 16: Depot Yard with Nose-to-Tail Bus Parking Lanes (*Photo: Brisbane Transport*)

Perimeter bus parking bays afford considerably greater AM dispatch flexibility and easier management of bus yards than do nose-to-tail bus parking lanes, primarily because perimeter parking bays enable particular buses to be assigned by fleet number either to live service or scheduled maintenance the following day without concern as to where buses might be parked on their return to the depot yard.

In yards already configured for perimeter bay parking, mixed vehicle size capacity assessments have been generally based on one-for-one substitution of high capacity buses for standard 12.5m rigid buses in bays long enough to park such, and for which the vehicle's 5km/h turning template overlay proved the high capacity bus could be easily and safely manoeuvred into the parking bay without accidental collisions or restricting the circulation of other buses. Articulated bus 5km/h templates were used to test forward in-out parking on nose-to-tail parking lanes only. Double deck and 14.5m rigid bus 5km/h templates were used to test reverse or forward parking in perimeter bays and forward in-out parking on nose-to-tail lanes.

Figure 17: Depot Yard with Perimeter Bus Parking Bays (*Photo: Park Ridge Transit*)

2.3.4 High Capacity Vehicle Impact on Depot Equivalent Standard Bus Parking Capacity

During assessments, it was observed at depot sites with parking layouts configured to maximise 12.5m rigid bus storage, that collocating a just a few high capacity buses with 12.5m rigid buses in shared bus parking yards resulted in an immediate and sometimes quite substantial reduction in the depot's equivalent standard bus capacity. Changes to an existing depot's equivalent standard bus capacity have been considered in the assessments from two perspectives; by the net reduction in the depot's available maximum standard bus parking spaces, and by the net reduction or increase in the passenger carrying capacity of the depot's total fleet.

Table 2: High Capacity to Standard Bus Substitution Ratios Used for Nose-to-Tail Parking Lanes

12.5m Standard Rigid Bus	12.5m Double Deck Bus	14.5m Rigid Bus	18m Articulated Bus
2	2	1	1
3	3	2	2
4	4	3	2
5	5	4	3
6	6	5	4
7	7	6	5
8	8	7	5
9	9	7	6
10	10	8	7

<6% Equivalent Standard Bus Parking Capacity Loss

6% - 15% Equivalent Standard Bus Parking Capacity Loss

>15% Equivalent Standard Bus Parking Capacity Loss

In depot yards which were already configured or needed to be reconfigured for nose-to-tail lane parking of high capacity vehicles, maximum parking capacity assessments were based on resuming entire standard bus lane(s) and substituting the alternative bus type in the ratios summarised above in Table 2. Less than a 6% loss of equivalent standard bus parking capacity was readily achieved for all high capacity bus types in existing depots yards with 6 or 7 nose-to-tail standard bus parking lanes, but very significant losses occurred on short nose-to-tail parking lanes with 4 or less standard bus parking spaces when repopulated with 14.5m rigid and 18m articulated buses, generally in accordance with the shading legend specified under Table 2.

Significantly wider access corridor and circulation swept turning paths were needed to manoeuvre newly introduced high capacity vehicles in depot yards and/or into garage work bays than were needed for existing standard 12.5m rigid buses. Each high capacity vehicle's 5km/h turning template was therefore overlaid at the lead in(s) to and exit(s) from resumed high capacity bus lane(s), and their parking manoeuvres separately assessed for reverse or forward parking in yard perimeter bays. Only existing parking lanes and bays with a minimum clear width of 3.45m were assessed for high capacity vehicle parking in adjacent lanes and bays, and a minimum nose-to-tail spacing of 800mm was adopted between buses parked on lanes. At some depots, high capacity bus manoeuvring into and out of lanes and work bays resulted in a further loss of equivalent standard bus parking spaces.

2.3.5 High Capacity Vehicle Impact on Depot Equivalent Standard Bus Passenger Carrying Capacity

The maximum passenger carrying capacities of each bus type reviewed in the study were:

- 2 Door 12.5m Rigid Bus: 44 seated + 31 standing = 75 passengers,
- 2 Door 12.5m Double Deck Bus: 96 seated + 20 standing = 116 passengers,
- 2 Door 14.5m Rigid Bus: 56 seated + 36 standing = 92 passengers,
- 2 Door 18m Articulated Bus: 64 seated + 24 standing = 88 passengers, and
- 3 Door 18m Articulated Superbus: 52 seated + 60 standing = 112 passengers.

As illustrated below in Table 3, the equivalent standard bus carrying capacity of each high capacity bus type varies considerably, depending on the average standing passenger load typically carried during service peak periods.

Table 3: High Capacity Vehicle Equivalent Standard Bus Passenger Carrying Capacities

Bus Type	Maximum Passenger Capacity		Equivalent Standard Bus Passenger Capacity (At Percent Standing Capacity)						
	Seated	Standing	100%	75%	67%	50%	33%	25%	0%
2 Door 12.5m Standard Rigid Bus	44	31	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2 Door 12.5m Double Deck Bus	96	20	1.55	1.65	1.69	1.78	1.89	1.95	2.18
2 Door 14.5m Rigid Bus	56	36	1.23	1.23	1.24	1.24	1.25	1.26	1.27
2 Door 18m Articulated Bus	64	24	1.17	1.22	1.24	1.28	1.33	1.35	1.45
3 Door 18m Articulated Bus	52	60	1.49	1.44	1.42	1.38	1.33	1.29	1.18

An assumed mid-range loading of 100% seated + 50% standing passengers has been adopted to assess the impact of each high capacity bus type on the depot equivalent standard bus fleet passenger carrying capacity using:

- 2 Door 12.5m Double Deck Bus = 1.78 equivalent standard buses,
- 2 Door 14.5m Rigid Bus = 1.24 equivalent standard buses,
- 2 Door 18m Articulated Bus = 1.28 equivalent standard buses, and
- 3 Door 18m Articulated Bus = 1.38 equivalent standard buses.

2.4 Outlook for Natural Gas Powered High Capacity Buses

The cost of fuel represents a major bus operating expense for high capacity vehicles, second only to the driver wages. Between 2000 and 2008, Brisbane City Council placed 539 standard 12.5m rigid compressed natural gas (*CNG*) buses and 30 articulated CNG buses into service with the two key objectives of cutting its continually rising and volatile diesel fuel costs and cleaning up its city bus fleet tailpipe exhaust emissions.

Large scale deployment of CNG buses also occurred in most other Australian mainland capital cities from 2000 to 2005 at bus depots with ready access to utility high pressure natural gas pipelines, but began tailing off nationally from FY2004/05 when Australia's largest public transport operator, the NSW State Transit Authority reverted to procuring clean diesel buses in advance of then announced Commonwealth Government changes to the alternative fuel excise and diesel rebate scheme for public transport buses taking effect from 2012. Only 4[##] Brisbane Transport bus depots currently have a reticulated high pressure natural gas pipeline supply, gas compressor and bulk storage station suitable for daily refuelling of a large fleet of CNG buses in South East Queensland, namely the:

- Willawong Bus Depot,
- Garden City Bus Depot,
- Toowong Bus Depot, and
- Virginia Bus Depot.

[##]Note: Brisbane City Council's Carina Bus Depot has a medium pressure natural gas pipeline and small CNG compressor station suitable for daily refuelling of 15 standard size CNG buses, but the depot no longer operates CNG buses.

All four of these Brisbane Transport CNG bus depots have dual (CNG and diesel) refuelling bowsers and Adblue urea dispensers collocated within their refuelling sheds, and Council's diesel fleet strength is again growing as a result of the Federal Government's alternative fuel excise and diesel rebate policies which have overseen the decline in new CNG bus builds nationwide. Notwithstanding that imported new Euro 5 diesel engine exhaust emissions are as clean as their predecessor CNG engine emissions, a natural gas engine will always maintain a 6 to 12% lower greenhouse gas emission lead on the most efficient diesel engine available. Australian State and Territory Governments responsible for funding public transport are no longer able to recoup royalties on their indigenous natural gas reserves previously supplied to bus depots at State regulated prices to refuel CNG buses, and operators and State transit authorities remain vulnerable to highly volatile international market prices for imported crude oil and bulk distillate.

Confronted by an urgent need to replace its then aging fleet of high floor diesel buses stationed at older bus depots with diesel only refuelling, Brisbane City Council ceased construction of new CNG buses later than most other States in 2009 and reverted back to procurement of Euro 5 clean diesel buses only. Brisbane Transport has advised that Council has no immediate plans to resume construction of new CNG buses in the near future but has certainly not abandoned the option to resume constructing and deploying more natural gas fuelled buses over the long term, should the economics of fuelling its fleet again favour natural gas over diesel.

Council has experienced two high pressure CNG cylinder explosions over the past 6 years and the political appetite for more CNG buses has somewhat waned particularly with the shift in subsidised operating economics between diesel and CNG brought about by the 2012 changes to the federal alternative fuel excise and diesel rebate. It is however foreseen that depleting global crude oil reserves and increasing international demand for fossil fuels are more likely than not to shift the economic advantage back in favour of natural gas within the coming decade.

Brisbane Transport has stated in interviews that its CNG articulated buses suffer from a high CNG storage cylinder axle weight penalty of around 1.5t, very sluggish acceleration and limited daily operating range of less than 450km, and articulated buses are therefore no longer considered suitable future candidates for powering by compressed natural gas. It has been suggested that 14.5m rigid buses would however be suitable future candidates for CNG, but none has ever been built or trialled in service. As for articulated buses, the roof height and axle weight of double deck buses would also preclude them as suitable candidates for powering by compressed natural gas.

Emerging new technology natural gas to hydrogen fuel cell, liquid natural gas (LNG) and small gas engine LNG/L-Ion hybrid powered city buses already being trialled overseas are likely to entice Council and other Australian capital city bus operators to again consider natural gas as a viable alternative fuel to clean diesel. In South East Queensland, bulk LNG can now be trucked to Brisbane bus depots at prices per gigajoule lower than that of clean diesel and Adblue urea, but would require roll out of more new natural gas buses, on-site cryogenic storage tanks, and cryogenic liquid natural gas refuelling bowsers if these emerging alternative technologies proved more viable than diesel.

In countries with proven high indigenous reserves of natural gas such as Russia, Canada, Norway, USA, Indonesia and Malaysia which are also large natural gas exporters like Australia, the pressure to change energy security and balance of trade policies and to recover more State royalty revenues earned from increased local gas consumption could well reverse the Australian capital city bus operator trend back to natural gas fuelled buses. For those capital city bus operators such as Brisbane Transport with an existing large fleet of CNG buses, bulk LNG can now be tanker delivered, stored on-site in cryogenic tanks, warmed and flashed back to gas at ambient temperatures and compressed to CNG at large bus depots with no existing or future likely prospect of access to a gas utility installed high pressure pipeline.

3. Depot Assessments for High Capacity Bus Deployment

3.1 Bus Depots Assessed for Study

The following SEQ bus operators and depots were identified in consultation with *TransLink* as those most likely to deploy high capacity vehicles on high frequency priority (*HFP*) services, long haul *Rocket* and *Express* limited stop services, and proposed future new *UrbanLink* and *ExpressLink* trunk services over the coming decade.

- Clarks Logan City Bus Service
  - Loganlea Bus Depot, 42 Jutland Street, Loganlea
- Hornibrook Bus Lines
  - Clontarf Bus Depot, 19 Grice Street, Clontarf
  - North Lakes (Satellite) Bus Depot, Wills Street, North Lakes
- Park Ridge Transit
  - Park Ridge Bus Depot, 3830 Mount Lindsay Highway, Park Ridge
- Surfside Buslines
  - Coomera Bus Depot, Old Coach Road, Upper Coomera
  - Molendinar Bus Depot, 10 Mercantile Court, Molendinar
  - Tweed Heads Bus Depot, Ourimbah Road, Tweed Heads
- Veolia Transdev Queensland
  - Capalaba Bus Depot, 10 Smith Street, Capalaba
- Brisbane Transport
  - Bowen Hills Bus Depot, Abbotsford Road, Bowen Hills
  - Carina Bus Depot, Creek Road, Carina
  - Garden City Bus Depot, MacGregor Street, Upper Mount Gravatt
  - Richlands (Satellite) Bus Depot, Government Road, Richlands
  - Sherwood Bus Depot, Sherwood Road, Sherwood
  - Toowong Bus Depot, Dean Street, Toowong
  - Virginia Bus Depot, Ferric Street, Virginia
  - Willawong Bus Depot, Sherbrooke Road, Willawong
  - Trade Coast Bus Depot, Schneider Road, Eagle Farm (currently under construction).

3.2 Maximum Bus Depot High Capacity Bus Parking Capacity

Maximum bus depot parking capacities have been summarised overleaf in Table 4 for the 3 high capacity vehicle body sizes and compared with existing maximum standard 12.5m rigid bus parking capacities. Depot bus parking capacities have been calculated for existing yard layouts, depot circulations, turning directions, access corridor widths and perimeter bay and/or nose-to-tail parking lane schemes. Table 4 further nominates those depots with existing bus maintenance and servicing facilities considered to be already suitable for each high capacity vehicle type, or capable of being made ready for high capacity bus types at low cost with minor new plant procurements, yard modifications and garage building upgrades.

Maximum high capacity bus parking capacities listed in Table 4:

- Are for one high capacity vehicle type per depot only. For example, up to 54 x 12.5m double deck or 44 x 14.5m rigid or 28 x 18m articulated buses could be parked in Bowen Hills Bus Depot and supplemented with standard 12.5m rigid buses in unoccupied parking spaces; but 54 x double deck and 44 x 14.5m rigid buses could not be simultaneously parked in the depot,
- Assume selected bus and/or car parking spaces can be resumed as needed to widen circulation and access paths for high capacity vehicle turns into and out of existing bus parking bays and lanes. Specific depot bus and car parking space resumptions for high capacity vehicle yard circulations and garage work bay or parking manoeuvres are described later in Section 3.6, and
- Assume both forward in-out parking in nose-to-tail lanes and forward or reverse parking of 12.5m double deck and 14.5m rigid buses in perimeter bays, but only forward in-out parking of 18m articulated buses in aligned multiple perimeter parking bays and nose-to-tail parking lanes.

Attention is drawn to the notes appearing below Table 4. Whilst all depot yards have been identified as suitable for parking high capacity vehicles with appropriate modifications, not all depots have the maintenance, servicing and/or refuelling facilities necessary for particular high capacity bus types. It should be particularly noted that existing Brisbane Transport 18m articulated buses are natural gas vehicles and can only be stationed at depots with an existing reticulated natural gas supply, CNG bulk storage cylinders and refuelling bowsers.

Table 4: Assessed Maximum Depot Parking Capacities for All Vehicle Types

Bus Depot	Suitable (with Minor Upgrades)			Depot Refuelling Capability	TransLink Advised Depot Safe Working Capacity	Total TransLink Buses Currently Garaged	Assessed Maximum Depot Parking Capacity			
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses				12.5m Standard Rigid Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses
Brisbane Transport										
Bowen Hills	No	Yes	Yes (Note 9)	Diesel	112	111	112	54 (Note 6)	44	28
Garden City	Yes	Yes	Yes	CNG + Diesel	200	183	184	184	153	118
Carina	No	Yes	Yes (Note 10)	Diesel	160	174	185	183 (Note 6)	156	119
Virginia	No	Yes	Yes	CNG + Diesel	160	179	179	108 (Note 6)	80	58
Willawong	Yes	Yes	Yes	CNG + Diesel	200	193	222	222	185	148
Richlands	No	Yes	Yes (Note 9)	Diesel	45	32	56	49 (Note 6)	44	15
Toowong	No	Yes	Yes	CNG + Diesel	165	182	183	155 (Note 6)	132	108
Sherwood	Yes	Yes	Yes (Note 9)	Diesel	200	142	215 (Note 3)	215 (Note 6)	172	129
Trade Coast (Note 1)	Likely	Yes	Yes	Diesel (Note 2)	200	0	200 (Note 4)	200 (Note 4)	160 (Note 4)	120 (Note 4)
Clarks Logan City Bus Service										
Loganlea	Yes	Yes	Yes	Diesel	135	125	138 (Note 7)	136 (Note 7)	124 (Note 7)	51 (Note 7)
Hornibrook Bus Lines										
Clontarf	Yes	Yes	No	Diesel	60	48	52	25	21	9
North Lakes	Yes	Yes	Yes	Diesel	60	13	57	28	28	28
Park Ridge Transit										
Park Ridge	Yes	Yes	Yes	Diesel	120	80	121	119	74	19
Surfside Buslines										
Molendinar	Yes	Yes	Yes	Diesel	160	247	170	142	110	46
Tweed Heads	No	Yes	Yes	Diesel	150	61	150	113 (Note 6)	113	79 (Note 7)
Coomera	Yes	Yes	Yes	Diesel	125	0	190	186	144	126
Veolia Transdev Queensland										
Capalaba	No	Yes	Yes	Diesel	95	119	105 (Note 5)	50 (Note 8)	45 (Note 8)	12 (Note 8)

Note 1: As at 31 August 2012, the new Trade Coast (Eagle Farm) Bus Depot was still under development.
Note 2: Trade Coast is located close to a high pressure gas pipeline and could be developed as a new CNG + Diesel bus depot.
Note 3: Sherwood Bus Depot has sufficient reserve yard parking space to accommodate up to 258 standard 12.5m rigid buses.
Note 4: Based on TransLink advised depot parking capacity and similar yard lane layout to Willawong and Sherwood Bus Depots.
Note 5: Based on 105 first in-last out high density bus yard parking plus 26 standard 12.5m buses parked in on-site building.
Note 6: These depots are considered unsuitable for double deck buses because of building height or road access restrictions.
Note 7: Parking layout and access/circulation corridors to be modified at this depot for high capacity buses and numbers listed.
Note 8: Additional parking of high capacity vehicles in two on-site building through-running lanes would increase these capacities.
Note 9: BT articulated buses are currently CNG only. These depots would only be suitable for future diesel articulated buses.
Note 10: Carina Depot has an existing low pressure natural gas pipeline suitable for refuelling 10 CNG articulated buses/day.

3.3 Bus Depot High Capacity Vehicle Maintenance Capability

Table 5 below and Table 6 overleaf summarise the high capacity vehicle maintenance and servicing capability assessments for all Private Operator and Brisbane Transport Bus Depots respectively.

Table 5: Private Operator Bus Depot High Capacity Vehicle Maintenance & Servicing Capability

Bus Depot	Mech & Elect Maintenance			Body Maintenance			Bus Refuelling			Bus Exterior Washing			Bus Chassis Cleaning			Accommodation & Circulation		
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses
Clarks Logan City Bus Service																		
Loganlea	Yes	Yes	Yes	Yes. But With Minimal Height Clearance	Yes. With Partial Cover	Yes. With Partial Cover	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. Existing Yard Layout Could be Easily Modified Using Lanes for Improved High Capacity Bus Circulation		
Hornibrook Bus Lines																		
Clontarf	Yes	Yes	Yes. But Only In 3 Drive-Through Bays. Partial Cover Only in 16m Short Bays	Yes. Some Lights Would Need to be Raised in Drive-Through Bay	Yes	Yes. Partial Cover in Short Bays	Yes	Yes	Yes	Yes	Yes	Yes	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes	Yes	Yes
North Lakes	Yes. Basic Maintenance Only with All Hoisted Major Repairs and Maintenance Required at Clontarf Bus Depot			Yes. Basic Maintenance Only with All Major Maintenance and Repairs Required at Clontarf Bus Depot			Yes	Yes	Yes	Yes	Yes	Yes	Yes. With Chassis Cleaning at Clontarf Bus Depot			Yes. 6 Bus Bays at Rear and 1 Lane Bay on Eastern Side of Yard Would Need to be Kept Clear at All Times for High Capacity Bus Circulation		
Park Ridge Transit																		
Park Ridge	Yes. But 12 Bus Parking Bays in Front of Shed to be Kept Clear for Manoeuvring. Downpipe on Front of Shed to be Lifted			Yes	Yes	Yes	Yes. Would Need Adblue Dispenser for New High Capacity Buses			Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. On Hard Stand	Yes. But 12 Bus Parking Bays in Front of Maintenance Shed to be Kept Clear for High Capacity Bus Manoeuvring		
Surfside Buslines																		
Molendinar	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Tweed Heads	No. All Repairs and Maintenance Only on Hard Stand Area	No. Covered or Partially Covered. But Can Only be Hoisted for Major Repairs and Maintenance on Garage Hard Stand		No. All Repairs and Maintenance Only on Hard Stand Area	Yes. Covered	Yes. Partially Covered	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But 31 (Currently Unused) Standard Bus Parking Bays Would Need to be Given Up for High Capacity Bus Circulation in Parking Yard		
Coomera	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Veolia Transdev Queensland																		
Capalaba	No. Door Height Too Low. All Maintenance & Repairs Only on Hard Stand	Yes	Yes	No. Door Height Too Low. All Maintenance & Repairs Only on Hard Stand	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But This Depot Uses Highly Packed First In Last Out Yard Parking. High Capacity Bus Parking Would Require 7 Bus Parking Spaces in Access Corridor be Kept Clear Till Late Evening		

Table 6: Brisbane Transport Bus Depot High Capacity Vehicle Maintenance & Servicing Capability

Bus Depot	Mechanical Maintenance			Body/Electrical Maintenance			Bus Refuelling			Bus Exterior Washing			Bus Chassis Cleaning			Accommodation & Circulation		
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses
Brisbane Transport																		
Bowen Hills	No. Shed Roof Too Low	Yes	Yes. But Only Future Diesel Artics	No. Shed Roof Too Low	Yes	Yes	Yes	Yes	Yes. But Only Future Diesel Artics	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	No. Shed Roof Too Low	Yes	Yes	No. Will Need Resumption of Car Parking Spaces and Added High Capacity Bus Circulation and Exit on Gebbie Street		
Garden City	Yes	Yes	Yes	Yes. Will Need Elevated Catwalks	Yes	Yes	Yes	Yes	Yes	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	Yes	Yes	Yes	Yes. But Raise Water Harvest Pipe on Logan Rd Boundary	Yes	Yes
Carina	No. Won't Fit Under Roller Doors But Bus Can be Hoisted in North Building	Yes	Yes. Has Existing CNG Articulated Bus Maintenance Facilities	No. South Building Roof Too Low	Yes	Yes	No. South Building Roof Too Low	Yes	Yes. But Only 10 Max CNG Artic Buses or Future Diesel Artic Buses	Yes. Shed Height OK. Wash Rollers Too Short	Yes	Yes	Yes	Yes	Yes	Yes. But Would Need Bus Parking Lanes Along Eastern Boundary Kept Clear for Late Night High Capacity Bus Entry to Rear of Yard Lanes		
Virginia	No. Door Heights OK But Only Body Shed Roof High Enough	Yes	No. Shed Widths Too Short and Doors too Low to Hoist	Yes. Door Heights OK But Only Body Shed Roof High Enough	Yes	Yes. With Partial Cover	Yes	Yes	Yes	Yes. But Wash Roller Frame and Down Pipe Need To be Raised	Yes	Yes	Yes	Yes	Yes	Yes. But Existing Yard Lanes Would Need to be Shortened One 12.5m Rigid Bus Length to Enable High Capacity Bus Depot Circulation		
Willawong	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. Shed OK. Wash Roller Frame too Short	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Richlands	No. All Maintenance Required at Toowong Bus Depot	Yes. Partial Cover But All Hoisted Major Repair & Maintenance Required at Toowong Bus Depot		No. All Maintenance Required at Toowong Bus Depot	Yes	Yes	No. Roof Trusses & Braces Too Low	Yes	Yes. But Only Future Diesel Artics	No. Roof Too Low. Could Wash on Hard Stand	Yes	Yes	No. All Chassis Cleaning Would Need to be Completed at Toowong Bus Depot			Yes	Yes	Yes
Toowong	Yes	Yes	Yes	Yes	Yes	Yes	No. Service Shed Roof Trusses Too Low	Yes	Yes	No. Service Shed Roof Trusses Too Low	Yes	Yes	Yes	Yes	Yes	Yes. But Existing Yard Lanes Would Need to be Shortened One to Three 12.5m Rigid Bus Lengths in Sections to Enable High Capacity Bus Circulation		
Sherwood	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes. But Only Future Diesel Artics	Yes. Shed OK. Wash Roller Frame Too Short	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

3.4 Universal High Capacity Vehicle Compatible Bus Depots

6 new generation bus depots have been identified as universally suitable for parking, maintenance and servicing of a large fleet of any high capacity bus type or combination of high capacity bus types with minimal or no facility upgrades, yard parking or building modifications:

- Loganlea Bus Depot,
- Molendinar Bus Depot,
- Coomera Bus Depot,
- Garden City Bus Depot,
- Willawong Bus Depot, and
- Sherwood Bus Depot.

3.5 Barriers to Future Brisbane Transport Double Deck Bus Deployment

Low existing garage building and/or service shed roof heights present a major challenge to potential future deployment of double deck buses in old generation Brisbane Transport bus depots originally designed and constructed for maintenance of single deck buses. Whilst it has been established that high twin deck vehicles could be maintained in the less than 4 year old new Willawong and Sherwood Bus Depots, 4.3 to 4.4m high double deck buses will only just pass under fully raised garage doors with minimum acceptable clearance and double deck bus roofs would come precariously close to overhead fittings and building services within their new garage buildings when hoisted to 1750mm nominal AFL. (Refer to photograph of Willawong Bus Depot garage maintenance bay appearing at Figure 4).

Earlier high capacity bus studies have identified a large number of existing low clearance railway bridges on the Ipswich Railway Line. This railway line acts as a physical barrier to double deck bus operations in numerous locations from Darra inbound to the city, and in combination with other flood prone low railway bridge clearances over Oxley Road at Corinda and Muriel Avenue at Rocklea, effectively block off double deck bus road movements along the western, southern and eastern public road approaches to the Sherwood Bus Depot.

The inability to freely station double deck buses at so many existing old bus depots and operate them without excessive route diversions from the new Sherwood Bus Depot render double deck buses a less flexible and attractive high capacity vehicle option than single deck high capacity vehicles for Brisbane Transport suburban bus operations.

3.6 High Capacity Bus Depot Parking, Manoeuvring and Circulation Assessments

3.6.1 Swept Path Turning Template Overlay Colour Codes

Section 3.6 presents details of modifications required at specific bus depots to enable high capacity bus manoeuvres into and out of existing garage maintenance bays and service sheds, and for depot yard and inter-building circulation. Where turning templates have been included on depot aerial views appearing in the figures, they have been appropriately scaled to the aerial view and colour coded as follows:

- Green for 12.5m twin steer double deck bus swept paths (per Figure 11),
- Red for 14.5m steered tag axle rigid bus swept paths (per Figure 13), and
- Blue for 18m fixed rear axle pusher type articulated bus swept paths (per Figure 15).

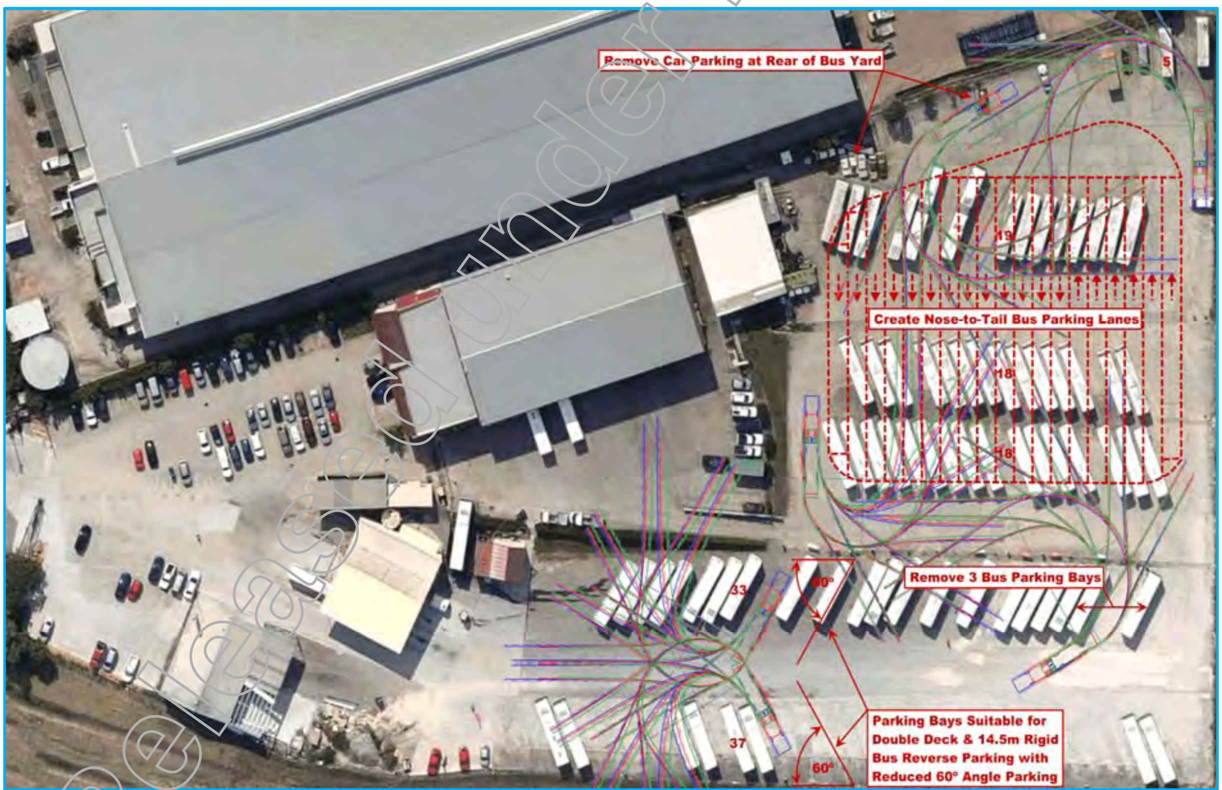
3.6.2 Loganlea Bus Depot

Loganlea Bus Depot has an existing large hardstand apron in front of its primary garage building and swept path turning template overlays identified no issues with manoeuvring any high capacity bus types into existing garage mechanical and electrical work bays, the body repair, tyre servicing, refuelling and wash sheds, or between any buildings on the depot site.

Perimeter bus parking bays in the southern section of the Loganlea yard shown in Figure 18 are currently used for reverse angle parking of standard 12.5m rigid buses and would also be suitable for reverse parking double deck or 14.5m rigid buses if permanently line marked as 60º angled parking bays on both sides of the southern yard central access corridor.

Clarks presently own and operate 4 articulated buses and park them in the rearmost northern yard row of perimeter parking bays, however turning template overlays have indicated the current northern yard parking arrangement would be unsuitable for more than a maximum of around 10 articulated buses, 25 double deck or 14.5m rigid buses due to existing narrow yard circulation and access corridors. The northern section of the yard has however been found deep enough to create 19 x 3.5m wide nose-to-tail bus parking lanes suitable for parking a large number of high capacity buses. This alternative parking scheme would necessitate elimination of all car parking along the northern yard perimeter and resumption of 3 bus bays at the entrance into the northern yard from the southern yard as shown below on Figure 18 to provide adequate turn-in and manoeuvring space to optimise the yard's combined high and low capacity bus parking density.

Figure 18: Loganlea Bus Depot Layout



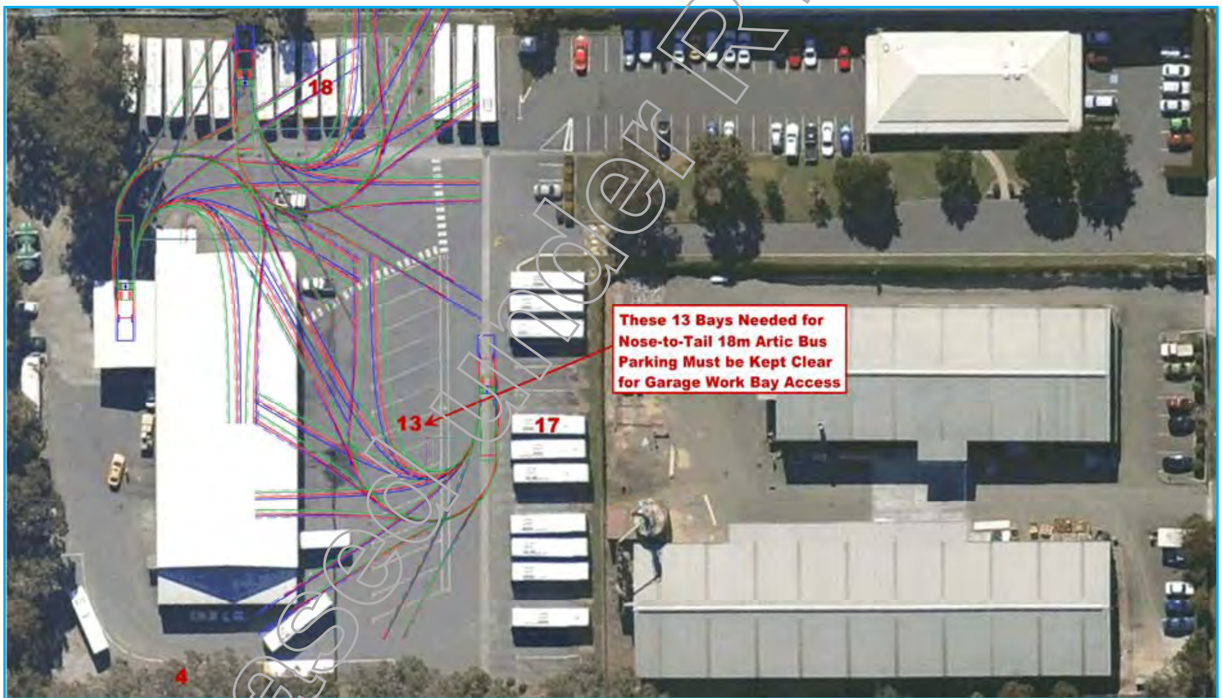
3.6.3 Clontarf Bus Depot

Clontarf Bus Depot currently has a total yard parking capacity of 52 standard 12.5m rigid bus spaces in the marked perimeter and island parking bays illustrated overleaf in Figure 19. Turning template overlays have confirmed that all high capacity bus types can manoeuvre into and out of existing garage maintenance and service bays and be driven around the garage building at a slow speed of 5km/h, but this depot only has 3 existing drive-through bays in the garage wide enough to hoist 18m articulated buses for chassis mechanical and electrical maintenance.

Double deck and 14.5m rigid buses already stationed at Clontarf Bus Depot are currently reverse parked on the eastern side of the 90° parking bays along the northern boundary of the depot yard, and turning template overlays have indicated that up to 9 articulated buses could potentially be reverse parked in these same bays. Reverse parking of 18m articulated buses in these 3.5m wide perimeter parking bays is considered to be a high collision accident risk and reverse parking of articulated buses would not therefore be recommended along the northern yard boundary.

Turning template overlays alternatively indicated that if the existing 13 island bays in front of the garage building were converted to south facing nose-to-tail parking lanes used exclusively for articulated bus parking, up to 6 articulated buses could be parked in the island parking area and a further 3 articulated buses in the existing southern perimeter standard 12.5m rigid bus bays. Some of the island parking bays would however need to be kept clear throughout the day for buses to access the 7 garage maintenance bays. This workaround option is considered practicable for standard size buses returning to depot in the late evening, but is not considered practicable for a small fleet of articulated buses returning to depot continuously throughout the day. Articulated buses have therefore not been recommended for Clontarf Bus Depot.

Figure 19: Clontarf Bus Depot Layout



3.6.4 North Lakes Satellite Bus Depot

North Lakes Bus Depot, shown overleaf in Figure 20, is a satellite of Clontarf and buses stationed at the former must periodically be swapped with similar size buses from Clontarf for hoisted major mechanical maintenance, chassis cleaning, electrical and body repairs.

North Lakes is a new Hornibrook facility and utilises nose-to-tail bus lanes suitable for parking of all high capacity vehicle types with yard circulation at a slow speed of 5km/h, but 6 rigid bus bays at the rear of the yard shown arrowed on Figure 20 would need to be kept clear throughout the day for returning high capacity bus lane turn-ins and rear of yard bus circulation. The 6 bays at the rear could be occupied by returning late night standard size buses, but only after high capacity buses stationed at the site had already occupied their allocated (bus type) lanes.

Albeit turning template overlays have indicated this depot would be suitable for accommodation of 18m articulated buses, this high capacity bus type could not be swapped with like-for-like buses from Clontarf Bus Depot and 18m articulated buses have therefore also not been recommended for North Lakes.

Figure 20: North Lakes Bus Depot Layout

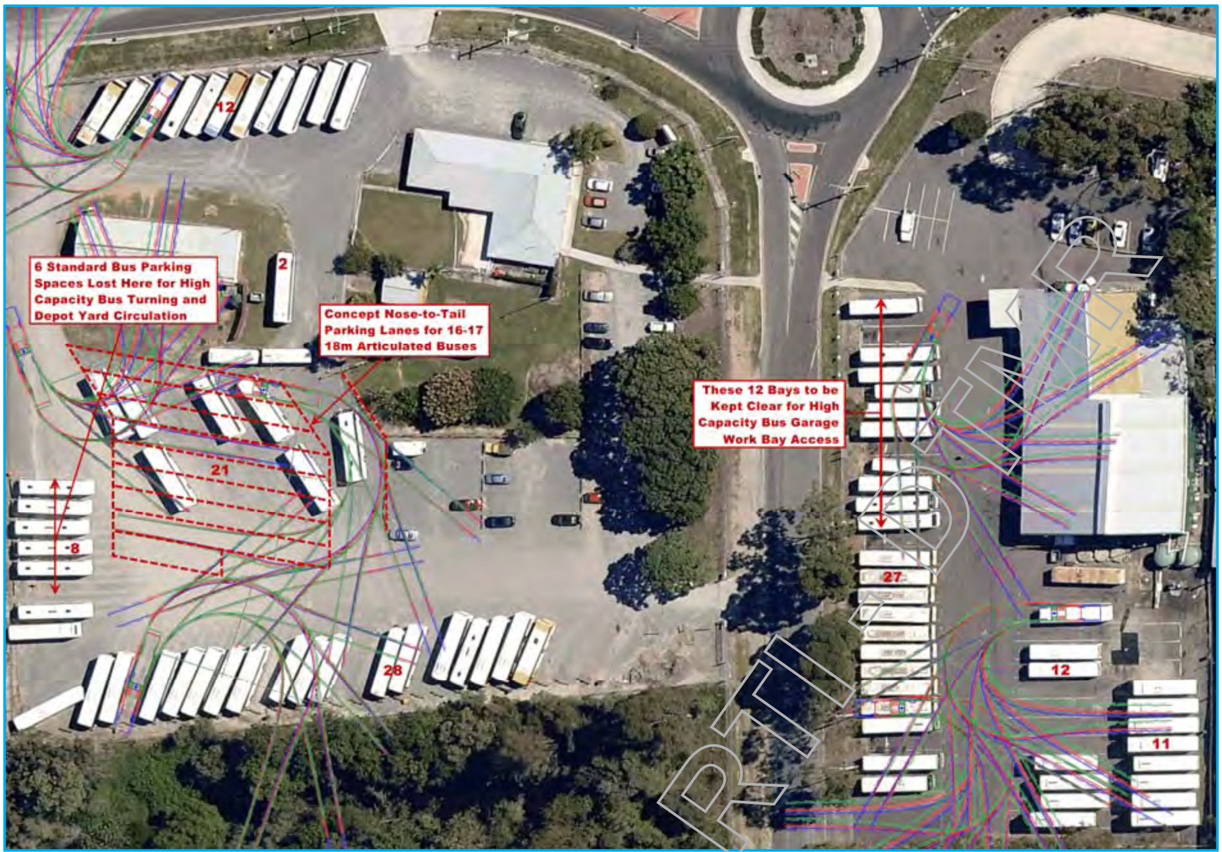
3.6.5 Park Ridge Bus Depot

Park Ridge Bus Depot is a medium size depot split across 2 properties either side of Talinga Drive in Park Ridge and has a combined total yard parking capacity of approximately 121 standard 12.5m rigid buses distributed where indicated overleaf in Figure 21. Turning template overlays have confirmed that all high capacity bus types could potentially operate from this depot, but up to 12 bus parking bays located in front of the primary garage building would need to be kept clear throughout the day for high capacity bus manoeuvring in and out of the existing garage maintenance work bays.

Every 12.5m rigid bus parking bay on both of the depot properties could potentially be used for reverse parking of 12.5m double deck buses, and up to 74 bays, mostly located on the southern depot property site (shown to the left hand side of Figure 21), were suitable for parking 14.5m rigid buses.

Only 2 informal parking locations on the southern depot property could be found where 18m articulated buses could be driven forward in-out using the current yard layout and circulation travel direction. A concept nose-to-tail parking lane design has therefore been presented in Figure 21 for parking of up to an additional 16 or 17 articulated buses on the southern depot property with a small loss of 6 standard 12.5m parking bays on the turn-in (left hand) side of the proposed articulated bus lanes.

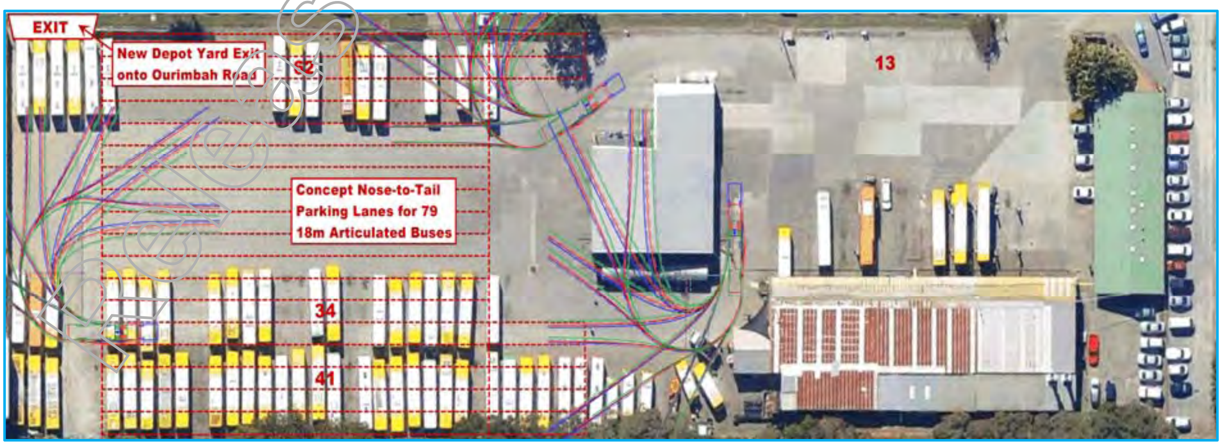
Figure 21: Park Ridge Bus Depot Layout



3.6.6 Tweed Heads Bus Depot

Tweed Heads Bus Depot has a long narrow yard capable of accommodating up to 150 standard 12.5m rigid buses reverse parked in first in-last out formation and distributed around the site where indicated in Figure 22. Because of its low access door heights, double deck buses cannot enter any of the existing covered garage maintenance work bays and would not therefore been recommended in substantial numbers at this depot. The existing low garage roof height prevents even single deck buses from being hoisted for underfloor mechanical and electrical repairs in the covered garage work bays, and all hoisted bus maintenance at this site is presently performed on the weather exposed exterior hardstand area in front of the main garage building. (Refer to Figure 1 for a photograph of the Tweed Heads Bus Depot garage hardstand area).

Figure 22: Tweed Heads Bus Depot Layout



The resident bus fleet at Tweed Heads Bus Depot is comprised almost entirely of standard single deck 12.5m route buses, supplemented with a few 6 to 8m long minibuses. The property alignment is long and narrow and maximum standard bus parking density has been attained on this site by reverse parking buses around the perimeter in rows of up to two deep, each served by a shared central access corridor. Because nearly all the resident buses are similar, they can be dispatched in first in-last out order generally irrespective of the previous day's return to depot bus arrival order, a strategy which works well for a depot with a large uniform fleet of similar sized buses.

The present yard layout would be suitable for mixed reverse parking of 12.5m double deck and 14.5m rigid buses, but turning template overlays have demonstrated that wherever either of these high capacity buses was reversed parked in the yard, the site depth would diminish the reverse in-forward out yard capacity from 4 to 3 opposing rows with a substantial loss of equivalent standard bus parking capacity. Further, the current yard parking configuration and layout is unconducive to mixed parking of standard 12.5m rigid and 18m articulated buses; the latter of which cannot be safely reverse parked in standard width bays without high ongoing risk of repeated in-yard reversing collisions.

A concept nose-to-tail forward in-forward out parking lane configuration has been presented in Figure 22 which would enable mixed parking of standard 12.5m rigid, 12.5m double deck, extended 14.5m rigid and 18m articulated buses on split "bus type" lanes suitable for first in-first out dispatching. The concept design shown retains near equivalent total standard 12.5m rigid bus parking capacity but utilises a new exit to, and Ourimbah Road for depot circulation. If this was unacceptable, an internal circulation access corridor could be included in the concept design at the rear of the yard but would result in a total yard parking capacity loss of approximately 18 standard 12.5m rigid bus parking spaces.

3.6.7 Capalaba Bus Depot

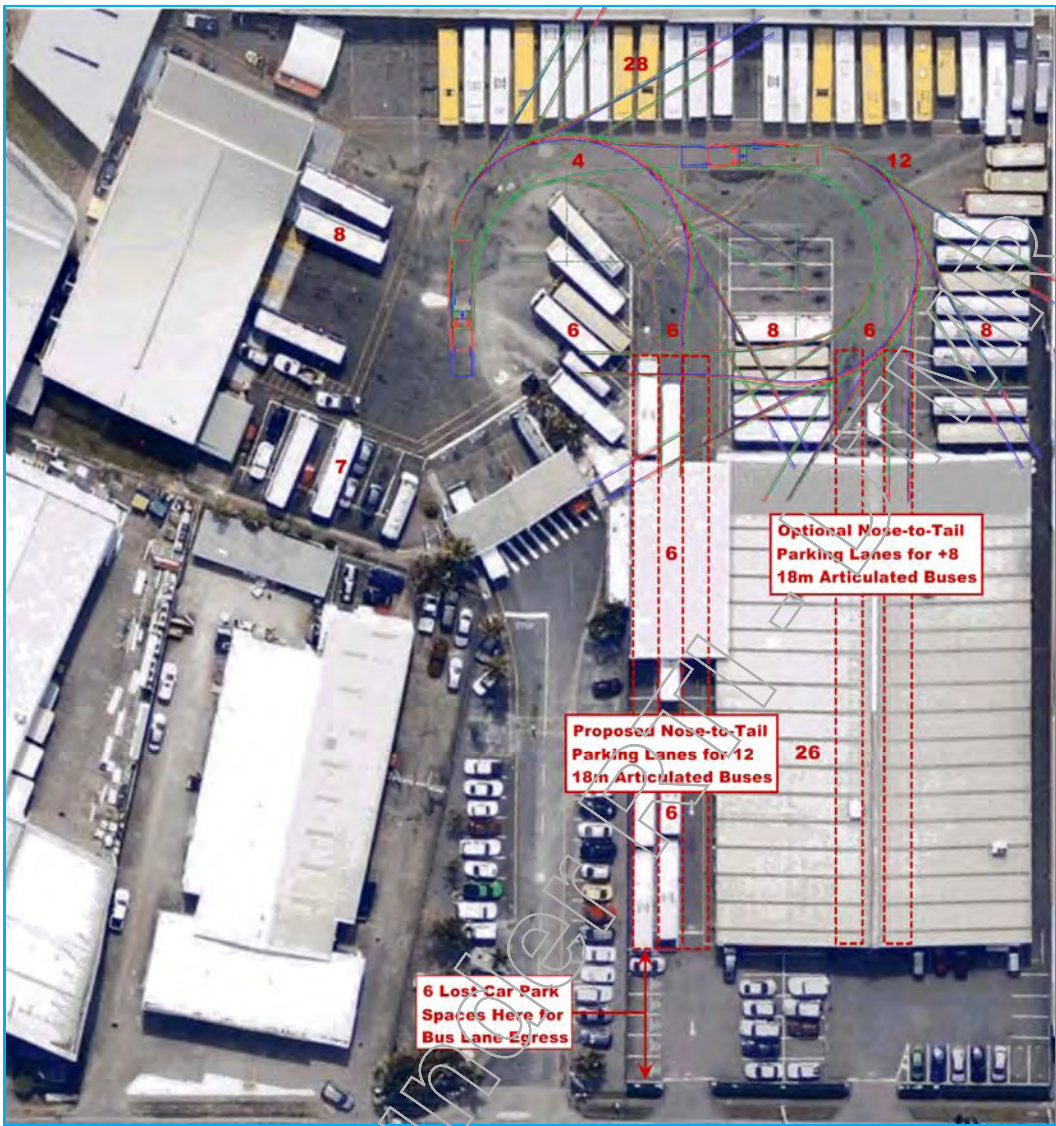
Capalaba Bus Depot adopts a very high density first in-last out bus parking scheme. The yard can accommodate up to 105 standard 12.5m rigid buses, but the depot boasts a spare building with access to Smith Street capable of stabling up to an additional 26 standard size buses under cover where indicated on Figure 23 overleaf. The spare building houses Veolia's front counter, depot office and store, and is not normally used for bus parking until the depot yard has been completely packed out with vehicles, including parking of last evening returning buses in the garage maintenance hardstand bays and in all the yard circulation accesses other than the primary accesses off Smith Street in front of the refuelling shed and garage hardstand apron.

Because of low access door heights, double deck buses cannot enter any of the existing covered garage maintenance work bays, but could enter all other onsite bus service sheds and the spare building. Double deck buses have not been recommended in substantial numbers at this depot, but Veolia has advised it could accommodate a small fleet of double deck buses on its site and presumably maintain them on the exterior garage hardstand apron.

Maximum high capacity bus parking estimates listed in Table 4 for Capalaba Bus Depot have assumed availability of and ready access to 3 through-running (forward in-out) parking lanes, and resumption of 6 existing car parking spaces where marked on the western side of the spare building in Figure 23. Circulation access to these 3 high capacity bus lanes is normally only blocked off by the last 7 buses returning to the depot in the late evening.

An additional 2 optional through-running lanes are available at the depot within the spare building itself, but access to them is blocked by the last 18 buses returning to depot at night. If used, these 2 covered through-running lanes would effectively prevent standard size buses being parked within the spare building if need to be dispatched prior to the high capacity buses and would only therefore be feasible high capacity bus parking lanes if all standard 12.5m rigid buses could be readily accommodated in the open yard. For these reasons, maximum high capacity bus counts presented for Capalaba in Table 4 exclude high capacity bus parking in the 2 optional covered through-running lanes shown on Figure 23.

Figure 23: Capalaba Bus Depot Layout



3.6.8 Bowen Hills Bus Depot

Most old Brisbane Transport depots such as Bowen Hills Bus Depot have existing shed roof heights too low for covered maintenance and servicing of double deck buses. Bowen Hills can however accommodate both 14.5m rigid and future diesel articulated buses under full cover, but does not have an on-site refuelling capability for current generation Brisbane Transport CNG articulated buses.

Buses parked in the unhatched lanes shown in the aerial view on Figure 24 overleaf face northward and exit directly to Geebie Street (i.e. to the right hand side on the layout view). Buses parked in the lanes shown hatched face towards, and exit oppositely to the southern end of the yard, and these are the only forward in-out lanes which could be used to park 18m long articulated buses and around 95% of 14.5m rigid buses. Turning template overlays have indicated that both these high capacity bus types can be turned into all maintenance and servicing sheds and back to Geebie Street at the southern end of the bus yard if the existing bus bay identified on the figure was kept permanently clear, but neither high capacity vehicle could exit to Gebbie Street at the northern end of the existing yard or circulate the yard unless driven inbound up Abbotsford Road and back into the depot at its southern entry gate. A new depot exit would therefore need to be created onto Gebbie Street in the approximate location shown on Figure 24 to enable both depot exiting to, and turn back circulation off Geebie Street. Creation of this new exit would necessitate resumption of 6 existing car parking spaces, 2 of which could be relocated to the opposite side of the proposed exit shown on Figure 24.

Figure 24: Bowen Hills Bus Depot Layout

3.6.9 Carina Bus Depot

There are two large garage buildings at Carina Bus Depot; the north garage building used primarily for hoisted and floor level bus mechanical maintenance, and the south garage building used for floor level electrical and body maintenance, bus servicing and refuelling. The north building roller door and south building roller door and roof truss clearance heights are too low for double deck bus entry.

Figure 25: Carina Bus Depot Layout

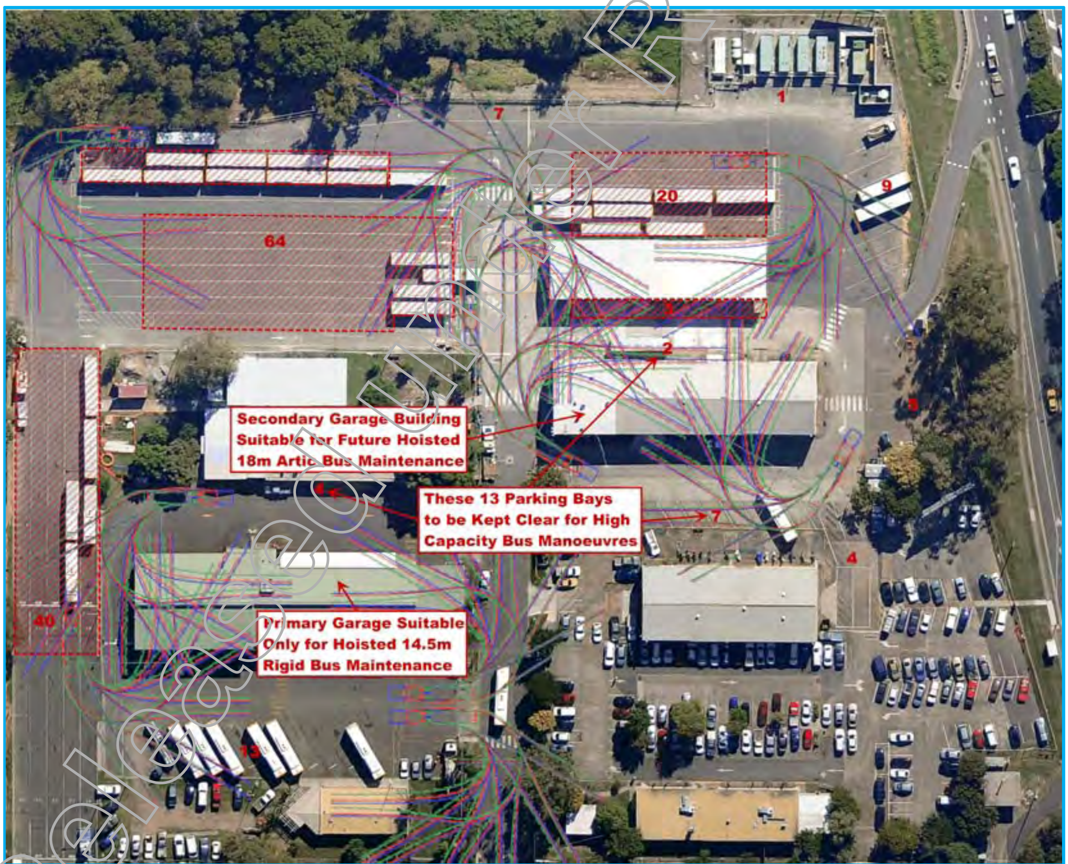
Both garage buildings, the bus washing and chassis cleaning sheds, and yard circulation corridors would be suitable for up to 156 14.5m rigid buses or 119 future 18m diesel articulated buses, and it is understood from Brisbane Transport that both these high capacity diesel vehicle types have previously operated from Carina Bus Depot. This depot houses an existing covered CNG refuelling station on site capable of refuelling up to 10 CNG articulated buses per night, but no CNG buses are currently being operated from the depot.

To maximise high capacity bus parking, the 16 bus parking bays (also occasionally used for driver car parking) along the eastern yard perimeter would need to be kept clear throughout the day, but could be filled in the late evening by late returning or late night refuelled and washed buses after all the high capacity bus lanes had been populated.

3.6.10 Virginia Bus Depot

Virginia Bus Depot is a dual fuel (CNG + diesel) bus depot but presently only CNG 12.5m rigid buses are being operated from the site. Significantly, Virginia is the only bus depot located in the Brisbane northern region which can currently refuel Brisbane Transport's existing CNG articulated buses. While the new Trade Coast Bus Depot still in development could potentially become a second dual fuel bus depot for both the Brisbane northern and eastern regions, Virginia is more centrally placed to deliver bus services in the northern suburbs and would incur considerably less dead running to and from the depot.

Figure 26: Virginia Bus Depot Layout



Existing primary (mechanical maintenance) garage building access doors are high enough to permit entry of double deck buses but the building's roof height is too low for hoisted undercarriage maintenance on a 4.3 – 4.4m high vehicle. Double deck buses could also potentially enter through the work bay access doors to other body and electrical, servicing and refuelling sheds on the Virginia site, but existing bus roof maintenance catwalks, washing machine roller frames and a stormwater harvesting downpipe would have to be raised for their maintenance, repairs and servicing.

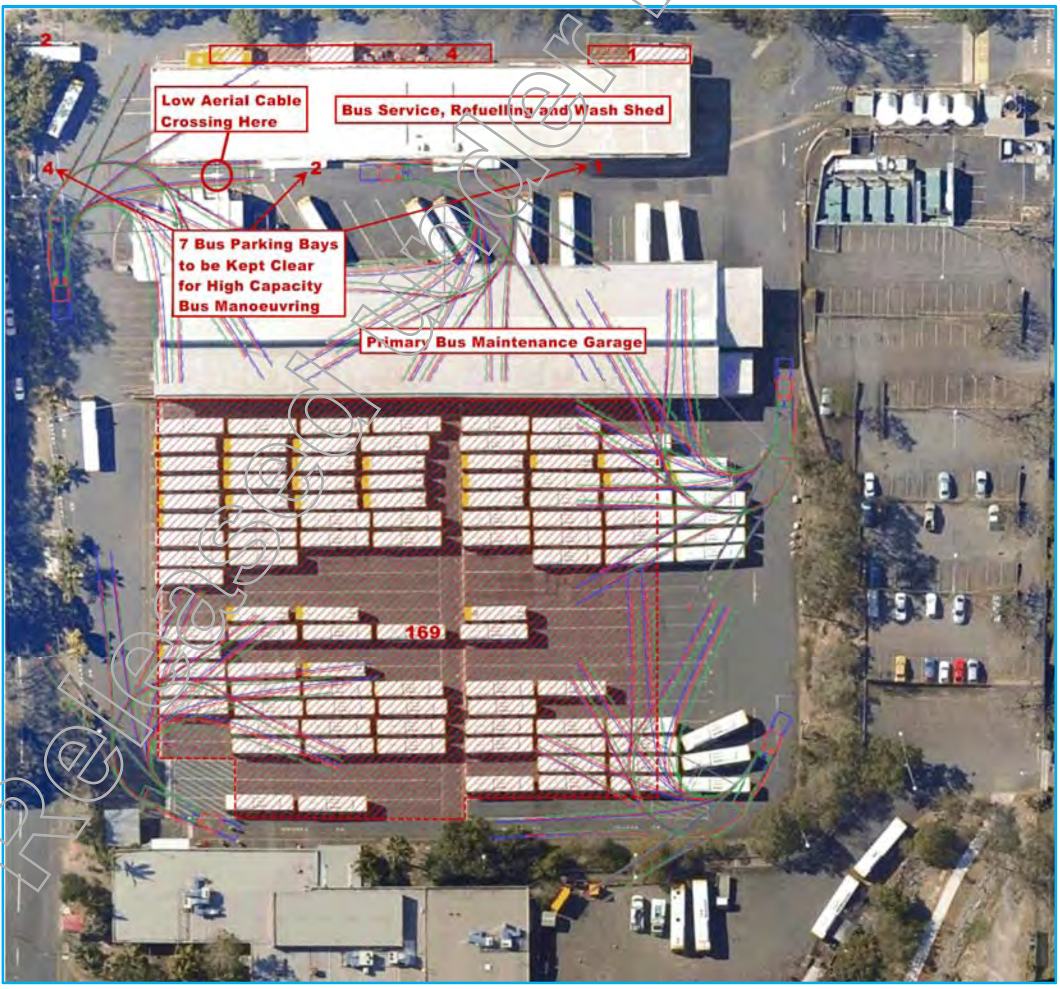
The primary garage is neither wide enough, nor its doors high enough, to enable hoisting of 18m articulated buses under partial cover, but the building is suitable for hoisting 14.5m rigid buses completely under cover. There are two other high bay maintenance buildings at Virginia Bus Depot currently being used for body and electrical maintenance but previously also utilised for hoisted bus mechanical maintenance; and although neither building is wide enough to fully cover an 18m articulated bus, one building has opposing drive-through access doors high enough for hoisting articulated buses under partial cover to an existing level concrete hardstand apron. This building could again be adopted as a secondary garage for future hoisted articulated bus undercarriage maintenance.

The hatched zones appearing on the existing yard nose-to-tail lanes in Figure 26 above identify where 18m articulated buses could potentially be parked on the Virginia site. Existing yard access and circulation corridors at Virginia Bus Depot have been designed exclusively for 12.5m standard bus turning and manoeuvring, and lanes would need to be shortened as illustrated in the aerial view for 14.5m rigid and/or 18m articulated bus turns. Because 14.5m rigid buses can be forward or reverse parked, additional perimeter parking bays have been identified at Virginia which are inaccessible to articulated buses, but both bus types exact a similar and very substantial reduction in the depot's parking capacity equivalent to approximately 25 standard bus spaces.

3.6.11 Toowong Bus Depot

Toowong Bus Depot is a dual fuel (CNG + diesel) bus depot and presently both CNG and diesel standard 12.5m rigid buses are operated to the Brisbane western region from this site.

Figure 27: Toowong Bus Depot Layout



Two large maintenance buildings exist at Toowong; a bus servicing, refuelling and washing shed, and a primary maintenance garage building in which all bus mechanical, electrical, body and tyre maintenance are undertaken. An existing low aerial cable crossing (refer to Figure 27 above) connects the two buildings and would have to be raised or buried to permit double deck bus entry into the primary garage work bays. The primary maintenance garage door and roof heights, and the building's adjoined chassis cleaning shed are high enough for pit, floor level and hoisted double deck bus undercarriage maintenance, but the roof truss height within the bus service, refuelling and wash shed is too low for double deck bus entry.

Toowong has a very densely packed bus parking scheme and is currently home to some 183 standard 12.5m rigid buses parked nightly to overflowing on every nose-to-tail parking lane and in every available yard and building perimeter parking bay. This depot also functions as the major maintenance and chassis cleaning centre for a further 32 standard size buses stationed offsite at the Richlands Satellite Bus Depot and all of the latter buses must periodically return to, exchange with and be stored at the Toowong mother depot.

Deployment of just a few 14.5m rigid and/or articulated buses at Towong Bus Depot would have a significant impact on its equivalent standard parking capacity as can be readily visualised from a cursory inspection of the aerial view appearing in Figure 27. All the high capacity bus turning template overlays shown on the aerial view identify locations where standard bus parking capacity would need to be crimped back for high capacity bus manoeuvring. Some 10 perimeter bus parking bays would immediately disappear from Toowong when the first high capacity buses were brought onto site, and from one to two standard bus parking spaces would further disappear off the end of each yard lane given over to parking either high capacity bus type. The hatched areas in Figure 27 show all the available parking spaces where 18m articulated buses could be parked, and aptly illustrate the parking capacity shrinkage caused by both high capacity bus types which have similar swept turning paths.

3.6.12 Richlands Satellite Bus Depot

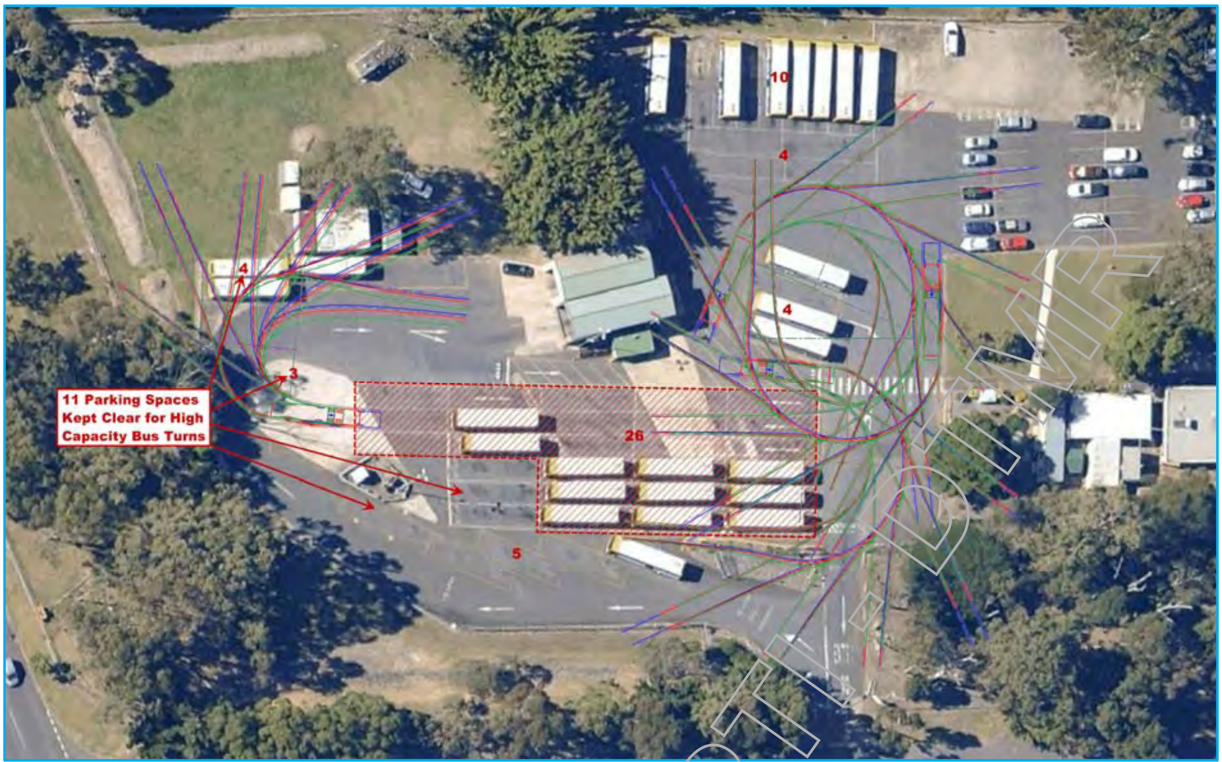
Richlands Bus Depot is currently a satellite of Toowong Bus Depot but major maintenance and chassis cleaning on the standard rigid 12.5m buses stationed at Richards could readily be transferred to Brisbane Transport's new Willawong Bus Depot.

Willawong has been identified elsewhere in this report as a double deck compatible bus depot and has no close low clearance bridges which would obstruct double deck bus movements on its surrounding public road network. Richlands could therefore conceivably become a double deck bus maintenance satellite of Willawong, but as for Sherwood Bus Depot, the suburban double deck bus services operating out of Richlands would effectively be hemmed in by existing low railway bridges to the near north, west and CBD inbound of Richlands, and the depot has not therefore been recommended as a potential home for double deck buses.

As for other bus depots presently only accommodating standard size buses, Richlands has a parking yard layout with very tight swept turning paths specifically tailored to maximise onsite storage of 12.5m rigid buses. A maximum of 15 future diesel articulated buses could potentially be stationed at Richlands Bus Depot in the hatched nose-to-tail parking area illustrated on the aerial view overleaf in Figure 28, but at a substantial depot holding capacity loss of equivalent to 10 standard bus parking spaces. The absolute minimum capacity loss to park as few as nine 14.5m rigid buses or six articulated buses on the existing Richlands bus lanes would be 3 standard bus parking spaces.

Richlands is a diesel only bus depot and none of Brisbane Transport's existing CNG articulated buses could currently be stationed at the site. This site is best suited to 14.5m rigid buses.

Figure 28: Richlands Bus Depot Layout



3.7 Impacts of High Capacity Vehicles on Depot Standard Bus Capacity

3.7.1 Depot Parking and Passenger Carrying Capacity Impacts

Table 7 below quantifies the impacts on each bus depot if it were to be populated to its maximum parking capacity with each high capacity bus type in the numbers earlier shown in Table 4. Whilst it would be unlikely that any bus depot would be populated to its maximum high capacity vehicle parking capacity in the near future, Table 7 provides a useful insight into the relative impacts on each depot of deploying the 4 alternative high capacity bus types.

Table 7: Recommendations Based on Depot Equivalent Standard Bus Capacity

Bus Depot	Suitable for This Depot (with Minor Upgrades)			Recommended for This Depot (as Ranked by Capacity)				Std Bus Capacity	Equiv Std Bus Parking Capacity Decrease			Equivalent Std Bus Passenger Capacity Increase/Decrease			
	12.5m Double Deck Buses	14.5m Rigid Buses	18m Articulated Buses	12.5m Double Deck Buses	14.5m Rigid Buses	2 Door 18m Artic Buses	3 Door 18m Artic Buses	12.5m Standard Rigid Buses	12.5m Double Deck Buses	14.5m Rigid Buses	18m Artic Buses	12.5m Double Deck Buses	14.5m Rigid Buses	2 Door 18m Artic Buses	3 Door 18m Artic Buses
Brisbane Transport															
Bowen Hills	No	Yes	Yes (Note 1)	No	1	3	2	112	-6	-11	-9	31	-5	-24	-19
Garden City	Yes	Yes	Yes	No	1	3	2	184	0	-12	-18	127	6	-37	-15
Carina	No	Yes	Yes (Note 1)	No	1	3	2	185	0	-7	-3	126	8	-18	3
Virginia	No	Yes	Yes	No	1	3	2	179	-13	-24	-25	62	-9	-35	-25
Willawong	Yes	Yes	Yes	No	1	3	2	222	0	-10	-14	153	7	-38	-12
Richlands	No	Yes	Yes (Note 1)	No	1	3	2	56	-7	-11	-10	27	-1	-15	-13
Toowong	No	Yes	Yes	No	1	3	2	183	-21	-25	-22	86	-12	-40	-21
Sherwood	Yes	Yes	Yes (Note 1)	No	1	3	2	215	0	-18	-35	148	-2	-55	-32
Clarks Logan City Bus Service															
Loganlea	Yes	Yes	Yes	1	4	3	2	138	-2	-15	-6	92	16	-11	-2
Hornibrook Bus Lines															
Clontarf	Yes	Yes	No	1	2	No	No	52	0	-1	-4	17	4	-6	-4
North Lakes	Yes	Yes	Yes	1	2	No	No	57	-17	-17	-17	5	-7	-7	-2
Park Ridge Transit															
Park Ridge	Yes	Yes	Yes	1	2	3	3	121	-2	-12	-9	80	9	-5	-2
Surfside Buslines															
Molendinar	Yes	Yes	Yes	1	4	3	2	170	0	-15	-2	98	-5	-14	-6
Tweed Heads	No	Yes	Yes	No	1	3	2	150	-31	-16	-16	59	8	-39	-25
Coomera	Yes	Yes	Yes	1	2	4	3	190	-4	-11	-22	124	-11	-34	-11
Veolia Transdev Queensland															
Capalaba	No	Yes	Yes	No	1	2	2	105	0	0	0	35	14	-3	-1
					Equivalent Std Bus			2319	-103	-205	-212	1271	19	-383	-186
					Percent of Std Bus Capacity				**-4%**	**-9%**	**-9%**	**55%**	**1%**	**-17%**	**-8%**

Note 1: BT articulated buses are currently CNG only. These depots would only be suitable for future diesel articulated buses.

Decreases in depot equivalent standard bus parking capacity listed in Table 7 have been determined from the total reduction in perimeter parking bays and summation of whole and partial standard bus parking spaces given over at the head and tail ends of lanes for high capacity bus manoeuvring and turning. Increases and decreases in depot equivalent standard bus passenger capacity have been determined for all bus types on the assumption that each would typically be loaded in peak service to its fully seated plus 50% standing passenger carrying capacity.

Findings and recommendations drawn from the comparison of equivalent standard bus capacity changes shown in Table 7 are:

- **Double Deck Buses:** In depots where they could be reasonably accommodated, maintained and operated, double deck buses caused the least reduction (averaging around 4%) in depot equivalent standard bus parking capacity, and were the only high capacity bus type which consistently generated a net increase in equivalent standard bus passenger carrying capacity. Across all depots assessed, double deck buses increased average passenger carrying capacity per standard bus parking space given over to their parking by 55%. Double deck buses have therefore been recommended and ranked highest for all bus depots where they could be accommodated, maintained and operated.

- 14.5m Rigid Buses: All 8 existing Brisbane Transport bus depots can accommodate double deck buses in their parking yards, but only 2 Brisbane Transport depots (Garden City and Willawong) could currently maintain and operate them. Single deck 14.5m rigid and 18m articulated buses are better suited to greater Brisbane suburban roads characterised by numerous obstacles to high profile vehicles such as low clearance bridges and tree branches, and poles, posts and shop awnings built out to the kerb against narrow left side lanes with high cross falls.

  When averaged across all depots, equivalent standard bus parking reductions caused by 14.5m rigid and 18m articulated buses were identical at around 9%, but actually varied quite significantly from depot to depot. Minimum equivalent standard bus parking capacity loss occurred with 14.5m rigid buses in large depot yards configured for perimeter parking and existing wide access corridors that could absorb their extra 2m length and wide swept path turning radii. For the majority of depots which utilised nose-to-tail parking lanes, the equivalent standard bus parking capacity loss was minimal only for existing lanes with 6 to 8 standard bus parking spaces.

  When the 2 single deck high capacity bus types were compared by relative price, maintainability, ease of deployment to existing depots and equivalent standard bus passenger carrying capacity, the 14.5m rigid bus easily outperformed both the 2 and 3 door articulated buses. For these reasons, the 14.5m rigid bus has been assessed as the best high capacity bus type for general deployment to all Brisbane Transport and most private operator bus depots where double deck buses were not considered a practical option.

- 18m Articulated Buses: Generally, articulated buses have proven to be the most expensive, space hungry and least attractive high capacity vehicle option to deploy at the majority of existing Brisbane Transport and private operator bus depots. These 18m long vehicles require both forward in-out yard parking lanes and generously wide yard turning accesses, making them particularly difficult to integrate at depots with yards configured for standard bus perimeter bay parking where space has needed to be found to create articulated bus parking lanes. These buses were highly wasteful of depot lane parking spaces other than in depots which already parked 3, 6 or 7 standard size buses per lane, and at some of these depots, were too long to maintain under cover within existing garage buildings.

  At approximately 50% of the bus depots assessed, deployment of articulated buses resulted in a lower net reduction of equivalent standard bus parking capacity than did 14.5m rigid buses, but for all depots assessed, including those with better parking space utilisation, the import of articulated buses onto site resulted in a very considerable reduction in equivalent standard bus passenger carrying capacity. An average 17% decrease in depot equivalent standard bus carrying capacity was calculated for 2 door articulated buses and an 8% decrease for 3 door articulated buses, where 14.5m rigid buses achieved slightly better than break even passenger carrying capacity with the standard buses they displaced.

  Articulated buses have therefore not been recommended for most depots and relegated to the lowest ranking for general deployment of all the high capacity bus types. In the two depots (Loganlea and Molendinar) where articulated buses were recommended ahead of 14.5m buses, the 3 door articulated bus was ranked higher than the 2 door articulated bus.

3.7.2 Alternately Extended High Capacity Bus Parking Lanes

In this section, we have described an alternately extended yard parking lane configuration which would significantly improve mixed standard and high capacity bus parking densities in most the existing bus depot yards assessed during the study, and describe how alternately extended lanes would operate in practice at the Sherwood Bus Depot. Sherwood is Brisbane Transport's second largest and newest bus depot, and is currently home to 102 standard 12.5m rigid diesel buses and 40 high capacity 14.5m rigid diesel buses. An aerial view of the Sherwood Bus Depot layout plan appears below in Figure 29.

Figure 29: Sherwood Bus Depot Layout

Albeit very similar in its yard parking scheme and site building layout to the new Willawong Bus Depot, Sherwood utilises 43 x 5 standard bus length parking lanes, where Willawong utilises 37 x 6 standard bus length parking lanes. Reference to Table 2 indicates that 6 and 7 standard bus length parking lanes minimise wasted parking lane space for all high capacity vehicle sizes, where 4 and 5 standard bus length parking lanes are highly wasteful of equivalent standard bus parking space for 18m articulated buses. With 43 lanes, Sherwood tops the wasted space list for all the assessed depots in this regard with a net reduction of around 17% storage capacity on every standard bus lane given over to articulated bus parking.

Figure 30 overleaf presents a section of the Sherwood depot bus yard and illustrates the concept for alternately extended high capacity bus parking lanes. While double deck buses have neither been recommended for Sherwood Bus Depot nor shown on
Figure 30, the alternately extended parking lane scheme works equally well for all high capacity bus types, and for mixed parking of high capacity and standard size buses.

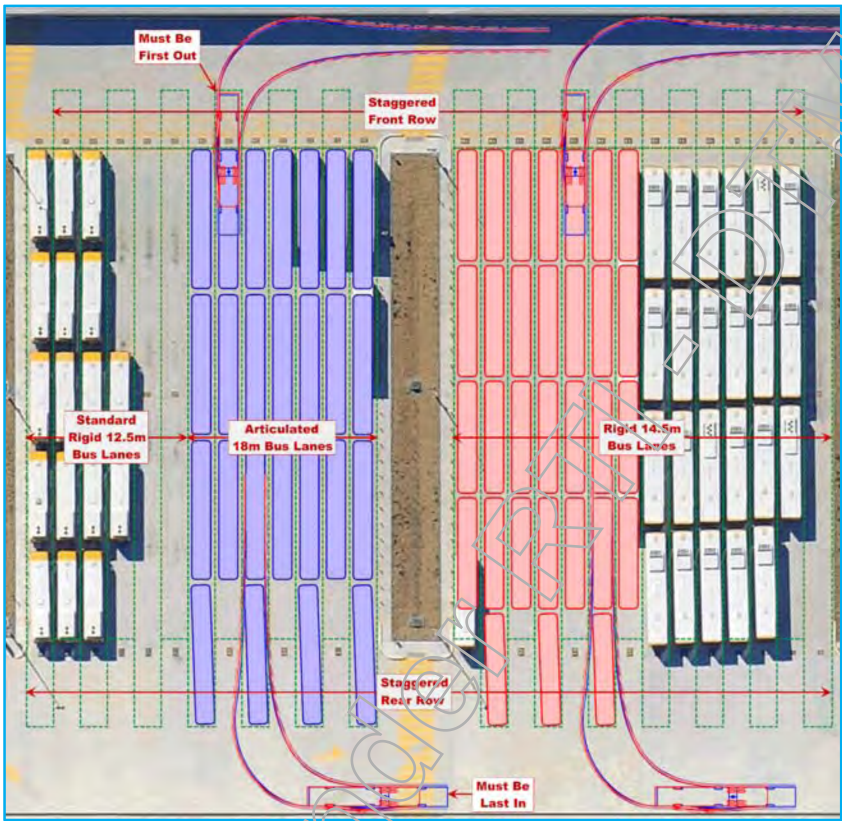
Alternate lane extensions can be utilised either at the rear or front, or at the rear and front of each nose-to-tail parking lane to recover lost parking space traded off for high capacity bus turn-ins from and turn-outs to perimeter circulation corridors respectively. Blue (articulated) and red (14.5m rigid) shaded bus outlines shown on
Figure 30 only use the rear of each alternately extended lane, increasing each by an additional high capacity bus space. Closer inspection of
Figure 30 will further reveal that an extra 14.5m rigid bus could be parked on every alternately extended lane using both their front and rear extensions.

Operating the concept alternately extended lane scheme at Sherwood would require driver, maintenance and servicing personnel adherence to 2 simple parking rules, namely:

1 All indented rear lanes to be filled before parking buses in the rear extended lanes, and

2 All front extended lanes to be cleared before taking buses from front indented lanes.

Figure 30: Alternately Extended High Capacity Bus Lane Concept Design



In the example illustrated, alternate rear lane extensions would improve the Sherwood Bus Depot 3 door articulated bus parking capacity by the equivalent of 42 standard buses and its passenger carrying capacity by the equivalent of 33 standard buses. The improvement gained for 14.5m rigid buses would be an increased parking capacity equivalent to 22 standard buses and passenger carrying capacity equivalent to 29 standard buses.

Appendix D

Performance Evaluation Report

Document Information

Client	TransLink Transit Authority
Job Number	4746
Title	Research and Analysis of High Capacity Vehicle Use - Operational Performance Evaluation of High Capacity Vehicles
Prepared by	MRCagney Pty Ltd Brisbane, Queensland
Date	6 August 2012

Quality Assurance Register

Issue	Description	Prepared by	Reviewed by	Authorised by	Date
1	Initial Issue for Review	MF, JH	BW, JV	LC	31/07/2012
2	Author Review and Edit	MF	BW, JV	LC	6/08/2012

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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by *TransLink Transit Authority (TransLink)* to undertake research and analysis of high capacity vehicle *(HCV)* use within its South East Queensland network. The subject high capacity vehicle types nominated by *TransLink* for this study are already in service on its network and include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

In this report, the operational performances of the 4 nominated high capacity vehicles are compared to that of the reference standard vehicle operated by all *TransLink* bus service providers in South East Queensland, namely the:

- Two Door 12.5m Rigid Bus.

1.2 Study Objectives

The objectives of this study were to:

1. Define bus stop dwell time, describe how excessive stop dwell time adversely impacts high capacity bus service timetables, scheduling, frequency and reliability, renders high capacity bus services non-competitive with private motor vehicles on long routes, and consumes valuable inner city station and kerbside stop capacity during peak service periods,
2. Explain why dwell time minimisation is crucial to high capacity vehicle operational performance, present international research into the key factors which increase stop dwell time, and outline world best practice bus configurations, station and stop geometrics, fare collection and bus operating strategies exploited by overseas mass transit agencies similar to *TransLink* to minimise stop dwell time,
3. Identify the significant differences between world best practice dwell time mitigation practices and contemporary route bus operating practices in South East Queensland,
4. Explain why all door boarding is considered crucial to the efficiency and viability of SEQ high capacity bus services, and profile compelling overseas case studies detailing where, why and how all door boarding has been successfully implemented in concert with random proof of payment fare evasion monitoring,
5. Measure and compare the average boarding and alighting times per passenger on the 4 high capacity vehicles with those of the reference standard vehicle, and determine the relative contributions of average passenger boarding and alighting times to average stop dwell time,
6. Measure and compare passenger alighting preferences on the 4 high capacity vehicles with those of the reference vehicle using front door only boarding, and determine the relative impacts of passenger alighting preferences on front door boarding conflicts that increase dwell time and rear door conflict-free concurrent alighting which reduces dwell time,
7. Measure and compare the average in-traffic service speeds, deceleration rates into, and acceleration rates out of bus stops on the 4 high capacity vehicles with those of the reference

vehicle, and determine the relative contributions of the number of stops per journey and dwell time per stop to the overall increase in total service delay and reduction in average service speed,

8 Measure and compare seated and standing passenger space utilisations during peak and off-peak services on the 4 high capacity vehicles with those of the reference vehicle, and determine the relationship between seating capacity, average standee counts and average standing times,

9 Develop a model based on and proofed against measured live service data to compare the relative operational performances of the 4 high capacity vehicles with that of the reference vehicle and a private motor vehicle over a broad range of typical SEQ operating parameters using front door only passenger boarding,

10 Modify the model to predict the operational performances of the 4 high capacity vehicles against the reference vehicle and private motor vehicle over an identical range of operating parameters using all door passenger boarding the determine its likely benefits,

11 Identify the service and route characteristics to which each high capacity bus type is best suited for front door and all door boarding, and

12 Define alternatives to optimise future mass transit high capacity vehicle operational performance on South East Queensland high capacity bus services.

1.3 Executive Summary

Rapid growth in high capacity vehicle fleet strengths has been identified over the past 3 years in all Australian State capital cities and the national capital. The rapid growth has been primarily driven by the progressive outstripping of standard 12.5m route bus capacity by rising patronage demand, and to a lesser extent, by the opportunity to fast track high floor low capacity route bus retirements before legislated 2012 and 2017 national transport disability target compliances fall due.

Only one capital city has the necessary bus rapid transit infrastructure already in place, or planned for future construction, to transition from the Australian traditional low speed, low capacity route service operating model to a world class high speed, high capacity mass transit operating model, and greater Brisbane stands well positioned in this regard to lead the nation in the exploitation of its young and still growing high capacity bus fleet.

Research undertaken during this study has uncovered very significant differences between overseas best practice mass transit high capacity bus operations and those in South East Queensland. To realise greater Brisbane's emerging opportunity, both *TransLink* and its high capacity bus operators will need to shift focus from what has in the past been best practice for traditional low speed, low capacity bus route operations to what is currently proven international best practice for mass transit high frequency, high capacity bus operations, and that has been clearly identified in our research as *Dwell Time Minimisation*.

The pivotal role of dwell time minimisation to high capacity bus service efficiency, performance and viability is such that international best practice mass transit agencies and their service operators go to extraordinary lengths to fine tune vehicle cabin layouts, station and kerbside stop geometrics, electronic signage systems, fare collection procedures and service operations to crimp just fractions of a second off their average passenger boarding and alighting times.

Overseas Mass Transit versus SEQ High Capacity Bus Operations

In stark contrast to contemporary South East Queensland high capacity bus operations which use bus cabin layouts designed for maximum seating capacity, front door only boarding, and drivers tasked with answering passenger travel enquiries, selling tickets, topping up *go cards* and monitoring fare evasion; world best practice mass transit bus service providers exploit:

1. All door passenger boarding and alighting at all bus stations and kerbside stops,
2. Cross platform interchanges for high loading capacity intermodal passenger transfers,
3. More and wider exterior bus plug doors carefully positioned and spaced to quickly distribute passengers to seated and standing areas with minimum platform and on-vehicle movements, and to equalise passenger boarding and alighting counts through all bus doors,
4. Optimisation (rather than maximisation) of bus seating capacity to afford wide aisle passenger circulation spaces throughout bus saloons, increased total passenger seated and standing capacity, improved standee comfort, and eliminate standee blockages and bottle necks to alighting and boarding passenger flows,
5. 100% step-free, ramp-free ultralow flat floor designs throughout bus saloons with minimum or no climb-on plinth mounted seats. This facilitates passenger movements aboard buses when decelerating and accelerating at stops by eliminating the potential hazards of passenger slips, trips and falls,
6. On-vehicle next stop visual and (public address) audible passenger cueing signs to advise passengers of the next stop in advance of arrival, and to request alighting passengers to begin to mobilise to doors. Similar passenger cueing signs and public address announcements are promulgated on bus station platforms to ready waiting passengers in advance for boarding at bus set downs,
7. Reserved passenger storage areas opposite and adjacent to bus doors to muster alighting passengers ready for disembarking prior to stop arrival, and to temporarily store boarding passengers during and after departing from stops,
8. Smartcard readers mounted at doors and in defined passenger door storage areas to enable alighting passengers to tag off both prior to stop arrival and while stopped, and boarding passengers to tag on both while stopped and after stop departure,
9. Dual berth inner suburban bus station designated stop bays and kerbside stops to obviate random high frequency bus arrival clashes,
10. Limited or no driver onboard ticket selling and interaction with passengers,
11. No onboard driver smartcard top up crediting, and
12. Roaming random “proof of payment” ticket inspections and hefty fines for non-valid smartcard and ticket holders applied uniformly across all travel modes (bus, train, light rail and ferry) to both monitor and manage modal and intermodal fare evasion.

In Part 2 of the study, the authors have measured average stop boarding, alighting and dwell times per passenger using *go card* ticketing data captured on several hundreds to thousands of bus services operated by the 4 high capacity vehicles, and both older high floor and new ultralow floor standard size buses between 1 March and 8 April 2012. The measured results have identified stop delays in the order of 2.5 to 4 times longer than best practice planning times adopted by overseas mass transit planners and station designers for similar length high capacity vehicles with 2 and 3 double width doors.

In a similar study undertaken by the Queensland University of Technology at the lead stop operated Mater Hill Busway Station just prior to smartcard implementation in 2004, very high peak period dwell times were cited ranging from 4.8s per passenger at the lead stop loading area up to 12.7s per passenger at the third rear of platform loading area, the latter proving to be almost an order of magnitude higher than best practice mass transit planning times for a comparable bus rapid transit (*BRT*) station.

The very high peak dwell time at lead stop busway stations is well known to be caused by passenger relocation delays along platforms to board buses, and modern GPS based real time passenger information systems installed on best practice mass transit bus stations cue passengers to relocate to predicted set down loading areas well in advance of bus arrivals and continuously monitor and sort service destinations displayed on signs into the sequential order of actual platform set downs. The authors have highlighted that similar functionality should be available on the new *TransLink INIT Customer First* real time passenger information system signs and is considered essential to efficient future peak period high capacity vehicle mass transit operations using busways.

Measured High Capacity Vehicle Operational Performance

Go card ticketing data measurements, on-vehicle trips and station passenger movement surveys have revealed the reasons why local SEQ high capacity bus services have underperformed their overseas mass transit counterparts. Key findings of the study have concluded that adoption of the earlier mentioned international best practice dwell time minimisation strategies will greatly improve future high capacity mass transit operations in South East Queensland. Relevant key findings from the study evidencing this conclusion were as follows:

1. The fastest average boarding, alighting and dwell times per passenger for the 4 high capacity vehicles were measured on the Brisbane Transport 2 door 18m articulated bus Route 111 services. On-vehicle observations clarified this occurred because alighting busway station passengers positioned themselves at bus doors in advance of station arrivals and double streamed off at rear doors and in single file at front doors with minimal conflict to boarding passengers. Route 111 high capacity services had a very high incidence of concurrent passenger rear door alighting and virtually no interaction took place between Brisbane Transport articulated bus drivers and boarding passengers.

2. In contrast to the Brisbane Transport Route 111 articulated bus services, Clarks Logan City Route 555 articulated bus drivers experienced a very high incidence of interaction with passengers primarily for requested paper ticket purchases and *go card* top ups. Driver-passenger interactions were observed to not only block off one channel of boarding passengers at the double width front doors, but to cause conflicts in the free flowing front door channel between boarding *go card* users and those passengers who chose to alight via the front door.

   Consequently, average boarding times per passenger measured on both Clarks Logan City articulated buses were 1 second (or 40%) longer than on the Brisbane Transport articulated buses, and monopolised total dwell time to the extent that no significant difference was found between the two Clarks Logan City bus variants. The total stop dwell time savings accrued from the very high middle door passenger alighting counts on the superbus were consequently fully negated out.

3. The longest average alighting time per passenger was measured on the double deck bus and passengers from its upper deck were frequently observed to continue alighting through the double width rear door in single file after all alighting passengers on the lower deck had fully disembarked. A near 50%:50% even split was measured during trips between the mostly young and able bodied passengers who elected to sit on the upper deck and generally older passengers who chose to sit on the lower deck.

   At the high AM peak offloading stops in Fortitude Valley and the CBD, passengers alighting from the upper deck continued to disembark for periods of up to 10 seconds after passengers on the lower deck had already exited. Boarding times on the double deck bus were found to be unaffected by upper deck use, but upper deck alighting times were randomly and frequently delayed by passengers fearful of descending the upper deck stairway until the double deck bus had completely come to rest.

4. Without exception, average boarding times per passenger greatly exceeded average alighting times on all bus types, including the double deck and standard 12.5m rigid buses, and dominated average dwell times. Average boarding times were increased on off-peak bus services

by passenger preferences to alight at the front door and block boarding passengers, were highest on the 2 door articulated buses, and lowest on the 14.5m rigid bus for which over 80% of passengers currently choose to alight via the rear door.

The impact of passenger front door alighting preferences proved to be much less significant however on peak period AM inbound and PM outbound services where boarding and alighting passenger flows were identified as predominantly non-conflicting and unidirectional, i.e. over 95% of passengers boarded or alighted in one direction only without door flow channel conflicts.

5 Examination of manufacturer floor layout plans for all 5 bus types examined identified a very high correlation between door alighting preferences and rear door proximity to passenger seating and standing areas. It has been consequently determined that passengers have no inherent preferences to alight at any particular door; they merely choose to exit via the nearest available door. This finding has proven to be very important to the future successful implementation of all door boarding because it enables high capacity bus passenger rear door alighting preferences to be tailored through careful design of high capacity bus seating and standing areas and selective positioning of their (middle and) rear door proximities.

6 Measured average passenger boarding, alighting and dwell times were unexpectedly found to be slightly higher on the all door boarding *CityGlider* ultralow floor 12.5m rigid buses than on similar front door only boarded Route 345 ultralow floor 12.5m *CityBuses*. Only around 1 in 4 passengers on the *CityGlider* service boarded at the narrow rear door and around 3 in 4 *CityGlider* passengers preferred to alight and conflict with rear door boarding passengers. This finding has discredited the mistaken notion that uncontrolled all door boarding reduces dwell time and has been explained by observing the imbalance between how passengers freely choose to board at the front door and alight at the rear door during off-peak services which comprise the vast majority of weekday high churn *CityGlider* bus services.

On several trips taken aboard the off-peak *CityGlider* service, it was observed that passengers who initially queued to board at the rear door deserted the queue to board at the front door while passengers were still alighting in single file through the narrow bus rear door. This often occurred after those who initially chose to board at the front door were already onboard and seated. When rear door queues occurred, they resulted in a longer stop dwell time because the bus had to hold over longer at the stop waiting for single file passenger boardings to finish at the rear door. Other notable contributors to poor dwell time performance sighted during the 10 – 15 minute driver variable off-peak services were the willingness of customer-friendly *CityGlider* drivers to hold over at stops for late arriving hailers and runners, and the laid back pace of alighting passenger movements to doors until after buses had stopped.

7 Measured in-service speeds and bus stop deceleration and acceleration rates were found to be lowest on the double deck and Brisbane Transport CNG 2 door articulated buses, and highest on the 14.5m rigid bus. In-service average stop acceleration and deceleration rates measured on every bus type were highly variable between drivers and found to be less related to vehicle brake/retarder performance and engine power than to personal driving habits. On identical buses for instance, some drivers were aggressive brake and accelerator users who pushed vehicle performance to the limit, whilst others were more passive and coasted into and slowly took off from bus stops. Irrespective of driving habits, average in-service stop deceleration and acceleration rates were found to be inversely proportional to incident average traffic speed for all bus types.

Average service speed was found to be proportional to average traffic speed and route length but inversely proportional to the number of stops per kilometre and average dwell time per stop. Ironically, aggressive acceleration and deceleration made little difference to average service speed, and aggressive drivers gained only fractions of a minute extra layover rest time at termini by pushing bus fuel consumption and brake lining wear to the limit. Buses on longer routes with few stops had the highest average speed, typically attaining greater than 50% average traffic speed, while buses on shorter routes with many stops attained speeds of around one third average traffic speed.

Very low average service speeds of around one fifth average traffic speed were recorded on sections of the Redcliffe 315 and Aspley 345 routes where stops were closely spaced and boarded or offloaded less than a few passengers.

8 Only 2% to 7% of high capacity vehicle weekday peak services carried standing loads, and for those that did, average standing times varied between 9 and 18 minutes, and maximum standing times between 19 and 37 minutes. No double deck peak period bus service carried standees other than those passengers who freely chose to stand when unoccupied seats were available.

Passengers on all bus types who observed to stand when seats were available and were predominantly young passengers who wanted to chat with friends or passengers who boarded for short trips and chose to stand near doors to be first off, avoid peak standing crushes or conflicts with other standees when alighting.

The majority of services operated by all bus types were in off-peak periods during which 56% to 73% of installed high capacity bus seats went unused and 57% to 61% of standard 12.5m rigid bus seats went unused.

9 Measured average and maximum standee counts and their standing periods were lowest on the high passenger turnover *CityGlider* and *Busway* 111 routes. Our analysis methodology has demonstrated that driver/operator overload reports and trip peak boarding counts do not provide reliable surrogates for determination of peak loading, overloading and overload duration periods, or for justifying replacement of standard 12.5m buses with larger high capacity buses.

We believe justification of high capacity bus deployment can only realistically be determined on high frequency, high passenger turnover services by measuring cumulative *go card* tag ons and tag offs incrementally along trips after each bus stop to calculate average and maximum standing loads and their durations. On high turnover, high frequency bus routes, average standing times were found to be very short and missed passenger pick-ups were collected within short headway periods by following services.

Impact of Maximised Seating on HCV Service Dwell Time and Lost Boarding Capacity

Interviews conducted by MRCagney consultants with 4 *TransLink* bus operators and 3 major Australian bus builders have established that SEQ route bus operators overwhelmingly advocate maximum seating capacity on their new ultralow floor buses. Only one bus operator interviewed declared its support for reduced seating on high capacity vehicles, but saw little merit in such on standard size route buses.

Common reasons given for maximising bus seat capacity were loss of seating capacity to wheelchairs and ultralow floor engine, transmission and wheel arch intrusions, increased peak period commuter comfort, and compliance with the *Queensland Transport Operations (Passenger Transport) Standard* which imposes strict time and distance limits for standing school children on Queensland bus services.

Most operators were unaware that the current *Standard* allowed for 3 children to be seated on a *Local Classification* route bus in each twin adult passenger seat, that the no standee rule only applied to *ADR58/00 Complying Buses* fitted with seat belts, the 90 minute school child maximum standing time limit only applied to school bus services operated on 40km and longer *Regional Classification* bus routes, and the *Standard* had been amended in December 2011 to remove the no standee rule for *Local Classification* school and route bus services operated over distances in excess of 20km.

It is evident that SEQ bus operator obsession with recovering lost seat capacity given over to wheelchair parking bays and to maximise seating capacity on new low ultralow floor buses has come at a very high cost to stop dwell time caused by:

- Abandonment of chassis manufacturer designed slip, trip and fall free 100% flat floors in favour of body manufacturer requested stepped up and ramped floors with climb-on passenger seats in cabin spaces to the aft of the rear door, (and in some cases even to the fore of the rear door),
- Abandonment of double width rear doors with adjacent passenger storage areas previously incorporated on all early vintage Brisbane high floor buses, in favour of narrow rear doors without passenger storage areas on new ultralow floor standard 12.5m buses. This has also been observed on some late model ultralow floor 14.5m rigid buses operating in greater Brisbane,
- Narrow aisle ways flanked either side by high plinth mounted seats, creating coach style seating layouts with no space for passengers to freely pass standees, and other constriction bottle necks to passenger movements both between doors and to the rear cabin spaces,
- Heighted standee discomfort caused by the need for standees to continually carry luggage to prevent trampling, to repeatedly lean over seated passengers or move toward doors to make way for alighting passengers, and highly crammed forward cabin areas because aisle ways rear of the aft door are too narrow, ramped and have low head clearances,
- Reduced total seated and standing capacity afforded by the extra tonne permitted axle weight (equal to 15 standing passengers) granted under new Australian design rules and heavy vehicle regulations exclusively to ultralow floor buses. SEQ bus operators prefer instead to convert their *COAG* granted concessional axle weight limits into underutilised seating capacity, and
- Higher bus procurement costs for extra seats, heavier plinth seat frames and floors; higher body frame, floor and seat maintenance and cleaning costs, and higher weight related fuel consumption and brake lining replacement costs for underutilised seating during off-peak services.

The longer total trip dwell time, resulting longer timetables and recurring operating expenses created by underutilised passenger seats are ultimately passed to *TransLink* through operating contracts, and the reduction in peak period boarding capacity translates to lost passenger revenue and higher subsidies throughout the 20 year average service life of every new ultralow floor bus currently entering service. The additional cost to *TransLink* of carrying underutilised seats increases in proportion to vehicle size and lost total passenger carrying capacity. This can be readily demonstrated by the 27.5% increase in total carrying capacity of the 3 door Logan City articulated superbus over the 2 door Brisbane Transport and Clarks Logan City articulated buses.

Modelling Analyses of High Capacity Vehicle Front Door Only Boarding

Operational performance modelling has been used in this study to evaluate the route characteristics best suited to each front door boarded high capacity vehicle type relative to both a standard 12.5m rigid bus and competing private motor vehicle during the AM inbound and PM outbound peak periods. The model developed has been used to test:

- Each bus type boarded to its respective maximum seated and standing capacity,
- On 5 different routes lengths between 5km and 25km,
- With between 2 and 32 bus stops per trip,
- Including average passenger walking or driving time to stops when comparing the competitiveness of each bus type to a private motor vehicle completing the same trip,
- Using measured average passenger door boarding and alighting times and passenger door alighting preferences for front door only boarding, and both calculated average passenger door

boarding and alighting times for balanced concurrent minimum dwell and unbalanced current passenger door alighting preferences for all door boarding,

- Operating at 3 peak period *RACQ* and *Translink* published Brisbane average traffic speeds of 30km/h for routes on CBD arterial, sub-arterial and local roads, 45km/h for routes on CBD multilane highways and motorways, and 75km/h for routes on busways, city ring roads and highways with dedicated bus only and T2/T3 transit lanes, and
- At measured average bus stop deceleration and acceleration rates applicable to each bus type.

For front door only boarding on all bus types during weekday peak periods, total trip dwell times were calculated as listed on the third line of the table below, and found to be independent of the total stops made. While total stop deceleration and acceleration times increased markedly with total stops made and average traffic speed, their combined total times shown shaded in green accounted for less than one third of total journey delay accrued by stopping, alighting and boarding passengers. Dwell time at stops to alight and board passengers dominated the operational performances of all bus types in proportion to their respective passenger capacities.

	Contribution of Bus Deceleration and Acceleration Time to Total Bus Stop Delay									
	Two Door 12.5m Standard Rigid Bus		Two Door 12.5m Double Deck Bus		Two Door 14.5m Extended Rigid Bus		Two Door 18m Articulated Bus		Three Door 18m Articulated Superbus	
Dwell	5.9 mins Total		11.0 mins Total		7.8 mins Total		6.3 mins Total		10.6 mins Total	
Bus Stops Per Trip	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay
30 Kilometre/Hour Average Traffic Speed										
2	0.2 min	1%	0.3 min	1%	0.2 min	1%	0.2 min	2%	0.2 min	1%
3	0.3 min	3%	0.6 min	3%	0.4 min	3%	0.5 min	4%	0.4 min	2%
4	0.5 min	4%	0.9 min	4%	0.6 min	4%	0.7 min	6%	0.7 min	3%
6	0.9 min	7%	1.5 min	6%	1.0 min	6%	1.2 min	9%	1.1 min	5%
8	1.2 min	9%	2.1 min	9%	1.4 min	8%	1.7 min	12%	1.6 min	7%
11	1.7 min	13%	3.0 min	12%	2.1 min	12%	2.5 min	16%	2.2 min	9%
16	2.6 min	18%	4.5 min	17%	3.1 min	17%	3.7 min	23%	3.3 min	14%
23	3.8 min	24%	6.6 min	23%	4.6 min	23%	5.5 min	30%	4.9 min	19%
32	5.3 min	31%	9.3 min	30%	6.4 min	29%	7.7 min	38%	6.9 min	24%
45 Kilometre/Hour Average Traffic Speed										
2	0.3 min	3%	0.5 min	2%	0.4 min	3%	0.4 min	3%	0.4 min	2%
3	0.6 min	5%	1.0 min	4%	0.8 min	5%	0.9 min	7%	0.8 min	4%
4	1.0 min	8%	1.4 min	6%	1.2 min	7%	1.3 min	10%	1.2 min	5%
6	1.6 min	12%	2.4 min	10%	2.0 min	12%	2.2 min	15%	2.0 min	9%
8	2.3 min	16%	3.3 min	13%	2.9 min	15%	3.1 min	20%	2.8 min	12%
11	3.2 min	22%	4.8 min	18%	4.1 min	21%	4.4 min	26%	4.1 min	16%
16	4.8 min	29%	7.2 min	25%	6.1 min	28%	6.7 min	35%	6.1 min	22%
23	7.1 min	38%	10.5 min	32%	9.0 min	37%	9.8 min	44%	8.9 min	30%
32	10.0 min	46%	14.8 min	40%	12.7 min	45%	13.8 min	52%	12.6 min	37%
75 Kilometre/Hour Average Traffic Speed										
2	0.9 min	7%	1.2 min	5%	1.1 min	7%	1.2 min	9%	1.0 min	5%
3	1.8 min	14%	2.3 min	10%	2.2 min	12%	2.5 min	16%	2.0 min	9%
4	2.8 min	19%	3.5 min	14%	3.3 min	17%	3.7 min	23%	3.0 min	12%
6	4.6 min	28%	5.9 min	21%	5.5 min	26%	6.2 min	33%	5.1 min	19%
8	6.5 min	35%	8.2 min	27%	7.7 min	33%	8.7 min	41%	7.1 min	25%
11	9.2 min	44%	11.7 min	35%	10.9 min	41%	12.4 min	50%	10.1 min	32%
16	13.8 min	54%	17.6 min	44%	16.4 min	51%	18.6 min	60%	15.2 min	42%
23	20.3 min	63%	25.8 min	54%	24.1 min	61%	27.2 min	68%	22.3 min	51%
32	28.6 min	71%	36.4 min	62%	33.9 min	68%	38.3 min	75%	31.4 min	60%

The impact of stop dwell time on high capacity bus service performance was found to diminish with increasing route lengths over 7.5km and falling average traffic speeds to the extent where high capacity buses began to alight and board their respectively higher passenger loads in total trip times only marginally higher than those achieved by standard rigid 12.5m buses. High capacity buses then jostled for highest overall operational performance ranking based on their respective passengers carried per unit total trip time as shown in the table below.

Further analyses of the modelling results showed that front door only boarding stop dwell times were highly unbalanced with current passenger alighting preferences, most particularly during off-peak periods and operational performance of all bus types could only be improved in both peak and off peak periods by reducing average boarding times per passenger and shifting passenger alighting preferences during off-peaks to 100% rear door alighting, other than at stops where no passengers were waiting to board.

Route Length	Routes Operated at 30km/h	Routes Operated at 45km/h	Routes Operated at 75km/h
	Mixed Traffic on Local, Arterial and Sub-Arterial Roads during Peak Period	Mixed Traffic on CBD Radial Highway or Motorway during Peak Period <u>OR</u> Off-Peak in Mixed Traffic on Local, Arterial and Sub-Arterial Roads	City Ring Road, Busway or Highway Bus Transit Lane during Peak Period <u>OR</u> Off-Peak in Mixed Traffic on a CBD Highway or Motorway
5km	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
10km	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
15km	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 2) 2 : 2 Door 14.5m Rigid (Note 2) 3 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
20km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic (Note 3) 1 : 2 Door Double Deck (Note 3) 2 : 2 Door 18m Artic 3 : 2 Door 14.5m Rigid 4 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
25km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 4) 2 : 2 Door 14.5m Rigid (Note 4) 3 : 2 Door 12.5m Rigid

<u>Note 1:</u> Up to a Limit of 22 Boarding/Alighting Stops
<u>Note 2:</u> Up to a Limit of 10 to 15 Boarding/Alighting Stops
<u>Note 3:</u> Up to a Limit of 10 Boarding/Alighting Stops
<u>Note 4:</u> Up to a Limit of 5 Boarding/Alighting Stops

The modelling analysis further verified that if it could be unshackled from the high average boarding time per passenger caused by driver ticket selling, *go card* top ups and passenger travel enquiries, the very high capacity 3 door articulated superbus with its very low 14% front door passenger alighting preference and very low average alighting time per passenger through the middle and rear doors would rise to number one ranking in all high capacity bus categories listed in the table above, other than those where 12.5m buses only have been nominated.

The ratio of average traffic speed to average service speed is a direct measure of the total time taken to complete a bus trip compared to the time taken to complete the same journey without stops using a private motor vehicle. An interesting phenomenon was identified in the modelling of high capacity front door loaded services at peak period bus service speeds, namely that their competitiveness with the private motor vehicle (including allowance for passenger walk or drive to stop times) improved with falling traffic speeds of 45km/h or lower. This occurred on city arterial, sub-arterial and local roads, highways and motorways at route lengths of 15km or longer and became increasingly independent of the actual number of stops made.

It has been found that with increasing congestion, for each percent drop in average traffic speed recorded over every successive RACQ Brisbane peak road speed survey, the percentage of service speed to traffic speed increased at a higher percentage rate, and favoured the higher 112 to 116 passenger 3 door articulated and double deck high capacity buses more so than it did the lower 88 – 92 passenger 14.5m rigid and 2 door articulated high capacity buses and the 75 passenger standard 12.5m rigid buses. Consequently, the outlook for high capacity buses looks set to continuously improve relative to the private motor vehicle.

Modelling Analyses of High Capacity Vehicle All Door Boarding

Modelling analyses have also been conducted to determine the likely improvement to operational performance of each high capacity vehicle type during peak periods using all door boarding.

All door boarding analyses have identified an infinite range of ratios exists between the percent of passengers who choose to alight through the (middle and) rear door(s) and the percent of passengers needed to board at the front door to equalise (or balance up) total boarding and alighting times through all doors in accordance with the average boarding and alighting times per passenger applicable to each bus type. If these percentages are not fully balanced, the stop dwell time increases above the ideal minimum to the longest time taken to alight and board the longest passenger queue(s) at any particular bus door, in much the same manner that was observed on the highly imbalanced all door boarded *CityGlider* 12.5m rigid buses.

It has been found that balanced concurrent alighting and boarding through all bus doors reduces dwell time to its ideal minimum by a factor very close to the ratio of total door channels divided by 2. For the 2 channel door double deck bus, 14.5m rigid bus and 2 door articulated bus, the minimum dwell time is half that currently obtained for front door only boarding. For the 3 door double deck bus, the minimum dwell time is a third of that currently obtained for front door only boarding, and for the standard bus with a single channel rear door, around 1.8 times lower.

Our analyses have also determined that a unique condition exists when alighting and boarding passenger percentages at every bus door are set proportional to their respective door loading channels. Under this special condition, minimum dwell time becomes totally independent of average boarding and alighting times per passenger for every given bus capacity. This unique condition occurs for each bus type when passengers are induced to alight and board in the following proportions:

- 2 Door 12.5m Rigid Bus: 2/3 Front Boarding, 1/3 Rear Boarding
  2/3 Front Alighting, 1/3 Rear Alighting
- 2 Door 12.5m Double Deck Bus: 50% Front Boarding, 50% Rear Boarding
  50% Front Alighting, 50% Rear Alighting
- 2 Door 14.5m Rigid Bus: 50% Front Boarding, 50% Rear Boarding
  50% Front Alighting, 50% Rear Alighting
- 2 Door 18m Articulated Bus: 50% Front Boarding, 50% Rear Boarding
  50% Front Alighting, 50% Rear Alighting
- 3 Door 18m Artic Superbus: 1/3 Front Boarding, 1/3 Middle and 1/3 Rear Boarding
  1/3 Front Alighting, 1/3 Middle and 1/3 Rear Alighting

An important property has been observed when passengers are induced to board and alight in proportion to all available bus door loading channels. The sensitivity of stop dwell time to the ratio of (middle and) rear door alighting percentage to front door boarding percentage mismatch is lower around the above listed unique conditions than at any other induced ratio. In practice, this would mean that if *TransLink* aimed to minimise dwell time on its high capacity bus services using all door boarding and chose to induce the unique ratio for each bus type listed above, actual dwell time achieved in service should remain close to its ideal minimum even if passengers didn't choose to exactly alight and board in ideal proportions at every door. Put simply, close enough would still prove to be good enough.

The authors have also further examined how well all door boarding would perform if current passenger (middle and) rear door alighting preferences were to stay unchanged. Based on current passenger rear door alighting preferences on each bus type, the percentage of passenger boardings needed to balance out their exits via the front and rear doors to achieve minimum stop dwell time would be:

- 2 Door 12.5m Rigid Bus: 81% Front, 19% Rear
- 2 Door 12.5m Double Deck Bus: 53% Front, 47% Rear
- 2 Door 14.5m Rigid Bus: 70% Front, 30% Rear
- 2 Door 18m Articulated Bus: 48% Front, 52% Rear
- 3 Door 18m Articulated Superbus: 44% Front, 28% Middle, 28% Rear.

These proportions indicate that only the double deck and 2 door articulated buses have close to ideal alighting preferences, but inducing the required ideal boarding percentages at both front and (middle and) rear bus doors for minimum dwell would prove far more difficult in practice than inducing passengers to simply equalise their boardings and alightings at all bus doors on all high capacity bus types.

It has been found that irrespective of the random choices of passengers to board and alight at particular doors, improved dwell times would still be achieved on all high capacity buses, but the dwell time reduction falls progressively with increasing shift from their ideal door alighting and boarding ratios. The changed relative rankings of high capacity bus operational performance with balanced all door boarding and alighting are presented in the table overleaf.

Approaches to Inducing Balanced All Door Passenger Boarding on High Capacity Buses

Based on overseas implementations that have already proven successful, the authors believe balanced all door boarding (but not alighting) can be induced by advertising the launch of, and repeated promotion of, a policy that passengers without tickets board at front doors and all other passengers with *go cards* form into equal length queues at all bus doors when boarding high capacity bus services. Human dislike of standing at the end of the longest queue should act to naturally balance boarding queues once the policy has been implemented and become common knowledge.

Learnings from both overseas research and the *CityGlider* experience are that passengers conditioned by decades of front door boarding need to be re-educated to board at all doors and signage at bus doors and on stop blades needs to reinforce the message to new passengers.

But there is a cause for caution. Equalised boarding through all doors on the narrow rear door ultralow floor rigid 12.5m standard bus does not minimise dwell time which requires that twice the number of passengers alight and board at the front door to the number who alight and board at the rear door. Rigid ultralow floor bus services are currently only suited to front door boarding and with so many now in service, it would be difficult to make these buses all door boarding compatible.

Route Length	Routes Operated at 30km/h	Routes Operated at 45km/h	Routes Operated at 75km/h
	Mixed Traffic on Local, Arterial and Sub-Arterial Roads during Peak Period	Mixed Traffic on CBD Radial Highway or Motorway during Peak Period OR Off-Peak in Mixed Traffic on Local, Arterial and Sub-Arterial Roads	City Ring Road, Busway or Highway Bus Transit Lane during Peak Period OR Off-Peak in Mixed Traffic on a CBD Highway or Motorway
5km	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
10km	1 : 2 Door 18m Artic 1 : 2 Door 14.5m Rigid 2 : 3 Door 18m Artic (Note 2) 2 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 3) 1 : 2 Door 14.5m Rigid (Note 3) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
15km	1 : 3 Door 18m Artic 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic 1 : 2 Door 14.5m Rigid 2 : 3 Door 18m Artic (Note 3) 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
20km	1 : 3 Door 18m Artic 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 4) 1 : 2 Door 14.5m Rigid (Note 4) 2 : 3 Door 18m Artic (Note 5) 3 : 2 Door 12.5m Rigid
25km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 3 Door 18m Artic (Note 5) 3 : 2 Door 12.5m Rigid

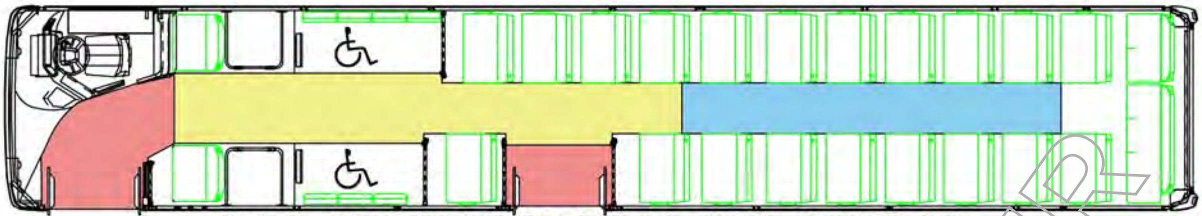
Note 1: Up to a Limit of 10 Boarding/Alighting Stops
Note 2: Up to a Limit of 20 Boarding/Alighting Stops
Note 3: Up to a Limit of 15 Boarding/Alighting Stops
Note 4: Up to a Limit of 8 Boarding/Alighting Stops
Note 5: Up to a Limit of 5 Boarding/Alighting Stops

Our analyses have shown that balanced alighting can only be induced through bus layout design. Measurements have clearly established that passenger alighting preferences can be manipulated by changing the proximity of (middle and) rear door positions to saloon seated and standing areas.

We have further determined that average boarding and alighting times per passenger could be almost halved again to further reduce peak period high capacity vehicle total trip dwell time by widening aisle ways for improved standee circulation and by creating dedicated passenger storage areas opposite and adjacent all doors. The highest reductions in average boarding and alighting times would occur if alighting cueing prompts to move passengers to these door storage areas prior to stopping were introduced, and if the on-vehicle *Cubic* card interface devices could be reprogrammed to enable *go card* tag offs before and during stops and *go card* tag ons during and after stops in the door passenger storage areas.

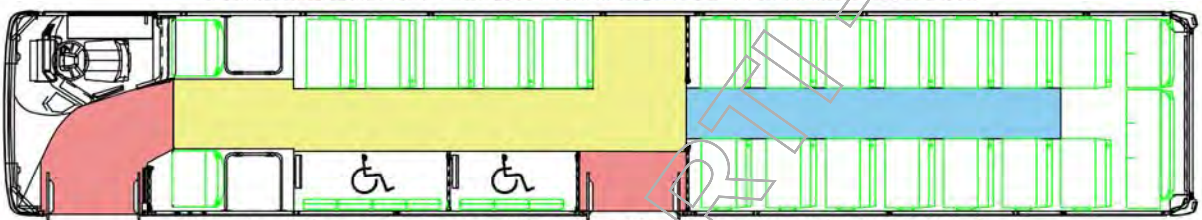
The most imbalanced passenger rear door alighting preference for future high capacity vehicle all door boarding was measured on the Brisbane Transport 14.5m rigid bus. Its layout is currently optimised for maximum seating capacity and front door only boarding, but is grossly unsuited to future all door boarding. We have demonstrated in the report (and reproduced overleaf) alternative layout modifications that would be needed to the 14.5m rigid bus rear door position, seating and standee areas, aisle way widths, and for creation of door storage areas to optimise the cabin layout for future minimum dwell balanced all door boarding and alighting. The layout modifications illustrated overleaf demonstrate how easily dwell time optimisation can be achieved on high capacity buses with as little as a 2 or 3 passenger seat reduction.

The authors have further recommended discontinuation of *go card top ups* and limited or preferably no ticket sales to induce balanced alighting and boarding through all high capacity vehicle front doors.

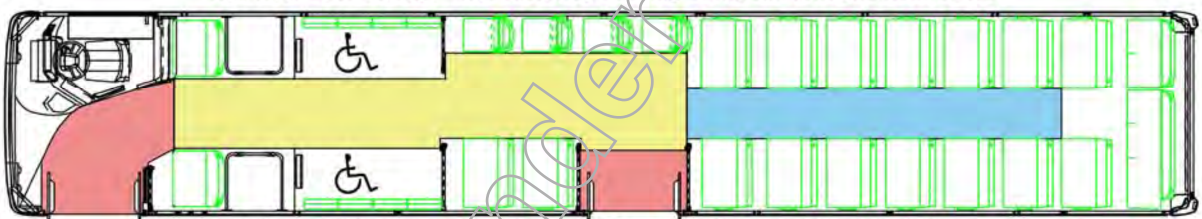


56 Seats - 7 Passenger Front Door Storage Overflow into Wheelchair Bays
No Rear Door Storage - No Aisleway Passing between Front and Rear Doors

54 Seats - 7 Passenger Front Door Storage Overflow into Wheelchair Bays
Has Rear Door Storage - No Aisleway Passing between Front and Rear Doors



54 Seats - 7 Passenger Front and Rear Door Storage Overflow into Wheelchair Bays
Has Rear Door Storage - Has Aisleway Passing between Front and Rear Doors



53 Seats - 7 Passenger Front Door Storage Overflow into Wheelchair Bays
Has Rear Door Storage - Has Aisleway Passing between Front and Rear Doors

53 Seats - 7 Passenger Front Door Storage Overflow into Wheelchair Bays
Has Rear Door Storage - Has Aisleway Passing between Front and Rear Doors

Door Entry No Standing Area | **Flat Aisle and Standing Area** | **Ramped Aisle and Standing Area**

2. Mass Transit Dwell Time Research

2.1 Study Background

This technical report investigates 4 high capacity vehicle (*HCV*) types already operating TransLink route bus services in South East Queensland (*SEQ*) and contrasts the impacts of bus stop dwell time of their operating performance relative to that of a standard two door 12.5m rigid bus. The 4 high capacity vehicle types analysed herein include the:

- Two Door 12 - 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

Representative examples of the 4 high capacity vehicle types and the standard reference vehicle are depicted overleaf in **Figure 1** and

Figure 2 respectively.

In Part 2 of this report, we define bus stop dwell time and present a brief overview of how the longer average dwell time of high capacity buses impacts their timetable schedules, service frequencies, service reliabilities and stop occupancies during the peak periods. We then take a look at 6 key parameters known from international research to increase stop dwell time and the bus cabin layout configurations, station/stop geometrics, fare collection and operating strategies exploited by international transit authorities and operators to reduce bus station dwell times on high frequency mass transit bus operations. Next we contrast these overseas dwell time mitigation best practices with contemporary operating practices in SEQ on TransLink route bus services, and spotlight the fundamental differences.

We first explore the benefits of all door boarding, wider cabin front aisle ways, next stop cuing annunciation, exterior plug doors and rear door passenger storage areas to high capacity vehicle operating performance. We then challenge some parochial bus operator misconceptions regarding narrow rear bus doors, rear door locations, flat floors and maximisation of seating capacity, and show why striving to trim a second or two off passenger boarding and alighting times is not inconsequential. We also challenge some long standing TransLink policies to continue driver *go card* top ups for the (in)convenience of bus passengers, to maintain front door only boarding as a fare evasion deterrent, to deploy high capacity buses on services based solely on driver or operator reported recurrent 12.5m rigid bus overloading, and the notion that onboard driver ticket sales are cheaper than off vehicle ticket sales.

In Part 3, we analyse live service data captured from thousands of *go card* transactions and a dozen onboard ride surveys carried out on 4 high capacity vehicle and 2 standard 12.5m rigid bus services. We present a comparison of the live service operating statistics for each bus type and explain how bus stop dwell time is being monopolised by average passenger boarding time and why driver ticket sale and *go card* top-up delays have negated the benefit of the middle door on the 3 door articulated superbus. We also explain why narrow rear bus doors and lack of passenger information have thwarted realisation of expected stop dwell reductions from all door boarding on the *CityGlider* service and show how rear door location will similarly prevent realisation of all door boarding dwell time reduction on the 14.5m rigid bus.

The final sections of Part 3 use our measured data to model operating performance of the 4 high capacity bus types against that of both a standard 12.5m rigid bus and a private motor car. The model identifies route characteristics suited to each bus type and explores how performance could be dramatically improved through initiatives such as all door boarding, bus redesign and ticketing policy changes.

Figure 1: Representative Examples of the 4 High Capacity Vehicles

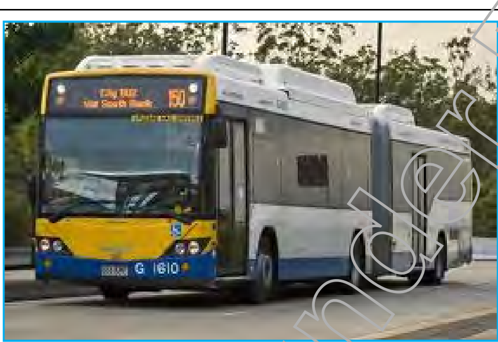
2 Door 12.5m Double Deck Bus		
2 Door 14.5m Rigid Bus		
2 Door 18m Articulated Bus		
3 Door 18m Articulated Superbus		

Figure 2: Representative Examples of the Standard Reference Vehicle

2 Door 12.5m Rigid Urban Route Bus		

2.2 Definition of Bus Stop Dwell Time

Dwell time is the time a bus remains stationary at a bus stop to enable passengers to board and alight, and includes the time required by the bus driver to open and close the bus doors. It is calculated as the difference between bus stop departure time and arrival time and includes the time taken at stops to mobilise passengers to bus doors.

Service planner scheduled dwell times may incorporate deliberate recovery time layovers at bus stops included in the driver's work block to resynchronise departure times from termini or selected mid-route timing point stops back to those appearing in published timetables, to sign off from a completed route, change destination signs and log back onto a new route assignment, to take an award stipulated comfort or meal break, or to give over the bus to another driver. This bus performance evaluation report excludes planner scheduled dwell times built into the driver's work block to enable a like-for-like comparison of high capacity and standard bus dwell times at bus stops used solely for the purpose of boarding and alighting passengers.

2.3 Dwell Time Impacts on High Capacity Bus Services

A serious concern with the large scale deployment of high capacity buses is the longer average dwell time accrued at bus stations and stops for increased passenger boardings and alightings than for standard capacity 12.5m rigid buses. The impacts of increased passenger boardings and alightings and resulting longer stop dwell times on high capacity bus services include:

- HCV Service Timetabling: Longer high capacity vehicle trip times create the need to publish different timetables for selected bus services according to the bus operator's preferred bus size allocation to the trip to meet its patronage demand. This causes drift in clock face scheduled start times from termini particularly on mixed runs scheduled for interleaving of different bus sizes. There is a strong temptation therefore by planners to shorten high capacity bus and extend low capacity bus layovers at termini to create a consistent clock face timetable. Once published timetables have been locked in for high capacity bus services, the operator must ensure it has similar size spare high capacity buses to cover HCV breakdowns, or suffer the added cost of substituting an extra driver and 2 standard capacity buses to cover the HCV service.
- Reduced Peak Period Service Frequency: In the twice daily service peak time windows, increased dwell time incurred by high capacity buses may limit their service frequency to say 3 services per hour, where previously 12.5m rigid buses carrying less passengers could provide a higher frequency of say 4 services per hour. Judged from a passenger perspective, operator substituted high capacity bus services would be viewed as less convenient and longer trips than the standard capacity bus services they replaced. Possible knock-on impacts of passenger disenchantment with substituted HCV services may be loss of patronage to the extent that it forces either reversion back to a high frequency low capacity bus service, or replacement of high with low capacity buses to match the bus size back to a permanently reduced passenger demand.
- Higher Bus Stop Occupancy Time: As multiple suburban route bus services converge on the major arterial, sub-arterial and busway corridors leading into the CBD, competition for available bus station and stop bays increases. High capacity buses not only take up a higher proportion of limited available station platform and bus stop kerbside space, but occupy the space for longer dwell periods. The impact of HCV stop occupancy is especially felt at bus stops located in the CBD where there is very limited available kerbside space and added competition from taxi ranks, car parking bays, loading zones, building accesses, pedestrian crossings, postal delivery zones and numerous other local government authority kerbside allocation demands. Where the option exists to lengthen station platform and bus stop bays in the CBD, such come at a high capital

cost to the transit or local government authority, and often at the expense of other important kerbside allocations which underpin the CBD business economy.

- Reduced Service Reliability: The cumulative effects of extended dwell time at bus stops can adversely impact on the reliability of sequentially blocked high capacity bus services. If one in a group of sequentially blocked high capacity bus services runs late due to excessive cumulative dwell time and insufficient terminus recovery time has been built into its scheduled layovers, late running cascades through all following services left in the driver's work block and may reach a point where the last service in the block may need to be cut or curtailed for the driver to comply with statutory *Fatigue Management Regulations*. TransLink's bus operators are presently penalised for late running and/or missed services not delivered in accordance with the performance management regime prescribed within operator *3G Contracts*.

2.4 Dwell Time Minimisation Research

According to the USA Transport Research Board's publication *Transit Capacity and Quality of Service Manual (2nd Edition)*, there are six key factors which influence bus stop dwell time, two of which relate to passenger demand (and therefore high capacity vehicles), and four which relate to average passenger service (alighting and boarding) times:

- Passenger Demand and Loading: The number of passengers passing through the highest volume bus door is considered a key factor in how long it will take for all passengers to be served (i.e. those alighted and boarded). The proportion of alighting to boarding passengers through the busiest bus door also affects how long it takes all passenger movements to complete as their respective movements are opposed.
- Bus Stop Spacing: The smaller the number of bus stops, the greater (in theory) the average number of passengers boarded and alighted per stop. A compromise is required between providing too few stops, each with relatively high dwell and passenger walking times, and too many stops which reduce the average number of passengers serviced per stop. Too many stops adversely impacts on average travel speed due to the lost time decelerating and accelerating the bus, and because of the increased probability of having to wait at traffic signals due to lower average speed, which is in turn further reduced by every stop needed to be made.
- Fare Payment Procedure: The time taken to pay fares has a significant influence over the total time required to serve boarding passengers. Some fare payment processes allow passengers to board through more than one door at busier stops, thus allowing multiple passengers to be served concurrently.
- Vehicle Type: Having to ascend and descend steps at or adjacent to doors while getting on and off a bus increases the average time required to serve each passenger.
- In-Vehicle Passenger Circulation: When standees are present on a bus, it takes more time for boarding passengers to clear the farebox area(s) and for alighting passengers to reach exiting doors. Standing passengers must move to the rear of the bus to make way for boarding passengers and clear aisle ways to enable free movement of alighting passengers to exit doors.
- Driver Passenger Assistance**: Dwell time can be randomly affected by the time taken to load and offload persons in wheelchairs, the elderly and other persons with mobility or visual disabilities, by drivers repeatedly answering ad-hoc passenger travel enquiries, selling tickets or crediting passenger smartcards, and from deliberately delaying stop departures for late arriving so-called 'bus hailers and runners'.

** Note: Driver passenger assistance is normally considered to be a random event rather than the norm, and is typically not included when measuring average stop dwell time, but as a measure of stop dwell time variability.

Optimising the abovementioned 6 factors can substantially reduce average bus stop dwell times. By way of example, the Denver (Colorado, USA) 16th Street Mall Shuttle operation has maintained an impressive short 75s peak headway with scheduled 12.5s average bus stop dwell times notwithstanding continuous high peak period passenger loadings on its 70 passenger capacity shuttle buses. This was accomplished through a deliberate combination of prepaid fares, fewer seats because typical passenger travel distances were known to be short, step free ultralow floor door entrances, and triple two-way full width streaming doors for concurrent all door boarding and alighting of passengers.

The following sections outline in greater detail various vehicle design, infrastructure design and ticketing policy initiatives known from international operator experience to significantly reduce average high capacity vehicle dwell times.

2.5 Vehicle Design Initiatives to Reduce Dwell Time

From acknowledged world best practice research paper - *Vehicle Selection for BRT: Issues and Options* which documents some 26 case studies of contemporary *Bus Rapid Transit (BRT)* systems operating successfully around the globe, important determinants of average stop dwell times were identified as bus seating, floor height, floor plan and door configuration, and important determinants of overall BRT system throughput capacity were identified as the physical vehicle size, aisle width, number of doors, door widths and positions, number of passenger seats and seating layout configuration.

2.5.1 Number and Width of Bus Doors

Irrespective of how fares are collected by a given transit agency, a large number of wide bus doors will markedly reduce average bus stop dwell time. Wide double flow channel doors generate less passenger movement conflicts than narrow single channel doors, and if wide enough, double doors can support either two-way streams (i.e. 2 opposing passenger flow channels) for boarding and alighting passengers through the same doors or two one-way flow streams through each door. Multiple doors have been found to promote linear and fast distribution of passengers throughout the vehicle cabin and take full advantage of the available seating and standing capacity with minimum passenger movements. A high capacity vehicle cannot maximise both its number of doors and number of available passenger seats, since both these passenger facilities compete for available wall space along the nearside of the vehicle.

A commonly employed design rule applied for determining the optimum number of boarding and alighting doors on high capacity route buses built for Canadian and USA prepaid city route services has been to fit at least one door every 3.05m of linear bus length. This rule is however not universal. For densely populated bus service corridors where simultaneous passenger boarding and alighting are continuously taking place, a larger number of passenger doors per vehicle length may be warranted, and on express services where most passengers alight en mass in the AM peaks and board en mass in the PM peaks at a limited number of bus stations and stops, fewer doors have been found more appropriate.

2.5.1.1 Single Door Channel Dwell Time Planning Estimates

Table 1 below presents estimated average bus stop dwell times per passenger used to plan services for single door route buses where only a one-way channel of passengers can pass through each bus door at a given time. The table also provides typical dwell time per passenger scheduling adjustments allowed for different fare collection situations, vehicles fitted with front only or front and rear single channel doors, when buses reach standing room only capacity, and for ultralow floor buses.

2.5.1.2 Multiple Door Channel Dwell Time Planning Estimates

Passengers can be boarded and alighted much more quickly through multiple bus door channels commonly utilised in North American cities on free shuttle high capacity bus services or prepaid route bus services exploiting prior proof-of-payment, pay-on-exit gates and prepaid smartcard fare collection systems. Multi-door multichannel bus services operated in this fashion adopt the tried and proven practices of heavy and light rail mass transit operators exploited to minimise train dwell times at busy inner city railway stations.

Table 1: Service Planning Dwell Times for Single Channel Bus Doors

PASSENGER DWELL TIME (seconds per passenger)		
SITUATION	OBSERVED RANGE	NOMINAL
BOARDING		
Prepaid Fares**	2.25 – 2.75	2.5
Single Ticket or Token	3.4 – 3.6	3.5
Exact Change	3.6 – 4.3	4.0
Swipe or Dip Card	4.2	4.2
Smart Card	3.0 – 3.7	3.5
ALIGHTING		
Front Door	2.6 – 3.7	3.3
Rear Door	1.4 – 2.7	2.1

Source: Transit Capacity and Quality of Service Manual, Ed 2, Transportation Research Board

** Includes no fare, bus pass, free transfer and pay-on-exit.

Add 0.5 seconds per passenger to boarding times when standees are present.

Subtract 0.5 seconds per passenger from boarding and alighting times for ultralow floor buses.

Table 2 below presents the planning average dwell times per passenger expected for multi-channel door boarding and alighting on high capacity bus services exploiting off-bus fare payment, and indicate up to a 4 fold reduction in the average bus stop dwell time per passenger is possible when compared with the dwell times shown above for single channel door buses in Table 1.

Table 2: Service Planning Dwell Times for Multi-Channel Bus Doors

NOMINAL PASSENGER DWELL TIMES (seconds per passenger)			
AVAILABLE DOOR CHANNELS	BOARDING	FRONT ALIGHTING	REAR ALIGHTING
1	2.5	3.3	2.1
2	1.5	1.8	1.2
3	1.1	1.5	0.9
4	0.9	1.1	0.7
6	0.6	0.7	0.5

Source: Transit Capacity and Quality of Service Manual, Ed 2, Transportation Research Board

Assumes no on-board fare payment required.

Increase boarding times by 20% when standees are present.

Reduce boarding times by 20%, front alighting times by 15% and rear alighting times by 25% for low-floor buses.

As another example, using Table 2 above for a busway station fitted with off-vehicle card interface devices similar to those deployed on QR railway stations, if all door boarding was permitted through both double (2 x 2 channel = 4 channel) doors on a typical Brisbane Transport low floor articulated bus, the average boarding time per passenger could be expected to reduce to around 0.7s (0.9s less 20%) per passenger. Similarly, with prepaid triple double door (3 x 2 channel = 6 channel) boarding at a busway station, the Clarks Logan City low floor articulated superbus could be expected to achieve a further reduction in dwell time to just 0.5s (0.6s less 20%) per passenger.

Similar dwell time reductions are theoretically possible for all door alighting from twin and triple dual channel bus doors, but the figures appearing in Table 2 assume both passenger movements to be mutually exclusive and therefore additive, where alighting passenger streams typically precede boarding passenger streams. It will be further noted from Table 2 that rear door passenger alighting is somewhat faster than front door alighting. This occurs primarily because a double rear door is centrally placed in the vehicle cabin and can therefore accommodate single file passenger streams off two opposing aisle sections forward and aft of the 2 channel door, where a double front door can only accommodate 2 single file passenger feeds from one aisle section aft of the front door which is constricted at the low floor vehicle's front wheel arches.

2.5.1.3 Effects of Multi-loading Channels on Mass Transit Bus Station Dwell Times

Table 3 below looks at the effects of concurrent multi-door, multi-channel passenger boarding and alighting during peak throughput periods at open platform mass transit bus and busway stations. This table calculates the complex interrelationships between platform loading areas, concurrent passenger boarding and alighting, vehicle capacity, number of doors and door widths. As would be anticipated, high capacity buses with multiple doors and wide 2 channel flow streams generate the fastest passenger throughputs.

Table 3: Bus Station Throughput for Multi-Door, Multi-Channel Passenger Loading

BUS LOADING CONDITION >>	A		B		C		D	
STATION THROUGHPUTS >>	Board	Alight	Board	Alight	Board	Alight	Board	Alight
PASSENGER BOARDINGS AND ALIGHTINGS AT BUS STATION PEAK LOADING CONDITION								
Passengers per Bus (No/bus)	20	20	20	20	20	20	30	30
Dwell Time per Passenger (s/pax)	2.0	2.0	1.2	1.2	0.7	0.7	0.5	0.5
Total Dwell Time (s)	40	40	24	24	14	14	15	15
VEHICLE LOADING CAPACITY								
Loading Area Capacity (buses/hr)	42	42	65	65	100	100	95	95
Effective Loading (m^2)	2.45	2.65	2.45	2.65	2.45	2.65	2.45	2.65
Station Capacity (buses/hr)	103	111	159	172	245	265	233	251
PASSENGER THROUGHPUT PER HOUR AT PEAK LOADING CONDITION								
Peak Flow Rate (4 x 15min/hr)	4120	4440	6360	6880	9800	10600	13980	15060
Average Pax Flow Rate (pax/hr)	2760	2970	4260	4600	6570	7100	9370	10090

Source: Highway Capacity Manual 2000, Transportation Research Board

Loading Condition A: Twin single door standard 12.5m route bus, simultaneous front door boarding and alighting.

Loading Condition B: Twin two door standard 12.5m bus, two door alighting then boarding, or dual stream simultaneous front door boarding and rear door alighting.

Loading Condition C: Twin two door extended 14.5m bus, double-stream boarding and alighting at both doors.

Loading Condition D: Triple two door 18m articulated bus, double-stream boarding and alighting at all 3 doors.

Note: Assumes 10s clearance time, 7.5% berthing failure rate, 60% coefficient of variation, 3 linear boarding areas, g/C = 1, random bus arrivals, PHF = 0.67, 50% of passengers board at busiest station, 40 seats per conventional bus, 60 seats per articulated bus and no standees.

2.5.1.4 Bus Door Placement

The objective with optimising door positioning is to ensure even passenger loading and unloading over the entire length of the vehicle cabin. Accordingly, doors should optimally be positioned to divide high capacity vehicle cabins into sections of approximately equal passenger capacity and aisle way circulation distance. A number of BRT applications, notably the Las Vegas and various European and South American BRT systems, employ an even distribution of doors and door channel entry/exit streams along the entire vehicle cabin length.

2.5.1.5 Exterior Opening Bus Door Mechanisms

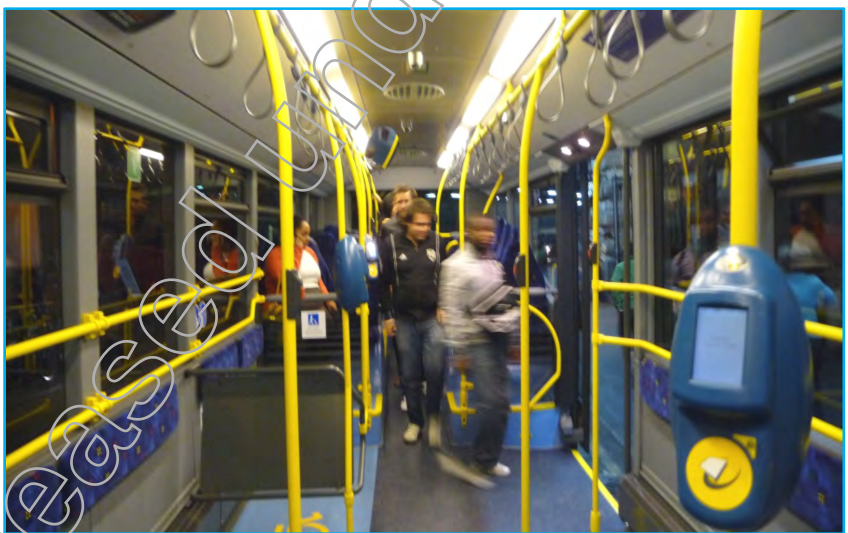
The time it takes for the bus driver to open and close the doors affects both the average stop dwell time and cabin passenger capacity. Most Australian manufactured buses employ either single leaf slide-glide or twin leaf bi-fold (also called 'Jack-knife') door mechanisms which open perpendicularly into the cabin, requiring passengers to stand clear of door swept paths to prevent accidental hand, arm, luggage and shoe entrapment. Such doors require constant driver vigilance to overview the front and rear door no standing access areas prior to and during the door opening and closing phases, and to delay door operations when requesting standees to stay clear of door access no standing areas.

Emerging new European bus door mechanisms use either single or twin leaf sliding plug doors similar to those used on modern aircraft, trams, light rail and heavy rail cars, which open outward and slide longitudinally over the exterior panelling of the vehicle. Such doors permit standing passengers to safely encroach further into preserved door access no standing spaces, thereby increasing total cabin standing capacity and mitigating the potential risk of passenger entrapment whilst opening.

2.5.1.6 Distributed Smartcard Reader Boarding Tag On and Alighting Tag Off

Another emerging trend on European and South American mass transit high capacity buses is to deploy one or two extra smartcard readers through the cabin space to reduce bus stop dwell time. Referred to as Cubic *OBCIDs* (*Onboard Card Interface Devices*) in South East Queensland, one or two such smartcard readers are typically only positioned at each door access on TransLink buses for boarding passengers to tag on and alighting passengers to tag off their *go cards*. Smartcard readers are located both at doors and on stanchions along the cabin in some European and South American bus designs so that passengers can tag on after bus departure from boarding stops and before bus arrival at alighting stops. Deactivation of these readers is typically timed out from door closures after bus stop departure and reactivated prior to the next stop arrival by stop centred GPS large radius geo-fence detections.

Figure 3: Distributed Smartcard Readers on a London Bus



An obvious downside to distributed Smartcard readers is the transit agency's reliance on passenger honesty. This fare collection strategy suffers to some extent from increased fare evasion as missed smartcard tagging cannot be visually or audibly monitored at bus doors by the driver.

2.5.2 Trading Increased Rear Door Width for Reduced Passenger Seating

Each additional entry/exit door added to the left hand side of a heavy omnibus passenger cabin above the compulsory minimum front entry/exit door specified by *Australian Design Rule ADR58/00* reduces available occupiable passenger floor space by approximately 0.7m^2 (namely 2 seat or 4 standee spaces) for a minimum 850mm wide single entry/exit door, and approximately 1.15m^2 (4 seat or 7 standee spaces) for a 1200mm wide double width entry/exit door. Most Australian bus operators currently strive to maximise bus seating capacity and to achieve such, show a overly keen willingness not mirrored by their overseas counterparts, to reduce the number of doors and/or door widths to cram as many seats into bus cabins as Australian heavy vehicle regulations and design rules will permit.

Prior to the introduction of ultralow floor buses with wheelchair parking spaces on SEQ route services in late 1997, earlier built high floor 12.5m rigid and 18m articulated buses traditionally incorporated front and rear double width 1200mm wide doors with a seat free passenger standing area opposite the rear door. To recover lost seating capacity begrudgingly given over to wheelchair parking spaces, all ultralow floor wheelchair accessible 12.5m rigid, 14.5m rigid and 18m articulated buses built for SEQ bus operators since 1997 have double seats installed opposite their rear doors, and most standard 12.5m, and some high capacity extended 14.5m rigid buses now in operation have a single narrow 850mm wide rear door capable of streaming only a one-way channel of alighting passengers.

2.5.3 Trading Increased Aisle Width for Reduced Passenger Seating

Bus door and aisle widths have a profound impact on average dwell time during peak service periods when high standing loads inhibit the free movement of boarding and alighting passengers. On modern ultralow floor buses, the maximum forward cabin aisle width to the busier front door is ultimately determined by intrusion of the front steering axle wheel arches above flat floor level, where aisle widths narrow down to between 750 and 860mm.

Wheel arch intrusion onto the centre aisle proves to be even greater at the dual tyred rear axles on 12.5m and 14.5m rigid buses and at both the mid and rear axles on 18m pusher type articulated buses. It has been common practice in Australia therefore to step and ramp up the height of the rear cabin aisle and to plinth mount climb-on passenger seats above the aisle way to the aft of the rear door. This design affords rear floor crossover of the rear wheel arches, power transmission train and engine bay intrusions above the otherwise flat floor level available on ultralow floor buses, but results in reduced head clearance preventing standee use at the far rear and deep narrow aisle widths of between 540 and 590mm which only permit a one-way stream of passenger movements at any given time.

Such has become bus operator demand for maximum passenger seating in ultralow floor bus cabins, that some reputable Australian bus body manufacturers have resorted to continuously ramping their aisle ways, stepping up seat plinths and external window lines from the front to rear of cabin to gain an extra row of seats on the inclined floor hypotenuse. This design technique results in sunken wheelchair parking spaces, deep aisle ways and rear door step wells and climb-on plinth mount seats throughout most of the cabin. So while international chassis and body manufacturers strive passionately to crimp the last centimetre from their door step levels and to flatten their floor chassis rails and floor outrigger frames throughout the cabin, Australian bus body manufacturers have chosen the opposite design strategy of increasing floor levels in pursuit of maximum seat capacity.

Narrowing between the mid wheel arches on an ultralow floor 18m articulated bus cannot be so easily crossed over by raised aisles and continuous plinth mounted passenger seats as they are in the rear cabins of 12.5m and 14.5m rigid buses. Articulated bus mid axle wheel arches with climb-on opposing full width front facing twin passenger seats act as an effective constriction to boarding passenger movements from the front door to the entire rear trailer section during peak periods with high standing passenger loads, yet bus operators and bus builders remain steadfastly opposed to sacrificing passenger seats even at this most obvious choke point to passenger circulation.

Persisting bus operator demand to maximise passenger seating effectively thwarts widening of bus aisles for optimum circulation because bus body and moulded twin transit seat widths must comply in Australia with national heavy omnibus design rules and State legislation. *Australian Design Rule ADR43/04* and Queensland regulated heavy omnibus dimensional limits set the maximum exterior width of a heavy omnibus at 2.5m, while *Australian Design Rule ADR58/00* prescribes a minimum seat cushion width of 400mm with side to side elbow room. This results in a maximum flat floor aisle width between two parallel rows of forward facing moulded twin transit seats of between 450 and 615mm, depending on the vehicle's panelled structural wall thickness. Australian bus body manufacturers publish misleading wider aisle widths of up to 850mm between seat plinths to entice unwary new bus purchasers, but fail to mention the much narrower 450 to 615mm clear widths between stanchions, seat cushions, squabs and handgrips overhanging their recessed seat plinths.

Widening of aisle ways to reduce bus stop dwell time can only be achieved practically by sacrificing the number of seats in critical passenger aisle circulation and passenger storage spaces from 2 x 2 (= 4) seat widths down to 2 + 1 (=3) seat widths, and by reducing or eliminating seats placed opposite the rear door. Figure 4 below illustrates a common approach used by European and South East Asian high capacity bus operators to improve passenger aisle way circulation using a wide spill out aisle width either side of, 2 seats opposite, and side facing seats flanking the rear door on an 18m articulated bus. It will be noticed in this photograph how side facing seats have also been installed over the mid axle wheel arches on this vehicle to improve boarding passenger movements from the front door to the rear cabin saloon.

Figure 4: Rear Door Circulation Using Wide Aisle, 2 Seats Offside and Side Facing Seats Nearside

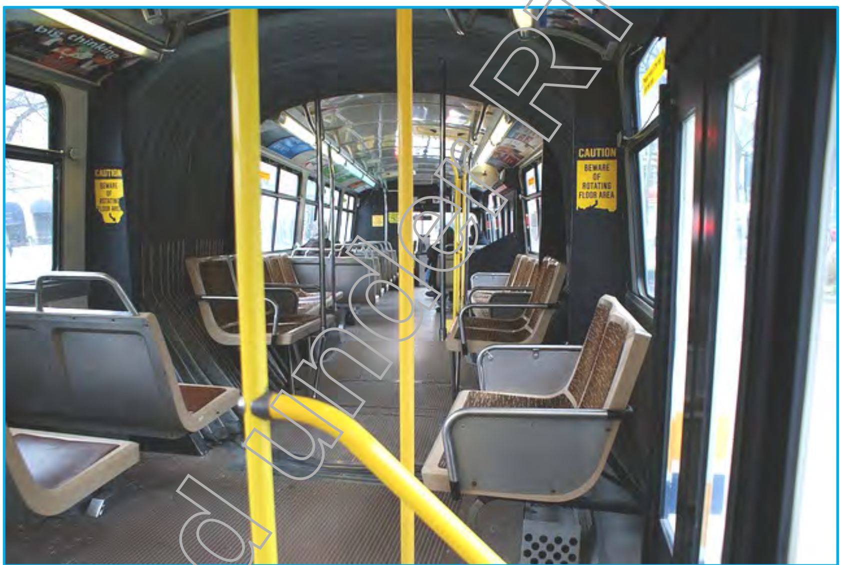
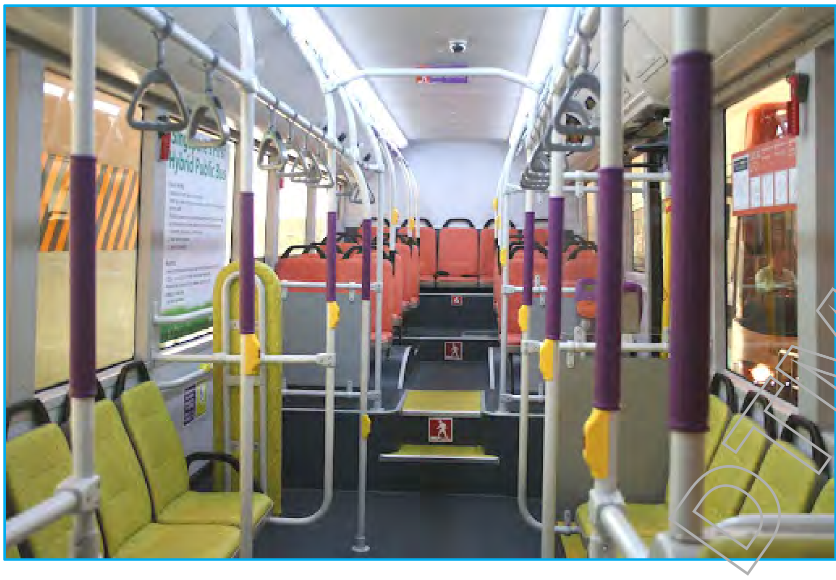


Figure 5 overleaf presents yet another overseas approach used on a 14.5m rigid bus with a stepped incline to the rear saloon similar to that on the Volvo and Scania 14.5m rigid buses operated in SEQ by Hornibrook and Brisbane Transport. The bus in this photograph has a normally unoccupied rear wheelchair parking bay, no fixed seats opposite, and side facing seats forward of the rear door which act as a standee circulation and temporary storage area for rear door alighting and boarding passengers.

In rapid passenger turnover high capacity bus operations characterised by short average trip lengths, mass transit agencies often elect to maximise passenger capacity and aisle way circulation, rather than maximising their passenger seat counts. It is particularly interesting to note a new emerging trend in USA capital city bus operations where transit agencies are actively removing passenger seats from their existing buses and installing so-called 'bum cushions' to enable more passengers to stand in comfort by leaning against these padded railings. Similar railing cushions have been installed in the aisles of the current Clarks Logan City 3 door articulated superbuses and on Sydney Buses and Brisbane Transport 14.5m rigid buses. They are considered by Australian operators to only be appropriate on short haul routes such as those operated on busways and transitways, but not for general route bus services.

Figure 5: Rear Door Circulation Using Wide Aisle, No Seats Offside, Side Facing Seats Both Sides



Ironically, the added vehicle capital cost and lost floor space so readily pursued by Australian bus operators and builders to pack ever more seats into route buses is rarely recouped when numerous seats go begging for occupants during off-peak services, and each additional seat installed adds significantly to the discomfort of standees crammed into narrow deep aisles and standing areas during peak services when luggage has to be continuously carried by standees and cannot be placed on narrow aisles for fear of trampling. The operator pays the ongoing fuel and maintenance cost of carrying the added weight of all unnecessary extra seats, the resultant loss of maximum seated plus standee carrying capacity and added dwell time at every peak service bus stop throughout the entire life of its maximum seated capacity vehicles.

2.5.4 Bus Cabin Design Options to Minimise Dwell Time

Most European, South East Asian, North and South American high capacity mass transit operators do not strive to maximise passenger seating as bus operators so eagerly do in Australia, but elect instead to minimise stop dwell time and optimise both seated and standee capacity on their high capacity vehicles. Notable significant differences between overseas best practice and Australian bus cabin designs include:

- Two-Way All Door Boarding and Alighting: As illustrated earlier in Tables 2 and 3, two-way all door boarding and alighting greatly reduces dwell time by enabling concurrent two-way flow of passenger movements through doors and minimisation of aisle circulation distances to all available passenger seat and standing areas.
- Distributed Smartcard Readers: Strategic placement of one or two additional smartcard readers at locations other than immediately adjacent doorway accesses enables passengers to tag off and tag on whilst a high capacity bus is still in motion. It is also common practice overseas to install smartcard readers at high turnover bus stations and bus stops to facilitate off-vehicle smartcard tag on and tag off, as is already commonplace on SEQ railway stations.
- 100% Flat Aisle Cabins: Ultralow floor bus manufacturers design their chassis for flat aisle ways throughout the bus cabin, but this feature is rarely exploited by Australian bus operators looking to maximise saloon seating capacity. Where flat aisle ways levelled with floors under seats are maintained from front to rear of cabin, stepped or plinth mounted seats may need to be used to optimise rear cabin seating capacity, but the resulting high climb-on seats tend to only be used by younger or more able bodied passengers. The removal of aisle way steps and ramps to the rear greatly speeds up passenger movements to the aft of the rear door, reduces passenger slips trips and falls, maximises rear aisle way and seated head clearances and rear saloon standing capacity. Low floor heights also enable optional installation of accessible overhead luggage

shelves throughout the cabin, so standing can readily stow luggage off aisle ways and above dedicated standing areas.

Figure 6: Examples of 100% Flat Ultralow Floor Articulated Bus Cabin Aisle Ways

- Door Passenger Storage Areas: Best practice international mass transit bus drivers neither sell tickets, handle cash, credit passenger smartcards, nor monitor passenger smartcard tag-ons and tag-offs. Their primary focus is to board and alight passengers as quickly and safety as possible at bus stops, and to recommence driving as soon as possible to clear congested bus stop bays for other arriving buses. There are no holdover delays granted by drivers at stops for late arriving hailers and runners or to allow boarded passengers to become seated or move to standing areas. Wide open floor areas and step free aisle ways are deliberately designed to prevent trips and falls during bus acceleration and deceleration and to temporarily store passengers for fastest possible passenger unloading and loading.

  Wheelchair parking spaces with side facing flip-up seats are utilised in the forward section of the bus cabin to maximise temporary storage and standing areas for passengers using the front door, whilst side facing flip-up or no seats are positioned opposite rear doors to provide wide open areas for temporary passenger circulation, storage and standing. These best practice designs enable a large number of alighting passengers to assemble, tag off and queue in temporary door storage areas prior to buses arriving at stops. After doors open, they disembark en mass while embarking passengers board and refill their vacated door storage areas. Boarded passengers continue tagging on and moving off to seats and other standing areas after the driver has closed the doors and the bus has moved off from the stop. This passenger loading strategy not only reduces stop dwell time between door opening and closing, but converts otherwise wasted bus stop deceleration and acceleration times into concurrent passenger mobilisation time savings.

- Outward Opening Slide and Plug Doors: Outward opening slide and plug doors maximise door opening widths, safety, temporary passenger storage, and standing area adjacent to door accesses.

Figure 7: In-Vehicle Real Time Bus Arrival Passenger Cueing Sign

- Real Time Bus Arrival Passenger Cueing: Bus arrival times are displayed visually on passenger information display signs erected at bus stations and stops, and next stops are displayed in vehicles together with audio public address cues to prepare passengers for all door concurrent boarding and alighting.

2.5.5 Cabin Interior Floor Height

USA *Transport Research Board* analysis of best practice large city route bus operations has determined that step less ultralow floor buses reap up to a 20% improvement in peak boarding and alighting times at major BRT bus stations and kerbside stops compared to similar size high floor buses with stepped floor levels. As at 31 March 2012, some 72% of TransLink's urban fleet of 2027 route buses (excluding dedicated high floor school buses and coaches) were classified as low floor, wheelchair accessible. However, no low floor buses in the TransLink fleet are true 100% low floor throughout the cabin, as aisle ways are stepped and ramped up to a high floor level aft of the rear door, and in some cases, from forward of the rear door to further increase seating capacity.

To compensate operators for lost cabin floor area turned over to wheelchair ramp loaders and parking spaces, more and wider doors, and wheel arch, drive train and engine compartment intrusions into the cabin saloon, existing State and Territory and pending national heavy vehicle regulations grant considerably higher axle mass limits to ultralow floor buses not available to high floor buses and coaches with similar overall dimensions but higher passenger floor area.

To fit within the legislated heavy vehicle definition of an ultralow floor bus as applied by TMR bus inspectors in Queensland, the cabin floor level accessible to doors must be 550mm or lower above ground level for a continuous length equal to at least 70% of the vehicle's registered wheelbase. This floor level is taken to be the vehicle's normal floor height when driving, and not the reduced floor height obtained when buses are kneeled for wheelchair boarding at bus stops.

A bus with an fully raised front door entry and aisle level under 550mm capable of boarding wheelchairs to 2 dedicated wheelchair parking spaces may comply with the national *Disability Standards for Accessible Public Transport 2002* and be classified by its operator and builder as a low floor wheelchair accessible bus, but this does not necessarily qualify the bus for the higher axle mass limits granted to an ultralow floor wheelchair accessible bus. For example, the wheelchair accessible lower floor height on the Bustech double deck bus complies with the *Disability Standards for Accessible Public Transport 2002,* but has not been classified under the heavy vehicle regulation as an ultralow floor bus or attracted an additional tonne combined axle weight concession to carry an additional 15 passengers granted to the other 3 ultralow floor high capacity buses studied in this report.

100% ultralow floor high capacity buses exploit the advantage of reduced boarding and alighting times and the optional capability to place an additional door behind the rear axle, however 100% low floor configurations typically lose up to 4 passenger seats to wheel arch and other underfloor component intrusions in the rear saloon avoided by stepping and ramping up the rear aisle and floor level. Ultralow floor bus manufacturer workarounds to recover seat capacity on their 100% low floor buses have in past times included use of low profile tyres and/or hybrid electric drives, but these alternatives either reduce ride quality or add cost, weight, and maintenance complexity to the vehicle design. Notwithstanding the reduced seating capacity caused by 100% low floor cabins, most European mass transit operators still prefer such to reduce their mass transit station dwell times, improve their station loading capacities, minimise stop bay occupancy times and increase their average service speeds.

2.6 Bus Stop Geometric Treatments to Reduce Dwell Time

The geometry of a stop affects its average bus dwell times, particularly those for large size high capacity buses alighting and boarding a high average number of passengers per stop. The *TransLink Transit Authority Public Transport Infrastructure Manual - May 2012* provides detailed planning and design guidelines for locating stops and geometric layout drawings for newly constructed bus stations, premium and signature standard stops suitable for 14.5m and 18m long high capacity vehicles. Premium and signature standard bus stops incorporate large open obstruction free platform loading areas and generous linear kerb lengths for berthing 2 high capacity buses nose to tail with 5m separation distance, and remove the variability to stop dwell time encountered at older generation bus stops built prior to 1995 for 12.5m buses.

Lack of sufficient footpath loading area, adequate lead in and pull out tapers on indented stop bays, undersized stop zone length and inadequate clearance distance from intersections and regulated parking zones at old generation kerbside stops constructed for 12.5m long buses have been identified as significant impediments to future widespread deployment of 14.5m rigid and 18m articulated buses on most existing SEQ urban bus routes. Undersize platform stop bays, overly tight turning circles and narrow width off-road accesses to some old generation bus stations and interchanges designed for 12.5m long buses have also been identified, and are discussed in more detail in the infrastructure performance evaluation report.

For those bus station and interchange platforms and kerbside stops where high capacity vehicles can be accommodated, but include no provision for more than one high capacity bus to berth at a time, variability in stop dwell time arises when there is strong competition between randomly arriving buses for single stop bays. The variability in stop dwell time arising from competition between buses is by no means unique to high capacity vehicles and affects 12.5m standard buses similarly, but to a lesser extent.

At single bus length kerbside stops on CBD streets and inner city suburban bus stops on major city arterial and sub-arterial roads where numerous bus services converge randomly during the peak periods, buses may arrive at the single bus length stop to find it occupied by another vehicle, or occasionally a convoy of bunched buses. If the stop is located just beyond an intersection, a pedestrian crossing or on the far side of parked vehicles in a regulated parking zone, the arriving bus may not have an opportunity to remain stopped in the left traffic lane and be forced to pull in ahead of the signed stop zone. Whether able to pull in behind the stop zone, ahead of the stop zone, or wait in traffic until the stop zone has cleared, stop dwell time will inevitably be increased. Alighting passengers for the stop can generally disembark without delay at any makeshift set down, but the dwell time at an off zone makeshift stop increases in proportional to the number of passengers who have to relocate to board the bus.

Similarly, at busy bus stations and interchanges where shared stop bays are assigned to a number of regional routes, the assigned stop bay may be occupied by a late departing bus forcing an arriving bus to either circuit the facility, pull into the nearest unoccupied stop bay or hold over in a bus parking area until its allocated stop bay has been vacated. The impact on dwell time variability is similar to that earlier described for an occupied kerbside stop.

Peak period dwell time can be increased by bus competition even more at busy inner suburban lead stop busway stations than at single bus length kerbside stops, bus stations and interchanges with shared but route dedicated stop bays. While busy lead stop busway stations do not generally suffer from a lack of platform kerb space to alight and board passengers during peak periods, boarding passengers at busway stations have no real certainty as to where their arriving buses will actually berth on the platform.

With busway station capability to simultaneously berth from 3 to 5 vehicles and buses arriving in rapid succession then stopping nose to tail at random loading areas rendering their destination signs impossible to read from the lead stop, waiting passengers at the lead stop loading area may need to relocate by up to 50m along the platform to board their chosen buses through crowds, which in some cases, may be mobilising in the opposite direction to board their chosen buses. Surveys undertaken by the Queensland University of Technology at Mater Hill Busway Station in 2004 have shown that the average alighting time per passenger of around 2.1s remained unaffected by where arriving buses happen to berth on a lead stop busway station platform, but average boarding time per passenger increased very significantly from 4.8s/passenger at the lead stop loading area, to 5.9s/passenger at the second loading area, to 12.7s/passenger at the third.

The following stop treatments can substantially reduce peak period dwell time variability at inner city high capacity bus stops:

- Kerbside Bus Stops: Queensland *Road Rules* afford exclusive rights to urban route buses to park outside signed bus stops and bus zones across private driveways and pedestrian accesses, in front of fire hydrants, on bicycle lanes, and in clearway, loading, parking, taxi, postal and other regulated vehicle zones if stopped solely for the purpose of pick up or set down of passengers. The right of urban buses to stop in regulated zones other than bus stops and bus zones does not apply if regulatory signs controlling the zone prohibit buses of a particular type or size from stopping, or if the rear of the vehicle overhangs an intersection or pedestrian crossing.

  Kerbside bus stop treatments to improve high capacity bus stop dwell time are essentially geometric in nature and need to be selectively targeted. It will be shown later in this report that high capacity bus services become economic to operate on off-busway suburban routes of 10km or longer when 12.5m rigid buses experience recurring overloads during peak periods.

  Stop zones on major arterial and sub-arterial roads within 8km route distance of the CBD need a clear kerb space of around 25m to berth one high capacity bus during off-peak periods, but to also be capable of simultaneously berthing 2 buses during peak periods necessitating a total clear kerb space of around 40m, with the additional 15m clear kerb space located behind the designated stop zone.

Given most kerbside stop zones on major arterial and sub-arterial roads within 8km of the CBD will be signed as clearways or no parking zones during peak traffic periods, and the road rules cited above, the additional 15m clear kerb space required behind an old generation bus stop zone may be seconded from virtually any regulated kerbside traffic zone by a bus driver, provided that the rear of his/her bus does not overhang a pedestrian crossing or road intersection. High capacity bus treatments for many existing old generation arterial and sub-arterial kerbside stops should therefore involve little more than lengthening existing undersized bus stop zones to 25m, and/or relocating zones downstream where less than 15m exists behind the zone to an existing road intersection or pedestrian crossing.

For bus stops on arterial or sub-arterial roads located beyond 8km route distance from the CBD, the stop zone only needs to be increased to 25m length to berth a high capacity bus, and the typical geometric treatments required would be those defined for a new TransLink premium bus stop.

- Bus Station and Bus Interchange Stop Bays: Treatments to improve dwell time performance at route dedicated bus station and interchange stop bays are also geometric in nature, but are generally more costly to implement if the station or interchange was initially designed for and is only accessible off-road to 12.5m rigid buses. If the existing facility is accessible off-road with 2 platform stop zone spaces of 25m length each, one located behind the other; or with one stop zone of 25m length with 15m clear platform and linear kerb space behind, the stop zone is suitable for simultaneous berthing of 2 high capacity buses.

  Stop bay bus conflicts at stations and interchanges can (in theory) be eliminated during peak periods by scheduling 10 minute or longer intervals between arriving bus services sharing a bay, but the reliability of scheduled mixed service separations diminishes over time with increasing shared use and variability in upstream traffic conditions encountered by competing bus services using the shared stop bay.

  Though not ideal, one alternative to avoid having to upgrade an existing 12.5m rigid bus station or interchange inaccessible off-road to high capacity buses, may be to construct two high capacity vehicle kerbside bus stops on and opposite the existing facility road frontage. This solution is considered practical where the facility is located close to an existing signalised intersection or pedestrian crossing such that passengers can safely cross the road to reach the station or interchange from the far stop on the opposite side of the road.

- Busway Station Platform Loading Areas: Treatments to improve dwell time performance at lead stop busway station platforms are non-geometic and utilise electronic real time passenger information display signs similar to those distributed by companies such as INIT, TransLink's appointed supplier for the *Customer First* real time passenger information system currently under trial on Clarks Logan City bus services. The INIT real time passenger information system continuously tracks bus services and predicts their arrival times at each busway station. Approaching bus service destinations and route numbers are normally displayed on busway station passenger information signs in their predicted order of arrival at platforms from top to bottom.

  On arrival at stations, buses normally fill vacant loading bays from the rear of the platform, but may alternatively leap frog around stopped buses to berth in vacated loading areas closer to the lead stop. The standard operation of the INIT passenger information display system would need to be modified to predict the platform loading area most likely to be occupied by approaching buses, to continuously monitor stopped buses already on the platform and re-sort their destination display order in accordance with actual locations occupied from the front to rear of platform. This would provide real time visibility over both approaching and stopped bus services from front to rear of platform to waiting passengers enabling them to mobilise to their correct platform loading areas in advance of bus arrivals.

2.7 Policy Options to Reduce Dwell Time

One option available to TransLink when considering the conversion of 12.5m standard bus services to high capacity vehicle services would be to allow operators to claim additional running time and/or layover recovery time at termini under their *3G Contracts* for services operated by the larger size buses, but this option comes at a recurring monthly claim expense to TransLink as the service funder. Better options would involve changing existing operating policies to proactively reduce stop dwell time on all bus services such as through implementation of prepaid bus stops, stations and zones, prepaid routes, discontinuation of onboard paper ticket sales and *go card* top ups, and all door boarding. All of these alternative policy initiatives have been previously trialled by TransLink, and in some cases, have been partially implemented in certain segments of its bus, rail and ferry network.

2.7.1 Prepaid Bus Stops, Bus Stations and Zones

In late 2007, TransLink trialled prepaid ticket closed platform operations at Cultural Centre Busway Station. During the trial, the busway station operated similarly to a manned railway station where boarding passengers could not enter onto the platform without a valid ticket or *go card* check and were thereby prevented from purchasing paper tickets from or requesting *go card* top-ups by drivers aboard arriving buses. The trial was considered highly effective at reducing average busway station dwell times and PM peak outbound bus queue lengths across the Victoria Bridge, so further prepaid ticket closed platform operations were subsequently rolled out at South Bank, Mater Hill, Roma Street, King George Square, Upper Mt Gravatt and Eight Mile Plains Busway Stations in 2008 and 2009.

Due to TransLink budget constraints, the trial program had to be terminated in 2010, and dwell times have again increased at these busway stations with outbound buses again queuing back from the Cultural Centre Busway Station to North Quay and Queen Street Bus Station in the PM peak period, drawing numerous complaints from bus operators and passengers. It is understood that TransLink is currently working with Brisbane Transport to reintroduce other prepaid ticket initiatives to reduce bus dwell times at its inner busway stations.

Other Australian State and Territory capital city bus authorities have already introduced prepaid ticket bus stops, stations and zones. Since 2009 for instance, the entire Sydney CBD has operated as a prepaid bus zone between 7:00am and 7:00pm weekdays, and an additional 18 major bus stops surrounding the Sydney CBD have progressively been added in as prepaid ticket only stops.

Figure 8: Prepaid Ticket Closed Access High Capacity Vehicle BRT Station in Curitiba, Brazil

Manned prepaid ticket closed access stops and stations are commonplace on the South American BRT systems operated in Curitiba, Brazil and Bogotá, Colombia. Due to their extremely high passenger turnover volumes, upward of some 43 thousand passengers per hour in both CBD travel directions, passengers using these BRT systems are required to exit closed tubular stop platforms from one end, enter from the other and purchase tickets from an attendant prior to entry, making it unnecessary for drivers to issue tickets or collect fares aboard buses. The outcome of this prepaid ticketing strategy has been a dramatic cut in average passenger boarding, alighting and stop dwell times.

Given the considerably greater volume of passengers serviced by these two BRT systems relative to the passenger volumes serviced by Brisbane busways, it is of particular interest to note the disproportionately smaller footprints of South American BRT stations and stops compared with those in Brisbane as clearly illustrated by Figure 8 and Figure 9 respectively. These incredibly small footprint bus stop facilities have been achieved through the greatly improved bus operating efficiency resulting from off bus prepaid ticket sales and significantly reduced average stop dwell times.

Figure 9: Prepaid Ticket Closed Access BRT Kerbside Stop in Curitiba, Brazil

In the South American example depicted above in Figure 8, BRT stations are effectively operated in a manner similar to attended railway stations in South East Queensland. Given the 16.5km South East Busway with only 11 stations carries more passengers per weekday than the entire 740km CityRail network with some 145 stations located in South East Queensland, reconsideration of the existing policy to discontinue prepaid ticket sales at busway stations would appear to be justified, even if only manned by *go card* inspector/ticket sellers during the weekday PM peak periods.

While *Add Value Vending Machines* installed at all busway stations self-serve paper tickets, give change and credit *go cards,* the continued policy enabling unpaid passengers to board buses and request these services from the driver will never obviate paper ticket sales, cash handling and *go card* top-ups aboard buses or eliminate the resulting increase in stop dwell time incurred as a consequence which impacts high capacity buses in proportion to their larger loading capacities.

The hidden costs of on-bus ticket sales and *go card* top-ups provided for the convenience of arguably lazy and/or late running passengers who choose not to use website and agency *go card* crediting alternatives or readily available station add value vending machines include:

- Delay and inconvenience to all boarding and boarded passengers on those buses where drivers have to issue paper tickets, handle cash and top-up *go cards* before unpaid passengers can board,
- Extended stop occupancy causing delay and inconvenience to following buses trying to access the station platform and their waiting and boarded passengers,
- Excessive mobilisation of waiting passengers along the station platform to board buses pushed further back by occupied platform bus loading areas,
- Busway traffic congestion and inefficient utilisation of high cost busway assets,

- Increased fare evasion by regular passengers who wait until the driver is distracted before boarding and pretending to swipe their *go cards*,
- Increased peak period service late running and unreliability, and
- Increased customer dissatisfaction with slow and inefficient bus services and consequential patronage loss to the private motor vehicle.

2.7.2 Prepaid Bus Routes

TransLink trialled prepaid bus routes in 2008 on 3 bus routes operating in Brisbane and Logan City. The trial was again proven successful at reducing stop dwell times and improving service reliability. The trial initiative was strongly supported by bus drivers and customers when assessed after its completion by driver focus groups and onboard passenger surveys. As a result of the successful trial outcome, TransLink now has some 43 prepaid bus routes operating in its network. These prepaid routes only permit passengers to use *go cards* aboard buses or present prepaid transfer tickets to the driver when boarding. Passengers cannot purchase paper tickets on board buses.

In Sydney, after a similar successful outcome on the 'Bondi Bendy' prepaid Route 333 articulated bus trial, there are now some 47 other prepaid routes in operation across the city. In Melbourne, high frequency Route 601 operating between Huntingdale Station and Monash University has been similarly designated a prepaid only route.

2.7.3 Pay-on-Exit Paper Ticket Sales

Seattle, Washington USA operates a novel alternative to the prepaid route service on which passengers without prepaid smartcards or tickets may board buses in the CBD during the PM outbound peak, but must purchase a paper ticket from the driver before exiting the bus. This ticket payment strategy prevents boarding delays in the CBD heart where busy stations and bus stop bays need to be quickly recycled to make way for other arriving buses, and effectively transfers the delays incurred by ticket sales to outer suburban bus stops where the delays arguably cause less inconvenience to less passengers and reduced disruption to peak network operations and drivers.

Dwell time savings yielded from this novel ticketing strategy prove even greater on AM inbound peak services to the CBD. Passengers with unpaid tickets are again permitted to board buses at suburban stops to prevent blockages to door boarding channels and reduce stop dwell times, but must purchase tickets from the driver before alighting. On AM inbound peak services, there are typically very few, if any, boarding passengers at CBD stops and very high numbers of alighting passengers, so the driver can productively apply the CBD stop dwell time otherwise wasted while alighting passengers to completing his/her paper ticket sales.

While it will may be argued in the TransLink context that pay-on-exit appears to be a recipe for increased fare evasion and that passengers without tickets would simply exit through the bus rear door without paying a fare, irregular bus users are the passengers most likely to purchase tickets and are considered less likely candidates than habitual regular fare evaders who board and alight buses and trains without tagging *go cards* at unmonitored card interface devices.

2.7.4 All Door Boarding

It is demonstrated later in this report that all door boarding has the potential to significantly cut high capacity bus peak period stop dwell times. While all door boarding has been common practice on heavy and light rail transport modes for more than a century in Australia, there are no known implementations of all door boarding on revenue scheduled route bus services anywhere in Australia, other than on the Brisbane Transport *CityGlider* service. All gate boarding is also a well established practice on large city ferry operations such as Sydney Ferries. Newly built Brisbane City Council ferry terminals now incorporate dual ferry berths and boarding gates for *CityCats*, and all gate alighting and boarding have been used for peak period *CityCat* dockings at the Riverside Ferry Terminal for several years.

All door boarding has been commonplace on high capacity, high frequency, high turnover route bus services operated in many European and Asian cities for decades, and there is an increasing trend to adopt all door boarding in Canadian and United States capital city bus operations where transit agencies with budgetary constraints have come under increasing pressure to cut government public transport subsidies and increase transit service reliability and speed.

The practice of all door boarding on overseas buses was copied from ferry, heavy and light rail mass transit services operated alongside mass transit bus services by public transport authorities who operated multiple modes. Proof of payment smartcard and paper ticket checking by roving ticket inspectors and security police was also adopted coincidentally with all door boarding on mass transit buses and identical fines applied to fare evasion infringements to those imposed on ferry, heavy and light rail passengers. Ticket inspectors and security (transit police) officers conduct smartcard and prepaid ticket checks aboard all vehicle types and randomly patrol across all the different modes.

Appendix A provides a summary of international capital city mass transit operators who have already successfully implemented all door boarding on their buses in combination with proof of payment roving smartcard/prepaid ticket inspections and issue of infringement notices with hefty fines to proactively deter fare evasion.

2.7.4.1 History of All Door Boarding in South East Queensland

All door boarding has been adopted throughout Australia for passenger loading on heavy and light rail vehicles. To maximise its all door alighting and boarding passenger movements, Queensland Rail electric cars utilise 2 wide loading plug doors per carriage with car floors deliberately levelled to station platforms. In the SEQ context, heavy rail cars have been successfully using all door boarding since 1865, and the same practice will be adopted on Gold Coast light rail cars from 2014.

Mass transit all door boarding was first trialled on route buses in South East Queensland at *Brisbane Commonwealth Games* venues in 1982, and again at the *Sydney 2000 Olympic Games Football Tournament* hosted by Brisbane in September 2001. Mass transport fares to and from these major events were included in the venue admission ticket price, and the latter 2001 trial was considered highly successful both for its integrated event ticketing solution and the effectiveness of all door boarding in clearing very large crowds in the shortest possible time following the event. Since the 2001 trial, all major events hosted in SEQ have adopted both integrated event ticketing and all door boarding on TransLink route buses. In FY2010/11, TransLink provided safe fast travel to and from some 178 major cultural events, concerts and sporting fixtures, and used all door boarding to move in excess of two million passengers to and from the major venues.

In 2009, Brisbane City Council and TransLink launched the *CityGlider,* a high frequency, prepaid all door boarding route service between West End and Teneriffe Ferry Terminals via Adelaide Street. Later in December 2010, TransLink introduced another prepaid high frequency route service, the P88, operating between Eight Mile Plains and Indooroopilly via King George Square Bus Station. The P88 service was initially launched with all door boarding at King George Square Bus station only during the PM peak to minimise stop bay dwell time because the new service shared its busy platform loading doors with the equally popular and busy Moggill Routes 443 and 444.

It is understood Brisbane City Council has recently expressed its interest to TransLink to co-launch a new service dubbed the *MaroonGlider* which would operate similarly to the *CiyGlider* as an all door boarding prepaid only route. Given Council's interest in operating a second all door boarding prepaid only route, a logical extension of the concept would be to permit all door boarding on the two free inner city shuttle services - the *DownTown Loop* and *Spring Hill Loop*.

2.7.4.2 *CityGlider* Case Study

The *CityGlider* service is presently ranked the fourth busiest bus route in Brisbane. Seventeen 12.5m rigid buses finished in special *CityGlider* livery ply the route daily, supported by 3 spare buses finished in identical livery to cover random peak demand step-ins and service breakdowns.

Routes such as the *CityGlider* operated through high population density precincts with multiple trip generators are characterised by both high passenger catchment loads and high passenger turnover churn. As such, these routes do not necessarily justify deployment of high capacity vehicles because the maximum passenger capacity of a conventional 12.5m bus will rarely be reached if the route is short, high churn and high frequency. Brisbane City Council originally intended to operate the *CityGlider* service with 8 new 14.5m high capacity buses, but opted instead to reallocate 20 of its standard 12.5m rigid diesel buses to the route and operate the service on a 5 minute peak – 10/15 minute off-peak headway.

To enable all door boarding, *go card* onboard card interface devices already installed at *CityGlider* bus rear doors had to be reprogrammed to recognise both alighting tag off and boarding tag on transactions. Card interface device software reconfiguration for rear door boarding was identified as a standard option available on the *Cubic* smartcard ticketing system, and *CityGlider* bus conversions to all door boarding involved little more than a *Cubic* technician logging on at each bus driver console unit with a maintenance card, and selecting the all door boarding option from its drop down menu. The software reconfiguration process for all door boarding took around 1 minute per bus to activate, and all TransLink bus operators have been issued with *Cubic* maintenance cards so any operator can self-convert its bus *go card* ticketing system for all door boarding.

The MAN ultralow floor 12.5m diesel buses chosen by Council to operate the *CityGlider* service only have a single width, single channel rear door which has effectively prevented simultaneous boarding and alighting of passengers and has half the rear door passenger boarding rate of the front door. Rear door boarding on the *CityGlider* has not been well promoted to the public and there are no permanent decals at either bus door and within the bus cabin, or information at any *CityGlider* bus stop blades to advise new passengers that they can opt to board at the rear door. Consequently, MRCagney survey results have verified that only 1 in 4 passengers presently board the *CityGlider* buses via the rear door (refer Table 5).

2.7.4.2.1 Perceived Risk of Al Door Boarding Fare Evasion

Modelling described later in this report has determined that high capacity buses become increasingly more economic to operate on 15km and longer routes at all typical highway, motorway, arterial, sub-arterial and local road peak period average traffic speeds. Implementation of all door boarding is therefore considered the most important initiative available to TransLink to reduce stop dwell times and increase service speed, operating efficiency and competitiveness of high capacity bus services with the private motor vehicle on longer routes. These longer route services operate to sprawled outlying communities where two or more car ownership and commuting by private motor vehicle have become a way of life passed from one generation to the next and reinforced in each from early childhood.

TransLink has estimated it presently loses around $18 million per annum to fare evasion. A perceived risk of all door boarding on high capacity bus routes is the potential of a further increase in fare evasion.

When passengers are only permitted to board through the front door of a bus, the bus driver can be tasked with the added responsibilities of ticket seller, *go card* creditor and *go card* revenue protection guardian. With the exception of 6 cross river ferries, these added responsibilities are not passed to vehicle drivers on other TransLink public transport modes, where passengers neither have access to, nor are permitted by regulation, to interact with vehicle drivers. For other that cross river ferries, ferry crew members are tasked to sell tickets, top up *go cards* and monitor fare evasion at passenger loading gates, and on heavy rail (and light rail from 2014), station masters and roaming transit officers are tasked to sell paper tickets and monitor fare evasion. It is understood that TransLink has recently employed 33 new senior network officers to augment its roaming fare evasion patrols.

The *CityGlider* has recently experienced an unanticipated boost to peak period patronage with the opening and *CityCat* servicing of the newly reconstructed Teneriffe Ferry Terminal where a large number of passengers appear to be transferring from *CityCat* to *CityGlider* services in the morning peak, initially presumed to be motivated by the desire to reach preferred stop destinations in Fortitude Valley and the inner CBD not directly accessible by ferry. All *CityCat* ferry terminals in the lower reaches of the Brisbane River between Sydney Street, New Farm and Northshore, Hamilton are located within Zone 2, and this has raised new concerns that the unexpected increase in passenger transfers between the two transport modes at Teneriffe Ferry Terminal may be occurring not so much as a matter of passenger destination convenience, but to exploit rear door boarding and alighting on the *CityGlider* to evade paying a two zone *go card* fare.

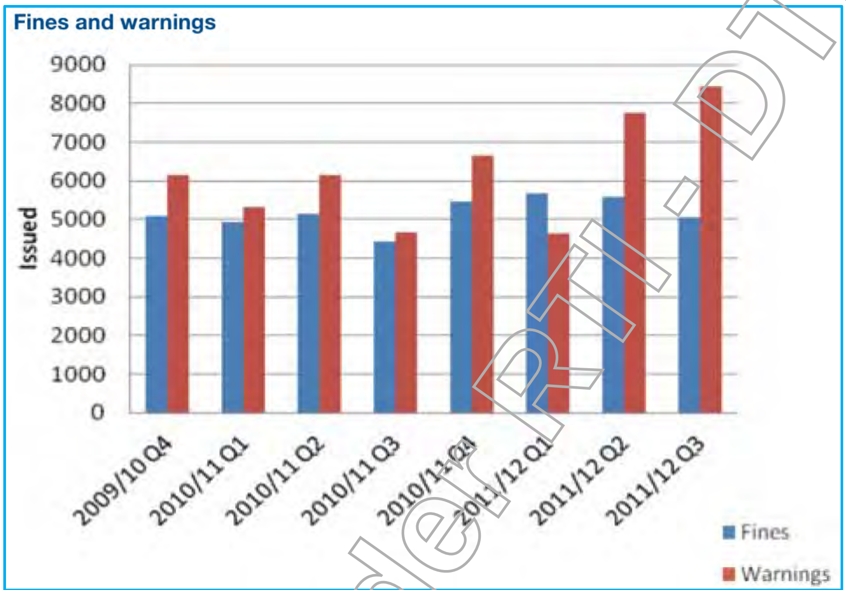
It is the considered view of the authors that endemic fare evasion is closely linked to the demographics and psychographics of residents living in particular socioeconomic service corridors, and the average incomes of passengers boarding *CityCats* in the lower reaches of the Brisbane River would not support the hypothesis that intermodal transfers to the *CityGlider* all door boarding service is significantly motivated by a 53¢ fare evasion. Evidence for this view has been found from previous analyses of the correlation between socioeconomic disadvantage and endemic fare evasion characterised on particular railway lines operated in the TransLink network; one notable example being the Beenleigh line.

Given TransLink's renewed vigour to tackle entrenched fare evasion on the bus network through the deployment of more transit officers, it is not unreasonable to expect that some of these transit officers could be deployed to specifically target standard bus routes converted to all door boarding high capacity vehicle routes to address the perceived increased risk of fare evasion. This has been the proof of payment strategy adopted by most overseas mass transit authorities to manage their all door boarding high capacity service roll outs described at rear in Appendix A. Most of the overseas mass transit operators nominated in Appendix A implemented all door boarding simultaneously with or shortly after their smartcard ticketing system roll outs to eliminate the traditional excuses that passengers normally posed when confronted without paid tickets by ticket inspectors, namely that they had no reasonable access to a prepaid ticket outlet. While there is no known research in TransLink on the reasons why particular SEQ passengers persist with evading fares, it could be reasonably assumed that a very small percentage of fare evaders are good citizens who just got caught on the rare occasion when they didn't happen to have the cash on hand to pay their ticket fares.

Fare evasion can occur for reasons other than a deliberate attempt by passengers to defraud the public transport provider of its rightful fare. One of the key reasons now better understood as to why fare evasion peaked on all door boarded Melbourne trams after the cessation of onboard conductors in 1998, was that the installed onboard ticket issuing machines that replaced conductors would not accept notes or credit/debit cards and therefore passengers had to have the necessary coins to self-purchase a ticket after boarding a tram. A similar finding occurred when all door boarding prepaid articulated bus routes were first trialled by London Transport prior to smartcard ticketing implementation where passengers could not buy tickets from drivers and had no readily accessible ticket channels from which to procure tickets at stops prior to boarding their buses.

TransLink no longer undertakes comprehensive fare evasion surveys to statistically measure the level of fare evasion by segment on particular transport modes, but does however record the number of fines and warnings issued by transit officers across its network as an indicator of the quarterly rise and fall in detected fare evasion. The number of fines and warnings is however unrelated to total passenger trips provided, the number of roving transit officers deployed, or the number of tagged passenger *go cards* and prepaid tickets checked; so meaningful comparisons of fare evasion between the different modes and service providers cannot be readily determined. In the example histogram appearing below at Figure 10, it would appear for example that total fines and warnings have increased in the past 2 quarters of FY2011/12, when this could merely reflect the increased number of transit officers deployed on train services to conduct ticket checks.

Figure 10: Histogram of TransLink Fines and Warnings (Source: *TransLink Tracker 2011-2012 Q3*)



Service reliability and efficiency have been consistently ranked in the 'high' category of target areas for improvement in TransLink bus service passenger customer satisfaction surveys. Because bus passengers in SEQ have always had to enter buses via the front door and conduct their ticket fare transactions with or in the presence of drivers, it could be argued that bus passengers, more so than rail or ferry passengers, have acquired a learnt behaviour to be honest and pay the ticket fare due. TransLink should be somewhat encouraged and comforted by the established behaviour of its existing bus passengers to not exploit all door boarding as a means to evading fare payment, given bus passengers are those most likely to appreciate faster and more reliable services that would flow from all door boarding.

2.7.4.2.2 Perceived Rear Door Safety Risk

The rear doors on high capacity buses may be obscured from the driver's view by standing passengers or acutely angled trailer articulations in the case of articulated buses. A safety concern often expressed in relation to all door boarding is that the bus driver will inadvertently close the rear door (or doors) on passengers still boarding the vehicle and not visible in either the interior or nearside exterior rear view mirror. It is common practice overseas for all passenger rear door boarding areas to be viewed on a driver's dashboard or overhead LCD monitor connected to closed circuit video cameras mounted opposite rear doors as have been fitted on the Clarks Logan City articulated superbuses and Bustech double deck bus.

In Paris, the passenger is able to remotely open bus rear doors when the vehicle is stopped or travelling at less than 3km/h as on Australian trams and trains, by pressing a button on the inside and outside of the rear door access. Feedback from TransLink's *Bus and Ferry Contracts* team has indicated that Brisbane Transport drivers on *CityGlider* buses have in the past simply forgotten to open the rear door to enable all door boarding. This issue could potentially be overcome by providing a single push button to open (but not close) the front and rear doors simultaneously and passenger operated door opening buttons similar to those fitted on Parisian buses.

2.7.5 Common Themes of Overseas All Door Boarding Implementations

Most of the transit agencies profiled in Appendix A introduced all door boarding on their high capacity bus services to improve service reliability and average speed, and to contain increasing operating costs.

San Francisco and Paris elected to allow all door boarding on all of their bus services, regardless of vehicle size or passenger demand. Vancouver and Ottawa only implemented all door boarding on their high capacity articulated and double deck bus services. In the case of Vancouver, all door boarding was limited to one particularly busy route, and only articulated buses were assigned to the route.

In all the overseas implementations investigated, the onus was placed on passengers to provide proof of purchase of a smartcard or valid ticket prior to boarding and to present such upon request to a transit agency appointed ticket inspector or security officer. Fines imposed for fare evasion were hefty, consistent across all travel modes managed by the transit agency, and considered a very strong deterrent to new and repeat offenders. Fare evasion monitoring was exclusively tasked to randomly deployed roving ticket inspectors and transit agencies increased the number of ticket inspectors in the lead up to the introduction of all door boarding services to mitigate the risk of elevated fare evasion.

No agencies chose to introduce prepaid only all door boarding services. They provided a mechanism for irregular passengers to still purchase tickets aboard buses using compulsory boarding at the front door for non-ticket holders and procurement of tickets from drivers. In some cases, tickets were sold onboard buses at a higher fare than a prepaid ticket bought off-vehicle, or the standard single trip fare electronically deducted from a prepaid smartcard.

Many transit agencies undertook all door boarding trials on targeted routes before proceeding to full scale rollout as a proof-of-concept verification to quantify benefits in terms of operating cost savings and travel time improvements, and to provide tangible evidence to politicians and other decision makers that safety and fare evasion risks could be appropriately managed. In all cases, the time and cost saving benefits yielded far outweighed the perceived costs of foregone ticket revenue, and quantification of benefits included passenger surveys to gauge customer responses to improved service reliability and speed.

All transit agencies undertook public advertising campaigns in the lead up to their introduction of all door boarding to educate customers on the benefits and fare rules, where to stand and how to distribute themselves evenly between doors at stops, and which door had to be used for ticket procurements. Mass communications about these new practices were continued well after the introduction of all door boarding or typically coupled with marketing campaigns for new service launches to proactively discourage fare evasion.

2.7.6 Australian Reluctance to Adopt All Door Boarding

So why has all door boarding on buses operated in Australian cities never been adopted as it has been in many other overseas countries? The authors can only surmise that this is an historical artefact of the transition from trams with drivers and conductors to driver only buses in the early 1970s, and Australia's relatively short history with operating large scale, high capacity, high frequency mass transit bus services.

Up until 2009, TransLink's largest capital city bus operator, Brisbane Transport, only had a fledgling fleet of 9 articulated buses which it operated on a select few high demand routes. But in a relatively short space of just the past 3 years, Brisbane Transport has substantially grown its high capacity fleet to 158 buses, representing more than 13% of its total current fleet strength, and proposes to further increase its high capacity vehicle fleet composition to 15% by FY2013/14.

Brisbane does not stand alone in its quest to fast track in more high capacity vehicles in an effort to arrest continuing rises in fuel and driver costs and to address increasing passenger demand which edges ever closer to the maximum boarding capacity tipping point of conventional 12.5m rigid bus viability. Sydney, Perth, Adelaide, Hobart and Canberra have progressively grown their respective high capacity fleet strengths over the last 3 years, and similarly begun to taper off their retiring conventional low capacity bus replacements. This fleet replacement strategy has been driven to some extent by the need to retire old high floor 12.5m rigid bus ahead of pending national public transport DDA compliance deadlines falling due in 2017, and to avoid any unnecessary State enforced old age bus body structural rebuilds.

In Melbourne, the only Australian capital city to have retained trams as its public transport vehicle of choice, A class and Z class trams of between 15m to 16.5m in length now represent 45% of the entire Yarra Tram fleet mix. These larger size tram classes have a seating capacity of 42 – 48 passengers, and a total passenger carrying capacity of around 100 with standees. Melbourne too, mirrors the national trend to high capacity vehicle fleet growth witnessed in all its sister State and Territory capitals.

Unlike any of its sister capital cities, greater Brisbane has also rolled out new busways, preserved bus transitway corridors and conducted public transport infrastructure upgrades over the past decade under TransLink and its predecessors, and this has uniquely positioned the city as the mass transit leader within Australia. Brisbane, more so than any other Australian capital city, is now ideally poised to implement high capacity vehicle all door boarding and reap similar benefits to those already being enjoyed by world's best practice BRT mass transit bus operators.

2.7.6.1 Reported Benefits of All Door Boarding by Best Practice Mass Transit Agencies

This following summarises the benefits of all door boarding on high capacity buses reported by overseas best practice government mass transit agencies similar to TransLink:

- Reduced stop dwell times,
- Reduced service travel times,
- Increased average service speed,
- Improved service reliability,
- Reduced operator penalties for failing to meet on-time performance,
- Higher user customer satisfaction, particularly with operating efficiency,
- Reduced bus queuing and congestion at stations,
- Improved bus station and stop bay turnover, resulting in deferred or cancelled need for capital investment to continually increase network and stop capacity,
- Improved utilisation of bus cabin interior passenger spaces,
- Reduced passenger circulation within buses,
- Increased standee comfort,
- Reduced conflicts and assaults between drivers and passengers, and
- Reduced total operating costs.

2.7.6.2 Reported Disadvantages of All Door Boarding by Mass Transit Agencies

This flowing summarises the disadvantages of all door boarding on high capacity buses reported by overseas mass transit agencies similar to TransLink:

- Heightened risk of fare evasion if targeted deployment of transit officers is not undertaken on all door boarding bus services,
- Heightened risk of implementation failure if rollout is not supplemented with a public education advertising campaign to train passengers on correct boarding procedures, and
- Safety concerns for rear door boarding of passengers if rear doors are not video monitored at the driver's position when doors are opened and closed.

2.7.6.3 All Door Boarding Pre-Implementation Check List

Based on overseas mass transit operating experience, the authors recommend that all door boarding be selectively implemented by TransLink as follows:

- On all high capacity bus services,
- Using only low floor buses to minimise average passenger boarding and alighting times,
- Using only buses with a minimum of 2 or preferably 3 full width (1200mm) two flow channel doors, each fitted with *go card* readers in each passenger flow channel,
- Using only buses where *go card* readers have been preconfigured to enable mixed tag on and tag off transactions at all doors,
- Using only buses fitted with video cameras opposite each rear door whose views can be monitored from the driver's seated position with standees and in all ambient lighting conditions,
- Preferably on new buses fitted with exterior opening plug doors and passenger operated interior and exterior push buttons to reopen doors when the bus is stationary or moving at less than 3km/h,
- Preferably with symbolic decals fitted on or adjacent to all doors identifying to passengers that the vehicle is an all door boarding and alighting bus,
- Preferably on routes where high average passenger loads can be boarded and alighted at the minimum number of stations and stops,
- Preferably with station and bus stop signage providing passenger information that instructs passengers on how to use all door boarding buses,
- With a well publicised all door boarding passenger advertising campaign, periodically rerun after initial service launch to reinforce the rear door boarding and fare evasion fine message,
- With targeted deployment of transit officers on all door boarding routes to mitigate the risks of creeping higher fare evasion,
- With front door boarding to enable infrequent passengers to purchase a ticket from the driver, and
- Where TransLink elects to operate all door boarding bus services as prepaid only routes, with adequate ticket outlets or add value vending machines provided on stations for passengers to prepay their tickets, until such time that cashless *go card* boarding has been fully implemented.

3. Operational Assessments

In this Part 3, we analyse live data captured from *go card* transactions and onboard ride surveys carried out on 4 high capacity vehicle and 2 standard 12.5m rigid bus services. The statistical measurements obtained from these data analyses are then used to model high capacity performance and to determine the specific route characteristics on which each bus type performs best.

3.1 Average Bus Stop Boarding and Alighting Times

3.1.1 Measurement Methodology

Detailed analyses have been undertaken by MRCagney to determine the variation in average passenger boarding and alighting times between the 4 high capacity bus types and 2 standard bus types based on live data captured from aboard the vehicles by the TransLink *Cubic go card* ticketing system. Ticketing data was reviewed for the inbound and outbound travel directions during peak and off-peak service periods between 1 March and 8 April 2012.

Source data was obtained from a netBi structured query of passenger *go card* tag on and tag off transaction times at all bus door card interface devices then sorted from first to last by time, date and trip direction for each card interface device and bus stop. After extensive data cleansing and sequential logic testing, 507,500 boarding and 469,700 alighting transaction records were recovered from the 538,500 total *go card* transactions loaded from netBi, and from these, 184,500 boarding and alighting passenger counts derived per stop and used to compute the average boarding and alighting time measurements.

Approximately 13% of netBi source transaction records were deemed invalid and rejected. Source records were rejected in cases where more passenger alightings than boardings occurred during the stop sequence along the route, the service or route number remained unchanged either before or after a terminus stop (i.e. because drivers had forgotten to log off and back onto a new service at the DCU), transaction time stamps were reversed in relation to the stop sequence or had stopped (i.e. due to drivers turning back without logging off/on at the DCU and equipment breakdowns) and unmatched boarding and alighting counts at end termini (i.e. sum of boardings not equal to sum of alightings).

Boarding time per passenger at each bus stop was computed from the time difference between the first and last valid *go card* tag on divided by the total number of tag ons. Alighting time per passenger at each bus stop was similarly computed from the time difference between the first and last valid *go card* tag off divided by the total number of tag offs. Dwell time per passenger was calculated from the time difference between the first and last *go card* tag on OR tag off divided by the total number of tag ons AND tag offs.

Boarded passenger loads were calculated sequentially for every serially sorted stop group identifier along each bus trip by computing the cumulative difference between passenger Σtag-ons and Σtag-offs following each stop. Standing loads were estimated by subtracting the seating capacity for each vehicle type from its boarded passenger load after each stop. Seated and standing passenger load profiles were then generated for each trip and bus type, and the results statistically analysed.

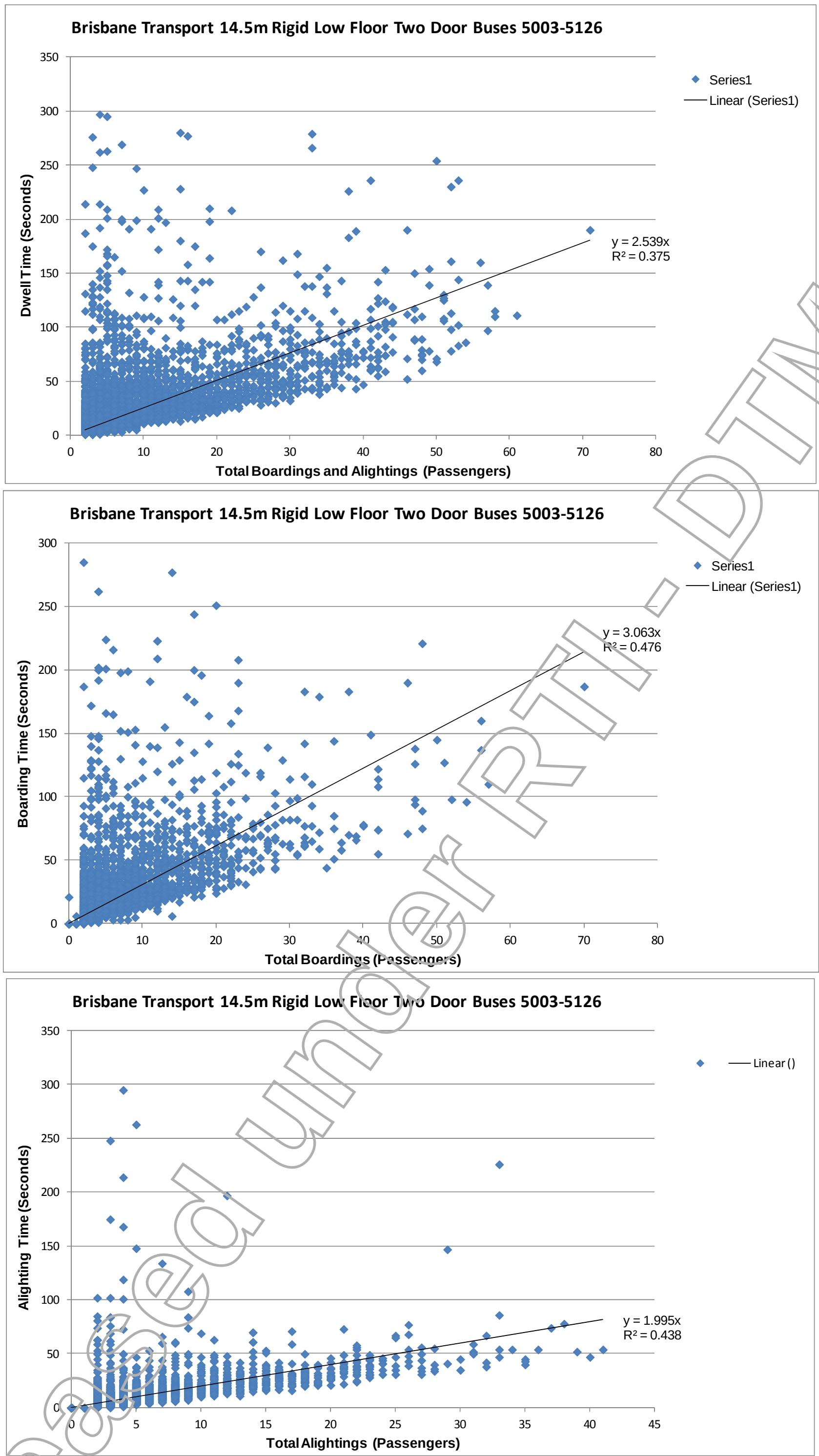
Our data analysts have recognised a number of potential error sources from using raw *go card* transaction data to assess bus operational performance as follows:

- Time delays caused by driver activated suspension lowering and raising and door opening and closing could not be measured from *go card* transactions and could not therefore be included in the measured final dwell times. The former were observed on ride surveys to occur rarely in live service - generally only when persons with disabilities sought driver assistance, and the latter was observed to add less than 3 seconds to overall bus stop dwell times;

- The ability of passengers to randomly tag off before buses had pulled into bus stops and to cancel tag ons by tagging off again within 20 seconds after leaving stops could not be detected and could result in the overestimation of actual bus stop dwell times. Occurrences of the latter event were however known to occur very infrequently in real live service;
- There was no practical way for our analysts to determine instances where buses were delayed at stations or stops while boarding passengers mobilised along platforms or to makeshift set downs because stops were already occupied by other buses at the time of arrival. On ride surveys, it was noticed that when this occurred, drivers tended to open their doors for alighting and boarding passengers but well before the latter actually began to board at front doors. This occurred frequently during the peak periods on inner city lead stop busway stations;
- There was no practical way for our analysts to determine instances where buses were delayed at stops when passengers interacted with the driver to ask questions, top-up *go cards,* procure paper tickets or seek front door boarding/alighting assistance as in the case of passengers with physical disabilities, all of which would act to increase *go card* transaction times recorded; and
- There was no practical way for our analysts to detect and count passengers who procured paper tickets. This type of error leads to an underestimation of the actual number of boarded and alighted passengers at stops and to longer average boarding times per passenger.

Final boarding, alighting and dwell times per passenger were computed using straight line regressions similar to those depicted below in Figure 11 for the Brisbane Transport 14.5m rigid high capacity bus. This statistical technique generates a best fit straight line relationship between measured passenger counts and times using the method of least square deviation to minimise the undesirable effects of random, unusual and extreme deviations illustrated by the coordinates appearing in the 3 scatter diagrams below and overleaf in Figure 11.

Figure 11: Straight Line Regression Results Obtained for Brisbane Transport 14.5m Rigid Buses



The bus types and routes analysed in the operational assessment survey were:

Two Door 12.5m Rigid Bus (Study Reference Standard Vehicle)

- Brisbane Transport Low Floor (LF) Buses 561 - 1055, Aspley Hypermarket to City Route 345
- Brisbane Transport High Floor (HF) Buses 320 – 539, Aspley Hypermarket to City Route 345
- Brisbane Transport Low Floor Buses 1030 - 1049, Teneriffe to West End Ferry Terminal CityGlider Route 60

- Two Door 12.5m Double Deck Bus
  - Hornibrook Bus Lines Bus 343, Redcliffe to City Route 315
- Two Door 14.5m Rigid Bus
  - Brisbane Transport Buses 5003 – 5126, Browns Plains to City Route 150
- Two Door 18m Articulated Bus
  - Clarks Logan City (LC) Buses 116 – 117, Loganholme Bus Station to City Route 555
  - Brisbane Transport (BT) Buses 1601 – 1630, Eight Mile Plains to City Route 111
- Three Door 18m Articulated Superbus
  - Clarks Logan City Buses 555 – 556, Loganholme Bus Station to City Route 555.

3.1.2 Results

The measured results of our statistical analyses appear overleaf in Table 4. Visual surveys were also conducted during the survey period at 5 busway stations and on 16 bus trips aboard the surveyed bus types to identify passenger boarding and alighting characteristics likely to affect the measured results. Our onboard observations are further discussed below in the key findings.

3.1.3 Key Findings

- The fastest average boarding, alighting and dwell times per passenger for the high capacity vehicles were measured on the Brisbane Transport two-door 18m articulated buses. Observations taken aboard all bus types surveyed suggest that this occurred on Brisbane Transport articulated buses primarily because alighting passengers positioned themselves at doors well in advance of busway station arrivals, then double streamed off at rear doors and in single file at front doors with minimal conflict to boarding passengers. The Brisbane Transport articulated bus Route 111 service surveyed had a very high incidence of concurrent passenger boarding and alighting and it was further noted that there was very little interaction on Brisbane Transport busway services between drivers and boarding passengers. Unlike either of the high capacity private bus operators, Brisbane Transport Route 111 drivers did not top up *go cards* and sold almost no paper tickets to boarding passengers.

Table 4: Measured Average Boarding, Alighting and Dwell Times per Passenger

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Average Boarding Time Per Passenger	2.7s (LF) 3.0s (HF)	3.0s	3.1s	3.1s	3.5s (LC) 2.6s (BT)	3.7s
Average Alighting Time Per Passenger	2.0s (LF) 2.0s (HF)	2.2s	2.6s	2.0s	2.1s (LC) 1.7s (BT)	2.0s
Average Dwell Time Per Passenger with No Standees	2.5s (LF) 2.9s (HF)	2.7s	3.0s	2.5s	2.9s (LC) 2.4s (BT)	2.9s
Average Dwell Time Per Passenger at >20% Standing Capacity	3.0s (LF) 3.1s (HF)	2.9s	Not Reached	3.3s	3.1s (LC) 2.8s (BT)	3.1s

- No significant differences in boarding, alighting and dwell time per passenger were measured between the Clarks Logan City two and three door articulated buses. Dwell time per passenger on the two Clarks articulated bus variants was found to be strongly dominated by their slow average boarding times rather than by faster average alighting times, which effectively negated the benefit of the Superbus double width middle alighting door.

Observations aboard the Clarks Logan City articulated buses and at busway stations uncovered a very high incidence of passenger interaction with drivers primarily for paper ticket purchases and *go card* top ups. Driver-passenger interactions were observed to not only block off one stream of boarding passengers at the double width front doors, but to set off conflicts in the freely streaming channel between alighting and boarding passengers. Comparison of boarding times per passenger between the near identically configured Brisbane Transport and Clarks Logan City two door articulated buses has highlighted that a Translink policy to eliminate paper ticket sales and *go card* top ups on buses would cut up to 1 second per passenger off average boarding times and half a second per passenger off front door average alighting times on the high capacity buses.

- Significantly higher average boarding times than alighting times per passenger were measured on all bus types. This suggests that dwell time at stops would be improved with concurrent all door alighting and boarding.
- The longest alighting times per passenger were observed on the double deck buses where passengers from the upper deck often continued to alight through the double width rear door in single file well after passengers on the lower deck had fully disembarked. At the high AM peak offloading stops in Fortitude Valley and the CBD, passengers alighting from the upper deck continued to disembark for periods of up to 10s after passengers on the lower deck had fully cleared. Boarding times on the double deck bus were found to be largely unaffected by upper deck use, but it was noticed that alighting times could be significantly delayed by passengers not descending the upper deck staircase until the double deck bus was stationary.
- Average alighting times per passenger were found to be similar between the older high floor 12.5m rigid buses with double width rear doors and two steps to the newer ultralow floor step-free 12.5m rigid buses with only single width rear doors. This indicates that the reduced rear door passenger alighting times afforded by an ultralow floor step free bus design have been effectively obliterated by the decision of bus operators to narrow rear doors on their standard rigid buses in an effort to regain two additional passenger seats.
- Marginally higher average boarding and alighting times per passenger were recorded on the all door boarding 12.5m low floor *CityGlider* buses than on the standard low floor 12.5m route buses. This was found to be due to the low concurrent utilisation of rear doors by boarding passengers, and the somewhat casual laid back nature of off-peak *CityGlider* users.

  Because this service has no fixed off-peak timetable and drivers can vary its pace by up to 5 minutes in each off-peak travel direction, it was found on 4 separate survey trips that the customer friendly *CityGlider* drivers repeatedly held over at bus stops for late arriving runner and hailer passengers, and most off-peak passengers made little or no effort to move to doors prior to bus stop arrivals. Further, because the *CityGlider* buses only had a single width rear door, those passengers who initially chose to board at the rear door had to wait until all onboard passengers had alighted, and in many cases relocated to the front door, or where they remained in the rear door queue, were still boarding well after passengers who boarded at the double width front door were already seated.

3.2 Passenger Alighting Preferences

3.2.1 Measurement Methodology

Passenger door alighting preferences have been summated and apportioned by percentage from netBi tag off records for all surveyed bus types and services, and have been observed from the data to be impacting on both average boarding and dwell times at bus stops. Alighting preference surveys were also conducted at five busway stations and on 16 separate bus trips to identify why passengers chose to alight at front doors and thereby delay boarding passengers, or at rear doors which enabled concurrent conflict-free boarding and alighting. All door boarding and alighting preferences were also observed on 4 Brisbane Transport *CityGlider* peak and off-peak services.

3.2.2 Results

Table 5 below summarises the measured passenger alighting preferences by door for each surveyed bus type. Passenger boarding preferences are also presented in the measured results for the all-door boarding Brisbane Transport *CityGlider* service and to the upper deck of the double deck bus.

3.2.3 Key Findings

While average boarding and alighting times per passenger are a valid measure of the efficiency of a given bus size and configuration to optimise concurrent passenger movements with minimal conflict, total bus stop dwell time was observed to be strongly impacted by passenger preferences to use specific bus doors when alighting. It can be proven mathematically that minimum total service dwell time at bus stops will be achieved when combined boarding and alighting movements occur concurrently without conflict in approximately equal time. This ideal only occurs under very specific operating conditions and real live services rarely meet these conditions with front door only boarding. The optimum conditions are derived by mathematical modelling later in the report.

For AM peak inbound bus services to stops dominated by passenger boardings, average dwell time per passenger converges toward the average boarding time per passenger. Total stop dwell time for most of the trip therefore becomes proportional to the total number of passengers boarded, and incidental concurrent passenger alightings from the rear door have no material effect on the total dwell time accumulated at most stops. For AM peak inbound services, the lowest total dwell time will therefore occur when all or most alighting passengers prefer to use the rear door.

Table 5: Passenger Alighting Preferences by Door for Each Surveyed Bus Type

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Percent Who Alighted at Front Door	31% (LF) 36% (HF)	27%	47%	19%	55% (LC) 52% (BT)	14%
Percent Who Alighted at Middle Door						44%
Percent Who Alighted at Rear Door	69% (LF) 64% (HF)	73%	53%	81%	45% (LC) 48% (BT)	42%
Percent Who Boarded at Rear Door		26%				
Percent Who Boarded to Lower Deck			49%			
Percent Who Boarded to			51%			

Upper Deck							

The opposite conditions prevail on PM peak outbound services to stops dominated by alightings where total bus stop dwell time becomes proportional to the total number of passengers disembarked. For PM peak outbound services, the lowest total dwell time will occur when alighting passengers prefer to alight equally at both doors, assuming both are double width doors.

These however were not the measured results obtained for most of the high capacity vehicles. Key findings from our survey measurements and visual observations of passenger alighting/boarding preferences were as follows:

- Passenger door alighting preferences measured on all bus types very closely correlated with the positioning of the rear doors relative to available onboard passenger seated and standing spaces and were unaffected by rear and/or middle door width in the case of the articulated superbus. Based on this finding, boarding and alighting times on single deck low floor high capacity buses with two doors would benefit from a more aftward positioning of rear doors and increased aisle width and standing space opposite rear doors to store their higher alighting passenger numbers relative to the standard rigid buses.
- The current Bustech double deck seating configuration suits limited stop and express long haul services which can exploit its high seating capacity. Given the seating capacity on the double deck bus was underutilised on the Hornibrook 315 commuter service and never reached anywhere close to full seating capacity utilisation, the double deck configuration would benefit most from an additional staircase off the upper deck to improve alighting times on shorter regular stop city commuter services.
- Concurrent passenger alightings from the Clarks Logan City three door articulated superbuses provided the shortest total trip alighting time and least conflict between boarding and alighting passenger streams. The middle and rear doors on the Clarks 3 door superbus were almost equally preferred by alighting passengers and only 1 in 7 passengers using this vehicle type chose to exit from the front door.
- 69% to 73% (more than 2 to 1) passengers preferred to alight from the rear door on a standard low floor rigid bus, where 81% (over 4 to 1) passengers preferred to exit from the rear door on the 14.5m rigid high capacity bus. Disproportionate use of the rear door to exit from 14.5m rigid buses was found to occur because its longer bus cabin layout placed 90% of all passenger seats and standee areas closer to the rear door than the front door. Cabin layout and rear door position were identified as the key reasons why 14.5m buses took longer to offload passengers en mass than rigid and articulated buses at the AM peak inbound stops in the CBD and other similar highly congested bus stops such as those at the Cultural Centre and UQ Lakes Bus Stations.
- It has been found that regular Hornibrook commuters were near evenly split on their preference for sitting on the upper and lower levels of the Bustech double deck bus. Our onboard observations found that the young and able bodied passengers under 40 years of age preferred to use the upper deck, whilst older passengers and those for whom the upstairs ride was no longer a novelty preferred the lower deck. It is nonetheless plausible that the upper deck would be popular on the Gold Coast 700 series routes, given the high proportion of tourists and regional visitors using these Surfside services. Double deck bus alighting times were found to suffer from extended stop dwell times caused by slow single file alighting down the staircase to the double width rear door, but as for the 14.5m rigid buses, highly extended stop dwells only occurred when a large number of passengers alighted en mass at high offloading stops and stations.

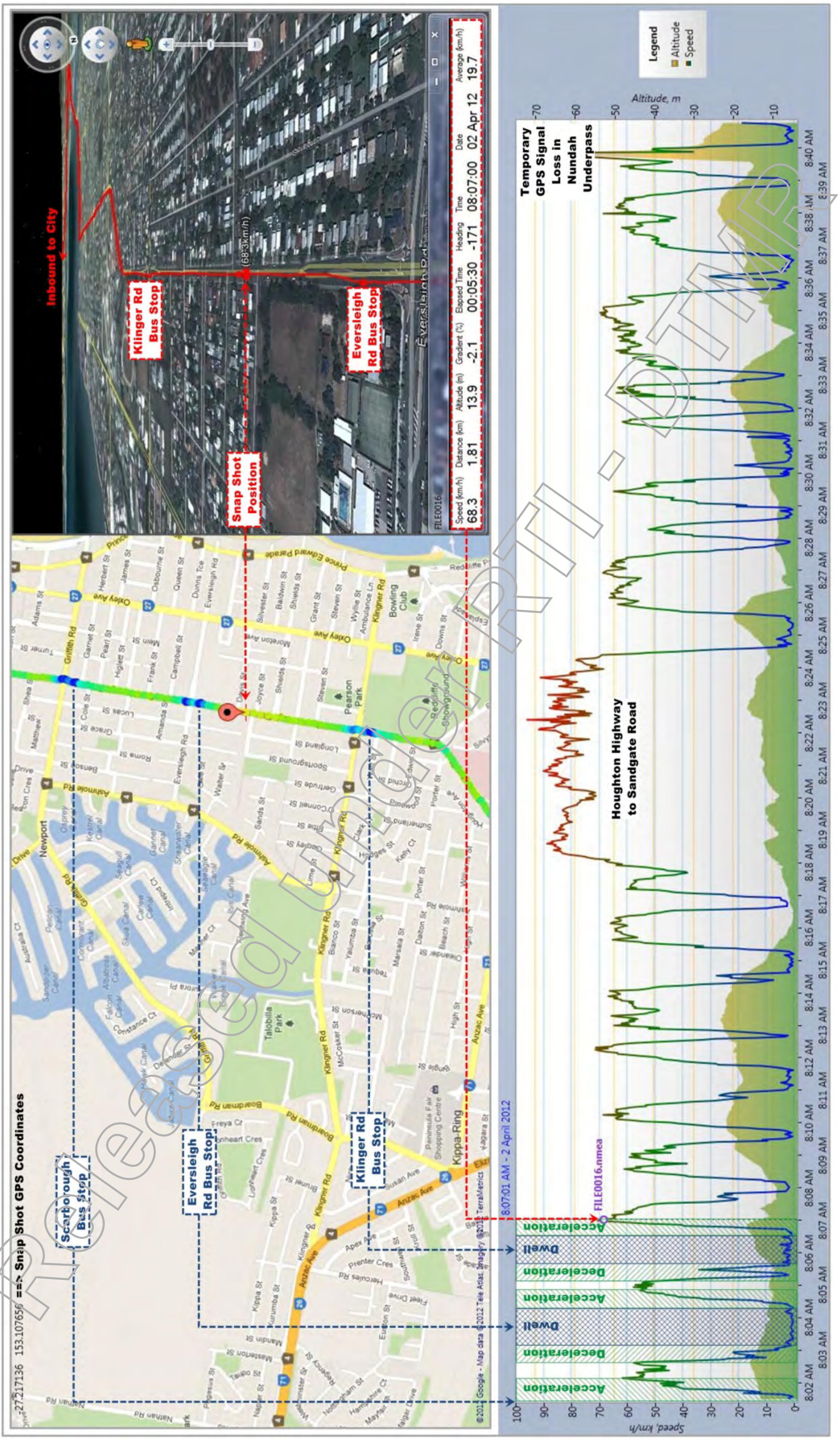
- Only 1 in 4 passengers on the *CityGlider* service chose to board at the rear door. It is considered this occurred because Brisbane bus passengers in the main have been conditioned over many decades only to board at the front door and because boarding passengers are reluctant to wait at the single width rear door for alighting passengers to fully disembark. It was noted on both peak and off-peak *CityGlider* trips that passengers who initially positioned themselves to board at the rear door frequently lost patience with alighting passengers from the narrow rear door and relocated to the front door boarding queue as it shortened. Single width rear doors appear to act as a strong deterrent to potential future all door boarding on standard low floor 12.5m rigid buses.

3.3 Average Deceleration, Acceleration and Speed

3.3.1 Measurement Methodology

Vehicle location and speed were measured on all bus types using a QStarz 66 channel, 5 acquisition/second high resolution differential GPS logger accurate to within +/- 2.5m resolution. Measurements were taken while riding aboard each bus type for 2 or 3 trips while in live passenger service. GPS logs were later downloaded from the logger and analysed using *ActiveGPX*, *Google Maps* and *Google Earth* to plot route and stop locations, speed and gradient charts similar to those illustrated in Figure 12 which were generated for the Hornibrook double deck bus on Route 315. *GPS Results* was also used to measure whole of trip average and best accelerations and decelerations to 50km/h and 90km/h.

Figure 12: Location, Speed and Gradient Charts Generated from GPS Log for Route 315



3.3.2 Results

Table 6 below presents the measured decelerations, accelerations and speeds recorded on each surveyed bus type.

Table 6: Measured Average Decelerations, Accelerations and Trip Speeds

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Typical Deceleration from 50km/h	-1.3 m/s²	-1.02 m/s²	-1.1 m/s²	-1.27 m/s²	-1.23 m/s²
Typical Deceleration from 90km/h	-0.86 m/s²	-0.64 m/s²	-0.72 m/s²	-0.64 m/s²	-0.8 m/s²
Average Trip Deceleration to Stop	-0.89m/s²	-1.04m/s²	-0.85m/s²	-0.6m/s²	-0.9m/s²
Typical Acceleration to 50km/h	1.1m/s²	0.76m/s²	0.96 m/s²	0.89m/s²	0.85 m/s²
Typical Acceleration to 90km/h	0.56m/s²	0.45 m/s²	0.54 m/s²	0.5 m/s²	0.48 m/s²
Average Trip Acceleration from Stop	0.9m/s²	0.7m/s²	0.76m/s²	0.67m/s²	0.8m/s²
Average Trip Speed	22km/h	41km/h	52km/h	43km/h	48km/h
Maximum Trip Speed	48km/h	92km/h	98km/h	92km/h	94km/h
Average/Maximum Speed	46%	45%	53%	47%	51%

3.3.3 Key Findings

Average deceleration to bus stops and acceleration back to incident left lane traffic speed (peak) or regulated traffic speed (off-peak) was determined to exhibit low variance for particular bus drivers, but not for particular bus types. It was found for instance that some drivers preferred to coast down to stops and accelerate off slowly, while others driving the same bus type were found to be more aggressive on the foot brake and throttle. The worst average acceleration and deceleration rates were measured on the 12.5m *CityGlider* off-peak services, and the results tabulated above were considered to reflect the norm of drivers' personal driving habits more so than optimum bus performance.

Key findings from the GPS measurements logged on each bus type were that:

- Average deceleration into bus stops and acceleration back to traffic speed fell inversely with increasing average traffic speed for all bus types.
- Of the high capacity vehicles, the fastest 50/90km/h to 0km/h deceleration and standstill to 50/90km/h acceleration rates were recorded on the 14.5m rigid bus and were similar to those measured for 12.5m standard low floor buses. When fully loaded and driven hard by more aggressive drivers, the 14.5m rigid buses outperformed all other bus types, including all standard high and low floor 12.5m rigid buses, for both combined foot braked plus retarder deceleration and take-off acceleration from bus stops.
- At stations and bus stops that boarded or alighted less than 4 passengers, the time taken to decelerate into and accelerate back out of the stop back to traffic speed typically exceeded the total bus stop dwell time.
- Average trip speeds were found to be around 48% of maximum service speed. In suburbs where bus stops were closely spaced within 450m, average speed fell to as little as 32% of the incident traffic speed, but on the busways where stations were spaced around 2.4km, average speed increased to 56% of the maximum busway speed (90km/h).

- Measured high capacity vehicle deceleration and acceleration results were found to be more closely related to stop spacing, driving performance and average traffic speed than to particular bus types or their manufacturer performance specifications.

3.4 Peak and Off-Peak Passenger Capacity Utilisation

3.4.1 Methodology

An assessment to determine the peak and off-peak passenger capacity utilisation on the different bus types was undertaken using data sourced from the Translink *go* card system. Data was collated for both the inbound and outbound directions during peak and off-peak operating periods between 1 March and 8 April 2012. The source data used was obtained from a netBi structured query of passenger *go* card tag on and tag off transaction times at all door onboard card interface devices to determine the boarded passenger loads on each route and trip, and the measured results discussed below therefore do not include passengers who boarded and purchased paper tickets.

The bus types and routes covered in our statistical analyses were identical to those earlier listed in Section 3.1.1. Seated and total (seated plus standing) passenger capacities for each bus type were obtained from bus manufacturer drawings and bus operators. Low floor (LF) and high floor (HF) standard rigid buses were separately assessed for Route 345, and Clarks Logan City (LC) and Brisbane Transport (BT) 18m articulated buses separately assessed for Routes 555 and 111 respectively.

The terms "peak" and "off-peak" where used in the table of results below do not strictly correlate with TransLink's defined AM/PM commuter peak and off-peak periods. It was found for instance that some bus loading peaks occurred on Route 345 during school runs, and before and after TransLink defined commuter peak periods on the longer 315, 150 and 555 routes.

When filtering the netBI ticket transaction data to assess the number of seated and standing passengers on each bus trip, it was assumed by our analysts that all seats were occupied before passengers began to stand and that the number of standees therefore equalled the difference between the boarded passenger load and bus type specific seating capacity. Observations made while travelling aboard bus services has indicated this assumption generally reflected how passengers distributed themselves between seated and standing areas, but it was noted that school and university students regularly chose to stand and socialise with friends, and passengers who boarded for short rides often chose to stand near rear exit doors when seats at the rear of the vehicle still remained unoccupied.

3.4.2 Results

Measured peak and off-peak passenger capacity utilisations for all surveyed bus types appear overleaf in Table 7.

3.4.3 Key Findings

- Only a very small percentage (2% to 7%) of high capacity vehicle weekday peak services carried standing loads as compared with the 12.5m standard rigid buses (typically 8% to 13%).
- For the high capacity vehicle peak weekday services on which passengers did stand, the average standing time varied between 9 and 18min, but for passengers who had to stand for most of the trip, the maximum standing time varied between 19 and 37 minutes. The worst case maximum standing time was very near to twice the average standing time for all high capacity buses.

- No double deck bus services were identified on which boarded passenger loads exceeded the bus seating capacity. It was presumed accordingly that no passengers ever stood on the double deck bus other than by personal choice.

Table 7: Measured Peak and Off-Peak Passenger Capacity Usage

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Standard CityGlider	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Seated Passenger Capacity	44 (LF) 47 (HF)	44	96	56	64 (LC) 63 (BT)	52
Maximum Passenger Capacity	75 (LF) 70 (HF)	69	116	92	90 (LC) 85 (BT)	95**
No of Services Operated Per Weekday	159 (LF) 159 (HF)	236	31	167	138 (LC) 199 (BT)	138
No of Peak Services Per Weekday with Standees	13 (LF) 21 (HF)	3	0	10	4 (LC) 4 (BT)	10
Percent of Services Per Weekday with Standees	8% (LF) 13% (HF)	1%	0%	6%	3% (LC) 2% (BT)	7%
Average Standees on Peak Services	10 (LF) 13 (HF)	8	0	10	9 (LC) 8 (BT)	10
Maximum Standees on Peak Services	34 (LF) 39 (HF)	38	0	44	39 (LC) 28 (BT)	40
Average Standing Time on Peak Services	13min (LF) 14min (HF)	8min	0min	18min	12min (LC) 9min (BT)	13min
Maximum Standing Time on Peak Services	27min (LF) 34min (HF)	25min	0min	37min	23min (LC) 19min (BT)	26min
Average No of Off-Peak Seats Occupied	17 (LF) 20 (HF)	11	26	23	24 (LC) 23 (BT)	23
Average Percent of Seat Capacity Used Off-Peak	39% (LF) 43% (HF)	25%	27%	41%	38% (LC) 37% (BT)	44%

Note: The Clarks Logan City 3 door *Superbus* was granted an exemption in its first year of operation to carry 112 passengers and is currently approved for 95 passengers. Future ultralow floor articulated superbuses with reduced seating are likely to have a capacity of around 112 – 115 passengers under proposed new *Heavy Vehicle National Regulation* axle load concessions.

- Only 27% - 44% of high capacity vehicle seats were occupied during off-peak services compared with 39% - 43% for the 12.5m standard rigid buses. Based on this and our preceding observations, all high capacity buses used on the services assessed could afford to reduce their seating capacity, increase their total (seated plus standing) capacity and improve their alighting, boarding and dwell times by widening of aisles and creation of standing areas opposite rear doors.
- Average and maximum standees and standing periods were found to be lowest on the high passenger turnover *CityGlider* and busway 111 routes. Our analysis methodology has demonstrated that driver overload reports and trip peak boarding counts do not provide accurate surrogates for the reliable determination of peak loading, overloading and overload duration, or for justifying replacement of standard 12.5m buses with high capacity buses based on such. Justification of high capacity bus deployment can only realistically be determined on high passenger turnover services by measuring cumulative tag ons and tag offs incrementally along trips measured after each bus stop and by measuring their whole-of-journey differences to calculate average and maximum standing loads and their standing durations.

3.5 Operational Performance Evaluation Model

3.5.1 Measurement Methodology

An operational performance evaluation model has been developed by MRCagney to compare the relative operating performance of the standard and high capacity vehicle types judged by the characteristics of the service routes to which they are proposed to be deployed. An overview of the assumptions and mathematical derivations used in the model is presented below. The evaluation model has been verified by comparison of output results with measured results obtained for the various bus types and services earlier listed in Section 3.1.1, but excluding the high passenger turnover *CityGlider* and South East Busway 111 routes for which the underlying assumptions could not be applied.

The performance evaluation model brings together all of the measured data gathered in the 4 preceding sections of this Part 3 and emulates both an AM peak inbound service whose stops are predominantly for passenger boardings and a PM peak outbound service whose stops are predominantly for passenger alightings. The model excludes concurrent passenger boardings and alightings, treating each as mutually exclusive so that inbound and outbound bus stop dwell times can be accurately estimated from measured boarding and alighting times per passenger applicable to each bus type, and so that the model results reflect those obtained for the worst case longest trip time.

3.5.2 Performance Evaluation Model Description

The operational performance model adopts the simplified speed-time graphs presented overleaf in 45km/h **Traffic Speed:** This is the typical peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb along a major highway such as the Bruce, Ipswich or Pacific Motorway. It is also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.

- 75km/h **Traffic Speed:** This is the typical peak period traffic speed achieved on TransLink busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It is also representative of the off-peak traffic speed between the CBD and an outer Brisbane or surrounding regional town or city suburb using a highway such as the Bruce, Ipswich or Pacific Motorway.

Figure 13 for an AM inbound peak trip and return PM outbound peak trip operated on a hypothetical bus route with 8 stops. To aid the reader in visualising the model concepts, the inbound speed-time graph shown in 45km/h **Traffic Speed:** This is the typical peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb along a major highway such as the Bruce, Ipswich or Pacific Motorway. It is also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.

- 75km/h **Traffic Speed:** This is the typical peak period traffic speed achieved on TransLink busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It is also representative of the off-peak traffic speed between the CBD and an outer Brisbane or surrounding regional town or city suburb using a highway such as the Bruce, Ipswich or Pacific Motorway.

Figure 13 should be compared with the GPS logged AM inbound peak speed-time chart appearing at Figure 12 which was rendered off the GPS log for the Hornibrook double deck Bus 343 travelling inbound along Route 315. The chart at Figure 12 has been labelled with some actual stop locations and marked up with corresponding colours to the inbound speed-time graph in 45km/h **Traffic Speed:** This is the typical peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb along a major highway such as the Bruce, Ipswich or Pacific Motorway. It is also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.

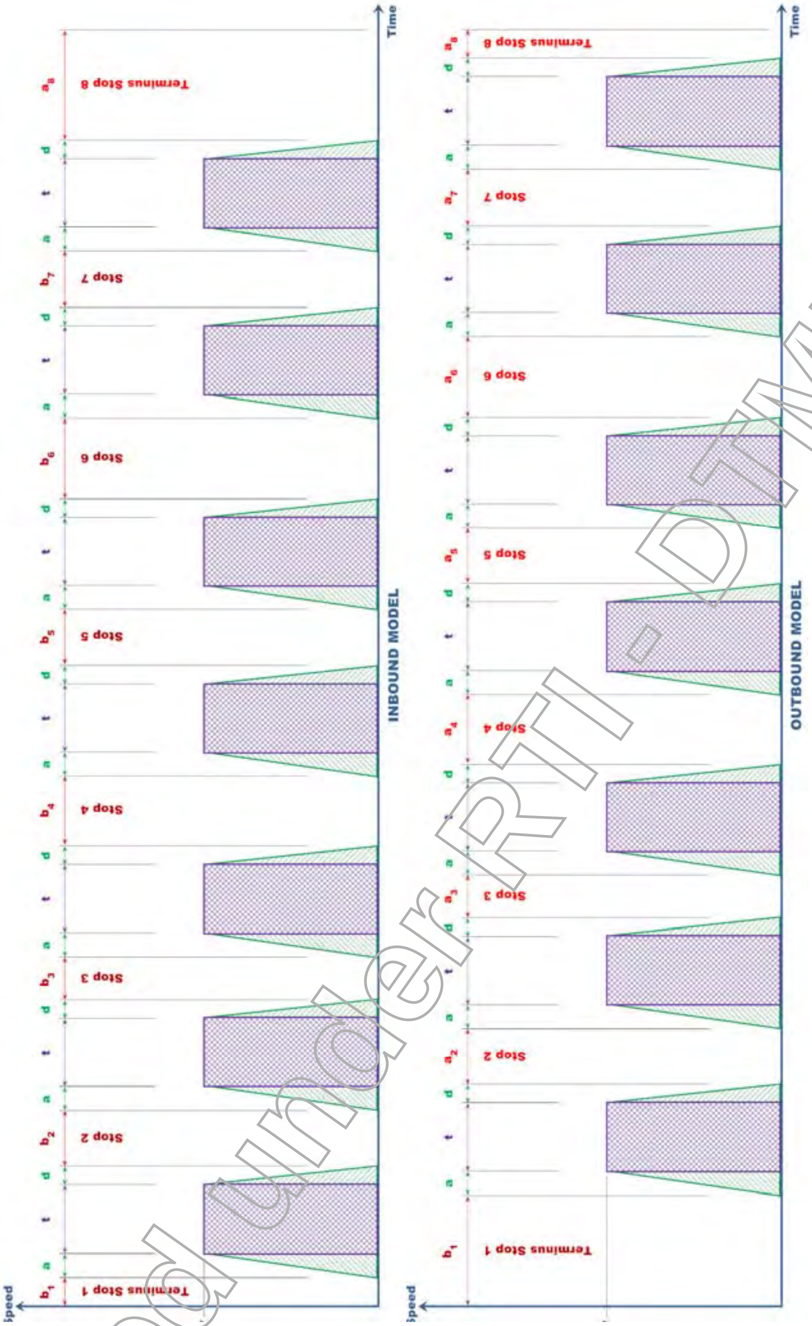
- **75km/h Traffic Speed:** This is the typical peak period traffic speed achieved on TransLink busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It is also representative of the off-peak traffic speed between the CBD and an outer Brisbane or surrounding regional town or city suburb using a highway such as the Bruce, Ipswich or Pacific Motorway.

Figure 13 as a quick visual aid to model interpretation.

Key assumptions, bus and route characteristics and derived mathematical equations used to evaluate the relative performance of each bus type follow:

- No of Bus Stops (*n*): For the inbound trip model speed-time graph shown in
- Figure 13, we have illustrated 7 boarding bus stops 1 through 7 with varying stop dwell times b_1, b_2, ..., b_7, and one alighting terminus stop 8 with dwell time a_8. Conversely, for the outbound trip model speed-time graph, we have indicated a single terminus boarding stop 1 with dwell time b_1, and 7 alighting stops 2 through 8 inclusive with varying stop dwell times a_2, a_3, ..., a_8. In both speed-time graphs, the total stops assumed was n = 8. The model tests routes with between n = 2 (one boarding terminus stop and one alighting terminus stop) and n = 32 total stops for each of the inbound and outbound travel directions.
- Traffic Speed (*v*): The model further tests each bus type's operational performance on the hypothetical route at 3 inbound/outbound traffic speeds selected from those published in the RACQ Brisbane City *Travel Time Survey – October 2010*:
  - **30km/h Traffic Speed:** This is the typical peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional suburb substantially via local roads then on a major city arterial or sub-arterial such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road. This traffic speed takes into account the higher travel speeds obtained while still driving through the outer suburbs on local roads and the typical slower speeds encountered during peak periods with traffic signals, congestion, stops and give-ways on major arterial or sub-arterial roads.
  - **45km/h Traffic Speed:** This is the typical peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb along a major highway such as the Bruce, Ipswich or Pacific Motorway. It is also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.
  - **75km/h Traffic Speed:** This is the typical peak period traffic speed achieved on TransLink busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It is also representative of the off-peak traffic speed between the CBD and an outer Brisbane or surrounding regional town or city suburb using a highway such as the Bruce, Ipswich or Pacific Motorway.

Figure 13: Speed-Time Graphs for Inbound and Outbound Bus Service Model



- Average Bus Stop Deceleration (*d*) and Acceleration (*a*) Time: Average bus stop deceleration and acceleration times are traffic speed dependent. The model adopts each bus type's measured average rates of deceleration (ø) and acceleration (µ) to determine the time actually expended decelerating into stops (*d*) and accelerating back out of stops (*a*) to the 3 above nominated average traffic speeds (*v*) tested by the model.
- Route Length (*l*): 5 hypothetical route lengths (*l* = 5km, *l* = 10km, *l* = 15km, *l* = 20km and *l* = 25km) are tested at the 3 nominated average traffic speeds (*v*) and cover the typical range of bus service route lengths operated by TransLink in South East Queensland.
- Passenger Carrying Capacity (*p*): The justification for deploying a high capacity bus size to any given route is the high capacity vehicle's capability to board a higher passenger load. To compare the different bus types on the 5 tested route lengths (*l*), the model forces each bus type to be loaded to its maximum (seated plus standing) passenger capacity (p).

Arguably, this model assumption disadvantages each high capacity vehicle type relative to the standard 12.5m reference vehicle since a higher average number of passengers needs to be boarded and alighted at bus stops in both travel directions as indicated below in Table 8. This incurs correspondingly higher cumulative dwell times for the high capacity vehicles at bus stops and the higher stop dwell times manifest themselves as longer overall trip times to complete any given route length (l). The relative performance of all 5 vehicle types has therefore been compared by their respective average service speeds, discussed shortly.

Table 8: Average Passenger Boardings and Alightings Per Stop

	Average Passengers Boarded or Alighted Per Stop				
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
2	75	116	92	88	112
3	38	58	46	44	56
4	25	39	31	29	37
6	15	23	18	18	22
8	11	17	13	13	16
11	8	12	9	9	11
16	5	8	6	6	7
23	3	5	4	4	5
32	2	4	3	3	4

- Average Travelling Time between Stops (t): All bus types have been assumed in the model to travel for an average period (t) between stops at the average traffic speed (v) depicted on Figure 13. The average travelling time (t) between stops has been calculated using Equation (ii) below derived as follows:

Let...

l = Route Length in metres
n = Total Number of Bus Stops on Route
v = Traffic Speed in metres/second
t = Average Travelling Time between Stops in seconds
$ø$ = Average Bus Stop Deceleration in metres/second^2
d = Average Bus Stop Deceleration Time in seconds
μ = Average Bus Stop Acceleration in metres/second^2
a = Average Bus Stop Acceleration Time in seconds

From the kinematic equations of linear motion and Figure 13, each bus travels a total trip distance of...

$$l = (n - 1) . [v.t + 0.5 v^2 (1/\mu + 1/ø)] = (n - 1) . [v.t + 0.5 v^2 (ø + \mu) / (ø . \mu)]$$

But $d = -v/-ø = v/ø$ and $a = v/\mu$, so...

$$l = (n - 1) . [v.t + 0.5 v (d + a)] \quad \text{......... (i)}$$

Therefore the average travelling time between stops is given by...

$$t = \frac{l}{(n - 1) . v} - \frac{(d + a)}{2} \quad \text{......... (ii)}$$

- Boarding Time per Passenger (t_b): The model uses the measured average boarding time per passenger (t_b) listed in Table 4 for each bus type.

- Alighting Time per Passenger (t_a): The model uses the measured average alighting time per passenger (t_a) listed in Table 4 for each bus type.
- Total Bus Stop Dwell Time (T): The model assumes that boarding and alighting of passengers at bus stops are non-concurrent and mutually exclusive. This assumption enables the total dwell time at bus stops along the hypothetical route to be calculated from the total bus passenger load (p) being carried, irrespective of where passengers choose to board or alight. Mathematical proof of this assumption follows:

Referring to Figure 13, let...

n = Total Number of Bus Stops on the Route
p_b = Number of Passengers who Boarded at Bus Stop "s"
b_s = Average Dwell Time at Bus Stop "s" to Board Passengers in seconds
t_b = Average Boarding Time per Passenger in seconds
p_a = Number of Passengers who Alighted at Bus Stop "s"
a_s = Average Dwell Time at Bus Stop "s" to Alight Passengers in seconds
t_a = Average Alighting Time per Passenger in seconds
p = Passenger Carrying Capacity of the Bus Type Deployed to the Route
T = Total Dwell Time Accumulated at Bus Stops in seconds

For the inbound model shown in Figure 13...

$T = (b_1 + b_2 + ... + b_7) + a_8 = (p_1 + p_2 + ... + p_7) . t_b + p_8 . t_a$

But the total passengers who boarded the bus must equal the total passengers alighted, so...

$p = p_8 = p_1 + p_2 + ... + p_7$

For the inbound model case where boarding and alighting are non-concurrent and mutually exclusive, it follows that the total dwell time at all stops depends only on the total number of passengers boarded and not on the particular stops at which passengers actually board, i.e...

$T = p . (t_a + t_b)$ .... (iii)

For the outbound model shown in Figure 13...

$T = b_1 + (a_2 + a_3 + ... + a_8) = p_1 . t_b + (p_2 + p_3 + ... + p_8) . t_a$

But the total passengers who alighted from the bus must equal the total passengers boarded so...

$p = p_1 = p_2 + p_3 + ... + p_8$

For the outbound model case where boarding and alighting are non-concurrent and mutually exclusive, it follows that the total dwell time at all stops depends only on the total number of passengers alighted and not on the particular stops at which passengers actually alight, i.e...

$T = p . (t_a + t_b)$ .... (iv)

Because equations (iii) and (iv) are identical and neither contains the variable n = *number of stops*, when boarding and alighting are assumed non-concurrent and mutually exclusive, the total dwell time at bus stops on any given route length becomes independent of the total number of stops, the stops at which passengers actually board or alight, or the direction of travel.

- Average Service Speed (s): Average service speed is considered to be a key measure of bus operational performance. The faster a bus travels, the lower its cost to operate and the faster it can be reallocated to another following service. The more passengers a bus carries, the lower TransLink's subsidy to operate the bus service. The model therefore calculates whole-of-trip average service speed (*s*) for each bus type over the entire period from the first passenger boarding to the last passenger alighting, not merely over the period between origin terminus departure and destination terminus arrival which ignores the end termini dwell times. This forces the model to account for all stop dwell times along the trip irrespective of where passengers decide to board and alight and provides a realistic comparison of each bus type's average service speed with that of a private motor vehicle completing the same journey.

The performance model equation used to determine average service speed (*s*) takes into account the route length (*l*), number of stops (*n*), incident traffic speed (*v*), bus specific deceleration time (*d*) to stop and accelerate time (*a*) back to the incident traffic speed (*v*) from each stop, total travelling time between stops ((*n-1*).*t*) at traffic speed (*v*), and total dwell time (*T*) accumulated while boarding and alighting the maximum bus specific passenger load (*p*) at its bus specific average boarding (t_b) and alighting (t_a) times.

From equations (iii) and (iv) and Figure 13, whole-of-trip average service speed is given by...

$$s = \frac{l}{(n-1).(d+t+a)+T} = \frac{l}{(n-1).(d+t+a)+p.(t_a+t_b)} \qquad \text{..........(v)}$$

And from equations (i), (ii) and (v)...

$$s = \frac{(n-1).[v.t+0.5\,v\,(d+a)]}{(n-1).(d+t+a)+p.(t_a+t_b)} = \frac{v.[t+0.5\,(d+a)]}{d+t+a+\frac{p.(t_a+t_b)}{n-1}} \qquad \text{..........(vi)}$$

- Traffic to Service Speed Ratio (*v/s*): From a passenger perspective, the choice either to drive a private motor vehicle or to catch a bus to complete a similar length journey boils down to a comparison of the relative times between the competing travel modes available to complete the trip. Given the best possible trip time achievable by private motor vehicle is inversely proportional to traffic speed (*v*), the relative time taken to travel by bus or private motor vehicle equals the ratio of average traffic speed (*v*) to average service speed (*s*).

From equation (vi), the ratio of average traffic to average service speed is given by...

$$\frac{v}{s} = \frac{d+t+a+\frac{p.(t_a+t_b)}{n-1}}{t+0.5\,(d+a)} = \frac{\text{Bus Trip Time}}{\text{Car Trip Time}} \qquad \text{.........(vii)}$$

- Average Bus Stop Spacing vs Longest Walk to Stop: Also from a passenger perspective, the whole-of-journey time comparison between driving a private motor vehicle or catching a bus must include the walking time to reach the nearest available bus stop. For passengers travelling to and from the CBD, the inconvenience of walking to a bus stop will be weighed up against the time expended to find a CBD parking space and park the private motor vehicle, and the added on cost of CBD parking charges. There is of course a practical limit to how far and for how long any passenger is prepared to walk, but the psychological limit increases in proportion to the overall trip time. A longer walk to the nearest bus stop will for instance be more readily tolerated by outer suburb passengers if it appears to take a relatively small fraction of the anticipated overall trip time. The model therefore evaluates the additional trip time needed to walk a maximum distance equal to 60% of average bus stop spacing up to a limit of 1km, the latter of which equates to a 12 minute walk at an average Australian adult walking speed of 5km/h. Beyond this limit, most passengers have been assumed to bike or drive and park, or be driven to the nearest bus stop by others.

Average bus stop spacing and longest passenger walking distance are related to the bus route length and the average number of bus stops made along the route as illustrated below in Table 9. The total stops listed in the left hand column of Table 9 have been scaled logarithmically to reflect the inverse log relationship between walk-to-stop passenger catchment, stop spacing and service route length. Yellow shaded entries in Table 9 cover average stop spacings of 1km and greater where passengers would most likely park and ride or kiss and ride from their nearest available bus stop or bus station.

Table 9: Stop Spacing versus Longest Walk to Bus Stop for Different Route Lengths

	Average Stop Spacing and Longest Walk to Stop									
Bus Stops	5 Kilometre Bus Route		10 Kilometre Bus Route		15 Kilometre Bus Route		20 Kilometre Bus Route		25 Kilometre Bus Route	
Per Trip	Stop Spacing (m)	Longest Walk (m)	Stop Spacing (m)	Longest Walk (m)	Stop Spacing (m)	Longest Walk (m)	Stop Spacing (m)	Longest Walk (m)	Stop Spacing (m)	Longest Walk (m)
2	5000	1000	10000	1000	15000	1000	20000	1000	25000	1000
3	2500	1000	5000	1000	7500	1000	10000	1000	12500	1000
4	1667	1000	3333	1000	5000	1000	6667	1000	8333	1000
6	1000	600	2000	1000	3000	1000	4000	1000	5000	1000
8	714	429	1429	857	2143	1000	2857	1000	3571	1000
11	500	300	1000	600	1500	900	2000	1000	2500	1000
16	333	200	667	400	1000	600	1333	800	1667	1000
23	227	136	455	273	682	409	909	545	1136	682
32	161	97	323	194	484	290	645	387	806	484

Route trip time increases with route length, number of stops and bus type specific passenger loading capacity; so for any given route length, a balance is needed between the inconvenience to individuals of having too few bus stops causing a longer walk (or drive) time to bus stops and having too many bus stops which exacts a longer trip time penalty to all upstream boarded passengers using the service. To test the relative performance of each bus type, the model calculates the percent of maximum walking time to total journey time for each route length and number of stops shown in Table 9 from the perspective of the outer suburban upstream passengers most affected by a high count of downstream bus stops.

3.5.3 Operational Performance Evaluation Model Results

Table 10 through Table 14 inclusive compare the relative operating performances of a standard 12.5m rigid and the 4 high capacity bus types on 5 different service route lengths between 5km and 25km using front door only boarding. The evaluation model measures performance of each bus type over a range of bus stops from 2 to 32 along the route to board and alight passengers up to each vehicle's maximum (seated plus standing) capacity. The model assumes stops are evenly spaced but the evaluated results are unaffected by where stops are actually located along the route, provided every stop is used.

The maximum passenger capacities assigned to each bus type by the performance evaluation model were:

- 2 Door 12.5m Rigid Bus: 44 seated + 31 standing = 75 passengers,
- 2 Door 12.5m Double Deck Bus: 96 seated + 20 standing = 116 passengers,
- 2 Door 14.5m Rigid Bus: 56 seated + 36 standing = 92 passengers,
- 2 Door 18m Articulated Bus: 64 seated + 24 standing = 88 passengers, and
- 3 Door 18m Articulated Superbus: 52 seated + 60 standing = 112 passengers.

All model output results tabulated below apply equally to an AM peak inbound bus service boarding its maximum complement of passengers at the number of stops indicated less one for alighting, and to a PM peak outbound service alighting its maximum load of passengers at the number of stops indicated less one for boarding. Model results are unaffected by how many passengers actually board or alight at any given stop, provided that total loading capacity is reached on the bus type and passengers board and alight once only and non-concurrently.

All 5 route lengths, each with from 2 to 32 bus stops have been tested by the model at 3 average traffic speeds:

- 30km/h Traffic Speed: This is the typical peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb substantially along local, arterial and sub-arterial roads.
- 45km/h Traffic Speed: This is the typical peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb substantially on a multilane highway or motorway. It is also representative of the off-peak traffic speed achieved by car between the CBD and an outer Brisbane or surrounding regional town or city suburb on local, arterial and sub-arterial roads.
- 75km/h Traffic Speed: This is the typical peak period traffic speed achieved by buses on TransLink busways to the CBD, on major city ring roads and motorways circling the city, and on exclusive bus use transit, T2 and T3 highway or motorway lanes. It is also representative of the off-peak traffic speed achieved by motor car between the CBD and an outer Brisbane or surrounding regional town or city suburb using a major multilane highway or motorway.

Model results in the 5 tables following have been colour coded as follows for quick interpretation:

- Average Service Speed – This is the whole-of-trip speed achieved by each bus type averaged over the period from its first passenger boarding to its last passenger alighting.

Colour Code	At 30km/h Traffic Speed	At 45km/h Traffic Speed	At 75km/h Traffic Speed
< $^2/_3$ x Traffic Speed	< 20km/h	< 30km/h	< 50km/h
$^2/_3$ – $^3/_4$ x Traffic Speed	20 – 23km/h	30 – 34km/h	50 – 56km/h
> $^3/_4$ x Traffic Speed	> 23km/h	> 34km/h	> 56km/h

- Traffic to Service Speed Ratio – This is the ratio of time taken to travel on each bus type compared to the time taken to travel the same journey by private motor vehicle.

Colour Code	At 30km/h Traffic Speed	At 45km/h Traffic Speed	At 75km/h Traffic Speed
<33% Longer Time	< 1.33	< 1.33	< 1.33
33% – 50% Longer Time	1.33 – 1.5	1.33 – 1.5	1.33 – 1.5
>50% Longer Time	> 1.5	> 1.5	> 1.5

- Percent of Journey Spent Walking to Nearest Bus Stop – This is the percent of total journey time (walking time plus bus trip time) expended by a passenger walking to the nearest bus stop calculated at 60% of the average distance between stops and capped to 1km (i.e. 12 minutes maximum walking time). The percentages indicated in the tables apply to a passenger who completed the whole (or near whole) bus trip from the origin terminus to the destination terminus and thereby had to endure the worst case maximum total dwell time along the route at every downstream bus stop.

Colour Code		At 30km/h Traffic Speed	At 45km/h Traffic Speed	At 75km/h Traffic Speed
>33%	x Journey Time	> 33%	> 33%	> 33%
20% – 33%	x Journey Time	20% - 33%	20% - 33%	20% - 33%
<20%	x Journey Time	< 20%	< 20%	< 20%

Optimum (yellow/green) combinations of average service speed, traffic speed ratio and percent of trip walking time have been printed in bold text in Table 10 through Table 14 inclusive to illustrate the service operating conditions under which particular bus types were found to perform well.

Table 10: Operation Performance Comparison of Bus Types on a 5 Kilometre Bus Route

Comparison of Bus Types on 5 Kilometre Bus Route															
Bus Stops	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
Per Trip	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	19	1.60	43%	14	2.12	36%	17	1.79	40%	18	1.64	42%	14	2.08	37%
3	19	1.60	43%	14	2.13	36%	17	1.80	40%	18	1.66	42%	14	2.09	37%
4	19	1.61	43%	14	2.15	36%	17	1.81	40%	18	1.67	42%	14	2.10	36%
6	18	1.63	31%	14	2.18	25%	16	1.83	28%	18	1.69	30%	14	2.12	25%
8	18	1.65	24%	14	2.21	19%	16	1.85	22%	17	1.72	23%	14	2.14	19%
11	18	1.67	18%	13	2.25	14%	16	1.89	16%	17	1.75	17%	14	2.18	14%
16	17	1.72	12%	13	2.33	9%	15	1.94	11%	17	1.82	12%	13	2.23	10%
23	17	1.78	8%	12	2.43	6%	15	2.01	8%	16	1.90	8%	13	2.31	7%
32	16	1.85	6%	12	2.57	4%	14	2.10	5%	15	2.02	5%	12	2.41	5%
45 Kilometre/Hour Average Traffic Speed															
2	24	1.91	49%	17	2.69	40%	20	2.20	45%	23	1.98	48%	17	2.63	41%
3	23	1.93	48%	17	2.72	40%	20	2.23	45%	22	2.01	47%	17	2.66	40%
4	23	1.95	48%	16	2.76	39%	20	2.26	44%	22	2.05	47%	17	2.69	40%
6	22	2.00	35%	16	2.83	28%	19	2.33	32%	21	2.11	34%	16	2.75	28%
8	22	2.05	27%	15	2.90	21%	19	2.39	24%	21	2.18	26%	16	2.81	22%
11	21	2.12	20%	15	3.01	15%	18	2.48	18%	20	2.28	19%	16	2.90	16%
16	20	2.24	14%	14	3.19	10%	17	2.63	12%	18	2.45	13%	15	3.05	11%
23	19	2.41	9%	13	3.44	7%	16	2.85	8%	17	2.68	8%	14	3.26	7%
75 Kilometre/Hour Average Traffic Speed															
2	29	2.58	54%	19	3.90	43%	24	3.09	49%	27	2.73	52%	20	3.79	44%
3	28	2.70	53%	19	4.05	43%	23	3.23	48%	26	2.89	51%	19	3.91	43%
4	27	2.81	52%	18	4.20	42%	22	3.37	47%	25	3.04	50%	19	4.04	43%
6	25	3.04	37%	17	4.49	29%	21	3.64	33%	22	3.35	35%	17	4.29	30%

Table 11: Operation Performance Comparison of Bus Types on a 10 Kilometre Bus Route

Comparison of Bus Types on 10 Kilometre Bus Route															
Bus Stops	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
Per Trip	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	23	1.30	32%	19	1.56	28%	21	1.40	30%	23	1.32	31%	20	1.54	28%
3	23	1.30	32%	19	1.57	28%	21	1.40	30%	23	1.33	31%	19	1.54	28%
4	23	1.31	31%	19	1.57	28%	21	1.41	30%	22	1.33	31%	19	1.55	28%
6	23	1.32	31%	19	1.59	27%	21	1.42	30%	22	1.35	31%	19	1.56	28%
8	23	1.32	28%	19	1.60	24%	21	1.43	26%	22	1.36	27%	19	1.57	25%
11	22	1.34	21%	18	1.63	18%	21	1.44	20%	22	1.38	21%	19	1.59	18%
16	22	1.36	15%	18	1.66	13%	20	1.47	14%	21	1.41	15%	19	1.62	13%
23	22	1.39	11%	17	1.72	9%	20	1.50	10%	21	1.45	10%	18	1.65	9%
32	21	1.43	8%	17	1.78	6%	19	1.55	7%	20	1.51	7%	18	1.70	6%
45 Kilometre/Hour Average Traffic Speed															
2	31	1.45	38%	24	1.84	33%	28	1.60	36%	31	1.49	38%	25	1.81	33%
3	31	1.46	38%	24	1.86	33%	28	1.62	36%	30	1.51	37%	25	1.83	33%
4	30	1.48	38%	24	1.88	32%	28	1.63	36%	30	1.52	37%	24	1.84	33%
6	30	1.50	37%	23	1.92	32%	27	1.66	35%	29	1.56	37%	24	1.87	32%
8	30	1.53	34%	23	1.95	28%	27	1.69	31%	28	1.59	33%	24	1.90	29%
11	29	1.56	26%	22	2.01	21%	26	1.74	24%	27	1.64	25%	23	1.95	22%
16	28	1.62	18%	21	2.10	15%	25	1.82	17%	26	1.72	17%	22	2.03	15%
23	26	1.71	13%	20	2.22	10%	23	1.92	11%	24	1.84	12%	21	2.13	10%
32	25	1.82	9%	19	2.38	7%	22	2.06	8%	23	1.99	8%	20	2.27	7%
75 Kilometre/Hour Average Traffic Speed															
2	42	1.79	46%	31	2.45	38%	37	2.05	42%	40	1.87	45%	31	2.39	39%
3	41	1.85	45%	30	2.52	37%	35	2.11	42%	39	1.94	44%	31	2.46	38%
4	39	1.91	44%	29	2.60	37%	34	2.18	41%	37	2.02	43%	30	2.52	37%
6	37	2.02	43%	27	2.74	35%	32	2.32	39%	34	2.17	41%	28	2.65	36%
8	35	2.14	38%	26	2.89	31%	31	2.46	34%	32	2.33	36%	27	2.77	32%
11	32	2.31	28%	24	3.11	22%	28	2.66	25%	29	2.56	26%	25	2.96	23%

Table 12: Operation Performance Comparison of Bus Types on a 15 Kilometre Bus Route

Comparison of Bus Types on 15 Kilometre Bus Route															
Bus Stops	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
Per Trip	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	25	1.20	25%	22	1.37	23%	24	1.26	24%	25	1.21	25%	22	1.36	23%
3	25	1.20	25%	22	1.38	23%	24	1.27	24%	25	1.22	25%	22	1.36	23%
4	25	1.20	25%	22	1.38	22%	24	1.27	24%	25	1.22	25%	22	1.37	23%
6	25	1.21	25%	22	1.39	22%	23	1.28	24%	24	1.23	25%	22	1.37	23%
8	25	1.22	25%	21	1.40	22%	23	1.28	24%	24	1.24	24%	22	1.38	22%
11	24	1.22	23%	21	1.42	20%	23	1.30	22%	24	1.25	22%	22	1.39	21%
16	24	1.24	16%	21	1.44	14%	23	1.31	15%	24	1.27	16%	21	1.41	15%
23	24	1.26	12%	20	1.48	10%	22	1.34	11%	23	1.30	11%	21	1.44	10%
32	23	1.28	8%	20	1.52	7%	22	1.37	8%	22	1.34	8%	20	1.47	7%
45 Kilometre/Hour Average Traffic Speed															
2	35	1.30	32%	29	1.56	28%	32	1.40	30%	34	1.33	31%	29	1.54	28%
3	35	1.31	31%	29	1.57	28%	32	1.41	30%	34	1.34	31%	29	1.55	28%
4	35	1.32	31%	28	1.59	27%	32	1.42	30%	33	1.35	31%	29	1.56	28%
6	34	1.33	31%	28	1.61	27%	31	1.44	29%	33	1.37	30%	28	1.58	27%
8	33	1.35	31%	28	1.63	27%	31	1.46	29%	32	1.39	30%	28	1.60	27%
11	33	1.37	28%	27	1.67	24%	30	1.49	27%	32	1.43	27%	28	1.63	25%
16	32	1.41	20%	26	1.73	17%	29	1.54	19%	31	1.48	20%	27	1.68	18%
23	31	1.47	14%	25	1.81	12%	28	1.62	13%	29	1.56	14%	26	1.75	12%
32	29	1.54	10%	23	1.92	8%	26	1.71	9%	27	1.66	9%	24	1.85	9%
75 Kilometre/Hour Average Traffic Speed															
2	49	1.53	40%	38	1.97	34%	44	1.70	37%	48	1.58	39%	39	1.93	34%
3	48	1.57	39%	37	2.02	33%	43	1.74	36%	46	1.63	38%	38	1.97	34%
4	47	1.60	38%	36	2.07	33%	42	1.79	36%	45	1.68	37%	37	2.01	33%
6	45	1.68	37%	35	2.16	32%	40	1.88	35%	42	1.78	36%	36	2.10	32%
8	43	1.76	36%	33	2.26	31%	38	1.97	34%	40	1.89	35%	34	2.18	31%
11	40	1.87	32%	31	2.41	27%	36	2.11	30%	37	2.04	31%	32	2.31	28%
16	36	2.07	23%	28	2.65	18%	32	2.34	20%	33	2.30	21%	30	2.52	19%

Table 13: Operation Performance Comparison of Bus Types on a 20 Kilometre Bus Route

Comparison of Bus Types on 20 Kilometre Bus Route															
Bus Stops	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
Per Trip	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	26	1.15	21%	23	1.28	19%	25	1.20	20%	26	1.16	21%	24	1.27	19%
3	26	1.15	21%	23	1.28	19%	25	1.20	20%	26	1.16	20%	24	1.27	19%
4	26	1.15	21%	23	1.29	19%	25	1.20	20%	26	1.17	20%	24	1.27	19%
6	26	1.16	21%	23	1.29	19%	25	1.21	20%	26	1.17	20%	23	1.28	19%
8	26	1.16	21%	23	1.30	19%	25	1.21	20%	25	1.18	20%	23	1.29	19%
11	26	1.17	20%	23	1.31	19%	25	1.22	20%	25	1.19	20%	23	1.29	19%
16	25	1.18	17%	23	1.33	15%	24	1.23	16%	25	1.20	17%	23	1.31	16%
23	25	1.19	12%	22	1.36	11%	24	1.25	12%	24	1.23	12%	23	1.33	11%
32	25	1.21	9%	22	1.39	8%	24	1.28	8%	24	1.25	8%	22	1.35	8%
45 Kilometre/Hour Average Traffic Speed															
2	37	1.23	27%	32	1.42	24%	35	1.30	26%	36	1.24	27%	32	1.41	24%
3	37	1.23	27%	31	1.43	24%	35	1.31	26%	36	1.25	26%	32	1.41	24%
4	36	1.24	27%	31	1.44	24%	35	1.32	25%	36	1.26	26%	32	1.42	24%
6	36	1.25	26%	31	1.46	24%	34	1.33	25%	35	1.28	26%	31	1.44	24%
8	36	1.26	26%	30	1.48	23%	33	1.35	25%	35	1.29	25%	31	1.45	24%
11	35	1.28	26%	30	1.50	23%	33	1.37	25%	35	1.32	25%	31	1.47	23%
16	35	1.31	22%	29	1.55	19%	32	1.41	20%	33	1.36	21%	30	1.51	19%
23	33	1.35	15%	28	1.61	13%	31	1.46	14%	32	1.42	15%	29	1.57	14%
32	32	1.41	11%	27	1.69	9%	29	1.53	10%	30	1.50	10%	28	1.63	10%
75 Kilometre/Hour Average Traffic Speed															
2	54	1.40	35%	43	1.73	30%	49	1.52	33%	52	1.43	34%	44	1.70	31%
3	53	1.42	34%	43	1.76	30%	48	1.56	33%	51	1.47	34%	43	1.73	30%
4	52	1.45	34%	42	1.80	29%	47	1.59	32%	50	1.51	33%	43	1.76	30%
6	50	1.51	33%	40	1.87	29%	45	1.66	31%	47	1.59	32%	41	1.82	29%
8	48	1.57	32%	39	1.95	28%	43	1.73	30%	45	1.66	31%	40	1.89	28%
11	45	1.66	31%	36	2.06	27%	41	1.83	29%	42	1.78	30%	38	1.98	27%
16	42	1.80	25%	33	2.24	21%	37	2.00	23%	38	1.97	23%	35	2.14	22%
23	37	2.00	17%	30	2.50	14%	33	2.24	15%	33	2.24	15%	32	2.36	15%

Table 14: Operation Performance Comparison of Bus Types on a 25 Kilometre Bus Route

Comparison of Bus Types on 25 Kilometre Bus Route															
Bus Stops	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
Per Trip	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking	Ave Speed (km/h)	Traffic Speed Ratio	Percent of Trip Walking
30 Kilometre/Hour Average Traffic Speed															
2	27	1.12	18%	25	1.22	16%	26	1.16	17%	27	1.13	18%	25	1.22	16%
3	27	1.12	18%	24	1.23	16%	26	1.16	17%	27	1.13	18%	25	1.22	16%
4	27	1.12	18%	24	1.23	16%	26	1.16	17%	26	1.13	17%	25	1.22	16%
6	27	1.13	18%	24	1.24	16%	26	1.17	17%	26	1.14	17%	25	1.22	16%
8	27	1.13	18%	24	1.24	16%	26	1.17	17%	26	1.14	17%	24	1.23	16%
11	26	1.13	17%	24	1.25	16%	25	1.18	17%	26	1.15	17%	24	1.24	16%
16	26	1.14	17%	24	1.27	16%	25	1.19	17%	26	1.16	17%	24	1.25	16%
23	26	1.16	12%	23	1.29	11%	25	1.20	12%	25	1.18	12%	24	1.26	11%
32	26	1.17	9%	23	1.31	8%	25	1.22	9%	25	1.20	9%	23	1.28	8%
45 Kilometre/Hour Average Traffic Speed															
2	38	1.18	23%	34	1.34	21%	36	1.24	22%	38	1.20	23%	34	1.33	21%
3	38	1.19	23%	33	1.34	21%	36	1.25	22%	37	1.20	23%	34	1.33	21%
4	38	1.19	23%	33	1.35	21%	36	1.25	22%	37	1.21	23%	34	1.34	21%
6	37	1.20	23%	33	1.37	21%	36	1.27	22%	37	1.22	23%	33	1.35	21%
8	37	1.21	23%	33	1.38	21%	35	1.28	22%	36	1.24	23%	33	1.36	21%
11	37	1.22	23%	32	1.40	20%	35	1.30	22%	36	1.26	22%	33	1.38	21%
16	36	1.25	22%	31	1.44	20%	34	1.33	21%	35	1.29	22%	32	1.41	20%
23	35	1.28	16%	30	1.49	14%	33	1.37	15%	34	1.34	16%	31	1.45	14%
32	34	1.33	12%	29	1.55	10%	32	1.42	11%	32	1.40	11%	30	1.51	10%
75 Kilometre/Hour Average Traffic Speed															
2	57	1.32	31%	47	1.58	28%	53	1.42	30%	56	1.35	31%	48	1.56	28%
3	56	1.34	31%	47	1.61	27%	52	1.45	29%	54	1.38	30%	47	1.58	27%
4	55	1.36	31%	46	1.64	27%	51	1.47	29%	53	1.41	30%	47	1.61	27%
6	53	1.41	30%	44	1.70	26%	49	1.53	28%	51	1.47	29%	45	1.66	27%
8	52	1.46	29%	43	1.76	25%	47	1.58	27%	49	1.53	28%	44	1.71	26%
11	49	1.52	28%	41	1.84	25%	45	1.66	26%	46	1.62	27%	42	1.79	25%
16	46	1.64	27%	38	1.99	23%	42	1.80	25%	42	1.78	25%	39	1.91	24%
23	42	1.80	19%	34	2.20	16%	38	1.99	17%	38	2.00	17%	36	2.09	16%
32	37	2.01	13%	30	2.46	11%	33	2.24	11%	33	2.27	11%	32	2.32	11%

3.5.4 Key Findings

The relative operational performances of the 5 bus types during peak periods using front door only boarding have been ranked below in Table 15. Rankings take into account average trip speed, time taken to complete trips relative a standard 12.5m bus, bus stop deceleration/dwell/acceleration times and passenger perceptions of increased journey time to walk to stops and travel by bus relative to driving a private motor vehicle. Where different bus types performed similarly for the same route length, number of stops and traffic speed, they have been ranked equivalently.

Table 15: Ranking of Bus Types with Front Door Only Boarding

Route Length	Routes Operated at 30km/h	Routes Operated at 45km/h	Routes Operated at 75km/h
	Mixed Traffic on Local, Arterial and Sub-Arterial Roads during Peak Period	Mixed Traffic on CBD Radial Highway or Motorway during Peak Period OR Off-Peak in Mixed Traffic on Local, Arterial and Sub-Arterial Roads	City Ring Road, Busway or Highway Bus Transit Lane during Peak Period OR Off-Peak in Mixed Traffic on a CBD Highway or Motorway
5km	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
10km	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
15km	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 2) 2 : 2 Door 14.5m Rigid (Note 2) 3 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
20km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic (Note 3) 1 : 2 Door Double Deck (Note 3) 2 : 2 Door 18m Artic 3 : 2 Door 14.5m Rigid 4 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
25km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 4) 2 : 2 Door 14.5m Rigid (Note 4) 3 : 2 Door 12.5m Rigid

Note 1: Up to a Limit of 22 Boarding/Alighting Stops
Note 2: Up to a Limit of 10 to 15 Boarding/Alighting Stops
Note 3: Up to a Limit of 10 Boarding/Alighting Stops
Note 4: Up to a Limit of 5 Boarding/Alighting Stops

Key findings drawn from examination of the results in Table 10 through Table 15 inclusive were as follows:

- High Capacity Bus Performance Generally: Operational performance of all high capacity bus types improves with increasing route length, reducing bus stops and reducing traffic speed. The higher the bus passenger capacity and incident traffic speed, the more sensitive high capacity bus performance becomes to the total number of stops along the route.

  All high capacity buses perform poorly on routes of around 7.5km or less and these routes are considered better suited to higher frequency 12.5m rigid bus services.

  The smaller (90 passenger) capacity 14.5m rigid and two door articulated buses become competitive with 12.5m rigid buses on 10km routes operated during the peak on local, arterial and sub-arterial roads where average peak traffic speeds are 30km/h or less. Ironically, the slower and more congested the incident traffic speed, the better these two smaller high capacity vehicles perform against the 12.5m rigid bus, and their average travel speed and performance is virtually unaffected by how many bus stops are used to board and alight to maximum capacity.

The larger (114 passenger) capacity three door articulated and double deck buses become competitive with 12.5m rigid and high capacity 14.5m rigid and two door articulated buses on 15km routes when traffic speeds are 30km/h or lower, and the smaller (90 passenger) capacity 14.5m rigid and two door articulated buses become competitive with 12.5m rigid buses on all highway or motorway services for peak period traffic speeds of 45km/h or lower. The slower and more congested the highway or motorway traffic becomes, the more relative performance against a 12.5m rigid bus improves.

At high traffic speeds of 75km/h, all bus types, including 12.5m rigid buses, were found to perform poorly on routes of less than 25km against a private motor vehicle, and relative performance to the private motor car falls off sharply with increasing bus capacity and number of stops. The reasons are readily understood from a simple example. In the case say of the 3 door 18m articulated superbus, a competing private car travelling inbound at an average traffic speed of 75km/h gains a 13.3km head start on the high capacity bus in the time taken just to board and alight its full load of 112 passengers. A further 0.63km gain is made by a private car in the time taken to decelerate down and accelerate back up to 75km/h at each bus stop on the route. Thus for a fastest possible express service from the Logan Hyperdome Bus Station to the CBD, a motor car gains a head start on the 3 door 18m articulated superbus equivalent to the entire length of the South East Busway.

- 5km Route High Capacity Vehicle Performance: No bus type, including the 12.5m rigid bus, has performed particularly well on short routes of 5km length or less. Routes around this length can be found operating in Brisbane on the CBD centric *CityGlider*, between the CBD and inner city suburbs such as Paddington and New Farm, and on a number of district feeder and school services operated from outlying bus interchanges, busway stations and railway stations. The 2 door 18m articulated bus with its double width front and rear doors performed nearly as well as 12.5m rigid buses for routes with 11 stops or less on a 5km route, notwithstanding that the 2 door articulated bus boarded and alighted 13 more passengers in the near same overall trip time.

  Unsurprisingly, the average service speed for all bus types falls sharply with the increasing number of bus stops on short routes, but the ratio of time taken to travel on fully loaded buses compared with a private motor vehicle increases exponentially with increased traffic speed due to the higher proportion of trip time consumed by all bus types decelerating down from and accelerating back up to a higher average traffic speed. Table 10 illustrates for example that a typical rigid bus boarded to full capacity at 10 bus stops takes around 67% longer than a private motor vehicle to complete a 5km bus journey at peak period traffic speeds of 30km/hour but around 2.12 times longer during the off-peak when average traffic speeds increase to 45km/h.

  Because short 5km routes typically operate all stops with high churn loads better suited to a 12.5m rigid bus, no high capacity buses are recommended on routes of less than 7.5km.

- 10km Route High Capacity Vehicle Performance: The performance of the 14.5m rigid bus and 2 door articulated bus becomes similar to that of a 12.5m low floor rigid bus on a 10km route with 22 or less stops during peak traffic periods for suburban route services operated substantially on local, arterial and sub-arterial roads at 30km/h, notwithstanding the additional boarding and alighting of some 17 and 13 more passengers respectively in nearly the same overall trip time.

The 14.5m and 2 door articulated bus performance drops off sharply at higher peak period traffic speeds on 10km mixed traffic motorway and highway services relative to the 12.5m rigid bus when boarded to full capacity due to the combined effects of higher boarded passenger loads and longer deceleration and acceleration times at stops. Inspection of Table 11 reveals poor performance of all HCV bus types against that of a private motor vehicle on 10km routes at motorway and highway traffic speeds of 45km/h or higher, and the 12.5m rigid bus is preferred to high capacity buses for services operated in this high speed range.

- 15km Route High Capacity Vehicle Performance: All 5 high capacity vehicles begin to perform very well against the 12.5m rigid bus on a 15km route with 22 or less stops during peak traffic periods for services operated substantially on local, arterial and sub-arterial roads at 30km/h, notwithstanding the boarding and alighting of their respectively much greater passenger loads. At the 15km route length, the 14.5m rigid bus and 2 door articulated bus will almost keep pace with a 12.5m rigid bus timetable on a 45km/h motorway or freeway route with up to 16 stops and still board to their maximum capacities. The double deck and 3 door articulated buses with their higher boarding capacities of around 40 more passengers than a 12.5m rigid bus however still perform poorly at traffic speeds of 45km/h or higher.

  No bus type, including the 12.5m rigid, could be considered truly competitive with a private motor vehicle at highway bus only transit lane speeds of 75km/h. With as few as just 5 bus stops to board or alight passengers, the HCV buses take from 1.8 to 2.2 times longer than a private motor car to complete a 15km journey and with 10 stops, HCV buses take between 2 and 2.4 times longer than a private motor car.

- 20km Route High Capacity Vehicle Performance: On 20km routes, including those with a large number of stops, all bus types spend a high proportion of their trip travelling at traffic speed and the slowing effects of passenger alighting and boarding and stop deceleration and acceleration become significantly diminished. On 20km routes, the 14.5m bus and 2 door articulated bus can board and alight passengers to maximum capacity and complete their trips in near identical time to a 12.5m bus at all traffic speeds up to 45km/h.

  At the 20km/h route length and traffic speeds of 30km/h, the double deck and 3 door articulated bus emerge to compete not only with the 12.5m rigid bus, but with the 14.5m rigid and 18m articulated buses, boarding and alighting up to 116 passengers but taking only around 9% longer to complete the same trip. At this speed, these 2 very high capacity buses also begin to seriously compete with private motor cars, taking only around 30% longer to complete a 20km trip with 16 or less stops. Their performance begins however to lag seriously behind that of the 12.5m rigid, 14.5m rigid and 2 door articulated buses on 45km/h highway and motorway bus routes but retain reasonable passenger attraction in terms of competitiveness with the private motor car and with walking or driving distances to 10 or less bus stops along the route.

- 25km Route High Capacity Vehicle Performance: On 25km long routes, all HCV bus types perform well against both the 12.5m bus and the private motor car at speeds of up to 45km/h. On 25km or longer routes with up to 32 stops, the time saving advantage gained by driving into the CBD and paying to park in lieu of taking a bus becomes considerably harder to justify from a passenger perspective when high capacity buses can complete the trip in marginally longer times of 30% or less and walking or driving times to the nearest bus stop represent less than 20% of the total trip time.

  At this route length, the 14.5m rigid and 2 door articulated bus remain highly competitive with the 12.5m bus with up to 6 stops but quickly lose passenger appeal as the number of stops increase beyond this limit and total trip times increase from 50% longer for 8 stops up to 125% longer for 32 stops.

- 30km Route High Capacity Vehicle Performance: On 30km and longer routes, all high capacity buses outperform 12.5m rigid buses at all traffic speeds up to 75km/h, and become very serious competitors with the private motor car if the number of stops along the route is kept to 10 or less.

3.5.5 HCV Performance Outlook with Reducing Average Traffic Speed

RACQ Brisbane City *Travel Time Surveys* conducted over the past 7 years indicate average inbound and outbound traffic speeds along the city's main highways and motorways and major arterials and sub-arterials have been progressively falling at an average rate of around 2.5% pa and 4.75% pa respectively. The following differential equation demonstrates that this continuing downward trend in average Brisbane city road traffic speeds favours high capacity buses more so than 12.5m rigid buses when compared with competing motor car travel speeds.

From equations (ii) and (v)...

$$s = \frac{l}{(n-1).(d+t+a)+p.(t_a+t_b)} = \frac{l}{0.5\,(n-1).(d+a)+l/v+p.(t_a+t_b)}$$

Multiplying the numerator and denominator by "v" then gives...

$$s = \frac{l.v}{\{(0.5\,(n-1).(d+a)+p.(t_a+t_b)\}.v+l}$$

Differentiating with respect to traffic speed (v) then inverting gives...

$$\frac{ds}{dv} = \frac{l^2}{[\{(0.5\,(n-1).(d+a)+p.(t_a+t_b)\}.v+l]^2} = \frac{1}{[\{(0.5\,(n-1).(d+a)+p.(t_a+t_b)\}.v/l+1]^2}$$

$$\frac{dv}{ds} = [\{(0.5\,(n-1).(d+a)+p.(t_a+t_b)\}.v/l+1]^2 = \frac{\text{Change in Bus Trip Time}}{\text{Change in Car Trip Time}} \qquad \text{.........(viii)}$$

Equation (viii) clearly indicates that falling average traffic speed (v) will provide greatest advantage to those bus types with the highest passenger capacity (p) when operating at highest traffic speed (v) on the shortest route lengths (l). Based on RACQ travel time statistics for the past 7 years, average traffic speeds on Brisbane highway, motorway, arterial and sub-arterial bus routes are expected to fall by at least a further 10% below current traffic speeds in the forthcoming 4 year period out to 2016.

Table 16 contrasts the relative percent improvement in bus trip times against private motor car travel times anticipated over the next 4 years for bus routes with an average of 16 bus stops. It will be observed from Table 16 that high capacity bus performance benefits most from falling traffic speeds on high speed short routes.

Table 16: 4 Year Outlook for Standard and High Capacity Vehicles on a 16 Stop Bus Route

Comparison of Bus and Private Motor Vehicle Travel Times for 16 Stop Bus Routes															
Route Length (km)	Two Door 12.5m Standard Rigid Bus			Two Door 12.5m Double Deck Bus			Two Door 14.5m Extended Rigid Bus			Two Door 18m Articulated Bus			Three Door 18m Articulated Superbus		
	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change	2012 Traffic Speed Ratio	2016 Traffic Speed Ratio	Percent Change
30 ==> 27 Kilometre/Hour Average Traffic Speed															
10	1.36	1.32	3%	1.66	1.59	4%	1.47	1.41	4%	1.41	1.36	4%	1.62	1.55	5%
15	1.24	1.21	2%	1.44	1.39	3%	1.31	1.28	3%	1.27	1.24	2%	1.41	1.36	3%
20	1.18	1.16	2%	1.33	1.29	3%	1.23	1.21	2%	1.20	1.18	2%	1.31	1.27	3%
25	1.14	1.13	1%	1.27	1.23	3%	1.19	1.17	2%	1.16	1.14	1%	1.25	1.22	3%
45 ==> 40.5 Kilometre/Hour Average Traffic Speed															
10	1.62	1.54	5%	2.10	1.96	7%	1.82	1.71	6%	1.72	1.63	5%	2.03	1.90	6%
15	1.41	1.36	3%	1.73	1.64	5%	1.54	1.48	4%	1.48	1.42	4%	1.68	1.60	5%
20	1.31	1.27	3%	1.55	1.48	4%	1.41	1.36	4%	1.36	1.31	3%	1.51	1.45	4%
25	1.25	1.22	3%	1.44	1.38	4%	1.33	1.29	3%	1.29	1.25	3%	1.41	1.36	3%
75 ==> 67.5 Kilometre/Hour Average Traffic Speed															
10	2.60	2.36	9%	3.48	3.13	10%	3.00	2.71	10%	2.95	2.65	10%	3.28	2.97	10%
15	2.07	1.91	8%	2.65	2.42	9%	2.34	2.14	9%	2.30	2.10	9%	2.52	2.31	8%
20	1.80	1.68	7%	2.24	2.07	8%	2.00	1.86	7%	1.97	1.82	7%	2.14	1.98	7%
25	1.64	1.54	6%	1.99	1.85	7%	1.80	1.68	6%	1.78	1.66	7%	1.91	1.79	6%

3.6 High Capacity Vehicle Dwell Time Reduction Options

3.6.1 Significance of Dwell Time to High Capacity Bus Performance

Table 15 above shows that high capacity buses perform well against conventional 12.5m rigid buses on routes of 15km or more whilst operating in typical peak period traffic conditions. While it is a useful exercise to compare the operational performance of high capacity buses with that of the standard 12.5m rigid bus, it is arguably more important to compare the performance of high capacity buses with that of the private motor vehicle with which all bus types, including 12.5m rigid buses, must compete for patronage. In this section, it will be demonstrated that bus stop dwell time plays a very significant role in high capacity bus performance and we will examine various TransLink options for reducing high capacity vehicle stop dwell times.

Table 17 below lists the total bus stop dwell time accrued by each bus type to non-concurrently board and alight passengers to maximum capacity (*p*) using front door only boarding. Each bus type is handicapped differently by its respective accrued dwell time to board and alight passengers relative to a private motor vehicle, but the handicap to all bus types increases with average traffic speed (*v*) because in a race to complete any given route length, the private motor vehicle gains increased separation distance from its rival buses proportional to the average traffic speed.

Table 17: Comparison of Full Capacity Boarding, Alighting and Dwell Times for Bus Types

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Passenger Capacity	75	116	92	88	112
Boarding Time per Passenger	2.7s	3.1s	3.1s	2.6s	3.7s
Alighting Time per Passenger	2s	2.6s	2s	1.7s	2s
Boarding Time to Fully Load	3.4 mins	6.0 mins	4.8 mins	3.8 mins	6.9 mins
Alighting Time of Fully Offload	2.5 mins	5.0 mins	3.1 mins	2.5 mins	3.7 mins
Cumulative Bus Stop Dwell Time	5.9 mins	11.0 mins	7.8 mins	6.3 mins	10.6 mins

Table 18 tabulates the average times expended by each bus type decelerating into and accelerating back out of bus stops at different average traffic speeds (v). Accrued delay spent decelerating and accelerating at bus stops further adds to the separation distance handicap between a bus and private motor vehicle.

Table 18: Comparison of Average Bus Stop Deceleration and Acceleration Times for Bus Types

Measurement Description	Two Door 12.5m Standard Rigid Bus	Two Door 12.5m Double Deck Bus	Two Door 14.5m Extended Rigid Bus	Two Door 18m Articulated Bus	Three Door 18m Articulated Superbus
Bus Stop Deceleration and Acceleration Time at 30km/h	10.3s	18.0s	12.4s	14.9s	13.4s
Bus Stop Deceleration and Acceleration Time at 45km/h	19.3s	28.7s	24.5s	26.7s	24.3s
Bus Stop Deceleration and Acceleration Time at 75km/h	55.3s	70.4s	65.7s	74.2s	60.8s

Because buses remain stationary whilst dwelling at bus stops but continue progress towards their destinations whilst decelerating into and accelerating out of bus stops, cumulative total stop dwell times cannot simply be added to total bus stop deceleration and acceleration times to measure bus performance relative to a private motor vehicle. To enable a like-for-like comparison, measured deceleration and acceleration rates for each bus type used to determine their deceleration (d) and acceleration (a) times appearing in Table 18 have been linearised using straight line numerical integration. This mathematical manipulation of the area under the speed-time curve enables total stop dwell time to be added to half the total deceleration and acceleration time to assess the combined bus stop delay exacted by any given combination of average traffic speed (v) and number of stops (n) appearing on the route. The mathematical derivation of this simple relationship is as follows:

The total dwell time (T) each bus type remains stationary to board and alight passengers non-concurrently to maximum capacity has been earlier derived at equations (iii) and (iv) as...

$$T = p\ .\ (t_a + t_b)$$

In this period, the competing private motor vehicle travels a distance (l_d) at the average traffic speed (v) given by...

$$l_d = v.T$$

Now from Figure 13, during the deceleration (d) and acceleration (a) periods based on linear (straight line) deceleration from traffic speed (v) to stop and linear acceleration back up to traffic speed (v), the distance travelled (l_{da}) by a competing motor vehicle while a bus decelerates and accelerates at all stops (n) is given by...

$$l_{da} = 0.5\ v\ (n - 1)\ .\ (a + d)$$

Therefore the contribution of total bus stop deceleration and acceleration time to total bus stop delay time (viz. dwell + deceleration + acceleration) relative to a competing private motor vehicle with no stops becomes...

$$\frac{l_{da}}{l_{da} + l_d} = \frac{0.5\ v\ (n-1)\ .\ (a+d)}{0.5\ v\ (n-1)\ .\ (a+d) + v.T} = \frac{0.5\ (n-1)\ .\ (a+d)}{0.5\ (n-1)\ .\ (a+d) + T} \quad \text{......... (ix)}$$

Calculated results based on equation (ix) have been tabulated overleaf in Table 19.

Table 19: Contribution of Bus Deceleration and Acceleration Time to Total Bus Stop Delay

	Contribution of Bus Deceleration and Acceleration Time to Total Bus Stop Delay									
	Two Door 12.5m Standard Rigid Bus		Two Door 12.5m Double Deck Bus		Two Door 14.5m Extended Rigid Bus		Two Door 18m Articulated Bus		Three Door 18m Articulated Superbus	
Dwell	5.9 mins Total		11.0 mins Total		7.8 mins Total		6.3 mins Total		10.6 mins Total	
Bus Stops Per Trip	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay	Total Stop Deceleration Acceleration Time	Percent of Total Stop Delay
30 Kilometre/Hour Average Traffic Speed										
2	0.2 min	1%	0.3 min	1%	0.2 min	1%	0.2 min	2%	0.2 min	1%
3	0.3 min	3%	0.6 min	3%	0.4 min	3%	0.5 min	4%	0.4 min	2%
4	0.5 min	4%	0.9 min	4%	0.6 min	4%	0.7 min	6%	0.7 min	3%
6	0.9 min	7%	1.5 min	6%	1.0 min	6%	1.2 min	9%	1.1 min	5%
8	1.2 min	9%	2.1 min	9%	1.4 min	8%	1.7 min	12%	1.6 min	7%
11	1.7 min	13%	3.0 min	12%	2.1 min	12%	2.5 min	16%	2.2 min	9%
16	2.6 min	18%	4.5 min	17%	3.1 min	17%	3.7 min	23%	3.3 min	14%
23	3.8 min	24%	6.6 min	23%	4.6 min	23%	5.5 min	30%	4.9 min	19%
32	5.3 min	31%	9.3 min	30%	6.4 min	29%	7.7 min	38%	6.9 min	24%
45 Kilometre/Hour Average Traffic Speed										
2	0.3 min	3%	0.5 min	2%	0.4 min	3%	0.4 min	3%	0.4 min	2%
3	0.6 min	5%	1.0 min	4%	0.8 min	5%	0.9 min	7%	0.8 min	4%
4	1.0 min	8%	1.4 min	6%	1.2 min	7%	1.3 min	10%	1.2 min	5%
6	1.6 min	12%	2.4 min	10%	2.0 min	12%	2.2 min	15%	2.0 min	9%
8	2.3 min	16%	3.3 min	13%	2.9 min	15%	3.1 min	20%	2.8 min	12%
11	3.2 min	22%	4.8 min	18%	4.1 min	21%	4.4 min	26%	4.1 min	16%
16	4.8 min	29%	7.2 min	25%	6.1 min	28%	6.7 min	35%	6.1 min	22%
23	7.1 min	38%	10.5 min	32%	9.0 min	37%	9.8 min	44%	8.9 min	30%
32	10.0 min	46%	14.8 min	40%	12.7 min	45%	13.8 min	52%	12.6 min	37%
75 Kilometre/Hour Average Traffic Speed										
2	0.9 min	7%	1.2 min	5%	1.1 min	7%	1.2 min	9%	1.0 min	5%
3	1.8 min	14%	2.3 min	10%	2.2 min	12%	2.5 min	16%	2.0 min	9%
4	2.8 min	19%	3.5 min	14%	3.3 min	17%	3.7 min	23%	3.0 min	12%
6	4.6 min	28%	5.9 min	21%	5.5 min	26%	6.2 min	33%	5.1 min	19%
8	6.5 min	35%	8.2 min	27%	7.7 min	33%	8.7 min	41%	7.1 min	25%
11	9.2 min	44%	11.7 min	35%	10.9 min	41%	12.4 min	50%	10.1 min	32%
16	13.8 min	54%	17.6 min	44%	16.4 min	51%	18.6 min	60%	15.2 min	42%
23	20.3 min	63%	25.8 min	54%	24.1 min	61%	27.2 min	68%	22.3 min	51%
32	28.6 min	71%	36.4 min	62%	33.9 min	68%	38.3 min	75%	31.4 min	60%

Table 19 presents total bus stop deceleration and acceleration times for each bus type for different bus stop counts per trip, and the percentage contributions of these periods to total stop trip delay relative to a private motor vehicle with no stops. The entries in Table 19 show clearly that while total time expended by buses decelerating and accelerating at stops may in many cases be considerably higher than total dwell time, it is total stop dwell time that dominates bus performance relative to a competing private motor car. To further highlight the dominant role bus stop dwell time plays, the green shaded entries in Table 19 map all service conditions where total dwell time accounts for more delay than twice that due to total deceleration and acceleration time.

3.6.2 All Door Boarding Dwell Time Reduction Assessment

For the majority of city route services, highest demand for maximum passenger capacity occurs during the AM inbound commuter and school peaks and PM outbound school and commuter peaks. The resultant one-way flows of either all boarding or all alighting passengers at the majority of bus stops during AM inbound peak and PM outbound peak services gives rise to the non-concurrent passenger boarding and alighting conditions earlier emulated by the *Operational Performance Evaluation Model*.

Review of netBi ticketing data has shown that average bus stop dwell times improve in the off-peak relative to peak services, even when average boarding and alighting times per passenger were known to have increased. The underlying reason for this phenomenon has been identified as the increased incidence of concurrent passenger boarding and alighting that occurs predominantly during the off-peak service periods, viz. simultaneous alighting of passengers at the rear door while boarding passengers at front door. Consider an off-peak bus service on which passengers already boarded can freely alight at bus stops without conflict to boarding passengers when exiting via the rear bus door.

Let...

c = Percent of Boarded Passengers Alighted Concurrently without Conflict to Boarding Passengers

From equations (iii) and (iv) for worst case non-concurrent boarding and alighting, total dwell time (T) was given by...

$$T = p \cdot (t_a + t_b)$$

When c% of total boarded passengers can alight concurrently without conflict to boarding passengers, the total dwell time falls to...

$$T = p \cdot t_b + p \cdot (1 - c) \cdot t_a = p \cdot \{t_b + (1 - c) \cdot t_a\} \qquad \text{......... (x)}$$

Equation (x) illustrates why off-peak high passenger churn front door only boarded services can have lower average dwell times than peak services. On inbound and outbound peak services where passenger boarding and alighting demands are essentially one-way and tending to non-concurrent operating conditions (i.e. $c = 0$), it can be readily shown that a significant reduction in average dwell time can still be achieved but only with concurrent all door passenger boarding and alighting. Equation (x) provides the foundation for assessing how all door boarding would improve high capacity bus dwell time performance. We now consider each of the bus type variants operated with front door only boarding and all door boarding.

Let...

t_f = Total Time to Complete Passenger Movements (Boarded and Alighted) through Front Door

f_b = Percent of Passengers Boarded at Front Door

t_m = Total Time to Complete Passenger Movements (Boarded and Alighted) through Middle Door

m_a = Percent of Passengers Alighted at Middle Door

t_r = Total Time to Complete Passenger Movements (Boarded and Alighted) through Rear Door

r_a = Percent of Passengers Alighted at Rear Door

Case 1: Boarding at Front Door Only
Mixed Flow Alighting at Front and Rear Doors
Double Width (2 Flow Channel) Front and Rear Doors

Case 1 represents the current situation for all TransLink bus services operated in SEQ other than the *CityGlider* and applies to all bus types studied in this report other than the low floor 12.5m rigid bus with single width rear doors and the 3 door articulated superbus. It is assumed each bus type will be loaded to its maximum capacity (p). For Case 1, two-way passenger flow clashes occur at the front door so the time to board all passengers (p) through the front door is extended by the time taken to alight any passengers who choose to exit via the front door and block one or both front door boarding channels.

The total time taken to board and alight all passengers at the front door therefore is...

$$t_f = p \cdot t_b + p \cdot t_a \cdot (1 - r_a) = p \cdot \{t_b + t_a \cdot (1 - r_a)\} \qquad \text{......... (xi)}$$

The total time taken to alight passengers without clashes at the rear door is...

$$t_r = p \cdot t_a \cdot r_a \qquad \text{......... (xii)}$$

It will be noted that for non-concurrent boarding and alighting at both doors where $r_a = 1$, equations (xi) and (xii) simplify down to the earlier derived equations (iii) and (iv) for total dwell time (T), namely...

$T = t_f + t_r = p \,.\, \{t_b + t_a \,.\, (1 - 1) + t_a\} = p \,.\, (t_a + t_b)$

For balanced concurrent boarding and alighting through the front and rear doors in equal time...

$t_f = t_r = p \,.\, \{t_b + t_a \,.\, (1 - r_a)\} = p \,.\, t_a \,.\, r_a$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = \{1 + (t_b / t_a)\} / 2$ .... (xiii)

For all bus types with double width front and rear doors, the measured ratio of average boarding time to alighting time per passenger was $1.2 < t_b / t_a < 1.67$, indicating the optimum percentage of passengers alighting at the rear door would need to be $110\% < r_a < 133\%$. Clearly the current situation is highly unbalanced and not conducive to minimum dwell time concurrent front door boarding and alighting on any two door bus type. Equation (xiii) indicates however that the next best possible choice to minimise dwell time would occur if average boarding time per passenger could be reduced and alighting of all passengers was only permitted via the rear door (i.e. by making r_a =100%).

Case 2: Mixed Flow All Door Boarding and Alighting Double Width (2 Flow Channel) Front and Rear Doors

Case 2 looks at all door boarding with mixed passenger alighting and boarding flows at both double width 2 flow channel doors. It applies to all bus types being studied other than the low floor 12.5m rigid bus with single width rear doors and 3 door articulated superbus. It is again assumed for Case 2 that each bus type will be loaded to its maximum capacity (p). With 2 boarding doors, the number of passenger boarding channels is doubled but the number of alighting channels remains unchanged from Case 1.

The time to board passengers (p) through both the front door and rear door is extended by the time taken to alight passengers who choose to exit at each respective door, blocking either one or both door boarding channels at the door accesses. The total time taken to board and alight all passengers at the front door now becomes...

$t_f = p \,.\, t_b \,.\, f_b + p \,.\, t_a \,.\, (1 - r_a) = p \,.\, \{t_b \,.\, f_b + t_a \,.\, (1 - r_a)\}$ .... (xiv)

Similarly, the total time taken to board and alight all passengers at the rear door becomes...

$t_r = p \,.\, t_b \,.(1 - f_b) + p \,.\, t_a \,.\, r_a = p \,.\, \{t_b \,.\, (1 - f_b) + t_a \,.\, r_a\}$ .... (xv)

For minimum dwell time balanced concurrent boarding and alighting through the front and rear doors in equal times...

$t_f = t_r = p \,.\, \{t_b \,.\, f_b + t_a \,.\, (1 - r_a)\} = p \,.\, \{t_b \,.\, (1 - f_b) + t_a \,.\, r_a\}$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = \{1 + (2\,f_b - 1) \,.(t_b / t_a)\} / 2$ and

$f_b = 1/2 + (2\,r_a - 1) / (2\,t_b / t_a)$ .... (xvi)

Equation (xvi) indicates that for minimum dwell balanced all door boarding and alighting, boarding counts at the front door must be matched to alighting counts at the rear door. For all bus types with double width front and rear doors, the measured ratio of average boarding time to alighting time per passenger was $1.19 < t_b / t_a < 1.67$. In this range, an infinite number of front door boarding percentages (f_b) and rear door passenger alighting percentages (r_a) exist which will satisfy equation (xvi) for minimum stop dwell time. Irrespective of average boarding and alighting times per passenger, balanced minimum dwell time on all bus types with double width rear doors will be achieved when $r_a = 0.5$, $f_b = 0.5$ and $f_b / r_a = 1$.

Case 3: Boarding at Front Door Only
Mixed Flow Alighting at Front, Middle and Rear Doors
Double Width (2 Flow Channel) Front, Middle and Rear Doors

Case 3 represents the current situation for the Clarks Logan City 3 door articulated superbus. It is again assumed this bus type will be loaded to its maximum capacity (*p*). For Case 3, two-way passenger flow clashes occur at the front door so the time to board all passengers (*p*) through the front door is extended by the time taken to alight passengers who choose to exit via the front door, thereby blocking one or both front door boarding channels.

Average boarding (t_b) and alighting (t_a) times per passenger used in Case 3 are those which have actually been measured on the 3 door articulated superbus. Review of measured passenger alighting preference split-ups listed in Table 5 for the 3 door articulated superbus indicate boarded passengers currently exit in almost equal counts through the middle and rear doors and this observation leads to the following 3 identities...

$m_a = r_a$

$m_a + r_a = 2\, r_a$

$t_m = t_r$

The total time taken to board and alight all passengers at the front door now becomes...

$$t_f = p \,.\, t_b + p \,.\, t_a \,.\, (1 - m_a - r_a) = p \,.\, \{t_b + t_a \,.\, (1 - 2\, r_a)\} \qquad \text{......... (xvii)}$$

It is noted that equation (xvii) limits $m_a = r_a <= 50\%$ as there cannot be negative alighting time. The total time taken to alight passengers concurrently at the middle and rear doors becomes...

$$t_m = t_r = p \,.\, t_a \,.\, m_a = p \,.\, t_a \,.\, r_a \qquad \text{......... (xviii)}$$

For minimum dwell time balanced boarding and alighting through the front door and concurrent alighting through both the middle and rear doors in equal time...

$$t_f = t_r = p \,.\, \{t_b + t_a \,.\, (1 - 2\, r_a)\} = p \,.\, t_a \,.\, r_a$$

Dividing both sides of the equation by "p" and rearranging gives...

$$r_a = m_a = \{1 + (t_b / t_a)\} / 3 \qquad \text{......... (xix)}$$

For the 3 door articulated superbus, the measured ratio of average boarding time to alighting time per passenger was $t_b / t_a = 1.85$, indicating the optimum percentage of passengers alighting at the middle and rear doors would need to be $m_a + r_a = 190\%$. Clearly the current situation is grossly unbalanced and not conducive to minimum dwell time concurrent front door boarding and alighting on the 3 door articulated superbus, and significantly more so than any of the double width 2 door bus types. Equation (xix) does however indicate that the next best possible choice to minimise dwell time would occur if average boarding time per passenger could be reduced and alighting of all passengers was only permitted via the middle and rear doors (i.e. making $m_a + r_a$ =100%).

Case 4: Mixed Flow All Door Boarding and Alighting
Double Width (2 Flow Channel) Front, Middle and Rear Doors

Case 4 examines all door boarding with mixed passenger alighting and boarding flows at the front, middle and rear double width 2 flow channel doors on the 3 door articulated superbus. It is again assumed for Case 4 that the bus will be loaded to its maximum capacity (*p*). With 3 boarding doors, the number of passenger boarding channels is tripled but passenger alighting channels remain unchanged from Case 3.

Average boarding (t_b) and alighting (t_a) times per passenger used in Case 4 are again those which have actually been measured on the 3 door superbus and the following 3 identities earlier cited in Case 3 again apply...

$m_a = r_a$

$m_a + r_a = 2\, r_a$

$t_m = t_r$

The time to board passengers (*p*) through the front, middle and rear doors is extended by the time taken to alight passengers who choose to exit at each respective door, blocking either one or both door boarding channels at the relevant door. The total time taken to board and alight all passengers at the front door now becomes...

$t_f = p.\, t_b \,.\, f_b + p \,.\, t_a \,.\, (1 - m_a - r_a) = p \,.\, \{t_b \,.\, f_b + t_a \,.\, (1 - 2\, r_a)\}$ .... (xx)

It is noted that equation (xx) limits $m_a = r_a <= 50\%$ as there cannot be negative alighting time. The total time taken to board and alight all passengers concurrently at the middle and rear doors becomes...

$t_m = t_r = 0.5\, p \,.\, t_b \,.(1 - f_b) + p \,.\, t_a \,.\, m_a = p \,.\, \{0.5\, t_b \,.\, (1 - f_b) + t_a \,.\, r_a\}$ .... (xxi)

For minimum dwell time balanced concurrent boarding and alighting through the front, middle and rear doors in equal time...

$t_f = t_r = p \,.\, \{t_b \,.\, f_b + t_a \,.\, (1 - 2\, r_a)\} = p \,.\, \{0.5\, t_b \,.\, (1 - f_b) + t_a \,.\, r_a\}$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = m_a = \{2 + (3\, f_b - 1) \,.(\, t_b / t_a)\} / 6 <= 50\%$ and

$f_b = 1/3 + (6\, r_a - 2) / (3\, t_b/t_a),\ r_a = m_a <= 50\%$ .... (xxii)

Equation (xxii) indicates that for minimum dwell balanced all door boarding and alighting of passengers, boarding counts at the front door must be matched with alighting counts at the middle and rear doors.

For the 3 door articulated superbus, the measured ratio of average boarding time to alighting time per passenger was $t_b / t_a = 1.85$. An infinite number of front door boarding percentages (f_b) and middle (m_a) and rear (r_a) door passenger alighting percentages exist which will satisfy equation (xxii) for minimum stop dwell time. Irrespective of average boarding and alighting times per passenger, balanced minimum dwell time on the 3 door articulated superbus will be achieved when $r_a = m_a = 1/3,\ f_b = 2/3$ and $f_b / r_a = f_b / m_a = 2$.

Case 5: Boarding at Front Door Only
Double Width (2 Flow Channel) Front Door
Mixed Flow Alighting at Front and Rear Doors
Single Width (1 Flow Channel) Rear Door

Case 5 represents the current situation for most new ultralow floor 12.5m rigid buses now operated in SEQ. Whilst not a high capacity vehicle per se, Case 5 identifies the impact of single width rear doors on average stop dwell times and enables comparison of contemporary ultralow floor 12.5m rigid buses with similar size buses incorporating double width rear doors. It is again assumed that the 12.5m rigid bus will be loaded to its maximum capacity (*p*). For Case 5, two-way passenger flow clashes will occur at the front door so the time to board all passengers (*p*) through the front door will be extended by the time taken to alight passengers who choose to exit via the front door.

Average boarding (t_b) and alighting (t_a) times per passenger used in Case 5 are those which have actually been measured on the 12.5m rigid bus. Reference to Table 5 indicates that approximately 70% of Brisbane Transport low floor 12.5m rigid *CityBus* and *CityGlider* passengers currently alight at the rear door. Because the front door has 2 boarding and alighting channels and the rear door has only one alighting channel, different average alighting times per passenger apply at each door...

Let...
t_{af} = *Average Alighting Time per Passenger at Front Door*
t_{ar} = *Average Alighting Time per Passenger at Rear Door*

$t_{ar} = 2\, t_{af}$

Now if "p" passengers are alighted through both the front and rear doors, they split in the relative proportions of 30% front door alightings to 70% rear door alightings giving...

$p \,.\, t_a \;=\; 0.3\, p \,.\, t_{af} + 0.7\, p \,.\, t_{ar}$

$t_a = \; 0.3\, t_{af} + 1.4\, t_{af} \; = 1.7\, t_{af}$

$t_{af} = t_a / 1.7$

$t_{ar} = t_a / 0.85$

The total time taken to board and alight all passengers at the front door becomes...

$t_f = p \,.\, t_b \,+\, p \,.\, t_{af} \,.\, (1 - r_a) = p \,.\, \{t_b \,+\, t_a \,.\, (1 - r_a) / 1.7\}$ .... (xxiii)

The total time taken to alight passengers without clashes at the rear door becomes...

$t_r = p \,.\, t_{ar} \,.\, r_a = p \,.\, t_a \,.\, r_a / 0.85$ .... (xxiv)

For balanced concurrent boarding and alighting through the front and rear doors in equal time...

$t_f = t_r = p \,.\, \{t_b \,+\, t_a \,.\, (1 - r_a) / 1.7\} = \, p \,.\, t_a \,.\, r_a / 0.85$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = \{1 + 1.7\, (t_b / t_a)\} / 3$ .... (xxv)

For the low floor 12.5m rigid bus, the measured ratio of average boarding time to alighting time per passenger was $t_b / t_a = 1.35$, indicating the optimum percentage of passengers alighting at the rear door would need to be $r_a = 110\%$. Clearly the current situation is unbalanced and not conducive to minimum dwell time concurrent front door boarding and alighting on the standard 12.5m rigid bus. Equation (xxv) does however indicate that the next best possible choice to minimise dwell time would occur if average boarding time per passenger could be reduced and alighting of all passengers was only permitted via the rear door (i.e. by making r_a =100%).

Case 6: Mixed Flow All Door Boarding and Alighting
Double Width (2 Flow Channel) Front Door
Single Width (1 Flow Channel) Rear Door

Case 6 examines all door boarding with mixed passenger alighting and boarding flows at the double width two channel front door and single width single channel rear door on the standard 12.5m rigid bus. It is again assumed for Case 6 that the bus will be loaded to maximum capacity (*p*). With 2 boarding doors, the number of passenger boarding channels is increased by 150%, but passenger alighting channels remain unchanged from Case 5.

Average boarding (t_b) and alighting (t_a) times per passenger used in Case 6 are those which have actually been measured on the 12.5m rigid bus. Because the front door has 2 boarding and alighting channels and the rear door has only one boarding and alighting channel, different average alighting and boarding times per passenger will apply at each door. From Case 5...

$t_{af} = t_a / 1.7$

$t_{ar} = t_a / 0.85$

Let...

t_{bf} = *Average Boarding Time per Passenger at Front Door*

t_{br} = *Average Boarding Time per Passenger at Rear Door*

$t_{br} = 2\ t_{bf}$

Now the average boarding time per passenger at the front door is identical to the measured average boarding time per passenger so...

$t_{bf} = t_b$

$t_{br} = 2\ t_b$

The time taken to board passengers (*p*) through both the front door and rear door is extended by the time taken to alight passengers who choose to exit at each respective door. The total time taken to board and alight all passengers at the front door becomes...

$t_f = p\ .\ t_{bf}\ .\ f_b\ +\ p\ .\ t_{af}\ .\ (1 - r_a) = p\ .\ \{t_b\ .\ f_b\ +\ t_a\ .\ (1 - r_a) / 1.7\}$ .... (xxvi)

Similarly, the total time taken to board and alight all passengers at the rear door becomes...

$t_r = p\ .\ t_{br}\ .(1 - f_b)\ +\ p\ .\ t_{ar}\ .\ r_a = p\ .\ \{2\ t_b\ .\ (1 - f_b) + t_a\ .\ r_a / 0.85\}$ .... (xxvii)

For minimum dwell time balanced concurrent boarding and alighting through the front and rear doors in equal times...

$t_f\ =\ t_r\ =\ p\ .\ \{t_b\ .\ f_b\ +\ t_a\ .\ (1 - r_a) / 1.7\}\ =\ p\ .\ \{2\ t_b\ .\ (1 - f_b) + t_a\ .\ r_a / 0.85\}$

Dividing both sides of the equation by "p" and rearranging gives...

$r_a = \{1 + (5.1\ f_b - 3.4)\ .(\ t_b / t_a)\} / 3$ and

$f_b\ =\ 2/3 + (3\ r_a - 1) / (5.1\ t_b/t_a)$ .... (xxviii)

Equation (xxviii) indicates that for minimum dwell balanced all door boarding and alighting of passengers, boarding counts at the front door must be matched with alighting counts at the rear door. For the 12.5m rigid bus, the measured ratio of average boarding time to alighting time per passenger was $t_b / t_a = 1.35$. An infinite number of front door boarding percentages (f_b) and rear door passenger alighting percentages (r_a) exist which will satisfy equation (xxviii) for minimum stop dwell time. Irrespective of average boarding and alighting times per passenger, balanced minimum dwell time on all bus types with single width rear doors will be achieved when $r_a = 1/3$, $f_b = 2/3$ and $f_b / r_a = 2$.

3.6.3 All Door Boarding Analysis Results

Table 20 below presents the anticipated reduction in peak period dwell time for each bus type if all door boarding was to be implemented by TransLink. Measured average boarding and alighting times and passenger alighting preferences have been applied to each bus type using equation (xvi) for the 3 bus types with double width front and rear doors, equation (xxii) for the 3 door articulated bus, and equation (xxviii) for the standard 12.5m rigid ultralow floor bus.

The third and fourth rows appearing in Table 20 compare total trip dwell times for current front door only boarding with those expected if passenger alightings and boardings at front doors were completed concurrently and in equal time with passenger alightings and boardings at rear doors (or middle and rear doors in the case of the articulated superbus). Total trip dwell times shown in Table 20 assume all bus types are fully loaded to their respective maximum capacities during peak periods.

Table 20: Estimated Peak Period Balanced All Door Boarding Stop Dwell Times

Peak Period Balanced All Door Boarding Bus Stop Dwell Times										
Total Trip Dwell Time	Two Door 12.5m Standard Rigid Bus		Two Door 12.5m Double Deck Bus		Two Door 14.5m Extended Rigid Bus		Two Door 18m Articulated Bus		Three Door 18m Articulated Superbus	
Current Front Door Boarding	5.9 mins		11.0 mins		7.8 mins		6.3 mins		10.6 mins	
Balanced All Door Boarding	3.2 mins		5.5 mins		3.9 mins		3.2 mins		3.5 mins	
Percent of Passengers Who Choose to Alight at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 69% of Passengers Alighting at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 53% of Passengers Alighting at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 81% of Passengers Alighting at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 47% of Passengers Alighting at Rear Door	Balanced Percent of Passengers Needed to Board at Front Door	All Door Boarding Dwell Time with 43% of Passengers Alighting at Middle and Rear Doors
0%	52%	5.3 mins	8%	8.2 mins	18%	6.4 mins	17%	4.3 mins	0%	5.2 mins
5%	54%	5.1 mins	12%	7.9 mins	21%	6.2 mins	21%	4.2 mins	3%	5.0 mins
10%	56%	5.0 mins	16%	7.7 mins	24%	6.1 mins	24%	4.1 mins	8%	4.8 mins
15%	59%	4.8 mins	21%	7.4 mins	27%	5.9 mins	27%	4.0 mins	14%	4.6 mins
20%	61%	4.7 mins	25%	7.2 mins	31%	5.8 mins	30%	3.8 mins	19%	4.4 mins
25%	63%	4.5 mins	29%	6.9 mins	34%	5.6 mins	34%	3.7 mins	24%	4.2 mins
30%	65%	4.4 mins	33%	6.7 mins	37%	5.5 mins	37%	3.6 mins	30%	4.0 mins
35%	67%	4.2 mins	37%	6.4 mins	40%	5.3 mins	40%	3.5 mins	35%	3.8 mins
40%	70%	4.1 mins	42%	6.2 mins	44%	5.2 mins	43%	3.3 mins	41%	3.7 mins
45%	72%	3.9 mins	46%	5.9 mins	47%	5.0 mins	47%	3.2 mins	46%	3.7 mins
50%	74%	3.8 mins	50%	5.7 mins	50%	4.9 mins	50%	3.2 mins	51%	4.1 mins
55%	76%	3.6 mins	54%	5.6 mins	53%	4.7 mins	53%	3.4 mins		
60%	78%	3.5 mins	58%	5.9 mins	56%	4.6 mins	57%	3.5 mins		
65%	80%	3.3 mins	63%	6.1 mins	60%	4.4 mins	60%	3.6 mins		
70%	83%	3.2 mins	67%	6.4 mins	63%	4.2 mins	63%	3.7 mins		
75%	85%	3.3 mins	71%	6.6 mins	66%	4.1 mins	66%	3.9 mins		
80%	87%	3.4 mins	75%	6.9 mins	69%	3.9 mins	70%	4.0 mins		
85%	89%	3.5 mins	79%	7.1 mins	73%	4.0 mins	73%	4.1 mins		
90%	91%	3.5 mins	84%	7.4 mins	76%	4.2 mins	76%	4.2 mins		
95%	94%	3.6 mins	88%	7.6 mins	79%	4.3 mins	79%	4.4 mins		
100%	96%	3.7 mins	92%	7.9 mins	82%	4.5 mins	83%	4.5 mins		

The percentage of passengers needed to board at the front door (f_b) to exactly balance delays caused by the percentage (r_a) of passengers who elect to alight at the rear door appears in the first column of Table 20 under each bus type. In the case of the 3 door articulated superbus, passenger alighting percentages have been assumed equal at the middle and rear doors based on measured passenger door alighting preferences, and therefore maximum alighting at the middle and rear door are limited to 50%.

Table 21: Comparison of Articulated Bus Front and All Door Boarding Performance on 5km Route

Comparison of Articulated Bus Performance on 5 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Boarding		All Door Boarding		Front Door Boarding		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	18	1.64	23	1.33	14	2.08	18	1.71
3	18	1.66	22	1.34	14	2.09	17	1.72
4	18	1.67	22	1.36	14	2.10	17	1.73
6	18	1.69	22	1.38	14	2.12	17	1.76
8	17	1.72	21	1.41	14	2.14	17	1.78
11	17	1.75	21	1.44	14	2.18	17	1.81
16	17	1.82	20	1.51	13	2.23	16	1.87
23	16	1.90	19	1.59	13	2.31	15	1.94
32	15	2.02	18	1.70	12	2.41	15	2.04
45 Kilometre/Hour Average Traffic Speed								
2	23	1.98	30	1.51	17	2.63	22	2.08
3	22	2.01	29	1.55	17	2.66	21	2.11
4	22	2.05	28	1.58	17	2.69	21	2.14
6	21	2.11	27	1.65	16	2.75	20	2.20
8	21	2.18	26	1.71	16	2.81	20	2.26
11	20	2.28	25	1.81	16	2.90	19	2.35
16	18	2.45	23	1.98	15	3.05	18	2.51
23	17	2.68	20	2.21	14	3.26	17	2.72
75 Kilometre/Hour Average Traffic Speed								
2	27	2.73	38	1.95	20	3.79	26	2.88
3	26	2.89	36	2.11	19	3.91	25	3.00
4	25	3.04	33	2.26	19	4.04	24	3.13
6	22	3.35	29	2.57	17	4.29	22	3.38

Table 22: Comparison of Articulated Bus Front and All Door Boarding Performance on 10km Route

Comparison of Articulated Bus Performance on 10 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Only		All Door Boarding		Front Door Only		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	23	1.32	26	1.17	20	1.54	22	1.36
3	23	1.33	26	1.17	19	1.54	22	1.36
4	22	1.33	25	1.18	19	1.55	22	1.37
6	22	1.35	25	1.19	19	1.56	22	1.38
8	22	1.36	25	1.20	19	1.57	22	1.39
11	22	1.38	25	1.22	19	1.59	21	1.41
16	21	1.41	24	1.25	19	1.62	21	1.43
23	21	1.45	23	1.30	18	1.65	20	1.47
32	20	1.51	22	1.35	18	1.70	20	1.52
45 Kilometre/Hour Average Traffic Speed								
2	31	1.49	36	1.26	25	1.81	29	1.54
3	30	1.51	35	1.27	25	1.83	29	1.56
4	30	1.52	35	1.29	24	1.84	29	1.57
6	29	1.56	34	1.32	24	1.87	28	1.60
8	28	1.59	33	1.36	24	1.90	28	1.63
11	27	1.64	32	1.41	23	1.95	27	1.68
16	26	1.72	30	1.49	22	2.03	26	1.75
23	24	1.84	28	1.61	21	2.13	24	1.86
32	23	1.99	26	1.76	20	2.27	23	2.00
75 Kilometre/Hour Average Traffic Speed								
2	40	1.87	51	1.48	31	2.39	39	1.94
3	39	1.94	48	1.55	31	2.46	37	2.00
4	37	2.02	46	1.63	30	2.52	36	2.06
6	34	2.17	42	1.79	28	2.65	34	2.19
8	32	2.33	39	1.94	27	2.77	32	2.32
11	29	2.56	35	2.17	25	2.96	30	2.51

Table 23: Comparison of Articulated Bus Front and All Door Boarding Performance on 15km Route

Comparison of Articulated Bus Performance on 15 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Only		All Door Boarding		Front Door Only		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	25	1.21	27	1.11	22	1.36	24	1.24
3	25	1.22	27	1.11	22	1.36	24	1.24
4	25	1.22	27	1.12	22	1.37	24	1.24
6	24	1.23	27	1.13	22	1.37	24	1.25
8	24	1.24	26	1.14	22	1.38	24	1.26
11	24	1.25	26	1.15	22	1.39	24	1.27
16	24	1.27	26	1.17	21	1.41	23	1.29
23	23	1.30	25	1.20	21	1.44	23	1.31
32	22	1.34	24	1.23	20	1.47	22	1.35
45 Kilometre/Hour Average Traffic Speed								
2	34	1.33	38	1.17	29	1.54	33	1.36
3	34	1.34	38	1.18	29	1.55	33	1.37
4	33	1.35	38	1.19	29	1.56	33	1.38
6	33	1.37	37	1.22	28	1.58	32	1.40
8	32	1.39	36	1.24	28	1.60	32	1.42
11	32	1.43	35	1.27	28	1.63	31	1.45
16	31	1.48	34	1.33	27	1.68	30	1.50
23	29	1.56	32	1.40	26	1.75	29	1.57
32	27	1.66	31	1.50	24	1.85	27	1.66
75 Kilometre/Hour Average Traffic Speed								
2	48	1.58	57	1.32	39	1.93	46	1.63
3	46	1.63	55	1.37	38	1.97	45	1.67
4	45	1.68	53	1.42	37	2.01	44	1.71
6	42	1.78	49	1.52	36	2.10	42	1.79
8	40	1.89	46	1.63	34	2.18	40	1.88
11	37	2.04	42	1.78	32	2.31	37	2.01
16	33	2.30	37	2.04	30	2.52	34	2.22

Table 24: Comparison of Articulated Bus Front and All Door Boarding Performance on 20km Route

Comparison of Articulated Bus Performance on 20 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Only		All Door Boarding		Front Door Only		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	26	1.16	28	1.08	24	1.27	25	1.18
3	26	1.16	28	1.09	24	1.27	25	1.18
4	26	1.17	28	1.09	24	1.27	25	1.18
6	26	1.17	27	1.10	23	1.28	25	1.19
8	25	1.18	27	1.10	23	1.29	25	1.19
11	25	1.19	27	1.11	23	1.29	25	1.20
16	25	1.20	27	1.13	23	1.31	25	1.22
23	24	1.23	26	1.15	23	1.33	24	1.24
32	24	1.25	26	1.18	22	1.35	24	1.26
45 Kilometre/Hour Average Traffic Speed								
2	36	1.24	40	1.13	32	1.41	35	1.27
3	36	1.25	40	1.14	32	1.41	35	1.28
4	36	1.26	39	1.15	32	1.42	35	1.29
6	35	1.28	39	1.16	31	1.44	35	1.30
8	35	1.29	38	1.18	31	1.45	34	1.32
11	35	1.32	37	1.20	31	1.47	34	1.34
16	33	1.36	36	1.25	30	1.51	33	1.38
23	32	1.42	35	1.30	29	1.57	31	1.43
32	30	1.50	33	1.38	28	1.63	30	1.50
75 Kilometre/Hour Average Traffic Speed								
2	52	1.43	61	1.24	44	1.70	51	1.47
3	51	1.47	59	1.28	43	1.73	50	1.50
4	50	1.51	57	1.32	43	1.76	49	1.53
6	47	1.59	54	1.39	41	1.82	47	1.60
8	45	1.66	51	1.47	40	1.89	45	1.66
11	42	1.78	47	1.59	38	1.98	43	1.75
16	38	1.97	42	1.78	35	2.14	39	1.91
23	33	2.24	37	2.05	32	2.36	35	2.13

Table 25: Comparison of Articulated Bus Front and All Door Boarding Performance on 25km Route

Comparison of Articulated Bus Performance on 25 Kilometre Bus Route								
Bus Stops Per Trip	Two Door 18m Articulated Bus				Three Door 18m Articulated Superbus			
	Front Door Only		All Door Boarding		Front Door Only		All Door Boarding	
	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio	Ave Speed (km/h)	Traffic Speed Ratio
30 Kilometre/Hour Average Traffic Speed								
2	27	1.13	28	1.07	25	1.22	26	1.14
3	27	1.13	28	1.07	25	1.22	26	1.14
4	26	1.13	28	1.07	25	1.22	26	1.15
6	26	1.14	28	1.08	25	1.22	26	1.15
8	26	1.14	28	1.08	24	1.23	26	1.16
11	26	1.15	28	1.09	24	1.24	26	1.16
16	26	1.16	27	1.10	24	1.25	26	1.17
23	25	1.18	27	1.12	24	1.26	25	1.19
32	25	1.20	26	1.14	23	1.28	25	1.21
45 Kilometre/Hour Average Traffic Speed								
2	38	1.20	41	1.10	34	1.33	37	1.22
3	37	1.20	41	1.11	34	1.33	37	1.22
4	37	1.21	40	1.12	34	1.34	37	1.23
6	37	1.22	40	1.13	33	1.35	36	1.24
8	36	1.24	39	1.14	33	1.36	36	1.25
11	36	1.26	39	1.16	33	1.38	35	1.27
16	35	1.29	38	1.20	32	1.41	35	1.30
23	34	1.34	36	1.24	31	1.45	33	1.34
32	32	1.40	35	1.30	30	1.51	32	1.40
75 Kilometre/Hour Average Traffic Speed								
2	56	1.35	63	1.19	48	1.56	55	1.38
3	54	1.38	61	1.22	47	1.58	54	1.40
4	53	1.41	60	1.25	47	1.61	53	1.43
6	51	1.47	57	1.31	45	1.66	51	1.48
8	49	1.53	54	1.38	44	1.71	49	1.53
11	46	1.62	51	1.47	42	1.79	47	1.60
16	42	1.78	46	1.62	39	1.91	43	1.73
23	38	2.00	41	1.84	36	2.09	39	1.91
32	33	2.27	35	2.12	32	2.32	35	2.13

The second column appearing under each bus type in Table 20 shows the impact on its total trip dwell time if the percent of passengers needed to board at the front door is mismatched to the percent of passengers who currently prefer to alight at the rear door. The red shaded bands in the first and second columns under each bus type indicate where total trip dwell time is minimised and the percent of passengers boarded at the front door is balanced with the percent of passengers who currently prefer to alight at the rear door.

Table 21 through Table 25 inclusive compare the operational performances of the 2 door articulated bus and 3 door articulated superbus with front only and all door boarding on route lengths of 5km to 25km. The all door boarding results in Table 21 through Table 25 are based on minimum dwell times for ideally balanced concurrent boarding and alighting shown in Table 20 for the two articulated bus types, and therefore represent the most optimistic performance that could be expected.

3.6.4 Key Findings

- Table 20 demonstrates that all door boarding, if implemented with appropriate passenger boarding and alighting guidelines, could potentially cut total stop dwell times by a factor of as much as 2 for high capacity buses with double width rear doors, and as much as a factor of 3 for the articulated superbus with double width middle and rear doors. The dwell time benefit of all door boarding on standard low floor 12.5m buses drops lower to around a factor of 1.8 due to their narrow single width rear doors.
- The Case 2, 4 and 6 analyses has further demonstrated that the higher the bus carrying capacity, the greater its net dwell time reduction during the peaks when boarding and alighting flows essentially become unidirectional with non-conflicting door flow channels.

- The hidden catch with all door boarding is that minimum stop dwell time can only be achieved by matching the percentage of passengers who board at the front door of each bus type to the percentage of passengers who choose to alight from the rear door (or middle and rear doors), so that boarding and alighting times through every door are balanced (i.e. completed concurrently in equal time). Balancing of alighting passenger flows via specific doors can be induced through careful positioning of rear door(s) in relation to passenger seat and standing areas to influence passenger alighting preferences, and is discussed further in Section 3.6.5.

  If unbalanced, a bus must continue to dwell at each stop for the longest time taken to board and alight passengers at the door with the longest boarding and alighting queue. The first column under each bus type in Table 20 shows the corresponding front door boarding passenger percentages needed to precisely balance the alighting preferences of onboard passengers to achieve minimum dwell time. The second column under each bus type shows how boarding percentage mismatching at the front door impacts dwell time if onboard passenger alighting door preferences were to be sustained as at present.

  Based on current passenger rear door alighting preferences, the percentage of passenger boardings needed to balance out their exits via the front and rear doors would be:

  - 2 Door 12.5m Rigid Bus: 81% Front, 19% Rear
  - 2 Door 12.5m Double Deck Bus: 53% Front, 47% Rear
  - 2 Door 14.5m Rigid Bus: 70% Front, 30% Rear
  - 2 Door 18m Articulated Bus: 48% Front, 52% Rear
  - 3 Door 18m Articulated Superbus: 44% Front, 28% Middle, 28% Rear.

- The variation in average boarding and alighting times per passenger, door counts and door channels applicable to the 5 different bus types make it difficult to specify a single boarding and alighting policy to minimise dwell time for all door boarding.

  Review of Case 2 equation (xvi), Case 4 equation (xxii) and Case 6 equation (xxvii) shows however that each bus type has a unique front door boarding to rear door alighting percentage ratio (f_b / r_a) which is completely independent of bus specific average boarding and alighting times per passenger. The applicable ratios translate to:

  - 2 Door 12.5m Rigid Bus: 2/3 Front Boarding, 1/3 Rear Boarding
2/3 Front Alighting, 1/3 Rear Alighting
  - 2 Door 12.5m Double Deck Bus: 50% Front Boarding, 50% Rear Boarding
50% Front Alighting, 50% Rear Alighting
  - 2 Door 14.5m Rigid Bus: 50% Front Boarding, 50% Rear Boarding
50% Front Alighting, 50% Rear Alighting
  - 2 Door 18m Articulated Bus: 50% Front Boarding, 50% Rear Boarding
50% Front Alighting, 50% Rear Alighting
  - 3 Door 18m Artic Superbus: 1/3 Front Boarding, 1/3 Middle & 1/3 Rear Boarding
1/3 Front Alighting, 1/3 Middle & 1/3 Rear Alighting

  These ideal ratios for each bus type can be readily recognised as the ratios of their respective door flow channel counts. The appropriate policy to obtain near minimum dwell times at stops would be one which encourages bus operators to install double width doors on all buses, passengers to board and alight equally through all doors, and is supported by an advertising campaign prior to roll out to explain boarding door and queuing procedures to passengers.

- Table 20 indicates that irrespective of which doors onboard passengers elect to alight from, all door boarding will still significantly reduce stop dwell times. Current passenger rear door alighting preferences are already close to ideal for balanced all door boarding on the double deck and 2 door articulated buses, but considerably too high at rear doors on the other 3 bus types.

- Tables 21 to 25 summarise the extraordinary benefits of all door boarding to high capacity bus operational performance during peak periods. The common advantage to all high capacity bus types is significantly improved performance relative to a standard 12.5m rigid bus on all route lengths of 10km and longer at peak period traffic speeds of 45km/h or less, and for bus types other than the double deck bus, on route lengths 20km and longer at traffic speeds up to 75km/h.

  All door boarding has been found to favour the performance of the 3 door very high boarding capacity articulated superbus more than the 2 door articulated and 14.5m rigid lower boarding capacity buses. Albeit improved by all door boarding, the ranking of the double deck and 12.5m rigid bus performances slips relative to the other 3 high capacity buses because of the single channel alighting flow from the upper deck to the rear door on the former, and the single channel alighting and boarding flows through the narrow rear door on the latter. This has resulted in the changed rankings of all bus types appearing below in Table 26 compared to those in Table 15 for front door only boarding.

Table 26: Ranking of Bus Types with All Door Boarding

Route Length	Routes Operated at 30km/h	Routes Operated at 45km/h	Routes Operated at 75km/h
	Mixed Traffic on Local, Arterial and Sub-Arterial Roads during Peak Period	Mixed Traffic on CBD Radial Highway or Motorway during Peak Period OR Off-Peak in Mixed Traffic on Local, Arterial and Sub-Arterial Roads	City Ring Road, Busway or Highway Bus Transit Lane during Peak Period OR Off-Peak in Mixed Traffic on a CBD Highway or Motorway
5km	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only	1 : 2 Door 12.5m Rigid Only
10km	1 : 2 Door 18m Artic 1 : 2 Door 14.5m Rigid 2 : 3 Door 18m Artic (Note 2) 2 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 3) 1 : 2 Door 14.5m Rigid (Note 3) 2 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
15km	1 : 3 Door 18m Artic 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic 1 : 2 Door 14.5m Rigid 2 : 3 Door 18m Artic (Note 3) 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 2 Door 12.5m Rigid Only
20km	1 : 3 Door 18m Artic 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door Double Deck 4 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 4) 1 : 2 Door 14.5m Rigid (Note 4) 2 : 3 Door 18m Artic (Note 5) 3 : 2 Door 12.5m Rigid
25km	1 : 3 Door 18m Artic 2 : 2 Door Double Deck 3 : 2 Door 18m Artic 4 : 2 Door 14.5m Rigid 5 : 2 Door 12.5m Rigid	1 : 3 Door 18m Artic 1 : 2 Door Double Deck 2 : 2 Door 18m Artic 2 : 2 Door 14.5m Rigid 3 : 2 Door 12.5m Rigid	1 : 2 Door 18m Artic (Note 1) 1 : 2 Door 14.5m Rigid (Note 1) 2 : 3 Door 18m Artic (Note 5) 3 : 2 Door 12.5m Rigid

Note 1: Up to a Limit of 10 Boarding/Alighting Stops
Note 2: Up to a Limit of 20 Boarding/Alighting Stops
Note 3: Up to a Limit of 15 Boarding/Alighting Stops
Note 4: Up to a Limit of 8 Boarding/Alighting Stops
Note 5: Up to a Limit of 5 Boarding/Alighting Stops

- The most important benefit yielded through all door boarding is the significantly improved average traffic to service speed ratio afforded to high capacity bus services, making them much more competitive with a private motor vehicle on peak period inner suburban routes of 10km or more operated along major arterial, sub-arterial and local roads, and outer suburban and regional routes of 15km or more operated along highways, motorways, arterial, sub-arterial and local roads. Tables 21 to 25 indicate that with 20 or less stops, the lower capacity 2 door articulated and 14.5m rigid buses can complete their routes within less than a 25% - 40% longer journey time than a private motor car; and with 16 or less stops, the higher capacity 3 door articulated bus can complete its routes within less than a 30% - 50% longer journey time.

3.6.5 Cabin Rear Door and Seating Configuration

When bus cabin seating and standing area layouts were compared with the measured preferences of passengers to alight from the front, middle and rear doors earlier listed in Table 5, the reason for such (earlier cited amongst the key findings in Section 3.2.3) was that seated and standing passengers in the main simply chose to disembark via the nearest available door and had no personal habits or inclinations to head for any particular door to exit.

Up until the point where all passenger seats have filled, the cabin seating layout dictates the percentage of passengers who will choose to exit from the rear door. After all seats become fully occupied, observations have shown standees fill the aisle way from the front door to the rear door of the cabin as the number of standees progressively increase, but do not begin to spill over into the vacant aisle space behind the rear door until the forward aisle way and wheelchair parking areas have packed because of the low head clearance and ramped aisle way aft of the rear door. Standing has the effect of increasing the front door alighting percentage and reducing the percentage of rear door alighting in full highly crammed buses, but this effect is moderated by the large proportion of seated passengers to the aft of the rear door who disembark almost exclusively via the rear door.

It has been demonstrated by the equations earlier developed for Cases 1, 3 and 5 that minimum dwell time occurs for front door only boarding on all bus types when 100% of onboard passengers alight through the rear door (or middle and rear doors) other than when no passengers are boarding, in which case minimum dwell time occurs at each stop when onboard passengers alight evenly through all available door channels. One-way passenger boarding and passenger alighting flows occur during the peaks, so dwell times can only really be improved on outbound services by rear door and seating configurations which promote greater rear door alighting.

It has been demonstrated that all door boarding would, if implemented, significantly cut dwell times on all bus types, most particularly the 4 high capacity bus types. The balanced concurrent boarding equations developed for Cases 2, 4 and 6 also show that minimum dwell time occurs when all available door channels are used evenly and equally for both boarding and alighting passengers during the peaks. The following modifications to current bus rear door and seating configurations would influence passenger alighting choices to minimise total stop dwell time for all door boarding:

- 2 Door 12.5m Rigid Bus: The preferred modification to the rear door on the 12.5m rigid bus would be to shift it aftward by one seat row and widen it to a full width two channel door. This would equalise the midpoint seated and standing distances from the front and rear doors and balance passenger alighting and boarding similarly to other two door high capacity buses.
- 2 Door 12.5m Double Deck Bus: Full seated loads were never approached on this bus type while it was operating on the Redcliffe 315 service, and average boarding and alighting times could not therefore be accurately measured at anywhere near maximum boarded capacity.

Passengers on the 315 route service were observed to split evenly to available seating on the upper and lower decks until all seats were filled on the latter, but alighted disproportionally through the rear door from the upper and lower deck because seats on the latter are concentrated to the aft of the rear door.

At maximum capacity, passenger loads would tend to equalise on both decks of the double deck bus because no passengers can stand on the upper deck due to its low head clearance. The average alighting time per passenger from the upper deck is also double that for passengers on the lower deck due to the single flow channel upper deck stairway.

The optimum solution for the double deck bus would be to turn the upper deck staircase 180° at its current lower deck landing to encourage all alighting passengers from the upper deck to exit via the front door, leaving most passengers on the lower deck to exit via the rear door. If a second stairway was also introduced on the nearside of the double deck bus and the wheelchair parking bays placed on both sides of the lower deck, the double deck bus could maintain most of its existing high seating capacity with the loss of as few as 6 seat positions, balance its alighting and boarding times at both doors, and halve its average peak period bus stop dwell time.

- 2 Door 14.5m Rigid Bus: All but 8 passenger seats and most of the available aisle standing space on the current Brisbane Transport 14.5m rigid bus are located closer to the rear door than the front door, explaining why 81% of passengers on this bus head straight for the rear door when alighting.

  Current State and future national heavy vehicle maximum rear axle load, rear overhang and wheelbase length regulations prevent the 14.5m rigid bus rear tandem axle from being relocated further to the aft, but sufficient room exists to relocate the rear door closer to the rear wheel arches, and an additional 6 to 8 seats placed forward of the rear door to encourage more passengers to alight via the front door. This would provide a better, though not fully balanced configuration for minimising dwell times for both future all door boarding and existing front door only boarding and is analysed further in the next section.

- 2 Door 18m Articulated Bus: The physical requirement to begin ramping the aisle way immediately to the aft of the rear door prevents the rear door on both the Clarks Logan City and Brisbane Transport 2 door articulated buses from being relocated an additional seat pitch further aftward to obtain the ideal 50%:50% split needed for fully seated all door boarding, but current rear door and seating locations are near ideally split for fully seated plus standing passenger capacity. The 2 door articulated buses already enjoy measured rear door alighting percentages of between 45% and 48%, which would guarantee near balanced passenger boarding and alighting at both doors if all door boarding was to be implemented.

- 3 Door 18m Articulated Superbus: The current middle door, rear door, seating and standing area configurations encourage 86% of passengers to alight via the middle and rear doors which is well suited to front door only boarding. A need exists however to encourage 20% higher alighting at the front door for minimum dwell all door boarding. Should this policy be adopted in future, it would be preferable to relocate both the middle and rear doors further to the aft by one seat pitch. The physical requirement to begin ramping the aisle way immediately to the aft of the rear door prevents the rear door from being relocated an additional seat pitch further afterward, but the middle door could be relocated aftward by one seat pitch to reduce the mid section seated and standing capacity, and shift an additional 4 seats closer to the front door. This does not provide the ideal passenger splits for all door boarding, but moves them close enough to obtain near ideal passenger distributions under maximum seated and standing load conditions.

3.6.6 Passenger Circulation and Rear Door Storage

Boarding passenger flow through any bus door is constrained to the maximum rate at which already boarded upstream passengers can freely flow into and along bus aisle ways leading off door accesses. Additionally, alighting passengers need to be able to freely overtake other non-alighting standees in aisle ways and boarding passengers both in aisle ways and in door access channels, especially if all door boarding was to be implemented.

A common practice employed on fast turnaround, high churn, high capacity BRT bus services in many overseas cities is to announce the next bus stop name using visual next stop cue signs and audible public address messages with verbal prompts for passengers to begin moving to doors in advance of bus stop arrival. This practice, already commonplace on Queensland Rail train services, has the highly desirable effect of initiating passenger alighting movements during the vehicle's otherwise wasted deceleration period. Unlike rail cars however, buses have narrow aisle ways which obstruct alighting passenger movements to doors on buses with high standee loads, and most alighting passengers need to tag off *go cards* before alighting. To minimise stop dwell time, best practice overseas BRT bus operators create passenger storage areas at all bus doors and widen aisle ways to improve passenger circulation during peak periods when standee loads are high.

Passenger storage areas at doors yield bidirectional dwell time reduction benefits for both alighting and boarding passengers. For alighting passengers, they provide temporary standing areas where a large number of passengers can muster in advance of stop arrival and quickly exit as soon as doors open. For boarding passengers, they provide a temporary holding area where a large number of boarded passengers can temporarily gather without blocking access to other boarding passengers, then filter out to seats and adjoining standing areas after the bus is underway. With appropriate software modifications and strategically positioned onboard card interface devices, alighting passengers can begin tagging off *go cards* before reaching their bus stops, and boarding passengers can finish (or even commence) tagging on their *go cards* after leaving bus stops. The benefit of increased alighting and boarding efficiency created through improved aisle way circulation and creation of door passenger storage spaces can be as high as a 50% reduction in average stop dwell time, but the benefits from increased efficiency cannot be realised without a corresponding reduction in passenger seat capacity.

The greatest obstacle to reducing stop dwell time through improved passenger movement efficiency has been, and is likely to remain, the Australian bus operator obsession with cramming as many passenger seats into new bus cabins as the heavy vehicle regulations will permit. When applied to high capacity vehicles, this continuing doctrine of maximising bus seating capacity comes at a very high price given the following key findings of this study:

- 56% - 75% of passenger seats presently go unoccupied during off-peak services on all high capacity bus services, and over 40% of 12.5m rigid bus services. The cost of off-peak seat underutilisation is higher fuel consumption, higher bus maintenance, higher dead axle weight and lower combined bus seated plus standing capacity.
- All door boarding and improved passenger alighting/boarding efficiency are incompatible with the doctrine of maximum seating capacity. Currently, some 6 to 11 minutes would be consumed on every peak service just to board and alight passengers to full bus capacity, and around 6 minutes on low floor 12.5m rigid bus peak services. All door boarding and improved passenger alighting/boarding efficiency could potentially cut stop dwell times by factors of 2 to 3, reducing driver labour costs and the potential to increase service frequencies on HFP routes. But the most important benefit to peak services of a 200% or greater reduction in dwell time would be the increased competitiveness of all high capacity buses with the private motor vehicle.

- Every twin passenger seat installed in a bus cabin occupies approximately the same floor space as 4 standees. On peak services with highly crammed standing passenger loads, the price most often paid for 2 comfortably seated passengers is 4 very uncomfortable standees. Maximisation of seat capacity at the expense of aisle width does not consider the comfort needs of those less fortunate passengers left standing.

  Average standing periods measured on some ten thousands of peak services studied for this report have shown that a typical standee endures uncomfortable standing conditions for at least half the total trip time before finding a vacant seat to reoccupy, must throughout the time of standing shuffle back and forth and lean over seated passengers on narrow aisles to let other passengers alight, and carry personal belongings for most of the time to prevent trampling damage or tripping other passengers. It is arguably a misnomer that adding more bus seats improves passenger comfort and safety on city peak services with high standing loads.

Third Seating Layout: The third seating layout is an optimisation of the second layout and maximises seating forward of the rear door. By relocating both wheelchair bays to the nearside, a rear door storage area is created with a wide aisle way between the front and rear storage areas where both alighting and boarding passengers can easily pass other standees. The adjoined wheelchair bays also double as off-aisle shared overflow areas for both the front and rear storage areas. The drawback with this layout design only becomes evident when 2 wheelchairs need to board. More passengers have to move to make way for the second wheelchair to load and unload, and the 2 wheelchair occupants can no longer sit opposite each other.

Figure 14 overleaf illustrates 4 optional cabin seating layouts to improve aisle way passenger circulation and create a new rear door passenger storage area on a high capacity 14.5m rigid bus. The 14.5m rigid bus has an extremely high r_a = *80%* rear (i.e. 4 rear to 1 front) door passenger alighting preference which would need to shift to around an r_a = *50%* rear (i.e. 1 rear to 1 front) alighting preference to afford balanced minimum stop dwell for all door boarding. Third Seating Layout: The third seating layout is an optimisation of the second layout and maximises seating forward of the rear door. By relocating both wheelchair bays to the nearside, a rear door storage area is created with a wide aisle way between the front and rear storage areas where both alighting and boarding passengers can easily pass other standees. The adjoined wheelchair bays also double as off-aisle shared overflow areas for both the front and rear storage areas. The drawback with this layout design only becomes evident when 2 wheelchairs need to board. More passengers have to move to make way for the second wheelchair to load and unload, and the 2 wheelchair occupants can no longer sit opposite each other.

Figure 14 demonstrates how standee comfort could be significantly improved, total passenger carrying capacity increased and all door boarding dwell time reduced on a Brisbane Transport 14.5m rigid high capacity bus with a reduction of as few as 2 or 3 passenger seats.

- Top (Current) Seating Layout: The top layout in Third Seating Layout: The third seating layout is an optimisation of the second layout and maximises seating forward of the rear door. By relocating both wheelchair bays to the nearside, a rear door storage area is created with a wide aisle way between the front and rear storage areas where both alighting and boarding passengers can easily pass other standees. The adjoined wheelchair bays also double as off-aisle shared overflow areas for both the front and rear storage areas. The drawback with this layout design only becomes evident when 2 wheelchairs need to board. More passengers have to move to make way for the second wheelchair to load and unload, and the 2 wheelchair occupants can no longer sit opposite each other.

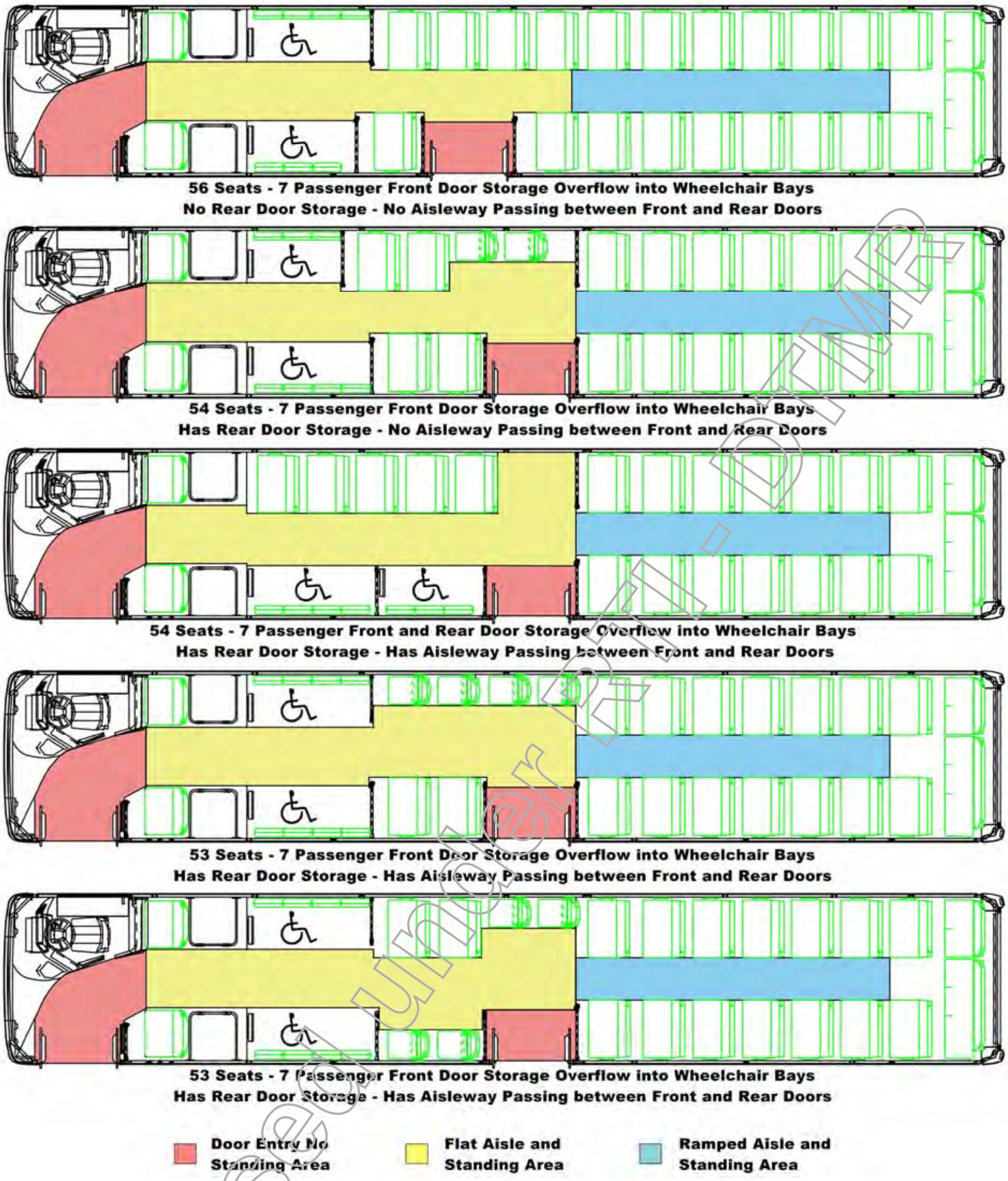
- Figure 14 is indicative of the current 14.5m rigid bus seating plan designed to maximise seating capacity to 56 seats. This layout has narrow aisles aft of the 2 wheelchair parking bays which effectively obstruct alighting passengers from easily passing other standees on the aisle, and no dedicated rear door passenger storage area. The yellow shaded area on the layout comprises flat low floor with no plinth mounted seats and is therefore well suited to standees. It includes a wide aisle front passenger door entry and storage area in front of the 2 wheelchair bays with off aisle passenger spill over into the 2 bays whether occupied or otherwise by seated passengers, but not when occupied by wheelchairs. The fourth seat in the extended wheelchair bay is reserved for a PWD carer but may be occupied by any passenger when not being used by a carer.

  The blue shaded aisle way on the layout to the aft of the rear door has a single high step up off the low floor area, and is then continuously ramped up to the rear with reducing head clearance, and flanked on both sides by climb-on high back plinth mounted seats. The blue shaded aisle way is typically avoided by standees until the yellow shaded flat floor area becomes full, but during peaks some standees may elect to stand in the rear aisle way and suffer the inconvenience of repeatedly moving to the rear door to allow seated passengers to alight in the hope of reoccupying their vacated seats. The red shaded areas are door entry no standing safety zones.

- Second Seating Layout: The rear door has been relocated aftward in the second and lower seating layouts to place more seats forward of the rear door. 2 twin passenger seats have been replaced by 2 single seats to create a large rear door passenger storage area but the narrow aisle way between the front and rear storage areas prevents alighting passengers from easily passing standees should they choose to exit by other than the nearest door.

- Third Seating Layout: The third seating layout is an optimisation of the second layout and maximises seating forward of the rear door. By relocating both wheelchair bays to the nearside, a rear door storage area is created with a wide aisle way between the front and rear storage areas where both alighting and boarding passengers can easily pass other standees. The adjoined wheelchair bays also double as off-aisle shared overflow areas for both the front and rear storage areas. The drawback with this layout design only becomes evident when 2 wheelchairs need to board. More passengers have to move to make way for the second wheelchair to load and unload, and the 2 wheelchair occupants can no longer sit opposite each other.

Figure 14: Improved Passenger Aisle Circulation and Rear Door Storage on a 14.5m Rigid Bus



- Fourth and Fifth Seating Layouts: The fourth and fifth seating layouts both maximise and join the two door passenger storage areas by placing opposing rows of twin and single passenger seats on either side of the front aisle, and restoring both wheelchair bays to their optimum positions for front door loading and unloading. These layouts require one wheelchair bay to be extended with a carer's seat in each at the cost of a third lost passenger seat relative to the original maximum seating capacity.

All of the above modified seating layouts 2 through 5 are suitable for all door boarding and have greater total seated and standing capacities than the original maximum seating capacity design. The fourth seating layout is considered to be close to optimised and could only be further improved by restoration of a near 100% flat floor aft of the rear door at a loss of a further 6 seats.

Modification for all door boarding and rear door storage areas on the articulated buses would involve little more than replacing twin seats fitted opposite and offside forward of the rear door to the turntable with single seats.

The double deck bus already has a joined front and rear door storage area, but cannot be fully optimised for all door boarding until the upper deck stairway is turned back 180° toward the front door, and preferably fitted with a second stairway to speed up alighting of passengers from the upper deck.

3.6.7 Onboard Ticket Sales and Go Card Top-Ups

Comparison of the measured average boarding time per passenger on the Clarks Logan City two and three door articulated buses with that of the Brisbane Transport two door articulated bus appearing at Table 4 has underscored how onboard ticket sales and *go card* top-ups extend trip stop dwell times on private operator bus services. Onboard ticket sales and *go card* top-ups added an additional second to the average boarding time per passenger, increasing it by 38% on the two Clarks Logan City articulated buses relative to a comparable Brisbane Transport articulated bus, and have extended the average stop dwell time per passenger by 0.5s, a relative increase of 21% on the Brisbane Transport articulated bus.

Comparison of the measured dwell times between the two Clarks Logan City articulated buses has further identified that the cumulative boarding delay at stops for driver paper ticket sales and *go card* top-ups has effectively negated out the time savings gained by having the third door on the articulated superbus.

Analyst notes from video recordings taken aboard the Clarks Logan City articulated buses and observations by MRCagney personnel travelling onboard the Logan Hyperdome 555 bus services reveal a high incidence of passenger interaction with Clark's bus drivers not observed on comparable Brisbane Transport bus services. These interactions were initiated in the main by passenger requests for paper tickets and *go card* top-ups. Driver-passenger interactions were repeatedly observed to not only block off one stream of boarding passengers at the double width front doors, but to occasionally set off flow conflicts in the free streaming channel between alighting and boarding passengers at the front door. Measured average alighting time per passenger on the two Clarks Logan City articulated buses has been found to be around 0.3 – 0.4s longer than for comparable Brisbane Transport 2 door articulated buses.

Onboard *go card* top-ups by regular bus commuters and students, rather than paper ticket sales to irregular bus users, has been identified as the more frequent cause of passenger-driver interaction delay. Translink has a well established network of several hundred add value vending machines, outlets and agencies where *go cards* can be credited off bus across South East Queensland, and a website where *go cards* can be either manually or automatically topped-up by credit card. Because high capacity buses carry a large number of passengers who are arguably being repeatedly inconvenienced by onboard *go card* top-ups, it is recommended that TransLink discontinue the current policy permitting go-card top-ups on private operator bus services. The requirement to reduce driver-passenger interaction on all door boarded high capacity bus services will be critical for balancing front door boarding and alighting with (middle and) rear door alighting and boarding to obtain minimum stop dwell times.

Appendix A

All Door Boarding and Proof of Payment Case Studies

San Francisco, California, USA

San Francisco Municipal Transportation Agency (SFMTA) will introduce all door boarding on its *Muni* bus routes, trolley coach and historic streetcar network from July 2012. At present, *Muni* buses are averaging just 13 km/h and struggling to achieve 80% on-time running performance, well below the minimum target of 85% on-time running performance benchmark set by the agency. Research has shown that many *Muni* bus routes were spending from 15% to 30% of total journey time dwelling at bus stops.

From July 2012, *SFMTA* will allow its passengers using the *Clipper* smartcard to board from the rear, while passengers requiring paper tickets must board from the front door and continue to purchase tickets from the bus driver. *Clipper* card readers have already been installed near the rear door on all vehicles to meet this need. The agency also has plans to increase enforcement to assure fare compliance. *Muni* plans to add another 10 fare inspectors to its current roster of 36 staff once the new all door boarding program has been implemented.

While *SFMTA* has concerns about the risk of increased fare evasion, the agency recognises that making its transit services more efficient will not only make them more attractive to regular *Muni* passengers, but all door boarding will have a significant effect on the bottom line of the agency's finances. A 2010 study found that speeding up services by just 1.6 km/h throughout the network would save $76 million annually for the agency.

This initiative has been supported by the *San Francisco Transit Riders Union*, a customer advocacy group that has long lobbied the agency for all door boarding. *SFMTA* intends to reinvest its travel time savings back into improving its service frequency and capacity, and *Muni* will become the first transit operator in North America to allow prepaid passengers to legally board through the rear door of every rail carriage and bus on its network. Currently, rear door boarding is only allowed on *Muni*'s light rail lines and some selected bus routes where a fare inspector is on hand to collect fares and check concession passes and transfer tickets.

According to a 2009 study undertaken by *SFMTA*, the fare evasion rate on *Muni's* light rail lines, which have employed roaming fare inspectors to monitor evasion for more than a decade, is less than half the rate it is on our *Muni* buses. On some *Muni* bus lines, more than 15% of riders don't pay a fare, and that number jumps to 55% for people who illegally board buses at the rear. Overall, *Muni* knows it loses an estimated $19 million to fare evasion every year, significantly less than its cost of $76 million to maintain service reliability.

San Francisco has taken the view that reducing stop dwell time through all door boarding was the best low cost alternative available to it to reducing journey travel times when compared to implementing other bus priority/dwell time reduction measures. The policy initiative is expected to induce a higher *Clipper* smartcard take-up rate as more customers appreciate the benefits of faster boarding through the rear door.

Vancouver, British Columbia, Canada

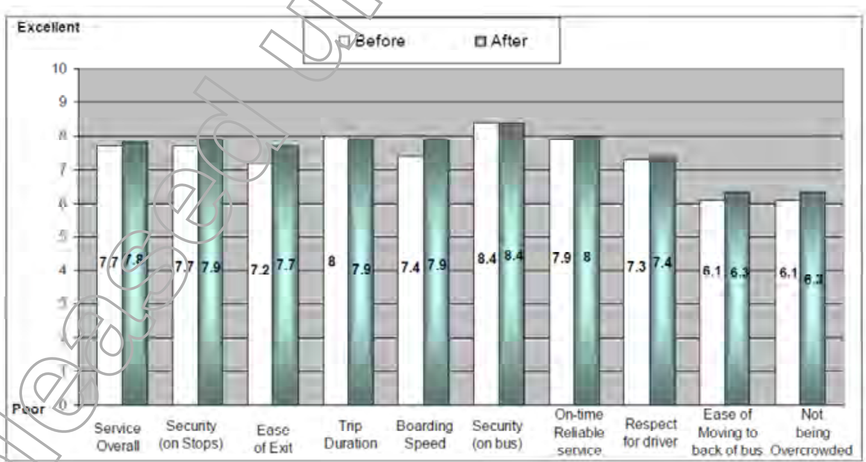
In 2007, the Greater Vancouver transit agency, *Translink*, undertook a 3 month trial of all door boarding on its 99 B-Line. Three door boarding had previously been allowed at the two termini of the 99 B-Line and on the Vancouver *Skytrain* only. Where non-articulated buses were deployed on the route, all customers could only board via the front door, and the all door boarding trial was adopted for high capacity articulated buses only.

220 physical assaults and serious verbal abuse attacks had been reported by bus drivers on the 99 B-Line in the 12 month period prior to the all door boarding trial, and a high percentage of these attacks were triggered when drivers attempted to collect ticket fares. The primary reason for the trial was to reduce the incidence rate of conflicts between bus drivers and passengers who refused to pay their ticket fares, and all door boarding was not specifically introduced to reduce stop dwell times.

During the trial, passengers who wanted to buy or validate tickets were still asked to board at the front door of the articulated buses, but other passengers with prepaid tickets could board the bus at the front, middle and rear doors.

Translink did not think fare evasion would be a significant issue during the trial because its $175 fine for being caught without a valid ticket would act as strong deterrent to fare evasion. The agency recruited an additional 40 transit police officers to augment its transit security workforce across the network to 150. The trial evaluation showed that at the busy stops along the route average dwell time per boarding and alighting fell from 5.8 seconds per passenger to 4.8 seconds, a reduction of 17%. The average total trip time between 6:00am and 6:00pm was also reduced by 8% in both the eastbound and westbound travel directions.

Market research was undertaken by Translink after the 3 month trial to gain an appreciation of what its regular customers had thought of all door boarding during the trial. The bar graphs below show customer responses to the trial which was considered a success, and Translink still operates all door boarding on all of its 99 B-Line articulated vehicles.



Translink commissioned two independent audits of its internal procedures for estimating fare evasion; the first conducted by KPMG in 2002, and the second by PricewaterhouseCoopers in 2008. Both audits found that Translink's fare evasion estimation methodology was sound and determined that fare evasion rates were around 4.8% and 2.5% respectively. The PriceWaterhouseCoopers audit report concluded that public and political perception of fare evasion was an order of magnitude (i.e. 10 times) higher than the actual fare evasion rate. Actual fare evasion has decreased in Vancouver as a result of increased random ticket inspection monitoring and hefty $175 fines for infringements.

Paris, France

Bus passengers in Paris can board any bus through any door, unless they want to purchase magnetic stripe tickets and pay higher cash fares to the driver than otherwise debited from smartcards, in which case they must board at the front door of the vehicle. Passengers who board buses at the middle or rear door may either tag on a *Navigo* smartcard at a card reader, or insert a prepaid magnetic stripe ticket into a validator. Both machines are collocated beside each other adjacent every bus access door.

Magnetic stripe tickets can be procured from the driver or off vehicle at agencies and public transport outlets, and are typically only used by itinerant city visitors and tourists, rather than regular Parisian bus commuters. Possession of either a tagged-on *Navigo* smartcard or a validated magnetic stripe ticket whilst boarded on any Paris bus constitutes the only satisfactory proof-of-payment of fare, and such are randomly and regularly monitored by a large contingent of roving ticket inspectors on all bus services.

Ottawa, Canada

Ottawa's BRT system permits rear door boarding on articulated buses for riders with valid proof of payment. As for the San Francisco *Muni* buses, customers must board at the front door if they need to purchase a ticket. Brisbane's busway system was modelled on the Ottawa BRT, but Brisbane never adopted Ottowa's long standing all door boarding policy.

Most of the buses operating on the Ottawa BRT are 18m articulated buses, but recently the transit agency *OC Transpo*, has initiated a trial of 3 Alexander Dennis Enviro500 double deck high capacity buses in an attempt to increase busway carrying and station loading capacity through vehicle changes rather that resorting to costly station platform extensions.

Passengers travelling on Ottowa BRT articulated or double deck buses and *O-Train* light rail vehicles are required to show proof of payment to transit fare and transit law enforcement officers upon request. Anyone unable to provide proof of payment is fined $150.

Western European Cities

Many cities in Western Europe have, for several decades, adopted uniform proof of payment ticketing and all door boarding policies on their heavy rail, light rail and bus services, generally in response to the shortage of drivers and conductors and the rising cost of operations.

Moscow, Russia

Proof of payment and all door boarding were introduced on Moscow buses in 1992.

Las Vegas, Nevada, USA

Proof of payment and all door boarding has been implemented on two major bus routes in Las Vegas.

Toronto, Canada

VIVA Buses in suburban Toronto provide off-vehicle ticket vending machines at its major stops and operates all door boarding on all of its bus services.

Portland, Oregon, USA

The Portland *Tri-Met* once operated all door boarding and universal proof of payment across its entire network but abandoned the policy in 1980. *Tri-Met* acknowledges it made a mistake to implement a universal all door boarding and proof of payment policy across its entire network, as it encompassed many routes that were neither frequent nor crowded at that time. As a result of the policy, *Tri-Met* ticket inspectors spent most of their paid time travelling on and waiting for partially loaded buses at stops with nothing to do, and the political and public credibility of its fare compliance enforcement was substantially tarnished.

Tri-Met's view now is that proof of payment fare evasion monitoring only really makes practical sense when targeted at busy peak period bus services randomly, and where inspectors can process a high number of ticket checks in a short period of time and move quickly onto other vehicles with minimum bus stop waiting time. Their current view of all door boarding and alighting is that it should be targeted at high capacity, high frequency services rather than universally across all bus services.

Czechoslovakia

Czechoslovakia has operated all door boarding on its city buses for many decades. Conductors were initially stationed onboard buses to sell tickets, but were replaced by random proof of payment inspectors in the late 1960's and early 1970's.

Los Angeles, California, USA

The *Metro Bus BRT Orange Line* in Los Angeles operates high capacity buses with all door boarding and *Metro Bus* claims to have reduced its fare evasion rate to just 0.8% using proof of payment random ticket inspections.

Appendix B

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Document Information

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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by the TransLink Division of the Queensland Department of Transport and Main Roads (*TransLink*) to undertake research and analysis of high capacity vehicle use within its South East Queensland network. The subject high capacity vehicle types nominated by *TransLink* for the study are already in service on its network and include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

This Stage 2 technical study evaluates and compares the costs of owning and operating each of the 4 high capacity vehicles relative to the costs of owning and operating a standard two door 12.5m rigid bus commonly deployed by most bus operators to *TransLink* route services in South East Queensland.

All relevant future value costs and cost recoveries have been estimated in Part 2 of this report for each vehicle type over its service life, backward converted to present value FY2012/13 dollars and summed to obtain a total whole-of-life net present value of its life cycle cash flows.

In Part 3 of the report, total (net present value) bus costs are compared and ranked for each vehicle type on a dollar per kilometre and cent per passenger-kilometre basis. Total (net present value) driver labour costs are also determined over each vehicle's service life at typical peak and off-peak traffic speeds on Brisbane roads, and total (net present value) bus and driver operating costs compared and again ranked for each bus type on a dollar per kilometre and dollar per passenger-kilometre basis.

Total bus and driver operating costs are then further examined to assess the economics of substituting a high capacity bus versus adding a second standard 12.5m bus on an overloaded peak service, and to determine the breakeven point between Translink ticket revenue and operator subsidy and bus operator cost plus profit margin.

Further into Part 3, we have also examined the difference between the *Two Door 18m Articulated Bus* and *Three Door 18m Articulated Superbus* life cycle costs and demonstrate the very significant impacts on operating and economic performance of a high capacity bus designed for minimum stop dwell time and a high capacity bus designed for maximum seating. We conclude the detailed cost analysis by then evaluating and comparing the relative performance benefit:cost ratios for every bus type.

Findings of the whole-of-life cost analysis have been consolidated with other relevant findings from earlier Stage 1 high capacity vehicle use assessments in Part 4 of the report and presented later in the *Summary of Key Findings*.

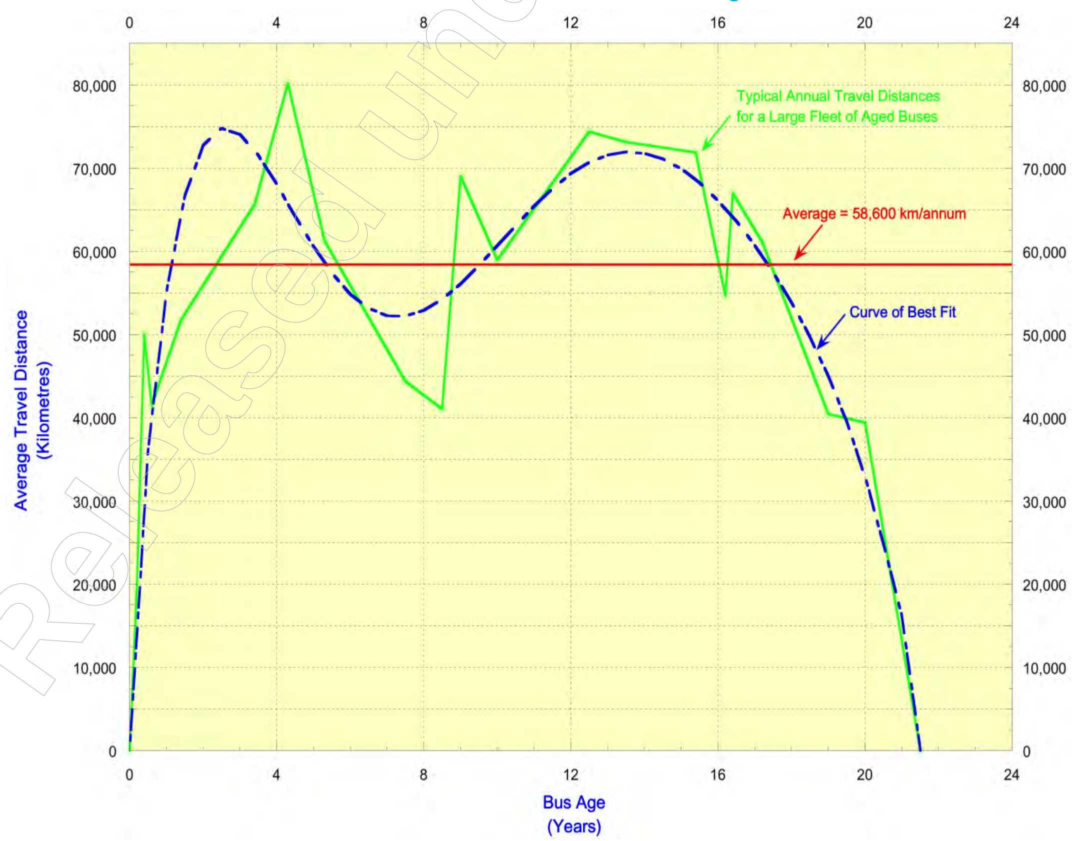
1.2 Assumptions Adopted for the Life Cycle Cost Analysis

The following assumptions have been adopted for the life cycle cost analysis:

- All quoted prices, costs, finance lease rates, *Consumer Price Indices*, annual inflation rates, fees, charges and other data obtained for cost calculations have been sourced in the second quarter of FY2012/13. Present values have therefore been provided throughout the report in current FY2012/13 dollars.

- All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.
- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing below. This curve was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have been listed in the table appearing overleaf, average at 58,600km/annum, and total to 1,230,600km over the assumed 21 year service life.
- New vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing bus depot only.
- Capital expenditures other than for new bus procurements have been assumed to be funded out of business equity (i.e. from business cash reserves or savings accounts). This includes final residual payouts on expired bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of operational cost evaluations, we have therefore assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, loading of buses to their maximum legal seated plus standee carrying capacities and typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Assumed Vehicle Travelled Distance vs Age Profile



Year Ending	Bus Age (years)	Travel Distance (kilometres)	Cumulative Odometer (kilometres)
2013	1	55,207	55,207
2014	2	72,781	127,988
2015	3	74,066	202,054
2016	4	68,080	270,134
2017	5	60,595	330,729
2018	6	54,863	385,592
2019	7	52,277	437,869
2020	8	52,932	490,801
2021	9	56,112	546,913
2022	10	60,695	607,608
2023	11	65,467	673,075
2024	12	69,360	742,435
2025	13	71,607	814,042
2026	14	71,805	885,847
2027	15	69,906	955,753
2028	16	66,123	1,021,876
2029	17	60,740	1,082,616
2030	18	53,857	1,136,473
2031	19	45,041	1,181,514
2032	20	32,900	1,214,414
2033	21	16,186	1,230,600

1.3 Summary of Key Findings

Bus ownership and operating costs are unaffected by road speed, but driver labour costs per kilometre have been shown to change markedly under different road traffic speed operating conditions. Driver labour costs have therefore been assessed in the life cycle cost study at 3 common Brisbane road peak and off-peak traffic speeds:

(a) 30km/h Average Traffic Speed:

Bus services operating in 30km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

(b) 45km/h Average Traffic Speed:

Bus services operating in 45km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Bus services operating in 45km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

(c) 75km/h Average Traffic Speed:

Bus services operating in 75km/h peak traffic speed conditions travel between the CBD and an outer Brisbane suburb substantially on a busway or bypass the CBD on a major ring road such as the Western, Gateway or Logan Motorway.

Bus services operating in 75km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

The following findings were obtained from a comparison of the net present values of all whole-of-life costs incurred by each high capacity bus relative to those incurred by a standard 12.5m rigid route bus under identical operating conditions.

1 Two Door 14.5m Extended Rigid Bus: This high capacity vehicle provided the best overall cost performance in the 90 passenger capacity category. It competes in this category with the 2 Door Articulated Bus.

At $2.30/km, this high capacity vehicle is 14% dearer to own and operate than a standard bus, but at 2.50¢/pax-km, is actually 7% cheaper in terms of its maximum 92 passenger carrying capacity. This bus breaks even with a standard bus at a load of 86 passengers, and has an increased future revenue generation potential of +7% when loaded with 6 additional passengers.

A standard bus MR licensed driver can legally drive this vehicle, but it is 11% dearer at $4.10/km (30km/h), 12% dearer at $3.74/km (45km/h) and 13% dearer at $3.46km/h (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 11% cheaper at 4.45¢/pax-km (30km/h), 9% cheaper at 4.06¢/pax-km (45km/h) and 8% cheaper at 3.76¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life this vehicle saves $1.341M (or $1.09/km) on 30km/h services, $1.179M (or $0.96/km) on 45km/h services and $1.101M (or $0.89/km) on 75km/h services, and is the best choice for any existing overloaded peak service only required to carry up to a maximum load of 92 passengers.

2 Two Door 18m Articulated Bus: The cost performance of this high capacity vehicle has been relatively poor compared to a standard bus and was assessed lowest for all high capacity buses.

At $2.58/km, this high capacity vehicle is 28% dearer to own and operate than a standard bus, and at 2.87¢/pax-km, remains 7% dearer to own and operate in terms of its maximum 90 passenger carrying capability. This bus does not break even with a standard bus at a comparable minimum load of 96 passengers. It carries 6 less passengers and therefore has a reduced future revenue generation potential -6% below that of the standard bus.

A HR licensed driver is needed to drive this vehicle. It is 19% dearer at $4.43/km (30km/h), 22% dearer at $4.04/km (45km/h) and 24% dearer at $3.78/km (75km/h) to operate than a standard bus and driver. At maximum passenger loads, it is 0.4% cheaper at $4.93¢/pax-km (30km/h), but 1% dearer at $4.49¢/pax-km (45km/h) and 3% dearer at $4.20¢/pax-km (75km/h) to operate than a standard bus and driver.

This vehicle could only be cost justified when substituted on an overloaded peak service in lieu of two standard buses and drivers. Over its whole-of-life, it saved $0.926M (or $0.75/km) on 30km/h services, $0.808M (or $0.66/km) on 45km/h services and $0.708M (or $0.58/km) on 75km/h services, but was ranked a poor second choice in the 90 passenger high capacity vehicle category, well behind the 14.5m extended rigid bus.

3 Three Door Articulated *Superbus*: The cost performance of this high capacity vehicle was judged best in the 110 passenger capacity category. It competes in this category with the double deck bus, but carries only 52 seated passengers onboard, where the double deck carries 96 seated passengers. It is in effect identical to the 2 door 18m articulated bus with 12 less passenger seats and an extra door fitted, but its reduced seating capacity and tare weight has had a profound effect on its cost performance.

At $2.56/km, this high capacity vehicle is 27% dearer to own and operate than a standard bus, but at 2.33¢/pax-km, is 15% cheaper in terms of its maximum 110 passenger carrying capacity. This was the lowest cost per passenger-kilometre assessed for all 4 high capacity buses. This bus breaks even with a standard bus at a load of 96 passengers, and has an increased future revenue generation potential of +15% when loaded with 14 additional passengers.

A HR licensed driver is needed to drive this vehicle. It is 24% dearer at $4.61/km (30km/h), 27% dearer at $4.21/km (45km/h) and 28% dearer at $3.89/km (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 18% cheaper at 4.19¢/pax-km (30km/h), 16% cheaper at 3.83¢/pax-km (45km/h) and 15% cheaper at 3.54¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life this vehicle saves $0.707M (or $0.57/km) on 30km/h services, $0.595M (or $0.48/km) on 45km/h services and $0.572M (or $0.47/km) on 75km/h services, and is the preferred choice for any existing overloaded peak service required to carry a maximum load of up to 110 passengers.

4 Two Door 12.5m Double Deck Bus: The cost performance of this high capacity vehicle was also found to be satisfactory in the 110 passenger capacity category. It competes in this category with the 3 door articulated *Superbus,* but carries 96 seated passengers, where the *Superbus* only carries 52 seated passengers.

At $2.88/km, this high capacity vehicle is 43% dearer to own and operate than a standard bus. This was the highest cost per kilometre rate for all 4 high capacity vehicles assessed. At 2.48¢/pax-km, it was a distant runner up to the 18m articulated *Superbus,* but still 8% cheaper to own and operate than a standard bus in terms of its maximum 116 passenger carrying capacity. This bus breaks even with a standard bus at a load of 107 passengers, and has an increased future revenue generation potential of +8% when loaded with 9 additional passengers.

A HR licensed driver is also needed to drive this vehicle. It is 34% dearer at $4.98/km (30km/h), 38% dearer at $4.59/km (45km/h) and 40% dearer at $4.28/km (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 15% cheaper at 4.30¢/pax-km (30km/h), 12% cheaper at 3.96¢/pax-km (45km/h) and 10% cheaper at 3.69¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life, this vehicle saves $0.249M (or $0.20/km) on 30km/h services, $0.129M (or $0.11/km) on 45km/h services and $0.096M (or $0.08/km) on 75km/h services, the lowest saving achieved by any of the high capacity buses. These relatively modest savings have been calculated at full load, a 21 year retirement age and 1.2306 million kilometre total service range. It is arguable whether substitution of a double deck bus would be cost justifiable against 2 rigid buses given its known service limitations in Brisbane western and eastern suburbs with so many existing low clearance railway bridges.

5 Ideal Retirement Age for a Standard 12.5m Rigid Bus: Based on whole-of-life costs, the ideal minimum cost retirement age for a new ultralow floor standard bus has been determined at 19 years. The detailed cost analysis has revealed that from age 14 to age 21, the annual total operating cost per kilometre for a typical SEQ standard route bus rises exponentially from $1.58/km to $2.58/km in present values, while its revenue/km declines proportionately in the negative direction. As a consequence each year of service life after age 16 requires a higher TransLink subsidy to the bus operator to keep its aging standard buses in service.

6 Ideal Retirement Age for All High Capacity Buses: Based on their whole-of-life costs, the ideal retirement age for all 4 high capacity buses also fell at age 19, but this was based on the assumption that aging high capacity buses could be deployed on school, shopper and district runs, private school and community charters, and breakdown standby bus duties, as is current practice for aging standard size route buses. It has been determined that the increase in annual operating cost per kilometre for a old age high capacity bus is much higher than for a standard bus, making it critical for TransLink that high capacity buses not be allowed to continue in service on light duties during the old age phase of their respective life cycles.

It has been further identified that high capacity buses have too many road use restrictions including over height limitations for the double deck bus, and restricted access, swept path/turning circle and bus stop length limitations for the 3 other bus sizes. High capacity buses do not therefore appear to fill the same universal “go anywhere” and “back up any service” niche traditionally filled by standard 12.5m rigid buses during their old age.

A different future life cycle scenario has therefore been envisaged for high capacity buses in which they will need to be worked harder on normal commuter services in old age, and their retirements brought forward one year earlier to age 18.

7 Maximum Seating vs Minimum Dwell Impacts on High Capacity Bus Operating and Economic Performance: Section 3.8 of the report has demonstrated the high operating and whole-of-life economic benefits to TransLink of actively striving to trade seating capacity on high capacity buses for reduced dwell time at bus stops using cabin layouts with:

- Wider front to rear door aisle widths for improved passenger circulation and standee comfort,
- Wider, and on 110 passenger buses - second rear doors, for all door boarding and alighting,
- Rear door positions which encourage boarded passengers to alight in equal numbers through all doors, and
- Defined front and rear door passenger storage areas where alighting passengers can temporarily queue, tag off their go cards and get ready to alight before reaching bus stops; and where boarding passengers can then temporarily queue, tag on their go cards and spill out progressively to wide aisle ways and seats after leaving bus stops.

Operating benefits to high capacity buses of these bus cabin and design design reforms included:

- 200% to 300% reduction in average bus stop dwell time for all door balanced alighting and boarding,
- Higher legal total seated plus standing capacity,
- Reduced dead axle weight and fuel consumption,

- Greatly reduced simultaneous bus arrival clashing, particularly in single stop bay bus interchanges, park ‘n rides and stations where arriving buses must circulate until allocated stop bays are cleared, at single bay roadside stops where arriving buses are forced to relocate off stop zones, and at busway stations where arriving bus queues force passengers to move long distances up platforms and delay service departures,
- Greatly improved utilisation of high cost bus stop infrastructure and bus depot equivalent standard bus space, and
- Improved service frequency and competitiveness with the private motor vehicle.

Over its whole-of-life, a 54¢ per pax-kilometre saving was realised by the *3 Door Articulated Superbus* relative to the *2 Door Articulated Bus* with 12 additional seats, but with future all door boarding and alighting, the total dwell time per peak trip would drop by 7 minutes for the former compared with only 3 minutes for the latter.

We have challenged the standing SEQ bus operator paradigm that more passenger seats on a high capacity bus equates to improved customer satisfaction, comfort and safety; and illustrated by example where all the above benefits could be realised on a current model *Two Door 14.5m Extended Rigid Bus* with just 3 less passenger seats. We have further highlighted that:

- 56% to 75% of passenger seats presently go unoccupied in Brisbane on existing off-peak high capacity bus services, and the cost of off-peak seat underutilisation translates to higher fuel consumption, bus maintenance, dead axle weight and lower combined bus seated plus standing capacity for 75 to 80% of a high capacity vehicle’s travelled life cycle kilometres,
- Every extra twin passenger seat crammed into the bus cabin occupies approximately the same floor space as 4 standees. On peak services with highly crammed standing passenger loads, the price paid for 2 comfortably seated passengers is 4 very uncomfortable standees. Maximisation of seat capacity at the expense of aisle width does not consider the customer satisfaction, comfort and safety needs of those passengers still left standing, and
- Average standing periods measured on some ten thousands of peak route services studied for the HCV operational performance evaluation showed that a typical standee endured uncomfortable crammed standing conditions for at least half the total trip time before finding a vacant seat to reoccupy. Throughout the time of standing, passengers had to shuffle back and forth and lean over seated passengers on exceptionally narrow aisle ways to let other passengers alight, and carry their personal belongings for most of the time to prevent trampling damage or tripping of other passengers.

The combined benefits of designing and operating high capacity buses for minimum stop dwell rather than maximum seating capacity pushes the peak service breakeven point significantly towards the ticket revenue side, and therefore significantly reduces TransLink’s subsidy for buses designed and operated for minimum dwell time.

8 Whole-of-Life High Capacity Bus Performance Benefit:Cost Assessment: Operating performance, driving performance, road handling, bus stop infrastructure compatibility and depot compatibility have been compared for every bus type using data from previous Stage 1 HCV technical studies and scores for each assessed criterion weighted by its relative importance. Total weighted scores for each bus type were then divided by their respective whole-of-life cost per kilometre and cost per pax-kilometre to obtain performance benefit:cost ratios and the ratios ranked between all bus types.

When taking into account vehicle operating performance, ease of driving and road manoeuvrability, compatibility with existing TransLink bus station and stop infrastructure and existing operator bus depots, the findings from the performance benefit cost results were as follows:

- On the basis of benefit to cost per kilometre, high capacity vehicle performance rankings shifted relative to cost only rankings in favour of the smaller 90 passenger buses, but rankings within the 90 passenger and 110 passenger categories remained unchanged. The shift in high capacity vehicle performance rankings by cost per kilometre relative to cost only rankings largely resulted from the shorter stop dwell times, faster operating speeds and superior driving and road manoeuvring capabilities of the 90 passenger buses, compared with those of the 110 passenger buses.
- On the basis of benefit to cost per pax-kilometre, high capacity vehicle performance rankings shifted relative to cost only rankings in favour of the larger 110 passenger buses, and the *2 Door 12.5m Double Deck Bus* was pegged equally with the *3 Door 18m Articulated Superbus*. The shift in performance rankings by cost per pax-kilometre relative to cost only rankings largely resulted from the superior compatibility of the double deck bus with existing bus station and roadside infrastructure, and its very high equivalent standard bus passenger and parking capacities in those bus depots where it could readily be accommodated without major upgrades.
- The *2 Door 14.5m Extended Rigid Bus* had the highest performance benefit:cost ratio both in the 90 passenger category and between the high capacity bus types. The *3 Door 18m Articulated Superbus* had the higher performance benefit:cost ratio in the 110 passenger category.
- The *2 Door 18m Articulated Bus* had the lowest performance benefit:cost ratio of all the high capacity bus types.
- No high capacity vehicle outranked the *Standard 2 Door 12.5m Rigid Bus* on the like-for-like performance benefit cost assessment. Notwithstanding it being the second dearest vehicle to operate based on cost per pax-kilometre, the standard bus significantly outperformed every high capacity bus and was fully compatible with all existing bus stations, stops and depots.

2. High Capacity Bus Cost Analysis

2.1 Background

This technical study investigates the costs of operating high capacity buses relative to those of a standard 12.5m rigid urban route bus. High capacity buses assessed in this technical study include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

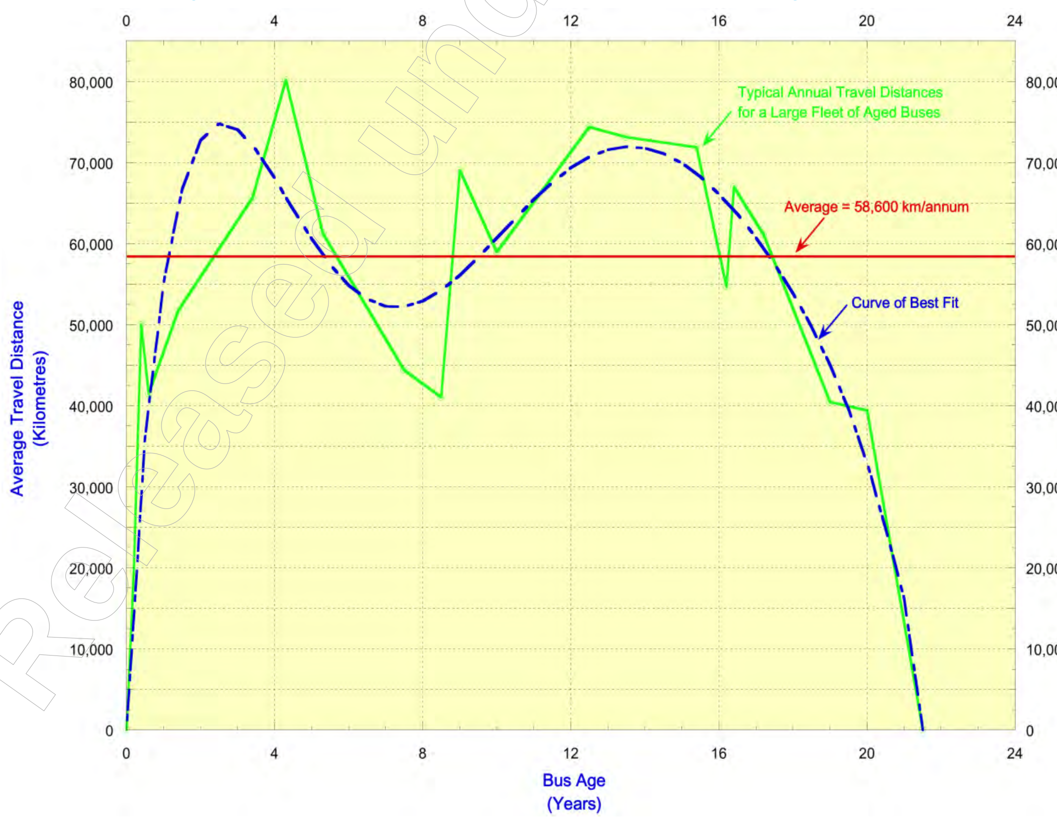
Part 2 of this report derives the ownership costs, fixed annual operating costs and variable operating costs for each bus type and explains where their reference cost data was sourced and how the present value of each cost element was calculated. Part 3 of the report summates the present values of all costs derived in Part 2, and compares the net present values for all bus types for their whole-of-life, both exclusive of, and inclusive of, bus driver operating costs.

2.1.1 Assumptions

The following assumptions have been adopted for this cost analysis:

- All quoted prices, costs, finance lease rates, *Consumer Price Indices*, annual inflation rates, fees, charges and other data obtained for cost calculations have been sourced in the second quarter of FY2012/13. Present values have therefore been provided in FY2012/13 dollars.

Figure 1: Assumed Vehicle Travelled Distance vs Age Profile



- All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.
- Assumed travel distances per annum in each year of the vehicle's service life have been based on the statistical polynomial *Curve of Best Fit* appearing above in
- Figure 1. This curve was sourced from a detailed review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile curve have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing depot only.
- Capital expenditures, other than for new bus procurements, have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or saving accounts). This includes all final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 20km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h, and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1: Assumed Annual Travel Distances and Odometer Kilometres in Each Year of Bus Life

Year Ending	Bus Age (years)	Travel Distance (kilometres)	Cumulative Odometer (kilometres)
2013	1	55,207	55,207
2014	2	72,781	127,988
2015	3	74,066	202,054
2016	4	68,080	270,134
2017	5	60,595	330,729
2018	6	54,863	385,592
2019	7	52,277	437,869
2020	8	52,932	490,801
2021	9	56,112	546,913
2022	10	60,695	607,608
2023	11	65,467	673,075
2024	12	69,360	742,435
2025	13	71,607	814,042
2026	14	71,805	885,847
2027	15	69,906	955,753
2028	16	66,123	1,021,876
2029	17	60,740	1,082,616
2030	18	53,857	1,136,473
2031	19	45,041	1,181,514
2032	20	32,900	1,214,414

2033	21	16,186	1,230,600

2.2 Future to Present Value Conversion Formula

2.2.1 Present Value of a Future Single Expense or Recovery Cash Flow

The general equation for converting any future dollar value (*FV*) spent (+) or received (-) in future year *t* to its present dollar value (*PV*) today is given by...

$$PV = \frac{FV}{(1+q)^t} = \frac{FV}{(1.0304)^t} = \frac{FV}{c^t} \qquad \text{..........(i)}$$

where ...

FV = Future Value of the Single Expense (+) or Recovery (-) (in dollars)

PV = Present Value of the Future Single Expense (+) or Recovery (-) (in dollars)

q = *Brisbane Consumer Price Index – All Groups* for Decade ending Q1, FY2012/13 = 3.04%/annum

c = Future to Present Value Conversion Factor = 1.0304

t = Elapsed Period from 1 January 2013 (in years).

2.2.2 Net Present Value of a Future Fixed Annuity Cash Flow

Let *a* = fixed annuity cash flow between year *1* and year *t*. The net (or total) present value of all successive annual cash flows between year *1* and year *t* becomes...

$$PV = a/c^1 + a/c^2 + a/c^3 + \ldots + a/c^t$$

Multiplying both sides of the equation by c^t gives...

$$c^t\, PV = a\,(c^0 + c^1 + c^2 + c^3 \ldots + c^{t-1}) = \frac{a\,(c^t - 1)}{c - 1}$$ for its standard form geometric series, then giving...

$$PV = \frac{a\,(c^t - 1)}{c^t\,(c - 1)} \qquad \text{..........(ii)}$$

Now let the fixed annuity cash flow start in year *n* and finish in year *m* which gives the general equation for the net present value of any future fixed annuity cash flow as:

$$PV = \frac{a\,(c^m - 1)}{c^m\,(c - 1)} - \frac{a\,(c^n - 1)}{c^n\,(c - 1)} = \frac{a\,\{(1 - c^{-m}) - (1 - c^{-n})\}}{c - 1}$$

$$PV = \frac{a\,(c^{-n} - c^{-m})}{c - 1} \qquad \text{..........(iii)}$$

where ...

a = Amount of a Fixed Future Expenditure (+) or Recovery (-) Annuity (in dollars)

PV = Net (or Total) Present Value of the Future Annuity Cash Flow (in dollars)

n = Elapsed Period from 1 January 2013 on which the Annuity Cash Flow Started (in years)

m = Elapsed Period from 1 January 2013 on which the Annuity Cash Flow Finished (in years)

c = Future to Present Value Conversion Factor = 1.0304.

2.2.3 Net Present Value of a Compounding Interest Future Cash Flow

Let *p* = principal of a future cash flow compounding at interest rate *i* between year *1* and year *t,* and *r* = *1* + *i*, its annual compound growth rate. The net present value of all successive cash flows between year *1* and year *t* becomes...

$$PV = pr^1/c^1 + pr^2/c^2 + pr^3/c^3 + \ldots + pr^t/c^t = p(r/c)^1 + p(r/c)^2 + p(r/c)^3 + \ldots + p(r/c)^t$$

Letting *k* = *r/c* yields...

$PV = p\,(k^1 + k^2 + k^3 + \ldots + k^t)$

Dividing both sides of the equation by k then gives...

$\frac{PV}{k} = p\,(k^0 + k^1 + k^2 + k^3 \ldots + k^{t-1}) = \frac{p\,(k^t - 1)}{k - 1}$ for its standard form geometric series, finally giving...

$$PV = \frac{p\,k\,(k^t - 1)}{(k - 1)} \qquad \text{..........(iv)}$$

Now let the compounding cash flow start in year n and finish in year m which gives the general equation for the present value of any future compounding cash flow as:

$$PV = \frac{p\,k\,(k^m - 1)}{k - 1} - \frac{p\,k\,(k^n - 1)}{k - 1} = \frac{p\,k\,\{(k^m - 1) - (k^n - 1)\}}{k - 1}$$

$$PV = \frac{p\,k\,(k^m - k^n)}{k - 1} \qquad \text{..........(v)}$$

where ...

k = Future to Present Value Compound Interest Conversion Factor = r/c
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Interest Growth Rate = $1 + i$
c = Future to Present Value Conversion Factor = 1.0304
p = Principal (in dollars)
PV = Net Present Value of the Compounding Interest Future Cash Flow (in dollars)
n = Elapsed Period from 1 January 2013 on which the Compounding Cash Flow Started (in years)
m = Elapsed Period from 1 January 2013 on which the Compounding Cash Flow Finished (in years).

2.2.4 Instalment and Account Balance for a Compound Interest Loan

Let...

- p = principal of a commercial loan,
- i = fixed compound interest rate paid over the term of the loan between year 1 and year t,
- s = the fixed instalment paid annually on the loan,
- t = the term of the loan,
- b = the loan balance remaining at the end of each successive year of the loan term after all preceding fixed instalments have been paid on time, and
- $r = 1 + i$, the annual compound interest growth rate of the account principal and balance.

From Eqt (i), the future value of each fixed instalment is:

$FV = s\,c^t$

Hence from Eqt (ii), the total future value of all fixed instalment cash flows paid to the financier up to and including year t simplifies down to...

$$FV = \frac{s\,(r^t - 1)}{r - 1}$$

At the end of year t, the future value of the principal has grown from p to...

$FV = p\,r^t$ so the future value of the remaining balance at the end of year t becomes...

$$b = p\,r^t - \frac{s\,(r^t - 1)}{r - 1} \qquad \text{..........(vi)}$$

For commercial loans, no GST is paid to the financier, but instalments must continue until the account balance has reached $b = 0$. This yields the fixed instalment as...

$$s = \frac{p\, r^t (r - 1)}{r^t - 1} \qquad \text{..........(vii)}$$

where ...

s = Future Value of the Fixed Annual Instalment (in dollars)
p = Loan Principal (in dollars)
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Interest Growth Rate = $1 + i$
t = Term of the Loan (in years).

The fixed instalments paid over the term of the loan represent a fixed expenditure cash flow which can be converted to a net present value using Eqt (iii) for a loan commencing in year n and terminating in year m. Substituting Eqt (iii) into Eqt (vii) gives...

$$PV = \frac{s\,(c^{-n} - c^{-m})}{c - 1} = \frac{p\, r^t (r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)}$$

Multiplying the numerator and denominator by c^m and substituting $t = m - n$ then gives the general equation for the net present value of any loan over term t ending in year m...

$$PV = \frac{p\, r^t (r - 1)\,(c^t - 1)}{c^m (c - 1)\,(r^t - 1)} \qquad \text{..........(viii)}$$

where ...

p = Loan Principal (in dollars)
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Interest Growth Rate = $1 + i$
t = Term of the Loan (in years)
c = Future to Present Value Conversion Factor = 1.0304
m = Elapsed Period from 1 January 2013 on which the Loan Finishes (in years).

2.2.5 Instalment and Residual for a Compound Interest Finance Lease

A new vehicle procured by commercial loan remains the property of the lessee (the bus operator) while the loan is being discharged. The new vehicle can be depreciated for tax purposes and the loan instalments attract no GST, but commercial loans contain no provision whatsoever for any residual pay out upon termination.

A new vehicle procured under a finance lease remains the property of the leasor until the lease has been fully discharged and its residual fully paid out. When a new vehicle is procured by finance lease, both the ongoing instalments and the residual left owing at termination of the lease attract GST. To determine the fixed instalment amount, the leasor and lessee must mutually agree upon the future value of the residual left to be paid out at the end of the lease, which is typically expressed as a percent of the principal, and has both a minimum and maximum dollar limit based on perceived risk. Residual percent limits are determined by the leasor in accordance with the amount borrowed, the term of the lease, the asset class and the credit worthiness of the lessee or its guarantor.

Let...

- p = principal of the finance lease, excluding GST,
- i = fixed compound interest rate paid over the term of the lease between year 1 and year t,
- s = the fixed instalments paid annually on the lease, excluding GST,
- t = the term of the finance lease,

- d = the residual remaining at the end of the lease term, excluding GST,
- j = the percentage future value of the residual to the principal, and
- $r = 1 + i$, the annual compound growth rate of the principal p.

The future value of the residual at the end of year t can be derived from Eqt (vi) by including the 10% GST applicable to both the ongoing instalments and the residual giving...

$$1.1\,d = p\,r^t - \frac{1.1\,s\,(r^t - 1)}{r - 1} \qquad \text{..........(ix)}$$

The ratio (in percent) of the residual to the principal is given by...

$$j = \frac{1.1\,d}{p} \qquad \text{..........(x)}$$

Therefore, an alternative form of Eqt (ix) for the future value of the residual is...

$$1.1\,d = j\,p = p\,r^t - \frac{1.1\,s\,(r^t - 1)}{r - 1} \qquad \text{..........(xi)}$$

Rearranging Eqt (xi) yields the future value of the ongoing fixed instalment (including GST) as...

$$1.1\,s = \frac{(p\,r^t - 1.1\,d)\,(r - 1)}{r^t - 1} = \frac{p\,(r^t - j)\,(r - 1)}{r^t - 1} \qquad \text{..........(xii)}$$

where ...

$1.1\,s$ = Future Value of the Fixed Annual Instalment, including GST (in dollars)
$1.1\,d$ = Future Value of the Final Residual, including GST (in dollars)
p = Finance Lease Principal, excluding GST (in dollars)
j = Percent Ratio of the Future Value of the Residual to the Principal (in percent),
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Interest Growth Rate = $1 + i$
t = Term of the Lease (in years).

The residual represents a fixed future lump sum expenditure paid at the end of the lease in year m, and its present value can be determined from Eqt (i) and Eqt (x) as...

$$PV = \frac{1.1\,d}{c^m} = \frac{j\,p}{c^m}$$

The fixed instalments paid over the term of the lease represent a fixed expenditure cash flow which can be converted to a net present value using Eqt (iii) for any lease commencing in year n and terminating in year m. Substituting Eqt (iii) into Eqt (xii) gives...

$$PV = \frac{(p\,r^t - 1.1\,d)\,(r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)} = \frac{p\,(r^t - j)\,(r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)}$$

Multiplying the numerator and denominator by c^m, substituting $t = m - n$, and adding the present value of the residual payout then gives the general equation for the net present value of both the instalments and residual for any finance lease over term t ending in year m as...

$$PV = \frac{(p\,r^t - 1.1\,d)\,(c^t - 1)\,(r - 1)}{c^m\,(c - 1)\,(r^t - 1)} + \frac{1.1\,d}{c^m} = \frac{p\,(r^t - j)\,(r - 1)\,(c^t - 1)\,(r - 1)}{c^m\,(c - 1)\,(r^t - 1)} + \frac{j\,p}{c^m} \qquad \text{..........(xiii)}$$

where ...

p = Future Value of Lease Principal, excluding GST (in dollars)
d = Future Value of the Residual, including GST (in dollars)
j = Percent Future Value of the Residual (including GST) to the Principal (in percent),
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Interest Growth Rate = $1 + i$

t = Term of the Lease (in years)
c = Future to Present Value Conversion Factor = 1.0304
m = Elapsed Period from 1 January 2013 on which the Lease Terminates (in years).

2.2.6 Annually Reducing to Monthly Reducing Cash Flow Conversions

The compound interest equations (iv) through (xiii) above apply strictly to annual periods only. Notwithstanding that financiers invariably quote their interest rates in percent per annum, they enforce repayment of instalments monthly and process account balances as monthly reducing, rather than annually reducing, which actually increases the total amount repaid. The following conversions enable all the above equations to be used for fixed monthly instalments paid on monthly reducing accounts:

- Substitute $i / 12$ to convert annual interest rate i to monthly interest rate,
- Substitute $r + i / 12$ to convert annual compound interest growth rate r to monthly growth rate,
- Substitute c = 1.0046376 to change the annual future to present conversion factor to a monthly future to present value conversion factor (calculated to 7 decimal places using Eqt (ii)), and
- Substitute $12\ t$, $12\ m$ and $12\ n$ to convert annual periods t, m and n to monthly periods.

2.2.7 Depreciated Book Value and Resale Value

The market resale value of a bus falls exponentially with age and whilst the resale price at any given time is driven by the economics of supply and demand, the book value can be modelled with high accuracy from a knowledge of that point in time when there is no market resale demand for the second hand vehicle, at which point its book value has fallen to the scrap (or salvage) value. For an old Queensland route bus, this occurs at age 25, and its future scrap metal salvage value is around 1% of the price of a new replacement vehicle (in present value).

Let p = price of a new replacement bus, v = its salvage value at age 25 and w = its market book value. The exponential rate of depreciation in the vehicle's market book value can be calculated as...

$r = 1 - (v/p)^{1/25} = 1 - (0.01)^{0.04} = 16.8236\%$ *per annum*. Its future book value in any given year t of its service life then solves as...

$w = p\ (1 - r)^t = p\ (1 - 0.168236)^t = p\ 0.831764^t$.

Hence on reaching retirement at assumed age 21, the expected resale value of the vehicle would be around 2.09% of its replacement purchase price in present value.

2.3 Average Labour Rates

Direct labour costs are the largest single contributor to the overall cost of operating, servicing and maintaining a route bus. The average labour rate per hour of a bus driver is needed to calculate the variable cost of operating a bus, the average labour rates of tradespersons and labourers (a.k.a. chassis cleaners, oiler-greasers and tyre repairers) to calculate the variable cost of maintaining the vehicle, and the average labour rate of cleaners (a.k.aa passenger services assistants, refuellers and yard persons) to calculate the annual cost of servicing the vehicle.

2.3.1 Average MR Licensed Bus Driver Labour Rate

Drivers holding an MR heavy vehicle licence can drive any standard 12.5m or extended 14.5m rigid bus. Their current award or certified agreement weekly rates vary markedly between bus operators in South East Queensland in the range of $638/week for a private bus operator up to $903/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $790/week.

An *Average MR Licensed Bus Driver Labour Rate = $33.94/hour* has been calculated from the cost and hours data appearing below in Table 2.

Table 2: Average Labour Rate Calculations for an MR Licensed Bus Driver

Annual Costs (Base = $790/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$41,080	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 17 hours/week over 6 shifts, including award night allowance rate	$22,865	Less 5 weeks/year for annual leave	-190 hours
Paid award allowances/year (training, meal and ticket/fare processing)	$2,416	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,697	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$3,037	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,936	Less an average of 3 days/year for compulsory authorised operator and driver training	-23 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$692	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Driver's uniform and accessories	$425	Less an average of 2.5 days/year for carer's, family and personal leave	-19 hours
Recruitment and training	$560	Less an average of 2.5 days/year for other paid leave (compassionate parental, bereavement, etc)	-19 hours
Total Labour Cost/Year	$76,708	Subtotal - Base Work Hours/Year	1563 hours (41 weeks)
Total Labour Costs/Year / Total Work Hours/Year	$76,708 / 2,260	Plus overtime worked on shift penalty rates for an average of 17 hours/week for 41 weeks/year covering night services, weekend and public holiday services and fill-ins for other drivers	+697 hours
Average Labour Rate	$33.94	Total Work Hours/Year	2,260 hours

2.3.2 Average HR Licensed Bus Driver Labour Rate

Drivers holding a HR heavy vehicle licence can drive the heavier 12.5m double deck and 18m articulated buses. Their award or certified agreement weekly rates vary markedly between operators in South East

Queensland in the range of $653/week for a private bus operator up to $948/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $840/week.

An *Average HR Licensed Bus Driver Labour Rate = $35.96/hour* has been calculated from the cost and hours data appearing below in Table 3.

Table 3: Average Labour Rate Calculations for a HR Licensed Bus Driver

Annual Costs (Base = $840/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$43,680	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 17 hours/week over 6 shifts, including award night allowance rate	$24,240	Less 5 weeks/year for annual leave	-190 hours
Paid award allowances/year (training, meal and ticket/fare processing)	$2,416	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,931	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$3,226	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$2,057	Less an average of 3 days/year for compulsory authorised operator and driver training	-23 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$735	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Driver's uniform and accessories	$425	Less an average of 2.5 days/year for carer's, family and personal leave	-19 hours
Recruitment and training	$560	Less an average of 2.5 days/year for other paid leave (compassionate parental, bereavement, etc)	-19 hours
Total Labour Cost/Year	$81,270	Subtotal - Base Work Hours/Year	1563 hours (41 weeks)
Total Labour Costs/Year Total Work Hours/Year	$81,270 2,260	Plus overtime worked on shift penalty rates for an average of 17 hours/week for 41 weeks/year covering night services, weekend and public holiday services and fill-ins for other drivers	+697 hours
Average Labour Rate	$35.96	Total Work Hours/Year	2,260 hours

2.3.3 Average Bus Cleaner Labour Rate

Bus cleaners are employed in South East Queensland bus depots under various role specific job titles including chassis cleaner, oiler-greaser, tyre repairer, yard person, refueller and passenger services assistant. Their roles have become interchangeable in most depots over the past decade and those working for particular bus operators are employed under similar pay rates and conditions of employment.

Their award or certified agreement weekly rates vary markedly between operators in South East Queensland in the range of $603/week for a private bus operator up to $876/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $740/week. For industrial harmony, the majority of bus cleaners currently work rotational shifts to equalise their take home pays.

An *Average Bus Cleaner Labour Rate = $30.97/hour* has been calculated from the cost and hours data appearing overleaf in Average Tradesperson Labour Rate

Tradespersons employed in South East Queensland bus garages include motor mechanics, automotive electricians and motor body builders. They are covered by similar trade skills based C10 through C5 pay rates and conditions of employment. Trade award or certified agreement weekly rates vary markedly between operators in South East Queensland in the range of $833/week for a private bus operator up to $1,104/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $985/week.

An *Average Tradesperson Labour Rate = $39.89/hour* has been calculated from the cost and hours data appearing overleaf in Table 5.

2.4 Bus Ownership Costs

All dollar amounts listed in the tables that follow have been expressed in FY2012/13 dollar values. Future values of expenditures and recoveries incurred during each vehicle's life have been backward converted to their equivalent present dollar values so that a like-for-like comparison can be made between the alternative bus types using dollar values as they are measured today. Outgoing expenses have been assigned positive present values. Incoming recoveries have been assigned negative present values and highlighted by red text. Where abbreviated in the following analysis, "*PV*" means *Present Value*, "*NPV*" means *Net Present Value,* and "*FV*" means *Future Value*.

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Table 4: Average Labour Rate Calculations for a Bus Cleaner

Annual Costs (Base = $740/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$38,480	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 10 hours/week over 6 shifts, including award night allowance rate	$12,949	Less 5 weeks/year for annual leave	-190 hours
Paid meal allowance/year	$2,016	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,463	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$2,443	Less an average of 6 days/year for sick leave (ie 60% of maximum entitlement)	-46 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,557	Less an average of 1 day/year for compulsory authorised operator, fire, driving and safety training	-8 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$648	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Safety vest, boots, goggles and raincoat	$125	Less an average of 2 days/year for carer's, family and personal leave	-15 hours
Recruitment and training	$200	Less an average of 2 days/year for other paid leave (compassionate parental, bereavement, etc)	-15 hours
Total Labour Cost/Year	$61,881	Subtotal - Base Work Hours/Year	1,578 hours (42 weeks)
Total Labour Costs/Year / Total Work Hours/Year	$61,881 / 1,998	Plus overtime worked on shift penalty rates for an average of 10 hours/week for 42 weeks/year covering night, weekend and public holiday bus servicing and fill-ins for other cleaners	+420 hours
Average Labour Rate	$30.97	Total Work Hours/Year	1,998 hours

2.4.1 Average Tradesperson Labour Rate

Tradespersons employed in South East Queensland bus garages include motor mechanics, automotive electricians and motor body builders. They are covered by similar trade skills based C10 through C5 pay rates and conditions of employment. Trade award or certified agreement weekly rates vary markedly between operators in South East Queensland in the range of $833/week for a private bus operator up to $1,104/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $985/week.

An *Average Tradesperson Labour Rate = $39.89/hour* has been calculated from the cost and hours data appearing overleaf in Table 5.

2.5 Bus Ownership Costs

All dollar amounts listed in the tables that follow have been expressed in FY2012/13 dollar values. Future values of expenditures and recoveries incurred during each vehicle's life have been backward converted to their equivalent present dollar values so that a like-for-like comparison can be made between the alternative bus types using dollar values as they are measured today. Outgoing expenses have been assigned positive present values. Incoming recoveries have been assigned negative present values and highlighted by red text. Where abbreviated in the following analysis, "*PV*" means *Present Value*, "*NPV*" means *Net Present Value,* and "*FV*" means *Future Value*.

Table 5: Average Labour Rate Calculations for a Tradesperson

Annual Costs (Base = $985/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$51,220	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime	$6,532	Less 4 weeks/year for annual leave	-152 hours
Paid tool, first aid and meal allowances/year	$1,052	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$4,610	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$2,743	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,749	Less an average of 4 days/year for compulsory QA, trade skills, environmental and OHS training	-30 hours
Annual Leave Loading (17.5% of 4 weeks paid annual leave)	$690	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Overalls, safety vest, boots, goggles, raincoat, hard hat and compensation for spectacles, hearing aids, tools and work clothing damaged on job	$500	Less an average of 2 days/year for carer's, family and personal leave	-15 hours
Recruitment and training	$1,500	Less an average of 2 days/year for other paid leave (compassionate parental, bereavement, etc)	-15 hours
Total Labour Cost/Year	$70,596	Subtotal - Base Work Hours/Year	1,602 hours (42 weeks)
Total Labour Costs/Year Total Work Hours/Year	$70,596 1,770	Plus an average of 4 hours overtime at time and a half rates for 2 nights per week or Saturday mornings for 42 weeks/year	+168 hours
Average Labour Rate	$39.89	Total Work Hours/Year	1,770 hours

2.5.1 Bus Procurement Costs

Bus procurement costs cover a new vehicle's purchase price, together with ancillary costs for axle weighing, ADR compliance certification, statutory on-road fees and charges, insurance, delivery, operator pre-service quality inspections and minor fit-outs totalling approximately $7,500 per new vehicle.

New bus chassis and body manufacturer purchase prices vary significantly with production run lot sizes and this analysis has been based on an assumed minimum lot size of 5 new buses per production run. FY2012/13 average procurement costs for new high capacity buses relative to that of the reference two door 12.5m rigid bus are listed below in Table 6.

Table 6: Procurement Costs for New High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Procurement Cost (Dollars)	Relative Procurement Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$480,000	141.7%	116.7%	158.3%	160.4%

2.5.2 Bus Procurement Financial Costs

While bus procurement costs are a one-off capital expenditure incurred at the time of purchase, they are normally amortised in practice as future instalments on borrowing expenses, and as future residual payouts in the case of a finance lease. Bus operators typically fund new bus procurements through a mix of debt (commercial business loans or finance leases) and equity (cash down deposits and finance lease residual payouts). The weighted cost of capital will therefore vary from operator to operator in accordance with its preferred leveraging of debt to equity funding, the term of the commercial loan or finance lease entered into, its fixed interest rate, and final residual payout if a finance lease.

For private bus operators, the cost of capital funded by loan can be offset through capital depreciation write-downs claimed back as BAS tax deductions, and any GST paid on finance lease instalments can similarly be recovered indirectly as an input tax credit by the leasor and as a BAS business operating expense by the lessee.

Whilst public bus operators similarly recognise capital depreciation expense for government accounting purposes, they have no recourse to depreciation cost recoveries through corporate business taxation, but otherwise fully recoup their GST payments on finance loan instalments and secure very low interest rates with finance leases sourced through the Queensland Treasury Corporation. To compare the cost of capital for all bus types and bus operators equitably, we have therefore adopted the following assumptions for our bus life cost analysis:

- 100% of new bus procurement capital costs will be funded by a TransLink guaranteed finance lease entered into for a 10 year term with a 20% residual payout from operator equity falling due upon termination of the lease at the end of year 10.
- The cost of debt funding for new buses procured through the finance lease has been set at a fixed interest rate of 7.25%/annum (the current finance industry median borrowing rate for long term truck and bus fleet finance leases effective as at Q2 FY2012/13), and the lease repaid in monthly reducing instalments.
- Capital depreciation for loans or GST tax deductions claimed for leases by private bus operators are considered comparable in value to GST recoveries obtained by public bus operators. To account for procurement cost tax offsets, the net cost of GST has been deducted from the net present value of the finance lease as an equivalent tax deduction recovery received by both private and public bus operators.

Table 7 below summarises the net present values of bus procurement financial costs for the 4 high capacity bus types relative to that of the reference two door 12.5m rigid bus. Amounts shown in the table have been calculated using Eqt (xiii) and independently verified by a spreadsheet for all monthly cash flows. Tax deductions indicated in Table 7 are equivalent to the net present value of all GST paid on the 120 monthly lease instalments and the residual payout at the end of year 10.

Table 7: Procurement Financial Costs for High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Procurement Financial Costs (Dollars)	Bus Procurement Financial Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$538,610 (Lease Repayments)	141.7%	116.7%	158.3%	160.4%
- $53,861 (Tax Deductions)	-141.7%	-116.7%	-158.3%	-160.4%

2.5.3 Bus Resale Price Recovery

The market value of a bus depreciates continuously throughout its service life until retirement, at which time the vehicle is either traded in, sold or salvaged to recover its remaining book value. Market resale prices closely mirror the exponential decay characteristic of a reducing balance depreciation curve and from the analysis appearing in Section 2.2.7, the anticipated resale price for all bus types at a retirement age of 21 would be around 2.09% of their respective new replacement bus price when expressed in present dollar values. The relative resale price recoveries for the 5 bus types (in present value dollars) are presented in Table 8 below.

Table 8: Resale Recovery for All Bus Types at a Retirement Age of 21

Reference 2 Door 12.5m Rigid Bus Resale Recovery (Dollars)	Relative Resale Price Recovery Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
-$10,000	-141.7%	-116.7%	-158.3%	-160.4%

2.5.4 Depot Costs for Initial High Capacity Bus Deployments

First-time deployment of longer, taller or wider swept path high capacity vehicles to an existing bus depot can potentially trigger major capital works for site modifications and other upgrades covering:

- Changed depot bus circulation paths,
- Dedicated HCV parking bays and/or lanes,
- Changed parking yard layouts and line remarking,
- Additional single post maintenance hoists or pit lengthening,
- Wheel brake and suspension shaker pit equipment modifications,
- Bus spray painting booth heightening or lengthening,
- Garage roller door and service shed widening or heightening,
- New bus roof access catwalks or tethered anti-fall personnel safety harnesses,
- Refuelling bay and washing machine modifications,
- AdBlue storage tank and dispenser hose installations in refuelling bays,
- Specialised HCV maintenance crew and driver orientation training sessions,
- Specialised HCV maintenance tools and test equipment procurements, and

- Specialised HCV spare parts procurements.

The *Depot Evaluation Technical Report* completed in Stage 1 of this study explored the likely impacts of deploying new high capacity vehicles to 16 existing bus depots in South East Queensland and concluded that specific high capacity bus types should be selected for each depot to obviate costly major building modifications for their initial accommodation.

During the course of the depot evaluation study, it was noted that most private operators had not as yet installed AdBlue storage tanks and dispensers in their refuelling bays, but it was clarified that such would become compulsory for any future new Australian Design Rule compliant buses entering service if fitted with SCR emission controlled diesel engines. We have therefore not included upgrade costs associated with retrofit tank and refuelling bay AdBlue installations as such would occur irrespective of whether retiring standard 12.5m rigid buses were replaced with new 12.5m rigid buses or high capacity buses.

Subject to economically justifiable selective deployment of those high capacity bus types best suited to existing depot constraints, we have surmised for costing purposes that a typical depot should only require the following minor capital works and equipment upgrades:

- HCV parking bay creation and line remarking at those depots with existing perimeter bus parking bays **or** parking yard layout modifications and line remarking at those depots with existing nose-to-tail parking lanes,
- 4 additional new maintenance post hoists per garage,
- 1 additional bus roof anti-fall safety work harness per garage,
- 2 washing machine top rail and roller height extension modifications **or** 1 new mobile bus washing machine per garage (for double deck buses only),
- 1 set of specialised HCV spare parts per garage,
- 1 set of specialised HCV maintenance tools and test equipment per garage,
- 5 onsite HCV maintenance crew technical training sessions per garage, and
- 90 HV licensed driver high capacity bus orientation training sessions per depot.

Depot upgrade, new equipment/spares and staff training costs arise as once-off capital outlays when any new bus type is first introduced into service at an existing bus depot, and the last 4 items listed above apply equally to the initial deployment of a new 12.5m rigid bus model. We have assumed for costing purposes that depot upgrade costs would be funded from the bus operator's business equity accounts but have apportioned the capital cost equally to the first lot of 5 new buses placed in service at a single existing depot. Depot upgrade costs applicable to the 5 new bus types are listed below in Table 9.

Table 9: Depot Upgrade Costs for 5 Initial Bus Deployments to a Single Depot

Reference 2 Door 12.5m Rigid Bus Depot Upgrade Cost (Dollars)	Average Total Costs and Relative Cost Factors for Initial 5 Bus Deployment			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$30,000 (total)	$115,000 (total)	$90,000 (total)	$90,000 (total)	$90,000 (total)
$6,000 (per bus)	383%	300%	300%	300%

2.5.5 Major Overhaul and Refurbishment Costs

Major drive train overhauls and structural frame and body refurbishments incur significant capital costs during a vehicle's life. They are triggered either by elapse of time (bus age), but are not recurring fixed annual costs; or by travelled distance (bus odometer reading), but are not variable costs proportional to kilometres travelled.

A typical distance:age profile for a route bus life cycle has been presented in
Figure 1. The underlying reasons for the characteristic saddle shape of this curve are due in part to operator and driver preferences to operate young and middle aged buses rather than old aged buses, and to major overhauls and refurbishments around the vehicle's mid-life which reduce its normal availability for route services.

The area under the bus distance:age profile curve in each year of service is a direct measure of the kilometres travelled by the vehicle in that year, and the cumulative area under the curve up to the end of each year is a direct measure of the vehicle's accumulated odometer kilometres since first entering service. Travelled annual and cumulative odometer kilometres for each year of the assumed 21 year service life have been listed in All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distances per annum in each year of the vehicle's service life have been based on the statistical polynomial *Curve of Best Fit* appearing above in
- Figure 1. This curve was sourced from a detailed review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile curve have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing depot only.
- Capital expenditures, other than for new bus procurements, have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or saving accounts). This includes all final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 20km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h, and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1, total 1,230,600 kilometres and average 58,600km/annum. This distance:age profile has been adopted to compare the relative costs of all 5 bus types under identical life cycle operating conditions.

Inspection of All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distances per annum in each year of the vehicle's service life have been based on the statistical polynomial *Curve of Best Fit* appearing above in
- Figure 1. This curve was sourced from a detailed review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile curve have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.

- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing depot only.
- Capital expenditures, other than for new bus procurements, have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or saving accounts). This includes all final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 20km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h, and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1 reveals that the characteristic trough in the distance:age profile occurs around age 8 when the bus odometer reaches 500,000km. This is the point in the vehicle's life where most chassis manufacturers specify their major engine and transmission overhauls, but new bus manufacturers today have managed to stretch this interval out to 700,000km, which occurs later on All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distances per annum in each year of the vehicle's service life have been based on the statistical polynomial *Curve of Best Fit* appearing above in
- Figure 1. This curve was sourced from a detailed review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile curve have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing depot only.
- Capital expenditures, other than for new bus procurements, have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or saving accounts). This includes all final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 20km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h, and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1 at around age 11 to 12. This 200,000km increase has ensured that the engine on a typical route bus only requires one major overhaul in the vehicle's service life.

By age 9 to 10, bus frame structural fatigue and rust have typically begun, triggering the urgent need for a major body frame refurbishment. Also around age 9 to 11, the cabin seat upholstery and aisle way floor vinyl also begin to look worn and deteriorated and the vehicle's tarnished finish could do with a fresh spray of 2 pack urethane. In the knowledge that the bus has attained its mid-life, the combined urgent need for all these refurbishments forces a decision on the bus operator either to sell the bus or give it a fresh makeover that would see it through to its retirement. The latter is invariably the cheaper option, and correspondingly, the one most frequently chosen.

700,000km Major Engine Overhaul at Age 11 to 12

$48,000 for the 12.5m rigid bus, $52,000 for all other bus types. These indicated PV costs cover removal, major overhaul and refit of the engine to the vehicle. Labour has been costed for 140 hours at the average tradesperson rate of $39.89/hour calculated in Section 2.4.1. Material costs have been adjusted for a typical manufacturer's list price discount of 20% available to most large private operators and include GST. The tasks costed include overhaul of the starter motor, alternator, intercooler, radiator, water pump, power steering pump, air compressor, air conditioner compressor, turbocharger and radiator, plus full replacement of the engine cylinder heads, liners, piston rings, filters, injectors, belts, hoses, oil and catalytic converter.

500,000km Major Gearbox and Retarder Overhaul at Age 8 to 10

$47,000 for all bus types. A similar model 5 speed automatic gearbox and retarder has been assumed fitted to all bus types. The PV cost indicated covers removal, transport to and from the repairer, overhaul by the transmission repairer, and refit to the bus. Removal, transport and refit labour have been costed for 15 hours total at the average tradesperson rate. Automatic transmission repairs prove very costly and notwithstanding that gearbox manufacturers specify 500,000km for their major overhauls, most private operators will typically hold off mid-life overhauls for as long as possible to avoid having to repeat overhaul the transmission in the vehicle's old age.

Mid-Life Body Frame & Upholstery Refurbishment and Exterior Repaint at Age 9 to 10

$34,000 for a 12.5m rigid, $51,000 for a double deck bus, $38,000 for a 14.5m rigid bus, $43,000 for a 2 door articulated bus and $41,000 for a 3 door articulated *Superbus*. For most private operators, bus mid-life is actually reached at around age 9 to 10, based on odometer kilometres half-life, rather than age mid-life. The cheapest way to complete the vehicle's mid-life makeover is to withdraw the bus entirely from service, send it to coach body repairers for competitive quotes, and raise an order to complete all body refurbishments in a single pass.

While floor vinyl replacement, seat fabric re-upholstery and exterior repainting can be estimated with reasonable accuracy, structural cracks and rust in zincalum steel frames or weld fractures and T-nut slippages in aluminium frames can cause severe collateral damage to door frames and window pillars, bonded glazing, floor laminates, seat frame anchors and interior bulkheads.

We have assumed only minor frame deterioration and collateral body repairs to a total value of $10,000 + GST per bus, and costed replacement of worn floor vinyl along the cabin aisle ways only.

Summated PV overhaul and refurbishment costs for the 5 bus types appear overleaf in Table 10. It has been assumed that these would be fully funded by the operator from equity accounts without the need to borrow.

Table 10: Major Overhaul and Refurbishment Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Major Overhaul and Refurbishment Cost (Dollars)	Relative Major Overhaul and Refurbishment Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$129,000	116.3%	106.2%	110.1%	108.5%

2.6 Fixed Annual Operating Costs

In this analysis, fixed operating costs refer to expenses incurred annually by the operator to keep each bus registered, insured, clean and service ready. Fixed annual operating costs accrue in each year of the vehicle's life irrespective of the service kilometres actually travelled in any given year.

2.6.1 Annual Statutory Compliance Costs

All urban buses used to deliver public transport route services within TranLink's operating area require annual registration and Class 10B compulsory third party insurance, as well as two bi-annual Department of Transport and Main Roads *Programmed Vehicle Safety Audits.*

Annual Registration Fees

Bus registration fees depend on the vehicle type, its number of axles and the vehicle manufacturer's rated axle gross vehicle mass. State registration fees are currently $488/annum for all bus types other than the 2 door 12.5m double deck bus, which is currently $2,429/annum because its front steer axle centres exceed the 1 metre maximum separation limit.

Compulsory Third Party Insurance Premiums

Class 10B CTP insurance premiums vary quite markedly between the 5 bus types and depend on each vehicle's total passenger plus driver seating capacity. CTP insurance premiums range from $4740/annum for the standard 12.5m rigid bus with 45 total seats up to $10,700/annum for the 2 door 12.5m double deck bus with 97 total seats.

Programmed Vehicle Safety Audits and Charges

$710/annum for a 12.5m rigid or double deck bus, $850/annum for a 14.5m rigid bus and $1,015/annum for an articulated bus.

Compulsory bi-annual programmed vehicle safety audits are typically conducted onsite in each bus depot. Visiting TMR safety auditors require that all vehicle undercarriages be pressure cleaned prior to inspection, every vehicle be brake and suspension shaker witness tested, then hoisted for a thorough chassis, steering, suspension, tyre wear and driveline inspection. Audits will also include cab interior and fire extinguisher safety checks, and may occasionally involve random road testing of some vehicles upon request by the auditor.

A certificate of inspection is issued by the auditor for safety defect rectifications on each bus, and a second round of inspections conducted to confirm their timely completion. Maintenance works generated by safety rectifications have been separately costed under bus maintenance.

Total annual statutory compliance costs for the 5 bus types are summarised overleaf in Table 11.

Table 11: Annual Statutory Compliance Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Statutory Compliance Cost (Dollars/Annum)	Relative Annual Statutory Compliance Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$5,938/annum	233%	125.5%	143.7%	120.6%

2.6.2 Annual Bus Insurance Costs

A range of insurance products is available for bus operators to manage their business risks, but the three most common policies taken up specifically for bus fleets are public liability, comprehensive commercial vehicle fleet insurance and depot insurance, the latter of which provides cover against theft, fire or flood damage sustained while buses are parked in depots. As the legal owner of a leased bus, the two former insurance policies will be invariably stipulated by financiers to be kept current throughout the term of any finance lease.

Insurance brokers frequently bundle their offerings at discount premiums to cover every possible type of fleet insurance imaginable from CTP to depot insurance, business interruption protection, business income assurance, directors' and officers' legal liability, public liability and even worker's compensation. Discount bundled premiums per bus increase with reducing fleet size, increasing average fleet age and average bus replacement price, the number of previous motor accident claims lodged by the fleet operator, and their total claim value.

With so many variables affecting discount annual insurance premiums, the following indicative costs would be considered typical of the average per unit unbundled insurance premium rates for a large private bus operator with a fleet of 100 buses of 10 years average age with a moderate to good previous claim history.

Public Liability Insurance

$1,160/annum for all bus types. Public liability insurance premiums are currently set independent of bus passenger carrying capacity, but this may change over time if future SEQ bus fleets begin to incorporate an increasing proportion of high capacity vehicles.

Comprehensive Commercial Vehicle Fleet Insurance

$865/annum for a standard 12.5m rigid bus, $1,440/annum for a 14.5m rigid bus and $1,480/annum for a double deck or articulated bus. Comprehensive insurance premiums are affected by vehicle purchase price and road accident susceptibility. We have nominated per vehicle premium rates for a $2,500 excess basic "no frills" comprehensive motor vehicle accident repair or replace, and personal injury or death coverage capped to $30 million.

It should be noted however that fleet insurance premiums could be up to 3 times those indicated above for small bus operators with a poor claim history who elect full coverage for added "frills". Such frills include options such as refund of tow back to depot and to/from the vehicle's place of repair, refund of temporary bus repair costs, refund of passenger expenses to complete their journeys by taxi, refund of temporary replacement bus hire charges, full passenger luggage damage cover and full replacement of vehicles under 12 months of age or pay out of their finance lease residual after 12 months of age in the case of a total accident write-off.

Depot Insurance

$150/annum for all bus types. Depot insurance provides low cost insurance coverage for buses whilst parked in depots and garages. Its main purpose is to insure vehicles against theft and catastrophes such as floods or fires, but not collisions or other accidents occasioned whilst buses are located in depots.

Total PV annual insurance costs for the 5 bus types are summated below in Table 12.

Table 12: Annual Insurance Costs for High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Annual Insurance Cost (Dollars/Annum)	Relative Annual Insurance Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$2,175	128.3%	126.4%	128.3%	128.3%

2.6.3 Annual Depot Bus Accommodation Cost

Many private bus operators around Australia elect to rent industrial properties to park and store their bus fleets, enabling property rental costs to be claimed back as BAS business expenses. Depot bus accommodation costs are in effect an accounting mechanism to apportion the annual cost of depot property purchase price amortisation, maintenance and upkeep, State land taxes and Council rates to the buses being accommodated.

For large operators who own their bus depots, depot building footprints are comparatively small in area relative to the garage, yard, temporary parking bays and circulation lanes provided for bus movements, temporary storage and parking, so the recurring annual costs of the entire depot site can reasonably be apportioned to each bus type by size and number as if the entire land parcel was being rented from a third party. Depot bus accommodation costs are a real fixed recurring annual cost to the operator, independent of the kilometres travelled by the buses actually being stabled and maintained at the depot.

Depot Bus Accommodation

$1,350/annum for a standard 12.5m rigid or double deck bus, $1,550/annum for a 14.5m rigid bus and $1,900/annum for an articulated bus. To cost depot bus accommodation, we have obtained long term annual rentals from realty agents for industrial properties located near, and similar in size, to existing bus depots in Brisbane, Redcliffe and the Gold Coast hinterland, averaged their rentals per unit area, and apportioned the rental per unit area to the parking space needed for each bus type as follows:

- 12.5m Rigid and Double Deck Bus Parking Space: (12.5m long + 1m clearance) x (2.5m wide + 1m clearance) = 47.25m^2 = 1 Standard Bus Space
- 14.5m Rigid Bus Parking Space: (14.5m length + 1m clearance) x (2.5m width + 1m clearance) = 54.25m^2 = 114.8% x Standard Bus Space
- 18m Articulated Bus: Parking Space: = (18m length + 1m clearance) x (2.5m width + 1m clearance) = 66.5m^2 = 140.7% x Standard Bus Space.

Table 13: Annual Depot Accommodation Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Depot Accommodation Cost (Dollars/Annum)	Relative Annual Depot Accommodation Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,350/annum	100%	114.8%	140.7%	140.7%

2.6.4 Annual Bus Refuelling, Fluid Top-Up and Cleaning Costs

Bus servicing encompasses a broad range of routine refuelling, fluid top-up, greasing, cleaning, inspection, testing and checking activities to maintain the vehicle in a state of service readiness, and are generally performed by unskilled cleaners or bus drivers. Bus servicing does not generally require trade accredited technical skills, fault diagnostics or dismantling of vehicle components; and may either be performed at fixed time or travelled kilometre intervals. Fixed time based activities include the following:

Daily or Nightly Refuelling, AdBlue and Water Level Topping and Bus Exterior Lighting and Panel Damage Inspections

$1,065/annum for all bus types. Refuelling, AdBlue, demister and radiator water level top-ups may be undertaken by drivers when returning to depot or by rostered shift cleaners during rostered day and late evening shifts. The 4 tasks take around 4 to 5 minutes per bus to complete and occur at an average frequency of 6 times per week. While tanks are being automatically topped, the bus exterior will typically be checked for signs of damage and if completed at night, operation of exterior lights (a legal requirement) will also be checked.

Consumables (viz. electricity and water) for these tasks amount to around $5 per bus per week. Because diesel and Adblue consumption costs increase with kilometres travelled, they are not included in the fixed annual costs of servicing the vehicle.

Daily or Bi-Daily Cab Interior Cleaning

$622/annum for a 12.5m or 14.5m rigid bus, $985/annum for a double deck bus, $804/annum for an articulated bus. Bus cabins need to be swept or vacuumed, and hand cleaned free of dust, spills and litter once daily (6 times per week) or bi-daily (3 times per week). Interior cleaning takes around 3 minutes for a 12.5m or 14.5m rigid bus, 4.5 minutes for an 18m articulated bus and 6 minutes for a double deck bus, and is normally assigned to cleaners, but may in rare cases, be assigned to bus drivers.

Operators who deploy 2 man cleaner teams at night combine refuelling, fluid top-up inspections and cab cleaning as concurrent activities to avoid double handling their buses. Consumables (viz. detergent and water, glass cleaner and paper towels) amount to around $5 per bus per week.

Daily, Bi-Daily or Weekly Bus Exterior Washing and Tyre Pressure Checking

$738/annum for all bus types. Large bus operators who have installed automatic washing machines combine drive-through exterior bus washing and tyre checking with their daily refuelling or bi-daily interior cleaning procedures to obviate double handling of buses. Small bus operators typically wet detergent broom-wash their bus exteriors by hand on a weekly or fortnightly cycle.

Our costing has been based on drive-through automatic machine washing by a cleaner 6 times per week at around 2 minutes per bus wash with a visual tyre pressure check, as large operators with washing machines are those more likely to deploy high capacity buses, and because hand washing of large buses is extremely laborious, costly and inefficient.

Consumables for automatic washing machines include electricity, water, water treatment, recycling chemicals, detergent and ongoing machine maintenance worth around $8 per bus per week for 6 washes.

Bi-Annual Chassis Pressure Cleaning

Bus chassis, engine bay and undercarriage pressure cleaning are required to remove the build up of road grime, dust and small stones which progressively accumulate in the vehicle's undercarriage, and the oil and distillate leak soaked dust residues which accumulate around and on top of the drive train components.

The latter are a recognised fire safety hazard, and consequently bus undercarriage pressure cleaning cycles are synchronised by bus operators to occur before bi-annual TMR safety audits in the knowledge that the safety auditor will automatically stop any vehicle found with a known fire safety hazard.

We have consequently costed bi-annual chassis pressure cleans in with the costs of programmed safety audits previously discussed.

Summated PV annual refuelling, fluid top-up and cleaning costs for the 5 bus types appear below in Table 14.

Table 14: Annual Refuelling, Fluid Top-up and Cleaning Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Refuelling, Top-Up and Cleaning Cost (Dollars/Annum)	Relative Refuelling, Top-Up and Cleaning Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$2,425/annum	115%	100%	107.5%	107.5%

2.6.5 Fixed Annual Cost Inflation Factors

Fixed annual costs inflate throughout the vehicle's service life. Inflation factors for the 4 identified fixed annual operating costs have been sourced as follows:

- Statutory Compliance Cost Inflation Factor: There are no motor industry price indices available which directly track annual increases in Queensland heavy vehicle registration and CTP charges, however Brisbane motor transport and private motoring costs have inflated at an average of 2.87%/annum over the past decade. The annual inflation factor for statutory charges has therefore been set at 1.0287 (Source: *ABS CPI A2326041L*).
- Bus Insurance Cost Inflation Factor: Over the past decade, the cost of Brisbane motor insurance premiums have increased at an average of 6.7%/annum. The annual inflation factor for bus insurance cost has therefore been set at 1.067 (Source: *ABS CPI A3602803R*).
- Depot Bus Accommodation Cost Inflation Factor: Over the past decade, the cost of Brisbane property rents have increased at an average of 5.12%/annum. The annual inflation factor for depot bus accommodation cost has therefore been set at 1.0512 (Source: *ABS CPI A2331846T*).
- Bus Servicing Cost Inflation Factor: Over the past decade, the Queensland public and private wage CPI has increased at an average of 4.2%/annum. The annual cost inflation factor for bus servicing by cleaners and drivers has therefore been set at 1.042 (Source: *ABS CPI A2711844F*).

2.6.6 Total Fixed Annual Operating Cost

The NPV of all vehicle fixed annual operating costs has been calculated using Eqt (v) and verified independently by spreadsheet. The calculated NPVs of all fixed annual operating costs for the 5 bus types are summarised below in Table 15.

Table 15: Total Fixed Annual Operating Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Total Fixed Annual Operating Cost (Dollars)	Relative Total Fixed Annual Operating Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$284,336	167.2%	119.2%	132.3%	122.3%

2.7 Variable Operating Costs

Variable operating costs are operating expenses which increase in proportion to the kilometres travelled while delivering bus services. Kilometres travelled vary each year with vehicle age as earlier illustrated by the distance:age profile curve in

Figure 1. The area under the distance:age profile curve in each year of its service life is a direct measure of the kilometres travelled in that year, and these have been listed in All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distances per annum in each year of the vehicle's service life have been based on the statistical polynomial *Curve of Best Fit* appearing above in
- Figure 1. This curve was sourced from a detailed review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile curve have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing depot only.
- Capital expenditures, other than for new bus procurements, have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or saving accounts). This includes all final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 20km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h, and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1. Leading contributors to variable operating costs are diesel and AdBlue consumption, kilometre based bus servicing and maintenance and driver wages.

2.7.1 Diesel and AdBlue Consumption Cost Rates

Low sulphur clean diesel and AdBlue urea are the two primary consumables of any modern bus fitted with an SCR diesel engine complying with exhaust emission standards defined in *Australian Design Rule ADR 80*. The federal diesel excise rebate previously available to public transport bus operators has now ceased and delivered prices for bulk clean diesel (inclusive of federal excise) and bulk AdBlue urea in 1,000 litre or larger drums are $1.47/litre and $1.20/litre respectively for large fleet operators.

PV average diesel and Adblue consumption rates per kilometre are summarised below in Table 16 for the 5 bus types.

Table 16: Average Diesel and AdBlue Consumption Rates per Kilometre for the 5 Bus Types

Average Diesel Consumption Rate per Kilometre for the 5 Bus Types				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus

43 litres/100km	60 litres/100km	48 litres/100km	49 litres/100km	49 litres/100km
$0.63/kilometre	$0.88/kilometre	$0.71/kilometre	$0.72/kilometre	$0.72/kilometre
Average AdBlue Consumption Rate per Kilometre for the 5 Bus Types				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
2.1 litres/100km	3.9 litres/100km	2.8 litres/100km	3.2 litres/100km	3.2 litres/100km
$0.03/kilometre	$0.05/kilometre	$0.03/kilometre	$0.04/kilometre	$0.04/kilometre

2.7.2 Servicing and Maintenance Cost Rates

Routine garage kilometre based servicing activities include the following inspection, test and lubrication services:

- Brake roller and suspension shaker tests,
- Tyre wear inspection, rotation, rebalance, pressure checking and replacements,
- Chassis, suspension, axle and drive train greasing,
- Alternator, water pump, air conditioning compressor and radiator fan belt replacements,
- Engine, transmission, fuel, water, air conditioner and air system filter replacements,
- Engine, transmission, differential, steering box, etc. oil top-ups or replacements,
- Water additive, air conditioner refrigerant and hydraulic oil top-ups or replacements, and
- Door lubrication, operation and safety checks.

Regular garage kilometre based mechanical maintenance checks, diagnostics, replacements and repairs are undertaken for the:

- Tyres, wheels, shock absorbers and wheel alignments,
- Linings, drums, brake pads, discs, slack adjusters, etc,
- Compressor, air filter, air dryer, air bags, air valves, air hoses, etc,
- Brake and suspension compressed air tanks, valves and hoses,
- Water pump, radiator, intercooler, coolant hoses, thermostat, etc,
- Turbocharger, exhaust pipe(s), muffler and catalytic converter,
- Power steering, park brake and foot brake valves,
- Air conditioner compressor, evaporator, condenser, TX valve and fan motors,
- Driver seat suspension, door and wheelchair loader mechanisms,
- Vehicle road handling and stability tests,
- Injection pump, fuel lines and SCR mixer,
- Bus towing and on-road breakdown assistance, and
- Energy guidance system (articulated buses only).

Regular garage kilometre based electrical maintenance checks, diagnostics, replacements and repairs are undertaken for the:

- Alternator, starter motor, regulator, batteries and master switch contactor,
- CAN comms cable pairs, looms, harnesses, earths, power cables and connectors,
- Switches, fuses, circuit breakers, relays and protection devices,
- Driver instruments, LCD panels, audible alarms and visual indicators,
- Electric motors, solenoids, tachometers, senders and sensors,
- Lamps, LED lights, bulbs, CFLs, inverters, fluorescent tubes and ballasts,

- Windscreen wipers, washers and demisters,
- CAN, instrument cluster, gearbox, engine and ABS brake control modules,
- PLC, door, air conditioner, safety interlock and body control units,
- Mobile radio, air conditioner, destination sign(s), cameras, driver's video monitor and DVR,
- Turntable articulation control unit, angle/pressure sensors and proportional valve (articulated buses only), and
- TransLink smartcard DCU, PIM and door OBCIDs.

Regular garage kilometre based body maintenance checks, replacements and repairs are undertaken for:

- Body water leaks, structural rust, T-nut slippage and frame corrosion,
- Floor laminate rot and vinyl wear and tear damage,
- Cracked windscreens and glazing,
- Exterior panel damage fibreglass, bog, sand and repaints,
- Exterior panel and FRP mould replacements and repaints,
- Bumper bar and dumb iron straightening and repaints,
- Rear view mirror, roof hatch, air conditioner pod, destination and rear numeral headers,
- Interior panel lifted fabric adherence and repaints,
- Graffiti removal and seat upholstery replacements,
- Hand grip, strap hanger, hand rail and stanchion tightening or replacements,
- Articulation bellows wear and tear (articulated buses only), and
- Driver and passenger seat cushion and squab replacements.

Present value bus servicing and maintenance cost rates per kilometre for the 5 bus types are given overleaf in Table 17.

Table 17: Average Servicing and Maintenance Cost Rates per Kilometre for the 5 Bus Types

Average Servicing and Maintenance Cost Rate per Kilometre				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
\$0.37/kilometre	\$0.51/kilometre	\$0.42/kilometre	\$0.47/kilometre	\$0.48/kilometre

2.7.3 Driver Labour Cost Rates

Notwithstanding a driver is paid at an average 38 hour/week labour rate, labour cost per kilometre is needed to compute the cost of bus service(s) delivered on road. The mathematical relationship between the driver's average labour rate per hour and his/her average labour cost per kilometre is given by....

$$\text{Average labour cost per kilometre} = \frac{\text{Average labour rate per hour}}{\text{Average service speed}} \quad \begin{matrix}\text{(in dollars per hour)} \\ \text{(in kilometres per hour)}\end{matrix}$$

An average labour rate of \$33.94 per hour was calculated for an MR licensed bus driver to drive either a 12.5m or 14.5m rigid bus in Section 2.3.1; and \$35.96 per hour for a HR licensed bus driver to drive either a double deck or articulated bus in Section 2.3.2.

Table 18: Average Service Speeds for Different Route Lengths, Traffic Speeds and Stops per Trip

Comparison of Bus Types on 10 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	22	18	21	22	19
16	22	18	20	21	19
23	22	17	20	21	18
32	21	17	19	20	18
45 Kilometre/Hour Average Traffic Speed					
11	29	22	26	27	23
16	28	21	25	26	22
23	26	20	23	24	21
32	25	19	22	23	20
75 Kilometre/Hour Average Traffic Speed					
11	32	24	28	29	25

Comparison of Bus Types on 15 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	24	21	23	24	22
16	24	21	23	24	21
23	24	20	22	23	21
32	23	20	22	22	20
45 Kilometre/Hour Average Traffic Speed					
11	33	27	30	32	28
16	32	26	29	31	27
23	31	25	28	29	26
32	29	23	26	27	24
75 Kilometre/Hour Average Traffic Speed					
11	40	31	36	37	32
16	36	28	32	33	30

Comparison of Bus Types on 20 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	26	23	25	25	23
16	25	23	24	25	23
23	25	22	24	24	23
32	25	22	24	24	22
45 Kilometre/Hour Average Traffic Speed					
11	35	30	33	35	31
16	35	29	32	33	30
23	33	28	31	32	29
32	32	27	29	30	28
75 Kilometre/Hour Average Traffic Speed					
11	45	36	41	42	38
16	42	33	37	38	35
23	37	30	33	33	32

Comparison of Bus Types on 25 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	26	24	25	26	24
16	26	24	25	26	24
23	26	23	25	25	24
32	26	23	25	25	23
45 Kilometre/Hour Average Traffic Speed					
11	37	32	35	36	33
16	36	31	34	35	32
23	35	30	33	34	31
32	34	29	32	32	30
75 Kilometre/Hour Average Traffic Speed					
11	49	41	45	46	42
16	46	38	42	42	39
23	42	34	38	38	36
32	37	30	33	33	32

Average bus service speeds (and hence driver labour cost rates) vary markedly with route length, incident traffic speed, number of bus stops and number of passengers boarded at stops, and have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*. Table 18 above presents an extract from the performance evaluation report showing the average service speeds attained on route lengths of 10 to 25km with more than 10 stops at 3 typical Brisbane traffic speeds determined from the last *RACQ Brisbane City Travel Time Survey* conducted in October 2010:

- 30km/h Traffic Speed: This was the typical 2010 peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional suburb substantially via local roads, then on a major city bound arterial or sub-arterial such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road. This traffic speed averaged the higher travel speeds achieved while still driving through the outer suburbs on local roads with the slower speeds later encountered during peak periods with traffic signals, congestion, stops and give-ways on the major arterial or sub-arterial roads.
- 45km/h Traffic Speed: This was the typical 2010 peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb on a major highway such as the Bruce, Ipswich or Pacific Motorway. It was also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.
- 75km/h Traffic Speed: This was the typical 2010 peak period traffic speed achieved on TransLink's busways leading into the CBD and on major city bypass ring roads such as the Western, Gateway and Logan Motorways. It was also representative of the off-peak traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a city bound highway such as the Bruce, Ipswich or Pacific Motorway.

RACQ has not published a revised *Brisbane City Travel Time Survey* since 2010, but it has been observed from identical RACQ surveys conducted over the previous 7 years that average inbound and outbound traffic speeds along the city's main corridors, highways and motorways progressively fell at a rate of 2.5%/annum as a consequence of continuously increasing traffic congestion.

Assuming that most high capacity bus routes would be in the range of 10km to 20km with 10 or more bus stops, the average speed data listed in Table 18 can be reduced down to a two tail distribution mean speed with a variance of less than +/-12.5% at each of the 3 common traffic speeds. Average current driver labour rates per kilometre appearing below in Table 19 have been calculated by dividing the applicable driver labour rates for each bus type by the 3 traffic speed distribution means, and decreasing the RACQ 2010 measured speeds for an additional 2 years @ 2.5%/annum to account for increased congestion since the last survey.

Table 19: Average Driver Labour Cost Rates per Kilometre for the 5 Bus Types

Average Driver Labour Rate per Kilometre at 30km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1.51/kilometre	$1.87/kilometre	$1.60/kilometre	$1.65/kilometre	$1.82/kilometre
Average Driver Labour Rate per Kilometre at 45km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1.16/kilometre	$1.52/kilometre	$1.28/kilometre	$1.30/kilometre	$1.47/kilometre
Average Driver Labour Rate per Kilometre at 75km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$0.92/kilometre	$1.25/kilometre	$1.03/kilometre	$1.07/kilometre	$1.18/kilometre

The estimates indicated in Table 19 assume each bus type will be loaded to its maximum carrying capacity and verify two key findings of the operational performance evaluation, namely that high capacity bus performance improves relative to both a standard 12.5m rigid bus and private motor vehicle with increasing traffic speed and route length.

2.7.4 Variable Operating Cost Rate Inflation Factors

The abovementioned variable operating cost rates inflate throughout each vehicle's service life. Inflation factors for the 4 identified variable operating cost rates have been determined as follows:

- Diesel Consumption Cost Rate Inflation Factor: In the 4 years since December 2008 following the global financial crisis, the Brisbane clean diesel price, inclusive of federal excise, has inflated at an average of 6.34%/annum. The diesel consumption cost rate annual inflation factor has therefore been set at 1.0634. (Source: *FuelTrac Capital City Diesel Prices*).
- AdBlue Consumption Cost Rate Inflation Factor: In the 4 years since December 2008 following the global financial crisis, the Australian average AdBlue price has remained flat and not inflated, effectively falling in price against the *Brisbane All Groups CPI*. The AdBlue consumption cost rate annual inflation factor has therefore been set at unity. (Source: *GreenChem AdBlue International Index*).
- Servicing and Maintenance Cost Rate Inflation Factor: Over the past decade, the cost of Brisbane motor vehicle maintenance and repairs has inflated at an average of 3.39%/annum. The annual inflation factor for the bus servicing and maintenance cost rate has therefore been set at 1.0339 (Source: *ABS CPI A2711844F*).
- Average Driver Labour Cost Rate Inflation Factor: Over the past decade, the Queensland public and private wage CPI has inflated by an average of 4.2%/annum. The annual inflation factor for average driver labour rates has therefore been set at 1.042 (Source: *ABS CPI A2711844F*).

2.7.5 Total Variable Operating Costs

Because kilometres travelled per annum change in each year of vehicle service life, the total NPV of all bus variable operating costs was computed by spreadsheet using the following calculations:

1) The kilometres travelled in each year of life were obtained from All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distances per annum in each year of the vehicle's service life have been based on the statistical polynomial *Curve of Best Fit* appearing above in
- Figure 1. This curve was sourced from a detailed review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile curve have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing depot only.
- Capital expenditures, other than for new bus procurements, have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or saving accounts). This includes all final residual payouts on expiring bus finance leases.

- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 20km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h, and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

2) Table 1 for bus ages 1 to 21,

3) These were then multiplied by the cost rates for diesel, Adblue, servicing and maintenance and driver labour listed in Table 16 through Table 19 respectively,

4) The future value of each annual variable operating cost was computed by multiplying its annual cost by its compounding inflation factor using Eqt (iv),

5) Each future value was then backward converted to its present value using Eqt (i), and the

6) Present values were summed for the 21 year service life to obtain their net present value.

Bus and driver total NPV variable operating costs are shown separately overleaf in Table 20 and Table 21 respectively, with breakdowns for the latter at the 3 typical traffic speeds of 30km/h, 45km/h and 75km/h encountered on Brisbane roads and busways during peak and off-peak traffic periods.

Table 20: Total Variable Operating Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Total Variable Operating Cost (Dollars)	Relative Total Variable Operating Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,582,105	140.3%	112.6%	119.2%	119.3%

Table 21: Total Variable Operating Costs for Bus Driver at Different Brisbane Road Traffic Speeds

Bus Driver Variable Operating Costs at 30km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$2,092,395	$2,591,968	$2,211,407	$2,281,983	$2,520,007
Bus Driver Variable Operating Costs at 45km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,610,812	$2,110,385	$1,771,340	$1,797,633	$2,030,121
Bus Driver Variable Operating Costs at 75km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,275,918	$1,724,288	$1,430,910	$1,479,345	$1,634,337

3. Net Present Value Whole-of-Life Costs

3.1 Background

Bus ownership, fixed annual operating and variable operating costs for the 4 high capacity bus types relative to those of a standard two door 12.5m rigid route bus have been estimated in Part 2 of this study. In this Part 3, the present values of all costs for the 5 bus types are summed to compare their net present values over whole-of-life, their average bus costs per kilometre and average bus costs per pax-kilometre.

The net present value of driver variable labour costs also calculated in Part 2 are then incorporated to assess whole-of-life average bus and driver costs per kilometre and per pax-kilometre at 3 traffic speeds commonly encountered on Brisbane roads during peak and off-peak traffic periods.

3.2 Net Present Value of Bus Whole-of-Life Costs

Table 22 below summarises the net present values of all expenses and cost recoveries incurred by a bus operator over the whole-of-life of the 5 alternative bus types. Based on their relative whole-of-life costs per kilometre, the 5 bus types have been ranked as follows:

1. Two Door 12.5m Rigid Bus - $2.01/km
2. Two Door 14.5m Extended Rigid Bus - $2.30/km
3. Three Door 18m Articulated *Superbus* - $2.56/km
4. Two Door 18m Articulated Bus - $2.58/km
5. Two Door 12.5m Double Deck Bus - $2.88/km.

Table 22: Total Net Present Value Whole-of-Life Bus Costs

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Bus Ownership Costs					
Bus Procurement Financial Costs	$538,610	$763,031	$628,378	$852,800	$864,020
Less Tax Deduction Recoveries	-$53,861	-$76,303	-$62,838	-$85,280	-$86,402
Less Resale Recoveries at Retirement	-$10,000	-$14,167	-$11,667	-$15,833	-$16,042
Depot Upgrade Costs Amortised to 5 Buses	$6,000	$23,000	$18,000	$18,000	$18,000
Major Bus Overhaul and Refurbishment Costs	$129,000	$150,000	$137,000	$142,000	$140,000
Total Ownership Costs	$609,749	$845,561	$708,873	$911,687	$919,576
Whole-of-Life Fixed Operating Costs					
Bus Statutory Compliance Costs	$122,464	$285,390	$153,712	$176,022	$147,661
Bus Insurance Costs	$68,562	$87,948	$86,687	$87,948	$87,948
Depot Bus Accommodation Costs	$35,578	$35,580	$40,851	$50,075	$50,075
Time Based Bus Servicing Costs	$57,732	$66,373	$57,731	$62,064	$62,064
Total Bus Fixed Operating Costs	$284,336	$475,291	$338,981	$376,109	$347,748
Whole-of-Life Variable Operating Costs					
Diesel Consumption Costs	$1,093,769	$1,526,189	$1,220,951	$1,246,387	$1,246,387
AdBlue Consumption Costs	$23,109	$42,918	$30,813	$35,215	$35,215
Distance Based Service & Maintenance Costs	$465,227	$650,043	$528,956	$604,157	$605,432
Total Bus Variable Operating Costs	$1,582,105	$2,219,150	$1,780,720	$1,885,759	$1,887,034
Total Whole-of-Life Bus Costs					
Total Bus Ownership + Fixed + Variable	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	$2.01/km	$2.88/km	$2.30/km	$2.58/km	$2.56/km
Bus Ranking by Cost per Kilometre	1	5	2	4	3
Maximum Seated Plus Standing Capacity	75	116	92	90	110
Whole-of-Life Cost per Pax-Kilometre	2.68¢/pax-km	2.48¢/pax-km	2.50¢/pax-km	2.87¢/pax-km	2.33¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	4	2	3	5	1

Based on their relative whole-of-life costs per pax-kilometre when carrying maximum passenger loads, the 5 bus types have however been ranked differently as follows:

1 Three Door 18m Articulated *Superbus* - 2.33¢/pax-km
2 Two Door 12.5m Double Deck Bus - 2.48¢/pax-km
3 Two Door 14.5m Extended Rigid Bus - 2.50¢/pax-km
4 Two Door 12.5m Rigid Bus – 2.68¢/pax-km
5 Two Door 18m Articulated Bus - $2.87¢/pax-km.

3.3 Net Present Value of Bus and Driver Whole-of-Life Costs

Driver variable labour rates and costs for the 5 bus types have been calculated in Part 2 and summarised in Table 19 and Table 21 respectively for 30km/h, 45km/h and 75km/h traffic speed conditions. In this section, NPV whole-of-life bus and driver costs have been consolidated to assess their combined effects on the cost per kilometre and cost per pax-kilometre of operating services in typical peak and off-peak traffic speed periods. Combined whole-of-life bus and driver costs have also been used to evaluate the expected cost savings of substituting a high capacity bus in lieu of operating two standard 12.5 rigid buses to augment overloaded peak services.

3.3.1 Whole-of-Life Bus and Driver Costs in 30km/h Traffic Speed Conditions

<u>Bus services operating in 30km/h peak traffic speed conditions travel</u> between the CBD and an outer Brisbane or surrounding regional suburb <u>via a combination of local and major arterial or sub-arterial roads</u> such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

Net present value whole-of-life bus and driver costs in 30km/hr traffic speed conditions have been consolidated below in Table 23. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 30km/h traffic speed conditions:

1 Two Door 12.5m Rigid Bus - $3.71/km
2 Two Door 14.5m Extended Rigid Bus - $4.10/km
3 Two Door 18m Articulated Bus - $4.43/km
4 Three Door 18m Articulated *Superbus* - $4.61/km
5 Two Door 12.5m Double Deck Bus - $4.98/km.

Table 23: Total Bus and Driver Costs Operating in 30km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 30km/h	$2,092,395	$2,591,968	$2,211,407	$2,281,983	$2,520,007
Total Bus and Driver Costs at 30km/h	**$4,568,585**	**$6,131,970**	**$5,039,981**	**$5,455,538**	**$5,674,365**
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	$3.71/km	$4.98/km	$4.10/km	$4.43/km	$4.61/km
Bus Ranking by Cost per Kilometre	1	5	2	3	4
Maximum Seated Plus Standing Capacity	75	116	92	90	110
Whole-of-Life Cost per Pax-Kilometre	4.95¢/pax-km	4.30¢/pax-km	4.45¢/pax-km	4.93¢/pax-km	4.19¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	5	2	3	4	1

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 30km/h traffic speed conditions:

1 Three Door 18m Articulated *Superbus* - 4.19¢/pax-km
2 Two Door 12.5m Double Deck Bus - 4.30¢/pax-km
3 Two Door 14.5m Extended Rigid Bus – 4.45¢/pax-km
4 Two Door 18m Articulated Bus - $4.93¢/pax-km
5 Two Door 12.5m Rigid Bus – 4.95¢/pax-km.

3.3.2 Whole-of-Life Bus and Driver Costs in 45km/h Traffic Speed Conditions

Bus services operating in 45km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Bus services operating in 45km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

Net present value whole-of-life bus and driver costs in 45km/hr traffic speed conditions have been consolidated below in Table 24. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 45km/h traffic speed conditions:

1 Two Door 12.5m Rigid Bus - $3.32/km
2 Two Door 14.5m Extended Rigid Bus - $3.74/km
3 Two Door 18m Articulated Bus - $4.04/km
4 Three Door 18m Articulated Superbus - $4.21/km
5 Two Door 12.5m Double Deck Bus - $4.59/km.

Table 24: Total Bus and Driver Costs Operating in 45km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 45km/h	$1,610,812	$2,110,385	$1,771,340	$1,797,633	$2,030,121
Total Bus and Driver Costs at 45km/h	**$4,087,002**	**$5,650,387**	**$4,599,914**	**$4,971,188**	**$5,184,479**
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	$3.32/km	$4.59/km	$3.74/km	$4.04/km	$4.21/km
Bus Ranking by Cost per Kilometre	1	5	2	3	4
Maximum Seated Plus Standing Capacity	75	116	92	90	110
Whole-of-Life Cost per Pax-Kilometre	4.43¢/pax-km	3.96¢/pax-km	4.06¢/pax-km	4.49¢/pax-km	3.83¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	4	2	3	5	1

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 45km/h traffic speed conditions:

1 Three Door 18m Articulated *Superbus* - 3.83¢/pax-km
2 Two Door 12.5m Double Deck Bus - 3.96¢/pax-km
3 Two Door 14.5m Extended Rigid Bus – 4.06¢/pax-km
4 Two Door 12.5m Rigid Bus – 4.43¢/pax-km
5 Two Door 18m Articulated Bus - $4.49¢/pax-km.

3.3.3 Whole-of-Life Bus and Driver Costs in 75km/h Traffic Speed Conditions

Bus services operating in 75km/h peak traffic speed conditions travel between the CBD and an outer Brisbane suburb substantially on a busway or bypass the CBD on a major ring road such as the Western, Gateway or Logan Motorway.

Bus services operating in 75km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Net present value whole-of-life bus and driver costs in 75km/hr traffic speed conditions have been consolidated below in Table 25. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 75km/h traffic speed conditions:

1. Two Door 12.5m Rigid Bus - $3.05/km
2. Two Door 14.5m Extended Rigid Bus - $3.46/km
3. Two Door 18m Articulated Bus - $3.78/km
4. Three Door 18m Articulated *Superbus* - $3.89/km
5. Two Door 12.5m Double Deck Bus - $4.28/km.

Table 25: Total Bus and Driver Costs Operating in 75km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 75km/h	$1,275,918	$1,724,288	$1,430,910	$1,479,345	$1,634,337
Total Bus and Driver Costs at 75km/h	$3,752,108	$5,264,290	$4,259,484	$4,652,900	$4,788,695
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	$3.05/km	$4.28/km	$3.46/km	$3.78/km	$3.89/km
Bus Ranking by Cost per Kilometre	1	5	2	3	4
Maximum Seated Plus Standing Capacity	75	116	92	90	110
Whole-of-Life Cost per Pax-Kilometre	4.07¢/pax-km	3.69¢/pax-km	3.76¢/pax-km	4.20¢/pax-km	3.54¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	4	2	3	5	1

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 75km/h traffic speed conditions:

1. Three Door 18m Articulated *Superbus* – 3.54¢/pax-km
2. Two Door 12.5m Double Deck Bus – 3.69¢/pax-km
3. Two Door 14.5m Extended Rigid Bus – 3.76¢/pax-km
4. Two Door 12.5m Rigid Bus – 4.07¢/pax-km
5. Two Door 18m Articulated Bus - $4.20¢/pax-km.

3.3.4 High Capacity Bus and Driver Substitution Cost Savings on Overloaded Peak Services

The fundamental question for any bus operator who currently operates only standard capacity 12.5m route buses, is whether it is cheaper over the long run to augment an overloaded peak service with a second 12.5m rigid bus and driver or to subsitute a new high capacity bus and driver on the overloaded peak service?

The decision to either augment an overloaded peak service with an additional 12.5m rigid bus and driver or to step in a new high capacity bus and driver poses 3 flow-on considerations, namely:

- No operator should consider procuring a high capacity bus solely to augment an overloaded peak service which otherwise sits idle in the depot yard for most of its service life during the off-peaks.
- A second standard 12.5m rigid bus would increase the peak service frequency and complete its journey marginally faster than a substituted high capacity bus carrying more passengers at a slower average service speed. Thus the former option would appear at first sight to have a more likely prospect for improving patronage and ticket revenue over the long run than the latter option.

  (Note: The Stage 1 operational performance study has identified that the average service speed difference between a standard rigid bus and high capacity bus loaded to their respective maximum capacities falls exponentially to a neglible difference in 45km/h or higher traffic speed conditions on route lengths of 15km or longer).
- A second standard 12.5m rigid bus could be returned to depot after the overloaded peaks had passed but a substituted high capacity bus would have to continue operating off-peak services for the day. On off-peak services, the high capacity bus would effectively be underutilised and cost more to operate than a 12.5m rigid bus.

The following costing assumptions have been applied to address the standard 12.5m rigid bus fleet operator's original question:

- We have assumed total passengers carried on the two 12.5m rigid buses would equal the total passengers carried by a substituted high capacity bus. The ticket revenues for both options are therefore equal, effectively cancel out, and do not enter into the net operating cost evaluation,
- Based on existing high capacity bus candidate HFP service timetables, a typical bus and driver would deliver peak weekday commuter and school service kilometres relative to off-peak weekday, weekend and public holiday service kilometres in the approximate ratio of 25% : 75%,
- Therefore 25% of whole-of-life bus variable operating costs and 100% of whole-of-life bus ownership and fixed operating costs for an additional 12.5m rigid bus would be avoided if a high capacity bus was to be substituted on the overloaded peak service,
- 25% of whole-of-life labour costs for an additional 12.5m rigid bus driver would also be avoided if a high capacity bus was to be substituted on the overloaded peak service, and
- The whole-of-life bus and driver total cost difference to operate all peak and off-peak services with a high capacity bus versus a 12.5m rigid bus would account for the added cost to operate off-peak services with the high capacity bus.

Because driver costs change with average traffic speed, the cost savings realised by substituting a high capacity bus in lieu of operating a second 12.5m rigid bus on an overloaded peak service have been calculated at Brisbane road traffic speeds of 30km/h, 45km/h and 75km/h, and presented respectively in Table 26, Table 27 and Table 28.

Substitution of the 4 alternative high capacity bus types has been ranked by their net whole-of-life cost savings per kilometre as follows:

1. Two Door 14.5m Extended Rigid Bus
2. Two Door 18m Articulated Bus
3. Three Door 18m Articulated Superbus
4. Two Door 12.5m Double Deck Bus.

The results indicate cost savings will be realised under all traffic conditions, but the savings diminish with increasing traffic speed and vehicle passenger capacity underutilisation.

Table 26: Net Cost Saving for High Capacity Bus Substitution at 30km/h Traffic Speed

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
100% x Whole-of-Life Costs for One Bus and Driver at 30km/h	$4,568,585	$6,131,970	$5,039,981	$5,455,538	$5,674,365
100% x Whole-of-Life Bus Ownership Costs for One Extra Bus	$609,749				
100% x Whole-of-Life Fixed Operating Costs for One Extra Bus	$284,336				
25% x Whole-of-Life Variable Operating Costs for One Extra Bus	$395,527				
25% x Whole-of-Life Driver Costs for One Extra Bus at 30km/h	$523,099				
Total Bus and Driver Costs at 30km/h	$6,381,296	$6,131,970	$5,039,981	$5,455,538	$5,674,365
Net Whole-of-Life Cost Saving for High Capacity Bus Option		-$249,326	-$1,341,315	-$925,758	-$706,931
Whole-of-Life Travelled Kilometres		1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre		-$0.20/km	-$1.09/km	-$0.75/km	-$0.57/km
High Capacity Bus Ranking by Cost per Kilometre		4	1	2	3

Table 27: Net Cost Saving for High Capacity Bus Substitution at 45km/h Traffic Speed

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
100% x Whole-of-Life Costs for One Bus and Driver at 45km/h	$4,087,002	$5,650,387	$4,599,914	$4,971,188	$5,184,479
100% x Whole-of-Life Bus Ownership Costs for One Extra Bus	$609,749				
100% x Whole-of-Life Fixed Operating Costs for One Extra Bus	$284,336				
25% x Whole-of-Life Variable Operating Costs for One Extra Bus	$395,526				
25% x Whole-of-Life Driver Costs for One Extra Bus at 45km/h	$402,703				
Total Bus and Driver Costs at 45km/h	$5,779,316	$5,650,387	$4,599,914	$4,971,188	$5,184,479
Net Whole-of-Life Cost Saving for High Capacity Bus Option		-$128,929	-$1,179,402	-$808,128	-$594,837
Whole-of-Life Travelled Kilometres		1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre		-$0.11/km	-$0.96/km	-$0.66/km	-$0.48/km
High Capacity Bus Ranking by Cost per Kilometre		4	1	2	3

Table 28: Net Cost Saving for High Capacity Bus Substitution at 75km/h Traffic Speed

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
100% x Whole-of-Life Costs for One Bus and Driver at 75km/h	$3,752,108	$5,264,290	$4,259,484	$4,652,900	$4,788,695
100% x Whole-of-Life Bus Ownership Costs for One Extra Bus	$609,749				
100% x Whole-of-Life Fixed Operating Costs for One Extra Bus	$284,336				
25% x Whole-of-Life Variable Operating Costs for One Extra Bus	$395,526				
25% x Whole-of-Life Driver Costs for One Extra Bus at 75km/h	$318,980				
Total Bus and Driver Costs at 75km/h	$5,360,699	$5,264,290	$4,259,484	$4,652,900	$4,788,695
Net Whole-of-Life Cost Saving for High Capacity Bus Option		-$96,409	-$1,101,215	-$707,799	-$572,004
Whole-of-Life Travelled Kilometres		1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre		-$0.08/km	-$0.89/km	-$0.58/km	-$0.47/km
High Capacity Bus Ranking by Cost per Kilometre		4	1	2	3

3.4 Accounting for Ticket Revenue and Operator Subsidy

The whole-of-life cost evaluation does not account for passenger ticket revenue or the cost of contract bus operator subsidy. All ticket revenue collected on SEQ bus services is returned to TransLink by its contract service providers, so from an operator's perspective, the cost analysis undertaken in this study accurately reflects the net present value of its whole-of-life costs for providing TransLink bus services using one of the 5 alternative bus types.

From TransLink's perspective however, the net cost of operating bus services needs to include whole-of-life subsidies paid to the bus operator less the ticket revenues received to fully complete the net whole-of-life cost evaluation. It is possible to apply a simplified breakeven analysis to compare the average number of passengers needed to be loaded on a high capacity bus relative to a standard 12.5m rigid bus to just break even because at this condition total revenue must balance out total costs, including paid subsidies.

Let...

OC_s = Total Whole-of-Life Bus Ownership Cost of a Standard 12.5m Rigid Bus (in dollars)
OC_h = Total Whole-of-Life Bus Ownership Cost of a High Capacity Bus (in dollars)
FC_s = Total Whole-of-Life Fixed Cost of a Standard 12.5m Rigid Bus (in dollars)
FC_h = Total Whole-of-Life Fixed Cost of a High Capacity Bus (in dollars)
VC_s = Total Whole-of-Life Variable Cost of a Standard 12.5m Rigid Bus (in dollars)
VC_h = Total Whole-of-Life Variable Cost of a High Capacity Bus (in dollars)
TR_s = Total Whole-of-Life Ticket Revenue Collected on the Standard 12.5m Rigid Bus (in dollars)
TR_h = Total Whole-of-Life Ticket Revenue Collected on the High Capacity Bus (in dollars)
v_s = Variable Cost per Kilometre for the Standard 12.5m Rigid Bus (in dollars/kilometre)
v_h = Variable Cost per Kilometre for the High Capacity Bus (in dollars/kilometre)
m = Margin paid to the Bus Operator (in percent)
f = *TransLink* Average Fare Collection Rate over the Vehicle's Service Life (in dollars/pax-kilometre)
p_s = Total Whole-of-Life Passengers Carried by the Standard 12.5m Rigid Bus (in pax)
p_h = Total Whole-of-Life Passengers Carried by the High Capacity Bus (in pax)
d = Total Whole-of-Life Distance Travelled by the Standard and High Capacity Buses (in kilometres).

For this simplified breakeven analysis, we assume that whole-of-life fare revenue collected on any bus is proportional to both the total distance travelled and total passengers carried in each vehicle's service life, and define a constant of proportionality *f* as the average fare per pax-kilometre rate set by TransLink over the vehicle's service life. We then obtain the revenue collected by TransLink from each bus as...

$$TR_h = f\, p_h\, d$$
$$TR_s = f\, p_s\, d$$

These paired equations indicate that the ratio of the revenue expected to be collected on the high capacity bus relative to that collected on the standard 12.5m rigid bus should be proportional to the ratio of their average passenger loads, that is...

$$\frac{TR_h}{TR_s} = \frac{p_h}{p_s}$$

Now if the total whole-of-life costs for each vehicle just breaks even with the whole-of-life revenue collected and the operator's total costs plus paid profit margin *m*, the net subsidy paid by TransLink vanishes to zero at the breakeven points given by...

$$TR_h = f\, p_h\, d = (1 + m)\,(OC_h + FC_h + VC_h) = (1 + m)\,(OC_h + FC_h + v_h\, d)$$
$$TR_s = f\, p_s\, d = (1 + m)\,(OC_s + FC_s + VC_s) = (1 + m)\,(OC_s + FC_s + v_s\, d)$$

It will be noted from these paired breakeven equations for each bus that both the revenue and variable operating costs increase with travelled distance *d*, while total ownership and fixed annual costs remain constant for the whole-of-life life of each vehicle. Rearranging these equations provides an important insight into the effects of travelled distance *d* on the breakeven point for each bus type...

$$\frac{f\, p_h}{1 + m} = \frac{OC_h + FC_h}{d} + v_h$$

$$\frac{f\, p_s}{1 + m} = \frac{OC_s + FC_s}{d} + v_s$$

In these paired equations, the only variables are the boarded passenger loads p_h and p_s which directly affect TransLink's revenue, and the travelled distance *d* which affects total operating cost, and thereby both TransLink and the bus operator. So for any given average boarded passenger load carried by the bus, the breakeven point between the revenue collected and operating cost falls with increasing distance travelled.

To compare the high capacity bus with a standard 12.5m rigid bus for their whole-of-lives, the above equation for the former vehicle is divided by the equation for the latter vehicle giving...

$$\frac{TR_h}{TR_s} = \frac{p_h}{p_s} = \frac{OC_h + FC_h + VC_h}{OC_s + FC_s + VC_s}$$

If a new standard ultralow floor 12.5m rigid bus can be loaded to its maximum carrying capacity of 75 passengers, then the high capacity bus will return a higher expected revenue and breakeven point if its carrying capacity equals or exceeds...

$$p_h = 75\ \frac{(OC_h + FC_h + VC_h)}{OC_s + FC_s + VC_s}$$

The following results are obtained by substituting the whole-of-life costs for each bus type from Table 22:

- Two Door 12.5m Double Deck Bus: Breaks even with a standard 12.5m rigid bus at a load of 107 passengers. Has an increased revenue potential of 8% to load 9 additional passengers.
- Two Door 14.5m Rigid Bus: Breaks even with a standard 12.5m rigid bus at a load of 86 passengers. Has an increased revenue potential of 7% to load 6 additional passengers.
- Two Door 18m Articulated Bus: Does not break even with a standard 12.5m rigid bus at the required minimum load of 96 passengers. Carries 6 less passengers and has a reduced revenue generation potential of -6% below that of the standard 12.5m rigid bus.
- Three Door 18m Articulated *Superbus*: Breaks even with a standard 12.5m rigid bus at a load of 96 passengers. Has an increased revenue potential of 15% to load 14 additional passengers.

3.5 Retirement Age for Lowest Whole-of-Life Cost per Kilometre

The impact of travel distance on the breakeven point between collected ticket revenue and operating cost has been highlighted in Section 3.4, but can best be appreciated by reference to the distance:age profile curve for a typical SEQ route bus earlier illustrated in Figure 1 and reproduced overleaf in
In the vehicle's normal life cycle, its first year of service commonly known as the run-in period, is beset with component infant mortality failures leading to repeated removal of the vehicle from service for warranty repairs and thereby causing its annual travel distance to drop below the whole-of-life life average. The vehicle's mid-life is later plagued by a succession of unavoidable major mechanical and electrical overhauls and body refurbishments, which again act to reduce the vehicle's mid-life annual travel distances below the average.

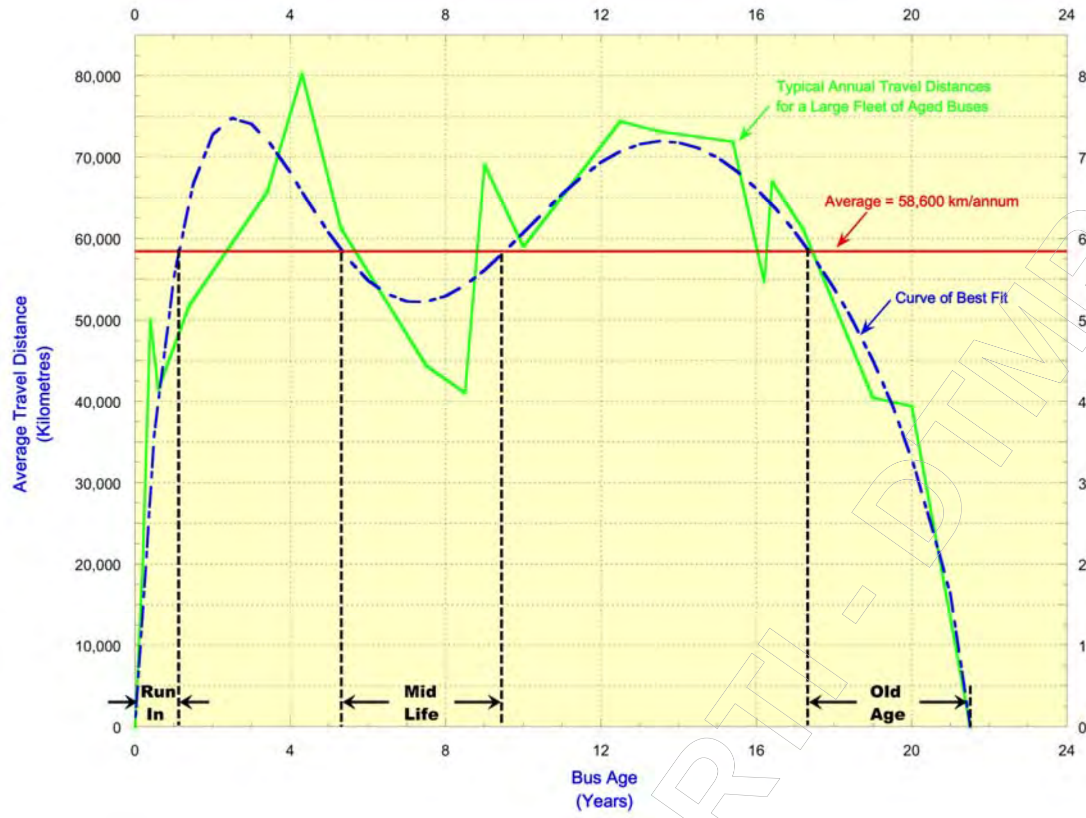
Annual travel distances resurge again following these typical life cycle events until the vehicle begins to reach its old age, when it loses popularity against younger buses as the vehicle of choice for delivery of commuter services. This period in the vehicle's life cycle becomes one of constantly declining annual travel distance and increasing maintenance cost per kilometre as its aging components fail more frequently after a life of hard work, wear and tear.

Figure 2.

In the vehicle's normal life cycle, its first year of service commonly known as the run-in period, is beset with component infant mortality failures leading to repeated removal of the vehicle from service for warranty repairs and thereby causing its annual travel distance to drop below the whole-of-life life average. The vehicle's mid-life is later plagued by a succession of unavoidable major mechanical and electrical overhauls and body refurbishments, which again act to reduce the vehicle's mid-life annual travel distances below the average.

Annual travel distances resurge again following these typical life cycle events until the vehicle begins to reach its old age, when it loses popularity against younger buses as the vehicle of choice for delivery of commuter services. This period in the vehicle's life cycle becomes one of constantly declining annual travel distance and increasing maintenance cost per kilometre as its aging components fail more frequently after a life of hard work, wear and tear.

Figure 2: Typical Route Bus Life Cycle



Old age is the period in a vehicle's life cycle when the breakeven point between fare revenue collected and operating cost grows exponentially with each passing year till retirement. It is also the period in the vehicle's life cycle when TransLink is heavily subsidising an aged and underutilised asset not owned by it, but by the bus operator.

Avoiding this cost can only realistically be achieved if the vehicle can be worked harder or sold off at an earlier age. Because the financial costs for its replacement vehicle are borne by the operator, its early retirement is resisted in an effort to improve the rate of return on its sunken capital investment.

The ideal retirement age for minimum whole-of-life cost per kilometre occurs after the second crest on the distance:age profile curve in Figure 2. After passing the second crest, all costs of bus ownership, with the sole exception of resale price recovery have passed and become sunken costs. Beyond the crest age, only the vehicle's fixed annual and variable operating costs continue to be incurred by the bus operator until its retirement is finally reached. The ideal retirement age occurs when the cumulative whole-of-life cost per kilometre reaches its minimum.

3.6 Ideal Retirement Age for Standard 12.5m Rigid Bus

PV annual total operating costs per kilometre and cumulative total costs per kilometre have been calculated in Beyond age 12, all operator capital investments in the vehicle have been completed and thereafter become sunken costs, so the cumulative cost per kilometre goes into a gradual decline. However, the annual kilometres travelled begin to tail off above age 14 and the annual cost per kilometre rises exponentially from \$1.58/km to \$2.58/km by age 21. This causes the cumulative cost per kilometre to turn and begin rising beyond age 19, which is the bus operator's ideal retirement age for maximum whole-of-life return on investment.

Table 29: PV Annual and Cumulative Costs per Kilometre for Standard 12.5m Rigid Bus

Net Present Value Whole-of-Life Costs	Year	2026	2027	2028	2029	2030	2031	2032	2033
	Year No	14	15	16	17	18	19	20	21
Bus Ownership Costs									
Bus Procurement Financial Cost		$538,610	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$53,861	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$36,309	-$30,201	-$25,120	-$20,894	-$17,379	-$14,455	-$12,023	-$10,000
Depot Upgrade Cost Amortised to 5 Buses		$6,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$129,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$619,749	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$5,803	$5,793	$5,783	$5,774	$5,764	$5,755	$5,745	$5,736
Bus Insurance Cost		$3,546	$3,671	$3,802	$3,937	$4,077	$4,222	$4,372	$4,527
Depot Bus Accommodation Cost		$1,786	$1,822	$1,859	$1,896	$1,934	$1,974	$2,013	$2,054
Time Based Bus Servicing Cost		$2,836	$2,868	$2,901	$2,933	$2,966	$3,000	$3,034	$3,068
Total Bus Fixed Operating Costs		$13,970	$14,155	$14,345	$14,540	$14,742	$14,950	$15,164	$15,384
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$70,569	$70,903	$69,214	$65,615	$60,043	$51,823	$39,066	$19,835
AdBlue Consumption Cost		$1,190	$1,124	$1,032	$920	$792	$643	$455	$217
Distance Based Service & Maintenance Cost		$27,483	$26,847	$25,481	$23,486	$20,895	$17,534	$12,851	$6,344
Total Bus Variable Operating Costs		$99,242	$98,874	$95,726	$90,021	$81,730	$69,999	$52,373	$26,396
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$113,212	$113,029	$110,071	$104,561	$96,472	$84,949	$67,536	$41,781
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		$1.58	$1.62	$1.66	$1.72	$1.79	$1.89	$2.05	$2.58
Cumulative Total Bus Cost at End of Year		$1,831,483	$1,950,620	$2,065,771	$2,174,559	$2,274,545	$2,362,418	$2,432,386	$2,476,189
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		$2.067	$2.041	$2.022	$2.009	$2.001	$1.999	$2.003	$2.012
Cost to Operator of Early/Late Retirement		$530,935	$411,798	$296,646	$187,859	$87,873	$0	$69,968	$113,772

Operators tend to relegate their aging buses to low profile services such as school, shopper and district runs, private school and community charters or to the menial rank of breakdown standby vehicle. Notwithstanding these arguably useful deployments for aging route buses, their sustained retention in the fleet on declining light duties after age 16 has to be subsidised by TransLink at lower revenue returns, and their reduced annual kilometres picked up by other younger buses in the operator's fleet.

Error! Not a valid bookmark self-reference. further shows the cost (in present dollar values) to the operator of retiring the standard 12.5m rigid bus before or after its ideal retirement age. Unfortunately, many bus operators do not fully appreciate the real costs of keeping aged buses in service, particularly when contemplating the high financial cost burden of their replacements, so the common misconception persists that it must be cheaper to keep aged buses running for as long as possible and simply place them on light service duties.

overleaf for a standard 12.5m rigid bus between the ages of 14 and 21.

Beyond age 12, all operator capital investments in the vehicle have been completed and thereafter become sunken costs, so the cumulative cost per kilometre goes into a gradual decline. However, the annual kilometres travelled begin to tail off above age 14 and the annual cost per kilometre rises exponentially from $1.58/km to $2.58/km by age 21. This causes the cumulative cost per kilometre to turn and begin rising beyond age 19, which is the bus operator's ideal retirement age for maximum whole-of-life return on investment.

Table 29: PV Annual and Cumulative Costs per Kilometre for Standard 12.5m Rigid Bus

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$538,610	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$53,861	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$36,309	-$30,201	-$25,120	-$20,894	-$17,379	-$14,455	-$12,023	-$10,000
Depot Upgrade Cost Amortised to 5 Buses		$6,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$129,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$619,749	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$5,803	$5,793	$5,783	$5,774	$5,764	$5,755	$5,745	$5,736
Bus Insurance Cost		$3,546	$3,671	$3,802	$3,937	$4,077	$4,222	$4,372	$4,527
Depot Bus Accommodation Cost		$1,786	$1,822	$1,859	$1,896	$1,934	$1,974	$2,013	$2,054
Time Based Bus Servicing Cost		$2,836	$2,868	$2,901	$2,933	$2,966	$3,000	$3,034	$3,068
Total Bus Fixed Operating Costs		$13,970	$14,155	$14,345	$14,540	$14,742	$14,950	$15,164	$15,384
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$70,569	$70,903	$69,214	$65,615	$60,043	$51,823	$39,066	$19,835
AdBlue Consumption Cost		$1,190	$1,124	$1,032	$920	$792	$643	$455	$217
Distance Based Service & Maintenance Cost		$27,483	$26,847	$25,481	$23,486	$20,895	$17,534	$12,851	$6,344
Total Bus Variable Operating Costs		$99,242	$98,874	$95,726	$90,021	$81,730	$69,999	$52,373	$26,396
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$113,212	$113,029	$110,071	$104,561	$96,472	$84,949	$67,536	$41,781
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		$1.58	$1.62	$1.66	$1.72	$1.79	$1.89	$2.05	$2.58
Cumulative Total Bus Cost at End of Year		$1,831,483	$1,950,620	$2,065,771	$2,174,559	$2,274,545	$2,362,418	$2,432,386	$2,476,189
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		$2.067	$2.041	$2.022	$2.009	$2.001	$1.999	$2.003	$2.012
Cost to Operator of Early/Late Retirement		**$530,935**	**$411,798**	**$296,646**	**$187,859**	**$87,873**	$0	**$69,968**	**$113,772**

Operators tend to relegate their aging buses to low profile services such as school, shopper and district runs, private school and community charters or to the menial rank of breakdown standby vehicle. Notwithstanding these arguably useful deployments for aging route buses, their sustained retention in the fleet on declining light duties after age 16 has to be subsidised by TransLink at lower revenue returns, and their reduced annual kilometres picked up by other younger buses in the operator's fleet.

Error! Not a valid bookmark self-reference. further shows the cost (in present dollar values) to the operator of retiring the standard 12.5m rigid bus before or after its ideal retirement age. Unfortunately, many bus operators do not fully appreciate the real costs of keeping aged buses in service, particularly when contemplating the high financial cost burden of their replacements, so the common misconception persists that it must be cheaper to keep aged buses running for as long as possible and simply place them on light service duties.

3.7 Ideal Retirement Age for High Capacity Buses

PV annual total operating costs per kilometre and cumulative total costs per kilometre have been calculated overleaf in Table 30 through Table 33 inclusive for the 4 high capacity buses between ages 14 and 21.

All 4 high capacity buses attain the same ideal retirement age of 19 calculated for the standard 12.5m rigid bus, but some 3 to 10 months later in the year due to their relatively higher procurement costs and resale values. While the underlying causes for declining cumulative cost per kilometre and increasing annual operating cost per kilometre are similar to those earlier explained for the standard rigid bus, the magnitudes of these costs and the penalty paid for premature or late retirement either side of the ideal age are significantly higher for all of the 4 high capacity vehicles.

Two hidden risks arise for the high capacity buses which wouldn't normally apply to a standard 12.5m rigid route bus:

- Unsuitability for Old Age Light Service Duties: As earlier indicated, operators tend to allocate their aging standard 12.5m rigid buses on low profile menial assignments such as school, shopper and district runs, private school and community charters, and breakdown standby duties.

High capacity buses have road use restrictions such as over height limits for the double deck bus or road turning and under length bus stop limits for the 3 other high capacity bus types. They do not therefore satisfy the same universal "go anywhere" and "back up any service" functions which a standard 12.5m rigid bus traditionally affords during its old age.

- Potential for Loss of Resale Value: Aftermarket second hand route bus resale values are controlled by the forces of supply and demand. Second hand route buses have traditionally been sold to small family business school and country bus service or tour operators from across Australia who can economically operate old buses out to their maximum retirement age of 25.

  Aftermarket demand for second hand articulated buses previously sold by Brisbane Transport have fetched high prices but there was a notable difference in the number of bidders searching for these high capacity buses. Should a large number of SEQ bus operators choose to begin operating high capacity buses in their fleets, the anticipated downstream effect on their aftermarket would be falling resale values.

These old age risks paint a very different future life cycle scenario for aging high capacity buses relative to a standard size route bus.

Unlike standard 12.5m rigid buses, high capacity buses will not be capable of being placed on universal light service duties in old age and will need to be worked hard for the whole of their service lives. The effect of this predicted high capacity vehicle life cycle scenario would be a shorter service life covering a similar total travel distance to the standard 12.5m rigid bus, but reaching ideal retirement around a year earlier at age 18.

Table 30: PV Annual and Cumulative Costs per Kilometre for Double Deck Bus

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$763,031	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$76,303	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$51,438	-$42,785	-$35,587	-$29,600	-$24,620	-$20,478	-$17,033	-$14,167
Depot Upgrade Cost Amortised to 5 Buses		$23,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$150,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$859,728	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$13,522	$13,500	$13,478	$13,455	$13,433	$13,411	$13,389	$13,367
Bus Insurance Cost		$4,548	$4,710	$4,877	$5,050	$5,229	$5,415	$5,608	$5,807
Depot Bus Accommodation Cost		$1,786	$1,822	$1,859	$1,896	$1,934	$1,974	$2,013	$2,054
Time Based Bus Servicing Cost		$3,261	$3,298	$3,335	$3,372	$3,410	$3,449	$3,488	$3,527
Total Bus Fixed Operating Costs		$23,117	$23,329	$23,548	$23,774	$24,008	$24,249	$24,497	$24,754
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$98,468	$98,934	$96,577	$91,556	$83,781	$72,311	$54,511	$27,677
AdBlue Consumption Cost		$2,210	$2,088	$1,916	$1,709	$1,470	$1,193	$846	$404
Distance Based Service & Maintenance Cost		$38,401	$37,512	$35,603	$32,816	$29,196	$24,500	$17,956	$8,864
Total Bus Variable Operating Costs		$139,078	$138,534	$134,096	$126,080	$114,447	$98,003	$73,313	$36,945
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$162,196	$161,863	$157,645	$149,854	$138,455	$122,252	$97,810	$61,699
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		$2.26	$2.32	$2.38	$2.47	$2.57	$2.71	$2.97	$3.81
Cumulative Total Bus Cost at End of Year		$2,613,151	$2,783,668	$2,948,510	$3,104,352	$3,247,786	$3,374,180	$3,475,435	$3,540,000
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		$2.950	$2.913	$2.885	$2.867	$2.858	$2.856	$2.862	$2.877
Cost to Operator of Early/Late Retirement		**$761,029**	**$590,512**	**$425,670**	**$269,828**	**$126,394**	$0	**$101,255**	**$165,820**

Table 31: PV Annual and Cumulative Costs per Kilometre for 14.5m Extended Rigid Bus

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$628,378	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$62,838	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$42,359	-$35,233	-$29,305	-$24,375	-$20,274	-$16,863	-$14,026	-$11,667
Depot Upgrade Cost Amortised to 5 Buses		$18,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$137,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$720,540	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$7,283	$7,271	$7,259	$7,247	$7,235	$7,223	$7,211	$7,199
Bus Insurance Cost		$4,483	$4,642	$4,807	$4,978	$5,155	$5,338	$5,527	$5,724
Depot Bus Accommodation Cost		$2,050	$2,092	$2,134	$2,177	$2,221	$2,266	$2,312	$2,358
Time Based Bus Servicing Cost		$2,836	$2,868	$2,901	$2,933	$2,966	$3,000	$3,034	$3,068
Total Bus Fixed Operating Costs		$16,653	$16,873	$17,101	$17,335	$17,577	$17,826	$18,084	$18,349
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$78,774	$79,147	$77,262	$73,245	$67,025	$57,848	$43,608	$22,141
AdBlue Consumption Cost		$1,586	$1,499	$1,376	$1,227	$1,056	$857	$607	$290
Distance Based Service & Maintenance Cost		$31,248	$30,525	$28,971	$26,703	$23,757	$19,936	$14,612	$7,213
Total Bus Variable Operating Costs		$111,609	$111,171	$107,609	$101,174	$91,838	$78,641	$58,827	$29,644
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$128,261	$128,044	$124,709	$118,510	$109,415	$96,468	$76,911	$47,993
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		$1.79	$1.83	$1.89	$1.95	$2.03	$2.14	$2.34	$2.97
Cumulative Total Bus Cost at End of Year		$2,095,832	$2,231,003	$2,361,639	$2,485,079	$2,598,595	$2,698,473	$2,778,221	$2,828,574
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		$2.366	$2.334	$2.311	$2.295	$2.287	$2.284	$2.288	$2.299
Cost to Operator of Early/Late Retirement		**$602,641**	**$467,471**	**$336,834**	**$213,394**	**$99,878**	$0	**$79,748**	**$130,101**

Table 32: PV Annual and Cumulative Costs per Kilometre for 2 Door Articulated Bus

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$852,800	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$85,280	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$57,485	-$47,814	-$39,770	-$33,079	-$27,514	-$22,885	-$19,035	-$15,833
Depot Upgrade Cost Amortised to 5 Buses		$18,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$142,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$927,520	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$8,340	$8,326	$8,313	$8,299	$8,285	$8,272	$8,258	$8,244
Bus Insurance Cost		$4,548	$4,710	$4,877	$5,050	$5,229	$5,415	$5,608	$5,807
Depot Bus Accommodation Cost		$2,513	$2,564	$2,616	$2,669	$2,723	$2,778	$2,834	$2,891
Time Based Bus Servicing Cost		$3,049	$3,084	$3,118	$3,153	$3,189	$3,225	$3,261	$3,298
Total Bus Fixed Operating Costs		$18,451	$18,684	$18,924	$19,171	$19,426	$19,689	$19,960	$20,240
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$80,415	$80,796	$78,871	$74,771	$68,421	$59,054	$44,517	$22,603
AdBlue Consumption Cost		$1,813	$1,713	$1,572	$1,402	$1,206	$979	$694	$331
Distance Based Service & Maintenance Cost		$35,690	$34,864	$33,090	$30,499	$27,135	$22,770	$16,689	$8,238
Total Bus Variable Operating Costs		$117,919	$117,373	$113,534	$106,672	$96,762	$82,803	$61,900	$31,172
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$136,370	$136,057	$132,457	$125,843	$116,189	$102,492	$81,860	$51,412
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		$1.90	$1.95	$2.00	$2.07	$2.16	$2.28	$2.49	$3.18
Cumulative Total Bus Cost at End of Year		$2,385,592	$2,531,320	$2,671,821	$2,804,355	$2,926,109	$3,033,230	$3,118,941	$3,173,555
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		$2.693	$2.649	$2.615	$2.590	$2.575	$2.567	$2.568	$2.579
Cost to Operator of Early/Late Retirement		**$647,639**	**$501,910**	**$361,409**	**$228,875**	**$107,121**	$0	**$85,710**	**$140,325**

3.8 Benefits of Reduced Seating on High Capacity Buses

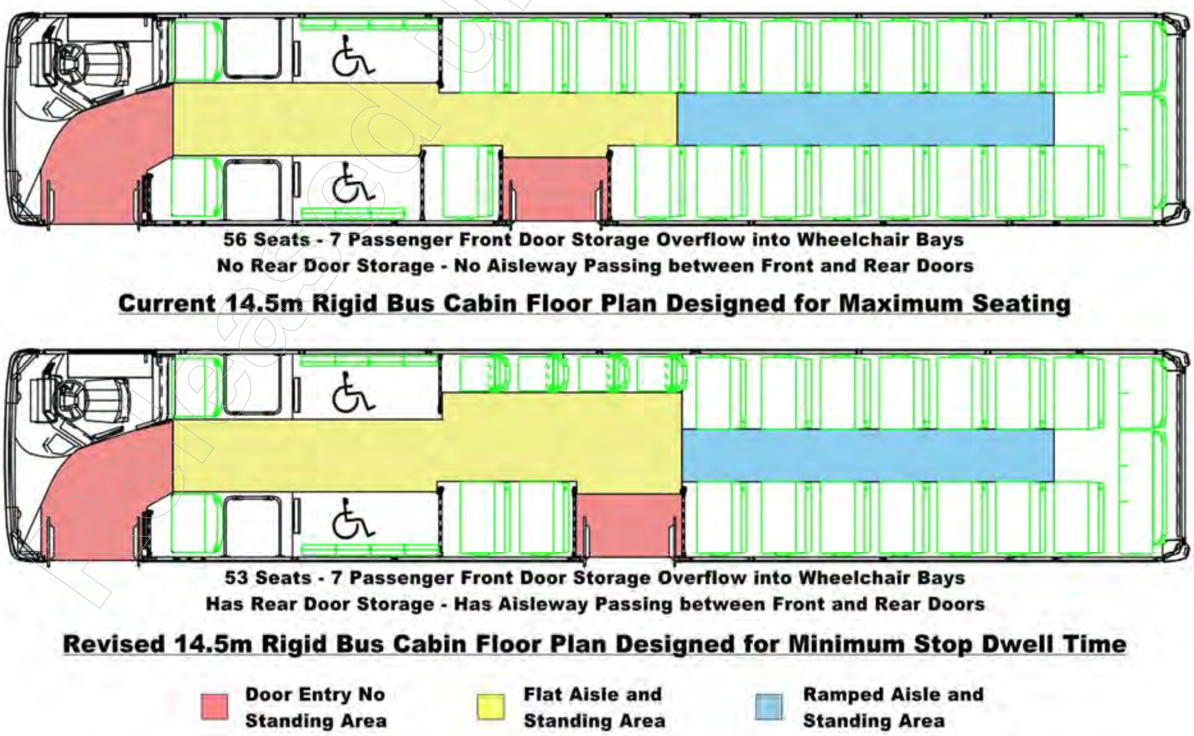
Comparison of the total life cycle costs captured in Table 22 for the *2 Door 18m Articulated Bus* and *3 Door 18m Articulated Superbus* have demonstrated that reduced onboard seating can significantly improve high capacity bus economic performance, and previous Stage 1 high capacity vehicle studies have similarly indicated improved total passenger carrying capacity, bus stop dwell time, service speed, station/stop infrastructure utilisation and depot standard bus equivalent passenger capacities for the *Superbus*. The combined benefits of reduced onboard seating to the performance of a high capacity vehicle are such that we revisit here several key findings drawn from our earlier HCV evaluation studies to reinforce its critical importance.

Table 33: PV Annual and Cumulative Costs per Kilometre for 3 Door Articulated *Superbus*

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$864,020	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$86,402	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$58,244	-$48,445	-$40,295	-$33,516	-$27,877	-$23,187	-$19,286	-$16,042
Depot Upgrade Cost Amortised to 5 Buses		$18,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$140,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$935,618	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$6,996	$6,985	$6,973	$6,962	$6,950	$6,939	$6,927	$6,916
Bus Insurance Cost		$4,548	$4,710	$4,877	$5,050	$5,229	$5,415	$5,608	$5,807
Depot Bus Accommodation Cost		$2,513	$2,564	$2,616	$2,669	$2,723	$2,778	$2,834	$2,891
Time Based Bus Servicing Cost		$3,049	$3,084	$3,118	$3,153	$3,189	$3,225	$3,261	$3,298
Total Bus Fixed Operating Costs		$17,107	$17,342	$17,585	$17,834	$18,091	$18,357	$18,630	$18,911
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$80,415	$80,796	$78,871	$74,771	$68,421	$59,054	$44,517	$22,603
AdBlue Consumption Cost		$1,813	$1,713	$1,572	$1,402	$1,206	$979	$694	$331
Distance Based Service & Maintenance Cost		$35,766	$34,938	$33,160	$30,564	$27,192	$22,818	$16,724	$8,256
Total Bus Variable Operating Costs		$117,994	$117,447	$113,603	$106,736	$96,820	$82,851	$61,935	$31,190
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$135,101	$134,789	$131,188	$124,570	$114,911	$101,208	$80,565	$50,101
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		$1.88	$1.93	$1.98	$2.05	$2.13	$2.25	$2.45	$3.10
Cumulative Total Bus Cost at End of Year		$2,374,824	$2,519,412	$2,658,750	$2,790,099	$2,910,649	$3,016,546	$3,101,012	$3,154,358
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		$2.681	$2.636	$2.602	$2.577	$2.561	$2.553	$2.554	$2.563
Cost to Operator of Early/Late Retirement		**$641,723**	**$497,135**	**$357,796**	**$226,447**	**$105,898**	$0	**$84,466**	**$137,812**

Figure 3 below illustrates two different *2 Door 14.5m Extended Rigid Bus* cabin floor plans. There are currently around 130 of these high capacity buses operating in SEQ with the upper floor plan shown in Figure 3, and more have already been planned for construction. The upper floor plan has been specifically designed by the bus manufacturer for maximum onboard seating capacity at the bus operator's request.

Figure 3: Two Door 14.5m Rigid Bus Cabin Plans for Seat Maximisation vs Dwell Minimisation



The upper cabin floor plan incorporates no aisle circulation space between the front and rear doors, or a defined rear door storage space where passengers can queue, tag off their go cards and get ready to alight before reaching bus stops. Because the cabin design lacks aisle width for passenger circulation and a defined rear door storage area, it is also unsuitable for temporarily storage and spill out of boarding passengers if future all door boarding was to be implemented. Additionally, the rear door position has been placed to cram two additional rows of passenger seats into the rear saloon, but its positioning has resulted in 4 out of 5 boarded passengers alighting via the rear door, which would in effect prevent any potential dwell time saving ever being achieved through rear door boarding.

The lower cabin floor plan in Figure 3 has been redesigned for minimum bus stop dwell time using double width front to rear door aisle way passenger circulation, increased front door storage space adjacent to the wheelchair parking bays, and a defined rear door passenger queuing storage area. Its aftward relocated rear door also shifts passenger alighting preferences forward towards the front door, and the seating layout has been optimised for future all door boarding and alighting.

At the cost of just 3 passenger seats, the 14.5m bus with the lower cabin floor plan could legally carry 6 more passengers with increased standing capacity in the aisle ways, door storage areas and 2 wheelchair bays when unoccupied. With all door boarding, the modified vehicle's full load bus stop dwell time would be cut by 4 minutes per peak service trip, and its economic performance improved by the additional revenue collected from more boarded passengers and reduced paid time to the driver. These combined benefits significantly shift the peak service breakeven point towards the ticket revenue side, and consequently reduce TransLink's subsidy for the services this high capacity vehicle delivers.

The author asserts that the primary objectives when deploying high capacity buses on route services are to both increase the average number of passengers carried per trip and to board and alight them as quickly as possible at bus stops. It was revealed in the international research study for the Stage 1 *Operational Performance Evaluation* that very significant differences had been identified between mass transit high capacity bus operations overseas and contemporary high capacity bus services operated in South East Queensland. Bus station and bus stop dwell time minimisation was repeatedly identified from the international research as the central focus of best practice leading international mass transit authorities, and all door boarding, wider centre aisles, rear door passenger storage spaces and reduced onboard seating were the strategies typically implemented for rapid alighting and boarding of passengers at stations and stops.

The operational performance evaluation study further highlighted an entrenched mindset prevalent amongst both Australian and South East Queensland bus operators that cramming more passenger seats onto buses somehow equates to increased customer comfort, safety and satisfaction, but when applied to high capacity buses, the bus operator paradigm of maximised bus seating capacity is totally unsupported by the facts that:

- 56% to 75% of passenger seats presently go unoccupied in Brisbane on existing off-peak high capacity bus services, and over 40% on standard 12.5m rigid bus services. From our life cycle economic analyses, the cost of off-peak seat underutilisation translates to higher fuel consumption, higher bus maintenance, higher dead axle weight and lower combined bus seated plus standing capacity for 75 to 80% of the vehicle's travelled life cycle kilometres.
- All door boarding and improved passenger alighting/boarding efficiency are also totally incompatible with the doctrine of maximising seating capacity. Currently, some 6 to 11 minutes are consumed on every high capacity bus peak service just to board and alight passengers to full load capacity, and around 6 minutes on typical low floor 12.5m rigid bus peak services. All door boarding and improved passenger alighting/boarding efficiency could potentially cut bus stop dwell times by factors of 2 to 3, reducing driver labour costs,

increasing infrastructure stop capacity utilisation, preventing bus arrival clashes and offering the potential to increase service frequencies on HFP routes. But the most important benefit to peak services of a 200% or greater reduction in stop dwell time would be the increased competitiveness of high capacity bus services with the private motor vehicle.

- Every twin passenger seat installed in a bus cabin occupies approximately the same floor space as 4 standees. On peak services with highly crammed standing passenger loads, the price most often paid for 2 comfortably seated passengers is 4 very uncomfortable standees. Maximisation of seat capacity at the expense of aisle width does not consider the comfort needs of those less fortunate passengers still left standing.
- Average standing periods measured on some ten thousands of peak route services studied for the HCV operational performance evaluation showed that a typical standee endured uncomfortable crammed standing conditions for at least half the total trip time before finding a vacant seat to reoccupy. Throughout the time of standing, passengers had to shuffle back and forth and lean over seated passengers on exceptionally narrow aisle ways to let other passengers alight, and carry their personal belongings for most of the time to prevent trampling damage or tripping of other passengers.

It is arguably a total misnomer that adding more seats improves passenger satisfaction, comfort or safety on peak services with high standing loads, and bus operators need to be actively encouraged by TransLink to design their new high capacity vehicles for minimum stop dwell time.

3.9 High Capacity Bus Performance Benefit:Cost Ratios

In this last section, we compare the performance benefit to cost ratios for the 4 high capacity buses with respect to a standard 12.5m rigid bus. Operational performance, driving performance, road handling manoeuvrability, bus stop infrastructure compatibility and depot compatibility advantages/disadvantages for each vehicle are compared using scores weighted by their relative importance. Data for the performance benefit to cost ratio evaluation have been sourced from our previous Stage 1 HCV technical studies.

The performance benefit to cost ratio analysis appears overleaf in

- On the basis of benefit to cost per kilometre, high capacity vehicle performance rankings have shifted relative to cost only rankings in favour of the smaller 90 passenger buses, but rankings within the 90 passenger and 110 passenger categories have remained unchanged. The shift in high capacity vehicle performance rankings by cost per kilometre relative to their cost only rankings has largely resulted from the shorter stop dwell times, faster operating speeds and superior driving and road manoeuvring capabilities of the 90 passenger buses compared to those of the 110 passenger buses.

Table 34. As a visual aid to its quick interpretation, we have colour coded the relative weighted scores, final assessment results and rankings as follows:

Highest Score for All Bus Types and High Capacity Buses Only
Second Highest Score for All Bus Types and High Capacity Buses Only
Second Lowest Score for All Bus Types and High Capacity Buses Only
Lowest Score for All Bus Types and High Capacity Buses Only

When taking into account vehicle operating performance, ease of driving and road manoeuvrability, compatibility with existing TransLink bus station and stop infrastructure and with existing operator bus depots, the conclusions drawn from the comparison of the performance benefit cost ratio results were:

- On the basis of benefit to cost per kilometre, high capacity vehicle performance rankings have shifted relative to cost only rankings in favour of the smaller 90 passenger buses, but rankings within the 90 passenger and 110 passenger categories have remained unchanged. The shift in high capacity vehicle performance rankings by cost per kilometre relative to their cost only rankings has largely resulted from the shorter stop dwell times, faster operating speeds and superior driving and road manoeuvring capabilities of the 90 passenger buses compared to those of the 110 passenger buses.

Table 34: Performance Benefit:Cost Ratios for the 5 Bus Types

Performance and Compatibility Assessment Criteria	Relative Importance Weighting (1 to 10)	75 Passenger Ref Bus 2 Door 12.5m Standard Rigid Bus			90 Passenger High Capacity Buses 2 Door 14.5m Extended Rigid Bus			90 Passenger High Capacity Buses 2 Door 18m Articulated Bus			110 Passenger High Capacity Buses 3 Door 18m Articulated Superbus			110 Passenger High Capacity Buses 2 Door 12.5m Double Deck Bus		
		Measured Value	Relative Score	Weighted Score	Measured Value	Relative Score	Weighted Score	Measured Value	Relative Score	Weighted Score	Measured Value	Relative Score	Weighted Score	Measured Value	Relative Score	Weighted Score
Operating Performance																
Seated Carrying Capacity (passengers)	6	44	46%	2.8	56	58%	3.5	64	67%	4.0	52	54%	3.3	96	100%	6.0
Total Seated and Standee Carrying Capacity (passengers)**	9	75	65%	5.8	92	79%	7.1	90	78%	7.0	110	95%	8.5	116	100%	9.0
Total Journey Bus Stop Dwell Time - Fully Loaded, Front Door Boarding Only, Rear Door Alighting Only (minutes)	9	5.9	100%	9.0	7.8	76%	6.8	6.3	94%	8.4	10.6	56%	5.0	11.0	54%	4.8
Total Journey Bus Stop Dwell Time - Fully Loaded, Balanced All Door Boarding, Balanced All Door Alighting (minutes)	8	3.2	100%	8.0	3.9	82%	6.6	3.2	100%	8.0	3.5	91%	7.3	5.5	58%	4.7
Average Service Speed - Fully Loaded, Front Door Boarding, 10km Route, 8 Stops, 30km/h Traffic Speed (kilometres/hour)	8	22.7	100%	8.0	21.0	93%	7.4	22.1	97%	7.8	19.1	84%	6.7	18.7	82%	6.6
Average Service Speed - Fully Loaded, Front Door Boarding, 15km Route, 11 Stops, 45km/h Traffic Speed (kilometres/hour)	8	32.7	100%	8.0	30.1	92%	7.4	31.5	96%	7.7	27.6	84%	6.8	26.9	82%	6.6
Average Service Speed - Fully Loaded, Front Door Boarding, 20km Route, 16 Stops, 75km/h Traffic Speed (kilometres/hour)	8	41.7	100%	8.0	37.5	90%	7.2	38.0	91%	7.3	35.1	84%	6.7	33.5	80%	6.4
Driving Performance and Road Manoeuvrability																
Maximum Rate of Acceleration from Bus Stop (metres/second^2)	8	1.1	100%	8.0	0.96	87%	7.0	0.89	81%	6.5	0.85	77%	6.2	0.76	69%	5.5
Maximum Service Speed (kilometres/hour)	7	95	97%	6.8	98	100%	7.0	92	94%	6.6	94	96%	6.7	92	94%	6.6
Road and Bridge Clearance Height Disadvantage (metres)	9	3.4	100%	9.0	3.4	100%	9.0	3.4	100%	9.0	3.4	100%	9.0	4.4	77%	7.0
15km/h Full Lock Turning Circle Disadvantage (metres)	8	14.98	100%	8.0	16.12	93%	7.4	15.96	94%	7.5	15.96	94%	7.5	16.46	91%	7.3
15km/h Full Lock Swept Path Width Disadvantage (metres)	8	4.38	100%	8.0	5.37	82%	6.5	5.19	84%	6.8	5.19	84%	6.8	5.74	76%	6.1
Pavement Damage Based on Gross Vehicle Mass Axle Load (tonne)	2	16	100%	2.0	20	80%	1.6	26	62%	1.2	26	62%	1.2	21	76%	1.5
Bus Station and Stop Infrastructure Compatibility																
Bus Stop Occupancy Space Disadvantage (metres)	9	12.5	100%	9.0	14.5	86%	7.8	18	69%	6.3	18	69%	6.3	12.5	100%	9.0
Bus Stop Rear Overhang Swing-In Disadvantage (metres)	3	3.24	64%	1.9	4.05	51%	1.5	3.33	62%	1.9	3.33	62%	1.9	2.08	100%	3.0
5km/h Bus Stop Full Lock Turn-Out Disadvantage (metres)	4	12.0	99%	6.0	12.11	98%	3.9	12.24	97%	3.9	12.24	97%	3.9	11.91	100%	4.0
5km/h Bus Stop Pull Out Swept Path Width Disadvantage (metres)	6	4.47	100%	8.0	5.86	76%	4.6	5.93	75%	4.5	5.93	75%	4.5	6.78	66%	4.0
Unobstructed Existing Bus Station & Park 'n Ride Accesses (percent)	8	100	100%	8.0	42	42%	3.4	42	42%	3.4	42	42%	3.4	82	82%	6.6
Accessible Existing Bus Station and Park 'n Ride Bus Stops (percent)	8	100	100%	8.0	55	55%	4.4	55	55%	4.4	42	42%	3.4	76	76%	6.1
Accessible Existing Roadside Bus Stops (percent)	8	100	100%	8.0	63	63%	5.0	63	63%	5.0	63	63%	5.0	100	100%	8.0
Bus Depot Compatibility																
Depot Accommodation Space Disadvantage (metres^2/bus)	7	47.25	100%	7.0	54.25	87%	6.1	66.5	71%	5.0	66.5	71%	5.0	47.25	100%	7.0
Recommended Depot Fleet Service Life (years)	4	19	100%	4.0	18	95%	3.8	18	95%	3.8	18	95%	3.8	18	95%	3.8
Existing Depots Assessed Suitable with Minor Upgrades (number)	9	17	100%	9.0	17	100%	9.0	16	94%	8.5	16	94%	8.5	10	59%	5.3
Assessed Depot Equivalent Parking Capacity (12.5m buses)	7	2,319	100%	7.0	2,114	91%	6.4	2,107	91%	6.4	2,107	91%	6.4	2,216	96%	6.7
Assessed Depot Equivalent Passenger Carrying Capacity (std buses)	6	2,319	70%	4.2	2,322	70%	4.2	1,860	56%	3.4	2,210	67%	4.0	3,314	100%	6.0
Whole-of-Life Peformance Benefit:Cost Ratios																
Total Weighted Performance Score		171			145			144			138			147		
Whole-of Life Cost per Kilometre		$2.01/km			$2.30/km			$2.58/km			$2.56/km			$2.88/km		
Performance Benefit:Cost Ratio by Whole-of-Life Cost per Kilometre		85			63			56			54			51		
Ranking by Whole-of-Life Cost per Kilometre		1			2			3			4			5		
Whole-of Life Cost per Passenger-Kilometre		2.68¢/pax-km			2.50¢/pax-km			2.87¢/pax-km			2.33¢/pax-km			2.48¢/pax-km		
Performance Benefit:Cost Ratio by Whole-of-Life Cost per Pax-Kilometre		64			58			50			59			59		
Ranking by Whole-of-Life Cost per Pax-Kilometre		1			3			4			2			2		

- On the basis of benefit to cost per pax-kilometre, high capacity vehicle performance rankings have shifted relative to cost only rankings in favour of the larger 110 passenger buses, and the *2 Door 12.5m Double Deck Bus* has been pegged equally with the *3 Door 18m Articulated Superbus*. The shift in performance rankings by cost per pax-kilometre relative to cost only rankings for all high capacity buses has largely resulted from the superior compatibility of the double deck bus with existing bus station and roadside infrastructure, and very high equivalent standard bus passenger and parking capacities in bus depots where it can readily be accommodated without major upgrades.
- The *2 Door 14.5m Extended Rigid Bus* had the highest performance benefit:cost ratio both in the 90 passenger category and between the high capacity bus types. The *3 Door 18m Articulated Superbus* had the higher performance benefit:cost ratio in the 110 passenger category.
- The *2 Door 18m Articulated Bus* had the lowest performance benefit:cost ratio of all high capacity bus types.
- No high capacity vehicle outranked the *Standard 2 Door 12.5m Rigid Bus* on the like-for-like performance benefit to cost ratio evaluation. Notwithstanding it being the second dearest vehicle to operate on cost per pax-kilometre, the standard bus significantly outperformed every high capacity bus and was fully compatible with all existing bus stations, stops and depots.

4. Key Findings

4.1 Key Findings from Whole-of-Life Cost Analyses

Bus ownership and operating costs were unaffected by road speed, but driver labour costs per kilometre have been shown to change markedly under different road traffic speed operating conditions. Driver labour costs have therefore been assessed in the study at 3 common Brisbane road peak and off-peak traffic speeds:

(d) 30km/h Average Traffic Speed:

Bus services operating in 30km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

(e) 45km/h Average Traffic Speed:

Bus services operating in 45km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Bus services operating in 45km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

(f) 75km/h Average Traffic Speed:

Bus services operating in 75km/h peak traffic speed conditions travel between the CBD and an outer Brisbane suburb substantially on a busway or bypass the CBD on a major ring road such as the Western, Gateway or Logan Motorway.

Bus services operating in 75km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

The following findings were determined from a comparison of the net present values of all whole-of-life costs incurred by each high capacity bus relative to those incurred by a standard 12.5m rigid route bus under identical operating conditions.

1 Two Door 14.5m Extended Rigid Bus: This high capacity vehicle provided the best overall cost performance in the 90 passenger capacity category. It competes in this category with the 2 Door Articulated Bus.

At $2.30/km, this high capacity vehicle is 14% dearer to own and operate than a standard bus, but at 2.50¢/pax-km is actually 7% cheaper in terms of its maximum 92 passenger carrying capacity. This bus breaks even with a standard bus at a load of 86 passengers, and has an increased future revenue generation potential of +7% when loaded with 6 additional passengers.

A standard bus MR licensed driver can legally drive this vehicle. It is 11% dearer at $4.10/km (30km/h), 12% dearer at $3.74/km (45km/h) and 13% dearer at $3.46km/h (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 11% cheaper at 4.45¢/pax-km (30km/h), 9% cheaper at 4.06¢/pax-km (45km/h) and 8% cheaper at 3.76¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life, this vehicle saves $1.341M (or $1.09/km) on 30km/h services, $1.179M (or $0.96/km) on 45km/h services and $1.101M (or $0.89/km) on 75km/h services, and is the best choice for any existing overloaded peak service only required to carry up to a maximum load of 92 passengers.

2 Two Door 18m Articulated Bus: The cost performance of this high capacity vehicle has been relatively poor compared to a standard bus, and was assessed lowest for all high capacity buses.

At $2.58/km, this high capacity vehicle is 28% dearer to own and operate than a standard bus, and at 2.87¢/pax-km it remains 7% dearer to own and operate in terms of its maximum 90 passenger carrying capability. This bus does not break even with a standard bus at a comparable minimum load of 96 passengers. It carries 6 less passengers and therefore has a reduced future revenue generation potential -6% below that of the standard bus.

A HR licensed driver is needed to drive this vehicle. It is 19% dearer at $4.43/km (30km/h), 22% dearer at $4.04/km (45km/h) and 24% dearer at $3.78/km (75km/h) to operate than a standard bus and driver. At maximum passenger loads, it is 0.4% cheaper at $4.93¢/pax-km (30km/h), but 1% dearer at $4.49¢/pax-km (45km/h) and 3% dearer at $4.20¢/pax-km (75km/h) to operate than a standard bus and driver.

This vehicle could only be cost justified when substituted on an overloaded peak service in lieu of two standard buses and drivers. Over its whole-of-life, it saved $0.926M (or $0.75/km) on 30km/h services, $0.808M (or $0.66/km) on 45km/h services and $0.708M (or $0.58/km) on 75km/h services, but was ranked a poor second choice in the 90 passenger high capacity vehicle category, well behind the 14.5m extended rigid bus.

3 Three Door Articulated *Superbus*: The cost performance of this high capacity vehicle was judged best in the 110 passenger capacity category. It competes in this category with the double deck bus, but carries only 52 seated passengers onboard, where the double deck carries 96 seated passengers. It is in effect identical to a 2 door 18m articulated bus with 12 less passenger seats and an extra door fitted, but its reduced seating capacity and tare weight has had a profound effect on its cost performance.

At $2.56/km, this high capacity vehicle is 27% dearer to own and operate than a standard bus, but at 2.33¢/pax-km is 15% cheaper in terms of its maximum 110 passenger carrying capacity. This was the lowest cost per passenger-kilometre evaluated for all the high capacity buses. This bus breaks even with a standard bus at a load of 96 passengers, and has an increased future revenue generation potential of +15% when loaded with 14 additional passengers.

A HR licensed driver is needed to drive this vehicle. It is 24% dearer at $4.61/km (30km/h), 27% dearer at $4.21/km (45km/h) and 28% dearer at $3.89/km (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 18% cheaper at 4.19¢/pax-km (30km/h), 16% cheaper at 3.83¢/pax-km (45km/h) and 15% cheaper at 3.54¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life this vehicle saves $0.707M (or $0.57/km) on 30km/h services, $0.595M (or $0.48/km) on 45km/h services and $0.572M (or $0.47/km) on 75km/h services, and is the preferred choice for any existing overloaded peak service required to carry a maximum load of up to 110 passengers.

4 Two Door 12.5m Double Deck Bus: The cost performance of this high capacity vehicle was also found to be satisfactory in the 110 passenger capacity category. It competes in this category with the 3 door articulated *Superbus,* but carries 96 seated passengers, where the *Superbus* only carries 52 seated passengers.

At $2.88/km, this high capacity vehicle is 43% dearer to own and operate than a standard bus. This was the highest cost per kilometre for all the high capacity vehicles assessed. At 2.48¢/pax-km, it was a distant runner up to the 18m articulated *Superbus,* but still 8% cheaper to own and operate than a standard bus in terms of its maximum 116 passenger carrying capacity. This bus breaks even with a standard bus at a load of 107 passengers, and has an increased future revenue generation potential of +8% when loaded with 9 additional passengers.

A HR licensed driver is needed to drive this vehicle. It is 34% dearer at $4.98/km (30km/h), 38% dearer at $4.59/km (45km/h) and 40% dearer at $4.28/km (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 15% cheaper at 4.30¢/pax-km (30km/h), 12% cheaper at 3.96¢/pax-km (45km/h) and 10% cheaper at 3.69¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life this vehicle saves $0.249M (or $0.20/km) on 30km/h services, $0.129M (or $0.11/km) on 45km/h services and $0.096M (or $0.08/km) on 75km/h services, the lowest saving achieved by any of the high capacity buses. These relatively modest savings have been calculated at full load, a 21 year retirement age and 1.2306 million kilometre total service range. It is arguable whether substitution of a double deck bus would be cost justifiable against 2 rigid buses given its known service limitations in Brisbane western and eastern suburbs with so many existing low clearance railway bridges.

5 Ideal Retirement Age for a Standard 12.5m Rigid Bus: Based on whole-of-life costs, the ideal retirement age for a new ultralow floor standard bus has been determined at 19 years. The detailed cost analysis has revealed that from age 14 to age 21, the annual total operating cost per kilometre for a typical SEQ standard route bus rises exponentially from $1.58/km to $2.58/km in present values, while its revenue/km declines proportionately in the negative direction. As a consequence, each year of service life after age 16 requires a higher TransLink subsidy to the bus operator to keep its aging standard buses in service.

6 Ideal Retirement Age for All High Capacity Buses: Based on their whole-of-life costs, the ideal retirement age for all 4 high capacity buses also fell at age 19, but this was based on the assumption that aging high capacity buses could be deployed on school, shopper and district runs, private school and community charters, and breakdown standby bus duties, as is current practice for aging standard size route buses. It has been determined that the increase in annual operating cost per kilometre for a old age high capacity bus is much higher than for a standard bus, making it critical for TransLink that high capacity buses not be allowed to continue in service on light duties during the old age phase of their respective life cycles.

It has been further identified that high capacity buses have too many road use restrictions including over height limitations for the double deck bus, and restricted access, swept path/turning circle and bus stop length limitations for the 3 other single deck bus sizes. High capacity buses do not therefore appear to fill the same universal "go anywhere" and "back up any service" niche traditionally filled by standard 12.5m rigid buses during their old age.

A different future life cycle scenario has therefore been envisaged for high capacity buses in which they will need to be worked harder on normal commuter services in old age, and their retirements brought forward one year earlier to age 18.

7 Maximum Seating vs Minimum Dwell Impact on High Capacity Bus Operating and Economic Performance: Section 3.8 of the report has aptly demonstrated the high operating and whole-of-life economic benefits to TransLink of actively striving to trade seating capacity on high capacity buses for reduced dwell time at bus stops using bus cabin layouts with:

- Wider front to rear door aisle widths for improved passenger circulation and standee comfort,
- Wider, and on 110 passenger buses - second rear doors, for all door boarding and alighting,
- Rear door positions which encourage boarded passengers to alight in equal numbers through all doors, and
- Defined front and rear door passenger storage areas where alighting passengers can temporarily queue, tag off their go cards and get ready to alight before reaching bus stops; and where boarding passengers can then temporarily queue, tag on their go cards and spill out progressively to wide aisle ways and seats after leaving bus stops.

Operating benefits to high capacity buses of these bus cabin design reforms included:

- 200% to 300% reduction in average bus stop dwell time for all door balanced alighting and boarding,
- Higher legal total seated plus standing capacity,
- Reduced dead axle weight and fuel consumption,
- Greatly reduced simultaneous bus arrival clashes, particularly in single stop bay bus interchanges, park ‘n rides and stations where arriving buses must circulate until allocated stop bays are cleared, at single bay roadside stops where arriving buses are forced to relocate off stop zones, and at busway stations where arriving bus queues force passengers to move long distances up platforms and delay service departures,
- Greatly improved utilisation of high cost bus stop infrastructure and bus depot equivalent standard bus space, and
- Improved service frequency and competitiveness with the private motor vehicle.

Over whole-of-life, a 54¢ per pax-kilometre saving was realised by the *3 Door Articulated Superbus* relative to the *2 Door Articulated Bus* with 12 additional seats, but with future all door boarding and alighting, the total dwell time per peak trip would drop by 7 minutes for the former compared with only 3 minutes for the latter.

We have challenged the standing SEQ bus operator paradigm that more passenger seats on a high capacity bus equates to improved customer satisfaction, comfort and safety; and illustrated by example where all the above benefits could be realised on a current model *Two Door 14.5m Extended Rigid Bus* with as few as 3 less passenger seats. We have further highlighted that:

- 56% to 75% of passenger seats presently go unoccupied in Brisbane on existing off-peak high capacity bus services, and the cost of off-peak seat underutilisation translates to higher fuel consumption, bus maintenance, dead axle weight and lower combined bus seated plus standing capacity for 75 to 80% of a high capacity vehicle’s travelled life cycle kilometres,
- Every extra twin passenger seat crammed into the bus cabin occupies approximately the same floor space as 4 standees. <u>On peak services with highly crammed standing passenger</u>

loads, the price paid for 2 comfortably seated passengers is 4 very uncomfortable standees. Maximisation of seat capacity at the expense of aisle width does not consider the customer satisfaction, comfort and safety needs of those passengers still left standing, and that

- Average standing periods measured on some ten thousands of peak route services studied for the HCV operational performance evaluation showed that a typical standee endured uncomfortable crammed standing conditions for at least half the total trip time before finding a vacant seat to reoccupy. Throughout the time of standing, passengers had to shuffle back and forth and lean over seated passengers on exceptionally narrow aisle ways to let other passengers alight, and carry their personal belongings for most of the time to prevent trampling damage or tripping of other passengers.

The combined benefits of designing and operating high capacity buses for minimum stop dwell time rather than maximum seating capacity pushes the peak service breakeven point significantly towards the ticket revenue side, and thereby significantly reduces TransLink's subsidy for services and buses designed and operated for minimum dwell.

8 Whole-of-Life High Capacity Bus Performance Benefit:Cost Assessments: Operating performance, driving performance, road handling, bus stop infrastructure compatibility and depot compatibility have been compared for every bus type using data from our previous Stage 1 HCV technical studies and scores for assessed criterion weighted by relative importance. Total weighted scores for each bus type were divided by their respective whole-of-life cost per kilometre and cost per pax-kilometre to obtain performance benefit:cost ratios and the ratios then ranked between all bus types.

When taking into account vehicle operating performance, ease of driving and road manoeuvrability, compatibility with existing TransLink bus station and stop infrastructure and compatibility with existing operator bus depots, the findings from the performance benefit cost analysis were as follows:

- On the basis of benefit to cost per kilometre, high capacity vehicle performance rankings were shifted relative to cost only rankings in favour of the smaller 90 passenger buses, but rankings within the 90 passenger and 110 passenger categories remained unchanged. The shift in high capacity vehicle performance rankings by cost per kilometre relative to cost only rankings largely resulted from the shorter stop dwell times, faster operating speeds and superior driving and road manoeuvring capabilities of the 90 passenger buses compared with those of the 110 passenger buses.
- On the basis of benefit to cost per pax-kilometre, high capacity vehicle performance rankings shifted relative to cost only rankings in favour of the larger 110 passenger buses, and the *2 Door 12.5m Double Deck Bus* pegged equally with the *3 Door 18m Articulated Superbus*. The shift in performance rankings by cost per pax-kilometre relative to cost only rankings largely resulted from the superior compatibility of the double deck bus with existing bus station and roadside stop infrastructure and its very high equivalent standard bus passenger and parking capacities in depots where it could readily be accommodated without major upgrades.
- The *2 Door 14.5m Extended Rigid Bus* attained the highest performance benefit:cost ratio both in the 90 passenger category and between all the high capacity bus types. The *3 Door 18m Articulated Superbus* attained the higher performance benefit:cost ratio in the 110 passenger category.
- The *2 Door 18m Articulated Bus* had the lowest performance benefit:cost ratio of all the high capacity bus types.

- No high capacity vehicle outranked the *Standard 2 Door 12.5m Rigid Bus* on the like-for-like performance benefit to cost evaluation. Notwithstanding being the second dearest vehicle to operate on cost per pax-kilometre, the standard bus significantly outperformed every high capacity vehicle and was fully compatible with all existing bus stations, stops and depots.

Stage 2: Operating Cost Evaluation Report

Research & Analysis of High Capacity Vehicles

TransLink Transit Authority

Prepared by:

MRCagney Pty Ltd

21 February 2013

Document Information

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Job Number	4746
Title	Research and Analysis of High Capacity Vehicle Use - Stage 2 Operating Cost Evaluation of High Capacity Vehicles
Prepared by	MRCagney Pty Ltd Brisbane, Queensland
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3	Final Review and Editing for *TransLink*	MF	JV	LC	21/02/2013

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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by the TransLink Division of the Queensland Department of Transport and Main Roads (*TransLink*) to undertake research and analysis of high capacity vehicle use within its South East Queensland network. The subject high capacity vehicle types nominated by *TransLink* for the study are already in service on its network and include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

This Stage 2 technical study evaluates and compares the costs of owning and operating each of the 4 high capacity vehicles relative to the costs of owning and operating the standard two door 12.5m rigid bus commonly deployed by bus operators to *TransLink* route services in South East Queensland.

Relevant future costs and cost recoveries have been estimated in Part 2 of this report for every vehicle type, backward converted to present value FY2012/13 dollars, and summed to obtain a total whole-of-life net present value for each vehicle type's life cycle cash flows.

In Part 3 of the report, total (net present value) bus costs are compared and ranked for each vehicle type on a dollar per kilometre and cent per passenger-kilometre basis. Total (net present value) driver labour costs are also determined over each vehicle's service life at typical peak and off-peak traffic speeds on Brisbane roads, and total (net present value) bus and driver operating costs compared and again ranked for each bus type on a dollar per kilometre and cent per passenger-kilometre basis.

Total bus and driver operating costs are also examined to assess the economics of substituting a high capacity vehicle versus adding a second standard 12.5m rigid bus on an overloaded peak service, and to determine the breakeven point between *Translink* ticket revenue plus operator subsidy and bus operator cost plus profit margin.

Further into Part 3, we examine the difference between the *Two Door 18m Articulated Bus* and *Three Door 18m Articulated Superbus* life cycle costs and demonstrate the very significant impacts on operating and economic performance of a high capacity bus designed for minimum stop dwell time and a high capacity bus designed for maximum seating. We conclude the detailed cost analysis by then evaluating and comparing the relative performance benefit:cost ratios for every bus type.

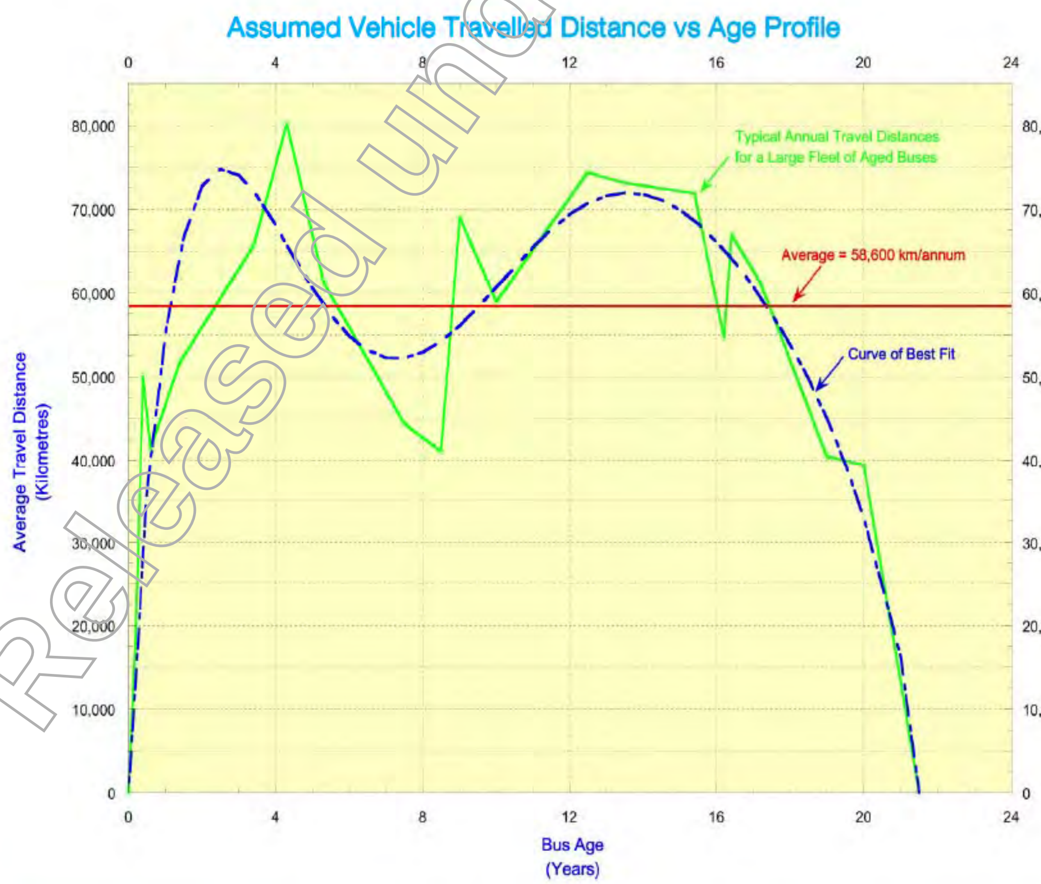
Findings of the whole-of-life cost analysis have been consolidated with other relevant findings from earlier Stage 1 high capacity vehicle use assessments in Part 4 of the report and have been presented later in the *Summary of Key Findings*.

1.2 Assumptions Adopted for the Life Cycle Cost Analysis

The following assumptions have been adopted for the life cycle cost analyses:

- All quoted prices, costs, finance lease rates, *Consumer Price Indices*, annual inflation rates, fees, charges and other data obtained for cost calculations have been sourced in the second quarter of FY2012/13. Present values have therefore been provided throughout the report in current FY2012/13 dollars.

- All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.
- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing below. This curve was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have been listed in the table appearing overleaf, average 58,600km/annum, and total to 1,230,600km over the assumed 21 year service life.
- New vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing bus depot only.
- Capital expenditures other than for new bus procurements have been assumed to be funded out of business equity (i.e. from business cash reserves or savings accounts). This includes final residual payouts on expired bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of operational cost evaluations, we have therefore assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, loading of buses to their maximum legal seated plus standee carrying capacities and typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.



Year Ending	Bus Age (years)	Travel Distance (kilometres)	Cumulative Odometer (kilometres)
2013	1	55,207	55,207
2014	2	72,781	127,988
2015	3	74,066	202,054
2016	4	68,080	270,134
2017	5	60,595	330,729
2018	6	54,863	385,592
2019	7	52,277	437,869
2020	8	52,932	490,801
2021	9	56,112	546,913
2022	10	60,695	607,608
2023	11	65,467	673,075
2024	12	69,360	742,435
2025	13	71,607	814,042
2026	14	71,805	885,847
2027	15	69,906	955,753
2028	16	66,123	1,021,876
2029	17	60,740	1,082,616
2030	18	53,857	1,136,473
2031	19	45,041	1,181,514
2032	20	32,900	1,214,414
2033	21	16,186	1,230,600

1.3 Summary of Key Findings

Bus ownership and operating costs are unaffected by road speed, but driver labour costs per kilometre have been shown in the Stage 1 *Operational Performance Evaluation Report* to change markedly under different road traffic speed operating conditions. Driver labour costs have therefore been assessed in this life cycle cost study at 3 common Brisbane road peak and off-peak traffic speeds:

(a) 30km/h Average Traffic Speed:

Bus services operating in 30km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

(b) 45km/h Average Traffic Speed:

Bus services operating in 45km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Bus services operating in 45km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

(c) 75km/h Average Traffic Speed:

Bus services operating in 75km/h peak traffic speed conditions travel between the CBD and an outer Brisbane suburb substantially on a busway or bypass the CBD on a major ring road such as the Western, Gateway or Logan Motorway.

Bus services operating in 75km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

The following key findings were obtained from a comparison of the net present values of all whole-of-life costs incurred by each high capacity bus relative to those incurred by a standard 12.5m rigid route bus under identical operating conditions.

1 **Two Door 14.5m Extended Rigid Bus:** **This high capacity vehicle provided the best overall cost performance in the 90 passenger capacity category. It competes in this category with the 2 Door Articulated Bus.**

At $2.30/km, this high capacity vehicle is 14% dearer to own and operate than a standard bus, but at 2.50¢/pax-km, is actually 7% cheaper in terms of its maximum 92 passenger carrying capacity. This bus breaks even with a standard bus at a load of 86 passengers, and has an increased future revenue generation potential of +7% when loaded with 6 additional passengers.

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If substituted on an existing overloaded peak service in lieu of two standard buses and drivers; over its whole-of-life this vehicle saves $1.341M (or $1.09/km) on 30km/h services, $1.179M (or $0.96/km) on 45km/h services and $1.101M (or $0.89/km) on 75km/h services, and is the best choice for any existing overloaded peak service only required to carry up to a maximum load of 92 passengers.

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A HR licensed driver is needed to drive this vehicle. It is 34% dearer at $4.98/km (30km/h), 38% dearer at $4.59/km (45km/h) and 40% dearer at $4.28/km (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 15% cheaper at 4.30¢/pax-km (30km/h), 12% cheaper at 3.96¢/pax-km (45km/h) and 10% cheaper at 3.69¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers; over its whole-of-life, this vehicle saves $0.249M (or $0.20/km) on 30km/h services, $0.129M (or $0.11/km) on 45km/h services and $0.096M (or $0.08/km) on 75km/h services, the lowest saving achieved by any of the high capacity buses. These relatively modest savings have been calculated at full load, a 21 year retirement age and 1.2306 million kilometre total service range. It is arguable whether substitution of a double deck bus would be cost justifiable against 2 rigid buses given its known service limitations in Brisbane western and eastern suburbs with so many existing low clearance railway bridges.

5 **Ideal Retirement Age for a Standard 12.5m Rigid Bus:** Based on whole-of-life costs, the ideal minimum cost retirement age for a new ultralow floor standard bus has been determined at 19 years. The detailed cost analysis has revealed that from age 14 to age 21, the annual total operating cost per kilometre for a typical SEQ standard route bus rises exponentially from $1.58/km to $2.58/km in present values, while its revenue/km declines proportionately in the negative direction. As a consequence, each year of service life after age 16 requires a higher *TransLink* subsidy to the bus operator to keep its aging standard 12.5m route buses in service.

6 **Ideal Retirement Age for All High Capacity Buses:** Based on their whole-of-life costs, the ideal retirement age for all 4 high capacity buses also fell at age 19, but this was based on the assumption that aging high capacity buses could be deployed on school, shopper and district runs, private school and community charters, and breakdown standby bus duties, as is current practice for aging standard size route buses. It has been determined that the increase in annual operating cost per kilometre for a old age high capacity bus is much higher than for a standard bus, making it critical for *TransLink* that high capacity buses not be allowed to continue in service on light duties during the old age phase of their respective life cycles.

It has been further identified that high capacity buses have numerous road use restrictions, including over height limitations for the double deck bus, and restricted access, swept path/turning circle and bus stop length limitations for the 3 other bus sizes. High capacity buses do not therefore appear to fill the same universal "go anywhere" and "back up any service" niche traditionally filled by standard 12.5m rigid buses during their old age.

A different future life cycle scenario has been envisaged for high capacity buses in which they will need to be worked harder on normal commuter services in old age, and their retirements brought forward one year earlier to age 18.

7 **Maximum Seating vs Minimum Dwell Impacts on High Capacity Bus Operating and Economic Performance:** Section 3.8 of the report has demonstrated the high operating and whole-of-life economic benefits to *TransLink* of actively striving to trade seating capacity on high capacity buses for reduced dwell time at bus stops using cabin layouts with:

- Wider front to rear door aisle widths for improved passenger circulation and standee comfort,
- Wider, and on 110 passenger buses - second rear doors, for all door boarding and alighting,
- Rear door positions which encourage boarded passengers to alight in equal numbers through all doors, and
- Defined front and rear door passenger storage areas where alighting passengers can temporarily queue, tag off their go cards and get ready to alight before reaching bus stops; and where boarding passengers can then temporarily queue, tag on their go cards and spill out progressively to wide aisle ways and seats after leaving bus stops.

Operating benefits to high capacity buses of these bus cabin design reforms included:

- 200% to 300% reduction in average bus stop dwell time for all door balanced passenger alighting and boarding,
- Higher legal total seated plus standing passenger carrying capacity,
- Reduced dead axle weight and fuel consumption,

- Greatly reduced simultaneous bus arrival clashing - in single stop bay bus interchanges, park 'n rides and stations where arriving buses must circulate until allocated stop bays are cleared; at single bay roadside stops where arriving buses are forced to relocate off stop zones; and at busway stations where arriving bus queues force passengers to mobilise for long distances up platforms and delay service departures,
- Greatly improved utilisation of high cost bus station/stop infrastructure and bus depot equivalent standard bus space, and
- Improved service frequency and competitiveness with the private motor vehicle.

Over its whole-of-life, a 54¢ per pax-kilometre saving was realised by the *3 Door Articulated Superbus* relative to the *2 Door Articulated Bus* with 12 additional seats, but with future all door boarding and alighting, the total dwell time per peak trip would drop by 7 minutes for the former compared with only 3 minutes for the latter.

We have challenged the standing SEQ bus operator paradigm that more passenger seats on a high capacity bus equates to improved customer satisfaction, comfort and safety; and illustrated by example where all the above benefits could be reaped on a current model *Two Door 14.5m Extended Rigid Bus* with just 3 less passenger seats. We have further highlighted that:

- 56% to 75% of passenger seats presently go unoccupied in Brisbane on existing off-peak high capacity bus services, and the cost of off-peak seat underutilisation translates to higher fuel consumption, bus maintenance, dead axle weight and lower combined bus seated plus standing capacity for 75 to 80% of a high capacity vehicle's travelled life cycle kilometres,
- Every extra twin passenger seat crammed into the bus cabin occupies approximately the same floor space as 4 standees. On peak services with highly crammed standing passenger loads, the price paid for 2 comfortably seated passengers is 4 very uncomfortable standees. Maximisation of seat capacity at the expense of aisle width does not consider the customer satisfaction, comfort and safety needs of those passengers still left standing, and
- Average standing periods measured on some ten thousands of peak route services studied for the HCV operational performance evaluation showed that a typical standee endured uncomfortable crammed standing conditions for at least half the total trip time before finding a vacant seat to reoccupy. Throughout the time of standing, passengers had to shuffle back and forth and lean over seated passengers on exceptionally narrow aisleways to let other passengers alight, and carry their personal belongings for most of the time to prevent trampling damage or tripping of other passengers.

The combined benefits of designing and operating high capacity buses for minimum stop dwell rather than maximum seating capacity pushes the peak service breakeven point significantly towards the ticket revenue side, and therefore significantly reduces *TransLink's* subsidy on buses designed and operated for minimum dwell time.

8 **Whole-of-Life High Capacity Bus Performance Benefit:Cost Assessment:** Operating performance, driving performance, road handling, bus stop infrastructure compatibility and depot compatibility have been compared for every bus type using data from previous Stage 1 HCV technical studies and scores for each assessed criterion weighted by its relative importance. Total weighted scores for each bus type were then divided by their respective whole-of-life cost per kilometre and cost per pax-kilometre to obtain performance benefit:cost ratios, and the ratios derived then ranked between all bus types.

When taking into account vehicle operating performance, ease of driving and road manoeuvrability, compatibility with existing TransLink bus station and stop infrastructure and existing operator bus depots, the findings from the performance benefit-cost results were as follows:

- On the basis of benefit to cost per kilometre, high capacity vehicle performance rankings shifted relative to cost only rankings in favour of the smaller 90 passenger buses, but rankings within the 90 passenger and 110 passenger categories remained unchanged. The shift in high capacity vehicle performance rankings by cost per kilometre relative to cost only rankings largely resulted from the shorter stop dwell times, faster operating speeds and superior driving performance of the 90 passenger buses, compared with those of the 110 passenger buses.
- On the basis of benefit to cost per pax-kilometre, high capacity vehicle performance rankings shifted relative to cost only rankings in favour of the larger 110 passenger buses, and the *2 Door 12.5m Double Deck Bus* was pegged equally with the *3 Door 18m Articulated Superbus*. The shift in performance rankings by cost per pax-kilometre relative to cost only rankings largely resulted from the superior compatibility of the double deck bus with existing bus station and roadside bus stop infrastructure, and its very high equivalent standard bus passenger and parking capacities in those bus depots where it could readily be accommodated without major upgrades.
- The *2 Door 14.5m Extended Rigid Bus* had the highest performance benefit:cost ratio both in the 90 passenger category and between the four high capacity bus types. The *3 Door 18m Articulated Superbus* had the higher performance benefit:cost ratio in the 110 passenger category.
- The *2 Door 18m Articulated Bus* had the lowest performance benefit:cost ratio of all the high capacity bus types.
- No high capacity vehicle outranked the *Standard 2 Door 12.5m Rigid Bus* on the like-for-like performance benefit-cost assessment. Notwithstanding it being the second dearest vehicle to operate based on cost per pax-kilometre, the standard bus significantly outperformed every high capacity vehicle primarily because it was fully compatible with all existing bus stations, stops and depots.

2. High Capacity Bus Cost Analyses

2.1 Background

This technical study investigates the costs of operating high capacity buses relative to those of a standard 12.5m rigid urban route bus. High capacity buses assessed in this technical study include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

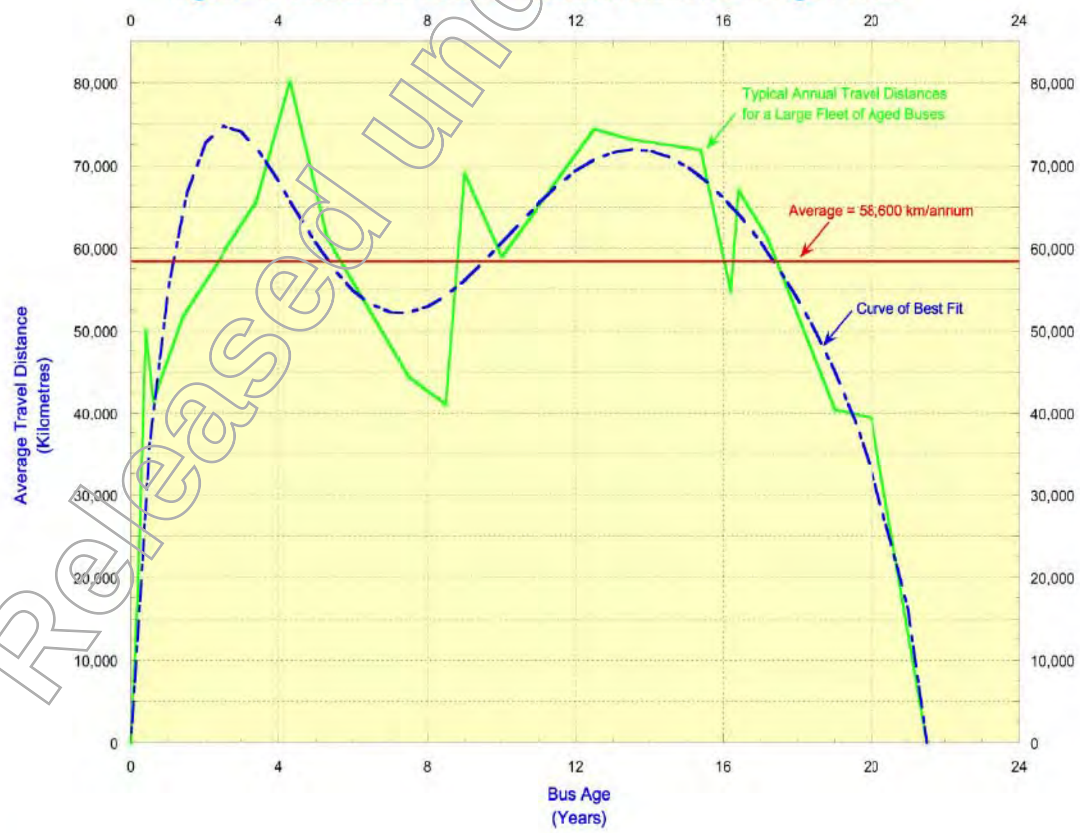
Part 2 of this report derives the ownership costs, fixed annual operating costs and variable operating costs for each bus type and explains where their reference cost data was sourced and how the present value of each cost element was calculated. Part 3 of the report summates the present values of all costs derived in Part 2, and compares the net present values for all bus types for their whole-of-life, both exclusive of, and inclusive of, bus driver operating costs.

2.1.1 Assumptions

The following assumptions have been adopted for this cost analysis:

- All quoted prices, costs, finance lease rates, *Consumer Price Indices*, annual inflation rates, fees, charges and other data obtained for cost calculations have been sourced in the second quarter of FY2012/13. Present values have therefore been provided in FY2012/13 dollars.

Figure 1: Assumed Vehicle Travelled Distance vs Age Profile



- All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.
- Assumed travel distances per annum in each year of the vehicle's service life have been based on the statistical polynomial *Curve of Best Fit* appearing above in Figure **1**. This curve was sourced from a detailed review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile curve have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and to provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses to one existing depot only.
- Capital expenditures, other than for new bus procurements, have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or saving accounts). This includes all final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h, and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1: Assumed Annual Travel Distances and Odometer Kilometres in Each Year of Bus Life

Year Ending	Bus Age (years)	Travel Distance (kilometres)	Cumulative Odometer (kilometres)
2013	1	55,207	55,207
2014	2	72,781	127,988
2015	3	74,066	202,054
2016	4	68,080	270,134
2017	5	60,595	330,729
2018	6	54,863	385,592
2019	7	52,277	437,869
2020	8	52,932	490,801
2021	9	56,112	546,913
2022	10	60,695	607,608
2023	11	65,467	673,075
2024	12	69,360	742,435
2025	13	71,607	814,042
2026	14	71,805	885,847
2027	15	69,906	955,753
2028	16	66,123	1,021,876
2029	17	60,740	1,082,616
2030	18	53,857	1,136,473
2031	19	45,041	1,181,514
2032	20	32,900	1,214,414
2033	21	16,186	1,230,600

2.2 Future to Present Value Conversion Formula

2.2.1 Present Value of a Future Single Expense or Recovery Cash Flow

The general equation for converting any future dollar value (*FV*) spent (+) or received (-) in future year *t* to its present dollar value (*PV*) today is given by...

$$PV = \frac{FV}{(1+q)^t} = \frac{FV}{(1.0304)^t} = \frac{FV}{c^t} \qquad \text{..........(i)}$$

where ...

FV = Future Value of the Single Expense (+) or Cost Recovery (-) (in dollars)

PV = Present Value of the Future Single Expense (+) or Cost Recovery (-) (in dollars)

q = *Brisbane Consumer Price Index – All Groups* for Decade ending Q1, FY2012/13 = 3.04%/annum

c = Future to Present Value Conversion Factor = 1.0304

t = Elapsed Period from 1 January 2013 (in years).

2.2.2 Net Present Value of a Future Fixed Annuity Cash Flow

Let *a* = fixed annuity cash flow between year *1* and year *t*. The net (or total) present value of all successive annual cash flows between year *1* and year *t* becomes...

$$PV = a/c^1 + a/c^2 + a/c^3 + \ldots + a/c^t$$

Multiplying both sides of the equation by c^t gives...

$$c^t\, PV = a\,(c^0 + c^1 + c^2 + c^3 \ldots + c^{t-1}) = \frac{a\,(c^t - 1)}{c - 1}$$ for its standard form geometric series, then giving...

$$PV = \frac{a\,(c^t - 1)}{c^t\,(c - 1)} \qquad \text{..........(ii)}$$

Now let the fixed annuity cash flow start in year *n* and finish in year *m* which gives the general equation for the net present value of any future fixed annuity cash flow as:

$$PV = \frac{a\,(c^m - 1)}{c^m\,(c - 1)} - \frac{a\,(c^n - 1)}{c^n\,(c - 1)} = \frac{a\,\{(1 - c^{-m}) - (1 - c^{-n})\}}{c - 1}$$

$$PV = \frac{a\,(c^{-n} - c^{-m})}{c - 1} \qquad \text{..........(iii)}$$

where ...

a = Amount of a Fixed Future Expenditure (+) or Recovery (-) Annuity (in dollars)

PV = Net (or Total) Present Value of the Future Annuity Cash Flow (in dollars)

n = Elapsed Period from 1 January 2013 on which the Annuity Cash Flow Started (in years)

m = Elapsed Period from 1 January 2013 on which the Annuity Cash Flow Finished (in years)

c = Future to Present Value Conversion Factor = 1.0304.

2.2.3 Net Present Value of a Compounding Interest Future Cash Flow

Let *p* = principal of a future cash flow compounding at interest rate *i* between year *1* and year *t*, and *r* = *1* + *i*, its annual compound growth rate. The net present value of all successive cash flows between year *1* and year *t* becomes...

$$PV = pr^1/c^1 + pr^2/c^2 + pr^3/c^3 + \ldots + pr^t/c^t = p(r/c)^1 + p(r/c)^2 + p(r/c)^3 + \ldots + p(r/c)^t$$

Letting $k = r/c$ yields...

$$PV = p\,(k^1 + k^2 + k^3 + \ldots + k^t)$$

Dividing both sides of the equation by k then gives...

$\frac{PV}{k} = p\,(k^0 + k^1 + k^2 + k^3 \ldots + k^{t-1}) = \frac{p\,(k^t - 1)}{k - 1}$ for its standard form geometric series, finally giving...

$$PV = \frac{p\,k\,(k^t - 1)}{(k - 1)} \qquad \text{..........(iv)}$$

Now let the compounding cash flow start in year n and finish in year m which gives the general equation for the present value of any future compounding cash flow as:

$$PV = \frac{p\,k\,(k^m - 1)}{k - 1} - \frac{p\,k\,(k^n - 1)}{k - 1} = \frac{p\,k\,\{(k^m - 1) - (k^n - 1)\}}{k - 1}$$

$$PV = \frac{p\,k\,(k^m - k^n)}{k - 1} \qquad \text{..........(v)}$$

where ...

k = Future to Present Value Compound Interest Conversion Factor = r/c
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Interest Growth Rate = $1 + i$
c = Future to Present Value Conversion Factor = 1.0304
p = Principal (in dollars)
PV = Net Present Value of the Compounding Interest Future Cash Flow (in dollars)
n = Elapsed Period from 1 January 2013 on which the Compounding Cash Flow Started (in years)
m = Elapsed Period from 1 January 2013 on which the Compounding Cash Flow Finished (in years).

2.2.4 Instalment and Account Balance for a Compound Interest Loan

Let...

- p = principal of a commercial loan,
- i = fixed compound interest rate paid over the term of the loan between year 1 and year t,
- s = the fixed instalment paid annually on the loan,
- t = the term of the loan,
- b = the loan balance remaining at the end of each successive year of the loan term after all preceding fixed instalments have been paid on time, and
- $r = 1 + i$, the annual compound interest growth rate of the account principal and balance.

From Eqt (i), the future value of each fixed instalment is:

$FV = s\,c^t$

Hence from Eqt (ii), the total future value of all fixed instalment cash flows paid to the financier up to and including year t simplifies down to...

$$FV = \frac{s\,(r^t - 1)}{r - 1}$$

At the end of year t, the future value of the principal has grown from p to...

$FV = p\,r^t$ so the future value of the remaining balance at the end of year t becomes...

$$b = p\,r^t - \frac{s\,(r^t - 1)}{r - 1} \qquad \text{..........(vi)}$$

For commercial loans, no GST is paid to the financier, but instalments must continue until the account balance has reached $b = 0$. This yields the fixed instalment as...

$$s = \frac{p\, r^t (r - 1)}{r^t - 1}$$ ....(vii)

where ...

s = Future Value of the Fixed Annual Instalment (in dollars)

p = Loan Principal (in dollars)

i = Compound Interest Rate (in percent/annum)

r = Annual Compound Interest Growth Rate = $1 + i$

t = Term of the Loan (in years).

The fixed instalments paid over the term of the loan represent a fixed expenditure cash flow which can be converted to a net present value using Eqt (iii) for a loan commencing in year n and terminating in year m. Substituting Eqt (iii) into Eqt (vii) gives...

$$PV = \frac{s\,(c^{-n} - c^{-m})}{c - 1} = \frac{p\, r^t (r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)}$$

Multiplying the numerator and denominator by c^m and substituting $t = m - n$ then gives the general equation for the net present value of any loan over term t ending in year m...

$$PV = \frac{p\, r^t (r - 1)\,(c^t - 1)}{c^m (c - 1)\,(r^t - 1)}$$ ....(viii)

where ...

p = Loan Principal (in dollars)

i = Compound Interest Rate (in percent/annum)

r = Annual Compound Interest Growth Rate = $1 + i$

t = Term of the Loan (in years)

c = Future to Present Value Conversion Factor = 1.0304

m = Elapsed Period from 1 January 2013 on which the Loan Finishes (in years).

2.2.5 Instalment and Residual for a Compound Interest Finance Lease

A new vehicle procured by commercial loan remains the property of the lessee (the bus operator) while the loan is being discharged. The new vehicle can be depreciated for tax purposes and the loan instalments attract no GST, but commercial loans contain no provision whatsoever for any residual pay out upon termination.

A new vehicle procured under a finance lease remains the property of the leasor until the lease has been fully discharged and its residual fully paid out. When a new vehicle is procured by finance lease, both the ongoing instalments and the residual left owing at termination of the lease attract GST. To determine the fixed instalment amount, the leasor and lessee must mutually agree upon the future value of the residual left to be paid out at the end of the lease, which is typically expressed as a percent of the principal, and has both a minimum and maximum dollar limit based on perceived risk. Residual percent limits are determined by the leasor in accordance with the amount borrowed, the term of the lease, the asset class and the credit worthiness of the lessee.

Let...

- p = principal of the finance lease, excluding GST,
- i = fixed compound interest rate paid over the term of the lease between year 1 and year t,
- s = the fixed instalments paid annually on the lease, excluding GST,
- t = the term of the finance lease,
- d = the residual remaining at the end of the lease term, excluding GST,
- j = the percentage future value of the residual to the principal, and

- $r = 1 + i$, the annual compound growth rate of the principal p.

The future value of the residual at the end of year t can be derived from Eqt (vi) by including the 10% GST applicable to both the ongoing instalments and the residual giving...

$$1.1\, d = p\, r^t - \frac{1.1\, s\, (r^t - 1)}{r - 1} \qquad \text{..........(ix)}$$

The ratio (in percent) of the residual to the principal is given by...

$$j = \frac{1.1\, d}{p} \qquad \text{..........(x)}$$

Therefore, an alternative form of Eqt (ix) for the future value of the residual is...

$$1.1\, d = j\, p = p\, r^t - \frac{1.1\, s\, (r^t - 1)}{r - 1} \qquad \text{..........(xi)}$$

Rearranging Eqt (xi) yields the future value of the ongoing fixed instalment (including GST) as...

$$1.1\, s = \frac{(p\, r^t - 1.1\, d)\,(r - 1)}{r^t - 1} = \frac{p\,(r^t - j)\,(r - 1)}{r^t - 1} \qquad \text{..........(xii)}$$

where ...

$1.1\ s$ = Future Value of the Fixed Annual Instalment, including GST (in dollars)
$1.1\ d$ = Future Value of the Final Residual, including GST (in dollars)
p = Finance Lease Principal, excluding GST (in dollars)
j = Percent Ratio of the Future Value of the Residual to the Principal (in percent),
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Interest Growth Rate = $1 + i$
t = Term of the Lease (in years).

The residual represents a fixed future lump sum expenditure paid at the end of the lease in year m, and its present value can be determined from Eqt (i) and Eqt (x) as...

$$PV = \frac{1.1\, d}{c^m} = \frac{j\, p}{c^m}$$

The fixed instalments paid over the term of the lease represent a fixed expenditure cash flow which can be converted to a net present value using Eqt (iii) for any lease commencing in year n and terminating in year m. Substituting Eqt (iii) into Eqt (xii) gives...

$$PV = \frac{(p\, r^t - 1.1\, d)\,(r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)} = \frac{p\,(r^t - j)\,(r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)}$$

Multiplying the numerator and denominator by c^m, substituting $t = m - n$, and adding the present value of the residual payout then gives the general equation for the net present value of both the instalments and residual for any finance lease over term t ending in year m as...

$$PV = \frac{(p\, r^t - 1.1\, d)\,(c^t - 1)\,(r - 1)}{c^m\,(c - 1)\,(r^t - 1)} + \frac{1.1\, d}{c^m} = \frac{p\,(r^t - j)\,(r - 1)\,(c^t - 1)\,(r - 1)}{c^m\,(c - 1)\,(r^t - 1)} + \frac{j\, p}{c^m} \qquad \text{..........(xiii)}$$

where ...

p = Future Value of Lease Principal, excluding GST (in dollars)
d = Future Value of the Residual, including GST (in dollars)
j = Percent Future Value of the Residual (including GST) to the Principal (in percent),
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Interest Growth Rate = $1 + i$
t = Term of the Lease (in years)
c = Future to Present Value Conversion Factor = 1.0304
m = Elapsed Period from 1 January 2013 on which the Lease Terminates (in years).

2.2.6 Annually Reducing to Monthly Reducing Cash Flow Conversions

The compound interest equations (iv) through (xiii) above apply strictly to annual periods only. Notwithstanding that financiers invariably quote their interest rates in percent per annum, they enforce repayment of instalments monthly and process account balances as monthly reducing, rather than annually reducing, which actually increases the total amount having to be repaid. The following conversions enable all the above equations to be used for fixed monthly instalments paid on monthly reducing accounts:

- Substitute *i / 12* to convert annual interest rate *i* to monthly interest rate,
- Substitute *r + i / 12* to convert annual compound interest growth rate *r* to monthly growth rate,
- Substitute *c* = 1.0046376 to change the annual future to present conversion factor to a monthly future to present value conversion factor (calculated to 7 decimal places using Eqt (ii)), and
- Substitute *12 t, 12 m* and *12 n* to convert annual periods *t, m* and *n* to monthly periods.

2.2.7 Depreciated Book Value and Resale Value

The market resale value of a route bus falls exponentially with age and whilst the resale price at any given time is driven by the economics of supply and demand, the book value can be modelled with high accuracy from a knowledge of that point in time when there is no market resale demand for the second hand vehicle, at which point its book value has fallen to the so-called scrap (or salvage) value. For an old Queensland route bus, this occurs at age 25, and its future scrap metal salvage value is around 1% of the price of a similar new replacement vehicle (in present value).

Let p = price of a similar new replacement bus, v = its salvage value at age 25 and w = its market book value. The exponential rate of depreciation in the vehicle's market book value can be calculated as...

$r = 1 - (v/p)^{1/25} = 1 - (0.01)^{0.04} = 16.8236\%$ *per annum*. Its future book value in any given year *t* of its service life then solves as...

$w = p\,(1 - r)^t = p\,(1 - 0.168236)^t = p\,0.831764^t$ ....(xiv)

Hence on reaching retirement at the assumed age of 21, the expected resale value of the vehicle would be around 2.09% of its replacement purchase price in present value dollars.

2.3 Average Labour Rates

Direct labour costs are the largest single contributor to the overall cost of operating, servicing and maintaining a route bus. The average labour rate per hour of a bus driver is needed to calculate the variable cost of operating a bus, the average labour rates of tradespersons and labourers (a.k.a. chassis cleaners, oiler-greasers and tyre repairers) to calculate the variable cost of maintaining the vehicle, and the average labour rate of cleaners (a.k.a. passenger services assistants, refuellers and yard persons) to calculate the annual cost of servicing the vehicle.

2.3.1 Average MR Licensed Bus Driver Labour Rate

Drivers holding an MR heavy vehicle licence can drive any standard 12.5m or extended 14.5m rigid bus. Their current award or certified agreement weekly rates vary markedly between bus operators in South East Queensland in the range of $638/week for a private bus operator up to $903/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $790/week.

An ***Average MR Licensed Bus Driver Labour Rate of $33.94/hour*** has been calculated from the cost and hours data appearing below in Table 2.

Table 2: Average Labour Rate Calculations for an MR Licensed Bus Driver

Annual Costs (Base = $790/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$41,080	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 17 hours/week over 6 shifts, including award night allowance rate	$22,865	Less 5 weeks/year for annual leave	-190 hours
Paid award allowances/year (training, meal and ticket/fare processing)	$2,416	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,697	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime))	$3,037	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,936	Less an average of 3 days/year for compulsory authorised operator and driver training	-23 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$692	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Driver's uniform and accessories	$425	Less an average of 2.5 days/year for carer's, family and personal leave	-19 hours
Recruitment and training	$560	Less an average of 2.5 days/year for other paid leave (compassionate, parental, bereavement, etc)	-19 hours
Total Labour Cost/Year	**$76,708**	**Subtotal - Base Work Hours/Year**	**1563 hours (41 weeks)**
Total Labour Costs/Year Total Work Hours/Year	$76,708 2,260	Plus overtime worked on shift penalty rates for an average of 17 hours/week for 41 weeks/year covering night services, weekend and public holiday services and fill-ins for other drivers	+697 hours
Average Labour Rate	**$33.94**	**Total Work Hours/Year**	**2,260 hours**

2.3.2 Average HR Licensed Bus Driver Labour Rate

Drivers holding a HR heavy vehicle licence can drive the heavier 12.5m double deck and 18m articulated buses. Their award or certified agreement weekly rates vary markedly between operators in South East

Queensland in the range of $653/week for a private bus operator up to $948/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $840/week.

An ***Average HR Licensed Bus Driver Labour Rate of $35.96/hour*** has been calculated from the cost and hours data appearing below in Table 3.

Table 3: Average Labour Rate Calculations for a HR Licensed Bus Driver

Annual Costs (Base = $840/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$43,680	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 17 hours/week over 6 shifts, including award night allowance rate	$24,240	Less 5 weeks/year for annual leave	-190 hours
Paid award allowances/year (training, meal and ticket/fare processing)	$2,416	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,931	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime))	$3,226	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$2,057	Less an average of 3 days/year for compulsory authorised operator and driver training	-23 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$735	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Driver's uniform and accessories	$425	Less an average of 2.5 days/year for carer's, family and personal leave	-19 hours
Recruitment and training	$560	Less an average of 2.5 days/year for other paid leave (compassionate, parental, bereavement, etc)	-19 hours
Total Labour Cost/Year	**$81,270**	**Subtotal - Base Work Hours/Year**	**1563 hours (41 weeks)**
Total Labour Costs/Year Total Work Hours/Year	$81,270 2,260	Plus overtime worked on shift penalty rates for an average of 17 hours/week for 41 weeks/year covering night services, weekend and public holiday services and fill-ins for other drivers	+697 hours
Average Labour Rate	**$35.96**	**Total Work Hours/Year**	**2,260 hours**

2.3.3 Average Bus Cleaner Labour Rate

Bus cleaners are employed in South East Queensland bus depots under various role specific job titles including chassis cleaner, oiler-greaser, tyre repairer, yard person, refueller and passenger services assistant. Their roles have become interchangeable in most depots over the past decade and those working for particular bus operators are employed under similar pay rates and conditions of employment.

Their award or certified agreement weekly rates vary markedly between operators in South East Queensland in the range of $603/week for a private bus operator up to $876/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $740/week. For industrial harmony, the majority of bus cleaners currently work on rotational shifts to equalise their take home pays.

An ***Average Bus Cleaner Labour Rate of $30.97/hour*** has been calculated from the cost and hours data appearing overleaf in Table 4.

Table 4: Average Labour Rate Calculations for a Bus Cleaner

Annual Costs (Base = $740/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$38,480	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 10 hours/week over 6 shifts, including award night allowance rate	$12,949	Less 5 weeks/year for annual leave	-190 hours
Paid meal allowance/year	$2,016	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,463	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime))	$2,443	Less an average of 6 days/year for sick leave (ie 60% of maximum entitlement)	-46 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,557	Less an average of 1 day/year for compulsory authorised operator, fire, driving and safety training	-8 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$648	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Safety vest, boots, goggles and raincoat	$125	Less an average of 2 days/year for carer's, family and personal leave	-15 hours
Recruitment and training	$200	Less an average of 2 days/year for other paid leave (compassionate, parental, bereavement, etc)	-15 hours
Total Labour Cost/Year	**$61,881**	**Subtotal - Base Work Hours/Year**	**1,578 hours (42 weeks)**
<u>Total Labour Costs/Year</u> Total Work Hours/Year	<u>$61,881</u> 1,998	Plus overtime worked on shift penalty rates for an average of 10 hours/week for 42 weeks/year covering night, weekend and public holiday bus servicing and fill-ins for other cleaners	+420 hours
Average Labour Rate	**$30.97**	**Total Work Hours/Year**	**1,998 hours**

2.3.4 Average Tradesperson Labour Rate

Tradespersons employed in South East Queensland bus garages include motor mechanics, automotive electricians and motor body builders. They are covered by similar trade skills based C10 through C5 pay rates and conditions of employment. Trade award or certified agreement weekly rates vary markedly between operators in South East Queensland in the range of $833/week for a private bus operator up to $1,104/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $985/week.

An ***Average Tradesperson Labour Rate of $39.89/hour*** has been calculated from the cost and hours data appearing overleaf in Table 5.

2.4 Bus Ownership Costs

All dollar amounts listed in the tables which follow have been expressed in FY2012/13 dollar values. Future values of expenditures and cost recoveries incurred during each vehicle's life have been backward converted to their equivalent present dollar values so that a like-for-like comparison can be made between the alternative bus types using dollar values as they are perceived and measured today. Outgoing expenses have been assigned positive present values. Incoming cost recoveries have been assigned negative present values and highlighted with red text. Where abbreviated in the following analyses, "*PV*" means *Present Value*, "*NPV*" means *Net Present Value,* and "*FV*" means *Future Value*.

Table 5: Average Labour Rate Calculations for a Tradesperson

Annual Costs (Base = $985/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$51,220	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime	$6,532	Less 4 weeks/year for annual leave	-152 hours
Paid tool, first aid and meal allowances/year	$1,052	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$4,610	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$2,743	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,749	Less an average of 4 days/year for compulsory QA, trade skills, environmental and OHS training	-30 hours
Annual Leave Loading (17.5% of 4 weeks paid annual leave)	$690	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Overalls, safety vest, boots, goggles, raincoat, hard hat and compensation for spectacles, hearing aids, tools and work clothing damaged on job	$500	Less an average of 2 days/year for carer's, family and personal leave	-15 hours
Recruitment and training	$1,500	Less an average of 2 days/year for other paid leave (compassionate parental, bereavement, etc)	-15 hours
Total Labour Cost/Year	**$70,596**	**Subtotal - Base Work Hours/Year**	**1,602 hours (42 weeks)**
Total Labour Costs/Year Total Work Hours/Year	$70,596 1,770	Plus an average of 4 hours overtime at time and a half rates for 2 nights per week or Saturday mornings for 42 weeks/year	+168 hours
Average Labour Rate	**$39.89**	**Total Work Hours/Year**	**1,770 hours**

2.4.1 Bus Procurement Costs

Bus procurement costs cover a new vehicle's purchase price, together with ancillary costs for axle weighing, ADR compliance certification, statutory on-road fees and charges, insurance, delivery, operator pre-service quality inspections and minor fit-outs totalling approximately $7,500 per new vehicle.

New bus chassis and body manufacturer purchase prices vary significantly with production run lot sizes and this analysis has been based on an assumed lot size of 5 new buses per production run. FY2012/13 average procurement costs for new high capacity buses relative to that of the reference two door 12.5m rigid bus are listed below in Table 6.

Table 6: Procurement Costs for New High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Procurement Cost (Dollars)	Relative Procurement Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$480,000	141.7%	116.7%	158.3%	160.4%

2.4.2 Bus Procurement Financial Costs

While bus procurement costs are a one-off capital expenditure incurred at the time of purchase, they are normally amortised in practice as future instalments repaid on borrowing expenses, and as future residual payouts in the case of a finance lease. Bus operators typically fund new bus procurements through a mix of debt (commercial business loans or finance leases) and equity (cash down deposits and finance lease residual payouts). The weighted cost of capital will therefore vary from operator to operator in accordance with its preferred leveraging of debt to equity funding, the term of the commercial loan or finance lease entered into, its fixed interest rate, and final residual payout if a finance lease.

For private bus operators, the cost of capital funded by loan can be offset through capital depreciation write-downs claimed back as BAS tax deductions, and any GST paid on finance lease instalments can similarly be recovered indirectly as an input tax credit by the leasor and as a BAS business operating expense by the lessee.

Whilst public bus operators similarly recognise capital depreciation expense for government accounting purposes, they have no recourse to depreciation cost recoveries through corporate business taxation, but otherwise fully recoup their GST payments on finance loan instalments, and are entitled to secure very low interest rates with finance leases sourced through the Queensland Treasury Corporation. To compare the cost of capital for all bus types and bus operators equitably, we have therefore adopted the following assumptions for our bus life cost analysis:

- 100% of new bus procurement capital costs will be funded by a finance lease entered into for a 10 year term with a 20% residual payout from operator equity falling due upon termination of the lease at the end of year 10.
- The cost of debt funding for new buses procured through the finance lease has been set at a fixed interest rate of 7.25%/annum (the current finance industry median borrowing rate for long term truck and bus fleet finance leases effective as at Q2 FY2012/13), and the lease repaid in monthly reducing instalments.
- Capital depreciation for loans or GST tax deductions claimed for leases by private bus operators are considered comparable in value to GST recoveries obtained by public bus operators. To account for procurement cost tax offsets, the net cost of GST has been deducted from the net present value of the finance lease as an equivalent tax deduction recovery received by both private and public bus operators.

Table 7 below summarises the net present values of bus procurement financial costs for the 4 high capacity bus types relative to that of the reference standard two door 12.5m rigid bus. Amounts shown in the table have been calculated using Eqt (xiii) and independently verified by spreadsheet for all monthly cash flows. Tax deductions indicated in Table 7 are equivalent to the net present value of all GST paid on the 120 monthly lease instalments and the residual payout at the end of year 10.

Table 7: Procurement Financial Costs for High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Procurement Financial Costs (Dollars)	Bus Procurement Financial Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$538,610 (Lease Repayments)	141.7%	116.7%	158.3%	160.4%
- $53,861 (Tax Deductions)	-141.7%	-116.7%	-158.3%	-160.4%

2.4.3 Bus Resale Price Recovery

The market value of a bus depreciates continuously throughout its service life until retirement, at which time the vehicle is either traded in, sold or salvaged to recover its remaining book value. Market resale prices closely mirror the exponential decay characteristic of a reducing balance depreciation curve and from Eqt (xiv) and the analysis appearing in Section 2.2.7, the anticipated resale price for all bus types at the assumed retirement age of 21 would be around 2.09% of their respective new replacement bus price expressed in present dollar values. The relative resale price recoveries for the 5 bus types (in present value dollars) are presented in Table 8 below.

Table 8: Resale Recovery for All Bus Types at a Retirement Age of 21

Reference 2 Door 12.5m Rigid Bus Resale Recovery (Dollars)	Relative Resale Price Recovery Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
-$10,000	-141.7%	-116.7%	-158.3%	-160.4%

2.4.4 Depot Upgrade Costs for Initial High Capacity Bus Deployments

First-time deployment of longer, taller or wider swept path high capacity vehicles to an existing bus depot can potentially trigger significant capital works for site modifications and other upgrades covering:

- Changed depot bus circulation paths,
- Dedicated HCV parking bays and/or lanes,
- Changed parking yard layouts and line remarking,
- Additional single post maintenance hoists or pit lengthening,
- Wheel brake and suspension shaker pit equipment modifications,
- Bus spray painting booth heightening or lengthening,
- Garage roller door and service shed widening or heightening,
- New bus roof access catwalks or tethered anti-fall personnel safety harnesses,
- Refuelling bay and washing machine modifications,
- AdBlue storage tank and dispenser hose installations in refuelling bays,
- Specialised HCV maintenance crew and driver orientation training sessions,
- Specialised HCV maintenance tools and test equipment procurements, and
- Specialised HCV spare parts procurements.

The *Depot Evaluation Technical Report* completed in Stage 1 of this study explored the likely impacts of deploying new high capacity vehicles to 16 existing bus depots in South East Queensland and concluded that specific high capacity bus types should be selected for each depot to obviate costly major building modifications for their initial accommodation.

During the course of the depot evaluation study, it was noted that most private operators had not as yet installed AdBlue storage tanks and dispensers in their refuelling bays, but it was clarified that such would become compulsory for any future new Australian Design Rule compliant buses entering service if fitted with SCR emission controlled diesel engines. We have therefore not included upgrade costs associated with retrofit tank and refuelling bay AdBlue installations as such would occur irrespective of whether retiring standard 12.5m rigid buses were replaced with new 12.5m rigid buses or high capacity buses.

Subject to economically justifiable selective deployment of those high capacity bus types best suited to existing depot constraints, we have surmised for costing purposes that a typical depot should only require the following minor capital works and equipment upgrades:

- HCV parking bay creation and line remarking at those depots with existing perimeter bus parking bays **or** parking yard layout modifications and line remarking at those depots with existing nose-to-tail parking lanes,
- 4 additional new maintenance post hoists per garage,

- 1 additional bus roof anti-fall safety work harness per garage,
- 2 washing machine top rail and roller height extension modifications **or** 1 new mobile bus washing machine per garage (for double deck buses only),
- 1 set of specialised HCV spare parts per garage.
- 1 set of specialised HCV maintenance tools and test equipment per garage,
- 5 onsite HCV maintenance crew technical training sessions per garage, and
- 90 HV licensed driver high capacity bus orientation training sessions per depot.

Depot upgrade, new equipment/spares and staff training costs arise as once-off capital outlays when any new bus type is first introduced into service at an existing bus depot, and the last 4 items listed above apply equally to the initial deployment of a new 12.5m rigid bus model. We have assumed for costing purposes that depot upgrade costs would be funded from the bus operator's business equity accounts but have apportioned the capital cost equally to the first lot of 5 new buses placed in service at a single existing depot. Depot upgrade costs applicable to the 5 new bus types are listed below in Table 9.

Table 9: Depot Upgrade Costs for 5 Initial Bus Deployments to a Single Depot

Reference 2 Door 12.5m Rigid Bus Depot Upgrade Cost (Dollars)	Average Total Costs and Relative Cost Factors for Initial 5 Bus Deployment			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$30,000 (total)	$115,000 (total)	$90,000 (total)	$90,000 (total)	$90,000 (total)
$6,000 (per bus)	383%	300%	300%	300%

2.4.5 Major Bus Overhaul and Refurbishment Costs

Major bus drive train overhauls and structural frame and body refurbishments incur significant capital costs during a vehicle's life. They are triggered either by elapse of time (bus age), but are not recurring fixed annual costs; or by travelled distance (bus odometer reading), but are not variable costs proportional to kilometres travelled.

A typical distance:age profile for a route bus life cycle has been presented earlier in Figure 1. The underlying reasons for the characteristic saddle shape of this curve are due in part to operator and driver preferences to operate young and middle aged buses rather than old aged buses, and to major overhauls and refurbishments around the vehicle's mid-life which reduce its normal availability for route services.

The area under the distance:age curve in each year of service is a direct measure of the kilometres travelled by the vehicle in that year, and the cumulative area under the curve up to the end of each year is a direct measure of the vehicle's accumulated odometer kilometres since first entering service. Travelled annual and cumulative odometer kilometres in each year of the assumed 21 year service life have been listed in Table 1, total 1,230,600 kilometres and average 58,600km/annum. This distance:age profile has been adopted to compare the relative costs of all 5 bus types under identical life cycle operating conditions.

Inspection of Figure 1 reveals that the characteristic trough in the distance:age profile occurs around age 8 when the bus odometer reaches 500,000km. This is the point in the vehicle's life where most chassis manufacturers specify their major engine and transmission overhauls, but new bus manufacturers today have managed to stretch this interval out to 700,000km, which occurs later in the vehicle's life cycle at around age 11 to 12. This 200,000km increase has assured that the engine on a typical route bus now only requires one major overhaul in the vehicle's service life.

By age 9 to 10, bus frame structural fatigue and rust have typically begun, triggering the urgent need for a major body frame refurbishment. Also around age 9 to 11, the cabin seat upholstery and aisle way floor vinyl have also begun to look worn and deteriorated, and the vehicle's tarnished exterior could do with a fresh spray of 2 pack urethane. In the knowledge that the bus has reached its mid-life, the combined urgent need for all these refurbishments forces a decision on the bus operator either to sell the bus or give it a fresh makeover that would see it through to retirement. The latter is invariably the cheaper option, and correspondingly, the one most frequently chosen by SEQ bus operators.

700,000km Major Engine Overhaul at Age 11 to 12

$48,000 for the 12.5m rigid bus, $52,000 for all other bus types. These indicated PV costs cover removal, major overhaul and refit of the engine to the vehicle. Labour has been costed for 140 hours at the average tradesperson rate of $39.89/hour calculated in Section 2.3.4. Material costs have been adjusted for a typical manufacturer's list price discount of 20% available to most large private operators and include GST. The tasks costed include overhaul of the starter motor, alternator, intercooler, radiator, water pump, power steering pump, air compressor, air conditioner compressor, turbocharger and radiator, plus full replacement of the engine cylinder heads, liners, piston rings, filters, injectors, belts, hoses, oil and catalytic converter.

500,000km Major Gearbox and Retarder Overhaul at Age 8 to 10

$47,000 for all bus types. A similar model 5 speed automatic gearbox and retarder has been assumed fitted to all 5 bus types. The PV cost indicated covers removal, transport to and from the repairer, overhaul by the transmission repairer, and refit to the bus. Removal, transport and refit labour have been costed for 15 hours total at the average tradesperson rate. Automatic transmission repairs prove very costly and notwithstanding that gearbox manufacturers specify 500,000km for their major overhauls, most private operators will typically hold off mid-life overhauls for as long as possible to avoid having to repeat overhaul the transmission in the vehicle's old age.

Mid-Life Body Frame & Upholstery Refurbishment and Exterior Repaint at Age 9 to 10

$34,000 for a 12.5m rigid, $51,000 for a double deck bus, $38,000 for a 14.5m rigid bus, $43,000 for a 2 door articulated bus and $41,000 for a 3 door articulated *Superbus*.

For most private operators, bus mid-life is actually reached at around age 9 to 10, based on odometer kilometres half-life, rather than age mid-life. The cheapest way to complete the vehicle's mid-life makeover is to withdraw the bus entirely from service, send it to coach body repairers for competitive quotes, and raise an order to complete all body refurbishments in a single pass.

While floor vinyl replacement, seat fabric re-upholstery and exterior repainting can be estimated with reasonable accuracy, structural cracks and rust in zincalum steel frames or weld fractures and T-nut slippages in aluminium frames can cause severe collateral damage to door frames and window pillars, bonded glazing, floor laminates, seat frame anchors and interior bulkheads.

We have assumed only minor frame deterioration and collateral body repairs to a total value of $10,000 + GST per bus, and costed replacement of worn floor vinyl along the cabin aisle ways only.

Summated PV overhaul and refurbishment costs for the 5 bus types appear overleaf in Table 10. It has been assumed that these would be fully funded by the operator from its business equity accounts without the need to borrow.

Table 10: Major Overhaul and Refurbishment Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Major Overhaul and Refurbishment Cost (Dollars)	Relative Major Overhaul and Refurbishment Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$129,000	116.3%	106.2%	110.1%	108.5%

2.5 Fixed Annual Operating Costs

In this analysis, fixed operating costs refer to expenses incurred annually by the operator to keep each bus registered, insured, clean and otherwise service ready. Fixed annual operating costs accrue in each year of the vehicle's life irrespective of the service kilometres actually travelled by the vehicle in any given year.

2.5.1 Annual Statutory Compliance Costs

All urban buses used to deliver public transport route services within *TranLink's* operating area require annual registration and Class 10B compulsory third party insurance, as well as two bi-annual Department of Transport and Main Roads *Programmed Vehicle Safety Audits.*

Annual Registration Fees

Bus registration fees depend on the vehicle type, its number of axles and the vehicle manufacturer's rated axle gross vehicle mass. State registration fees are currently $488/annum for all bus types other than the 2 door 12.5m double deck bus, which is currently $2,429/annum because its front steer axle centres exceed the 1 metre maximum separation limit.

Compulsory Third Party Insurance Premiums

Class 10B CTP insurance premiums vary quite markedly between the 5 bus types and depend on each vehicle's total passenger plus driver seating capacity. CTP insurance premiums range from $4740/annum for the standard 12.5m rigid bus with 45 total seats up to $10,700/annum for the 2 door 12.5m double deck bus with 97 total seats.

Programmed Vehicle Safety Audits and Charges

$710/annum for a 12.5m rigid or double deck bus, $850/annum for a 14.5m rigid bus and $1,015/annum for an articulated bus.

Compulsory bi-annual programmed vehicle safety audits are typically conducted onsite in each bus depot. Visiting TMR safety auditors require that all vehicle undercarriages be pressure cleaned prior to inspection, every vehicle be brake and suspension shaker witness tested, then hoisted for a thorough chassis, steering, suspension, tyre wear and driveline inspection. Audits will also typically include cab interior and fire extinguisher safety checks, and may occasionally involve random road testing of selected vehicles upon request by the auditor.

A certificate of inspection is issued by the auditor for safety defect rectifications on each bus, and a second round of inspections conducted to confirm their timely completion. Maintenance works generated by safety rectifications have been separately costed under bus maintenance.

Total annual statutory compliance costs for the 5 bus types are summarised overleaf in Table 11.

Table 11: Annual Statutory Compliance Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Statutory Compliance Cost (Dollars/Annum)	Relative Annual Statutory Compliance Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$5,938/annum	233%	125.5%	143.7%	120.6%

2.5.2 Annual Bus Insurance Costs

A range of insurance products is readily available for bus operators to manage their business risks, but the three most common policies taken up specifically for urban bus fleets are public liability, comprehensive commercial vehicle fleet insurance and depot insurance, the latter of which provides cover against theft, fire or flood damage sustained while buses are parked in depots. As the legal owner of a leased bus, the two former insurance policies will invariably be stipulated by fleet financiers to be kept current throughout the term of any finance lease.

Insurance brokers frequently bundle their offerings at discount premiums to cover every possible type of fleet insurance imaginable from CTP to depot insurance, business interruption protection, business income assurance, directors' and officers' legal liability, public liability and even worker's compensation. Discount bundled premiums per bus increase with reducing fleet size, increasing average fleet age and average bus replacement price, the number of previous motor accident claims lodged by the fleet operator, and their total claim value.

With so many variables affecting discount annual insurance premiums, the following indicative costs would be considered typical of the average per unit unbundled insurance premium rates for a large private bus operator with a fleet of 100 buses of 10 years average age with a moderate to good previous claim history.

Public Liability Insurance

$1,160/annum for all bus types. Public liability insurance premiums are currently set independent of bus passenger carrying capacity, but this may change over time if future SEQ bus fleets begin to incorporate an increasing proportion of high capacity vehicles.

Comprehensive Commercial Vehicle Fleet Insurance

$865/annum for a standard 12.5m rigid bus, $1,440/annum for a 14.5m rigid bus and $1,480/annum for a double deck or articulated bus.

Comprehensive insurance premiums are affected by vehicle purchase price and road accident susceptibility. We have nominated per vehicle premium rates for a $2,500 excess basic "no frills" comprehensive motor vehicle accident repair or replace, and personal injury or death coverage capped to $30 million.

It should be noted however that fleet insurance premiums could be up to 3 times those indicated above for small bus operators with a poor claim history who elect full coverage for added "frills". Such frills include options such as refund of tow back to depot and to/from the vehicle's place of repair, refund of temporary bus repair costs, refund of passenger expenses to complete their journeys by taxi, refund of temporary replacement bus hire charges, full passenger luggage damage cover and full replacement of vehicles under 12 months of age or pay out of the finance lease residual after 12 months of age in the case of a total accident write-off.

Depot Insurance

$150/annum for all bus types. Depot insurance provides low cost insurance coverage for buses whilst parked in depots and garages. Its main purpose is to insure vehicles against theft and catastrophes such as floods or fires; but does not cover collisions or other accidents occasioned whilst buses are located in depots.

Total PV annual insurance costs for the 5 bus types are summated below in Table 12.

Table 12: Annual Insurance Costs for High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Annual Insurance Cost (Dollars/Annum)	Relative Annual Insurance Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$2,175	128.3%	126.4%	128.3%	128.3%

2.5.3 Annual Depot Bus Accommodation Cost

Many private bus operators around Australia currently elect to rent industrial properties to park and store their bus fleets, thereby enabling property rental costs to be claimed back as BAS business expenses. Depot bus accommodation costs are in effect an accounting mechanism to apportion the annual cost of depot property purchase price amortisation, maintenance and upkeep, State land taxes and Council rates to the buses being accommodated.

For large operators who own their bus depots, depot building footprints are comparatively small in area relative to the garage, yard, temporary parking bays and circulation lanes provided for bus movements, temporary storage and parking, so the recurring annual costs of the entire depot site can reasonably be apportioned to each bus type by size and number as if the entire land parcel was being rented from a third party. Depot bus accommodation costs are a real fixed recurring annual cost to the operator, independent of the kilometres travelled by the buses actually being stabled and maintained at the depot site.

Depot Bus Accommodation

$1,350/annum for a standard 12.5m rigid or double deck bus, $1,550/annum for a 14.5m rigid bus and $1,900/annum for an articulated bus.

To cost depot bus accommodation, we have obtained long term annual rentals from realty agents for industrial properties located near, and similar in size, to existing bus depots in Brisbane, Redcliffe and the Gold Coast hinterland, averaged their rentals per unit area, and apportioned the rental per unit area to the parking space needed for each bus type as follows:

- 12.5m Rigid and Double Deck Bus Parking Space: (12.5m long + 1m clearance) x (2.5m wide + 1m clearance) = 47.25m^2 = 1 Standard Bus Space
- 14.5m Rigid Bus Parking Space: (14.5m length + 1m clearance) x (2.5m width + 1m clearance) = 54.25m^2 = 114.8% x Standard Bus Space
- 18m Articulated Bus: Parking Space: = (18m length + 1m clearance) x (2.5m width + 1m clearance) = 66.5m^2 = 140.7% x Standard Bus Space.

Table 13: Annual Depot Accommodation Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Depot Accommodation Cost (Dollars/Annum)	Relative Annual Depot Accommodation Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,350/annum	100%	114.8%	140.7%	140.7%

2.5.4 Annual Bus Refuelling, Fluid Top-Up and Cleaning Costs

Bus servicing encompasses a broad range of routine refuelling, fluid top-up, greasing, cleaning, inspection, testing and checking activities to maintain the vehicle in a state of service readiness, and are generally performed by unskilled cleaners or bus drivers. Bus servicing does not generally require trade accredited technical skills, fault diagnostics or dismantling of vehicle components; and may either be performed at fixed time or travelled kilometre intervals. Fixed time based activities include the following:

Daily or Nightly Refuelling, AdBlue and Water Level Topping and Bus Exterior Lighting and Panel Damage Inspections

$1,065/annum for all bus types. Refuelling, AdBlue, demister and radiator water level top-ups may be undertaken by drivers when returning to depot or by rostered shift cleaners during rostered day and late evening shifts. The 4 tasks take around 4 to 5 minutes per bus to complete and occur at an average frequency of 6 times per week. While tanks are being automatically topped, the bus exterior will typically be checked for signs of damage and if completed at night, operation of exterior lights (a legal requirement) will also be checked.

Consumables (viz. electricity and water) for these tasks amount to around $5 per bus per week. Because diesel and Adblue consumption costs increase with kilometres travelled, they are not included in the fixed annual costs of servicing the vehicle.

Daily or Bi-Daily Cab Interior Cleaning

$622/annum for a 12.5m or 14.5m rigid bus, $985/annum for a double deck bus, $804/annum for an articulated bus. Bus cabins need to be swept or vacuumed, and hand cleaned free of dust, spills and litter once daily (6 times per week) or bi-daily (3 times per week). Interior cleaning takes around 3 minutes for a 12.5m or 14.5m rigid bus, 4.5 minutes for an 18m articulated bus and 6 minutes for a double deck bus, and is normally assigned to cleaners, but may in rare cases, be assigned to bus drivers.

Operators who deploy 2 man cleaner teams at night combine refuelling, fluid top-up inspections and cab cleaning as concurrent activities to avoid double handling of buses. Consumables (viz. detergent and water, glass cleaner and paper towels) amount to around $5 per bus per week.

Daily, Bi-Daily or Weekly Bus Exterior Washing and Tyre Pressure Checking

$738/annum for all bus types. Large bus operators who have installed automatic washing machines combine drive-through exterior bus washing and tyre checking with their daily refuelling or bi-daily interior cleaning procedures to obviate double handling of buses. Small bus operators typically wet detergent broom-wash their bus exteriors by hand on a weekly or fortnightly cycle.

Our costing has been based on drive-through automatic machine washing by a cleaner 6 times per week at around 2 minutes per bus wash with a visual tyre pressure check, as large operators with washing machines are those more likely to deploy high capacity buses, and because hand washing of large buses is extremely laborious, costly and inefficient.

Consumables for automatic washing machines include electricity, water, water treatment, recycling chemicals, detergent and ongoing machine maintenance worth around $8 per bus per week for 6 washes.

Bi-Annual Chassis Pressure Cleaning

Bus chassis, engine bay and undercarriage pressure cleaning are required to remove the build up of road grime, dust and small stones which progressively accumulate in the vehicle's undercarriage, and the oil and distillate leak soaked dust residues which accumulate around and on top of the drive train components.

The latter are a recognised fire safety hazard, and consequently bus undercarriage pressure cleaning cycles are synchronised by bus operators to occur before bi-annual TMR safety audits in the knowledge that the TMR safety auditor will automatically stop any vehicle found with a known fire safety hazard. We have consequently costed bi-annual chassis pressure cleans in with the costs of programmed safety audits as previously discussed.

Summated PV annual refuelling, fluid top-up and cleaning costs for the 5 bus types appear below in Table 14.

Table 14: Annual Refuelling, Fluid Top-up and Cleaning Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Refuelling, Top-Up and Cleaning Cost (Dollars/Annum)	Relative Refuelling, Top-Up and Cleaning Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$2,425/annum	115%	100%	107.5%	107.5%

2.5.5 Fixed Annual Cost Inflation Factors

Fixed annual costs inflate throughout the vehicle's service life. Inflation factors for the 4 identified fixed annual operating costs have been sourced as follows:

- **Statutory Compliance Cost Inflation Factor:** There are no motor industry price indices available which directly track annual increases in Queensland heavy vehicle registration and CTP charges, however Brisbane motor transport and private motoring costs have inflated at an average of 2.87%/annum over the past decade. The annual inflation factor for statutory charges has therefore been set at 1.0287 (Source: *ABS CPI A2326041L*).
- **Bus Insurance Cost Inflation Factor:** Over the past decade, Brisbane motor insurance premiums have increased at an average of 6.7%/annum. The annual inflation factor for bus insurance cost has therefore been set at 1.067 (Source: *ABS CPI A3602803R*).
- **Depot Bus Accommodation Cost Inflation Factor**: Over the past decade, the cost of Brisbane property rents have increased at an average of 5.12%/annum. The annual inflation factor for depot bus accommodation cost has therefore been set at 1.0512 (Source: *ABS CPI A2331846T*).
- **Bus Servicing Cost Inflation Factor**: Over the past decade, the Queensland public and private wage CPI has increased at an average of 4.2%/annum. The annual cost inflation factor for bus servicing by cleaners and drivers has therefore been set at 1.042 (Source: *ABS CPI A2711844F*).

2.5.6 Total Fixed Annual Operating Cost

The NPV of all vehicle fixed annual operating costs has been calculated using Eqt (v) and verified independently by spreadsheet. The calculated NPVs of all fixed annual operating costs for the 5 bus types are summarised below in Table 15.

Table 15: Total Fixed Annual Operating Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Total Fixed Annual Operating Cost (Dollars)	Relative Total Fixed Annual Operating Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$284,336	167.2%	119.2%	132.3%	122.3%

2.6 Variable Operating Costs

Variable operating costs cover operating expenses which increase in proportion to the kilometres travelled. Leading contributors to variable operating costs are diesel and AdBlue consumption, kilometre based bus servicing and maintenance, and driver wages.

2.6.1 Diesel and AdBlue Consumption Cost Rates

Low sulphur clean diesel and AdBlue urea are the two primary consumables of any modern bus fitted with an SCR diesel engine complying with exhaust emission standards defined in *Australian Design Rule ADR 80*. The federal diesel excise rebate previously available to public transport bus operators has now ceased and delivered prices for bulk clean diesel (inclusive of federal excise) and bulk AdBlue urea in 1,000 litre or larger drums are $1.47/litre and $1.20/litre respectively for large fleet operators.

PV average diesel and Adblue consumption rates per kilometre are summarised below in Table 16 for the 5 bus types.

Table 16: Average Diesel and AdBlue Consumption Rates per Kilometre for the 5 Bus Types

Average Diesel Consumption Rate per Kilometre for the 5 Bus Types				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
43 litres/100km	60 litres/100km	48 litres/100km	49 litres/100km	49 litres/100km
$0.63/kilometre	$0.88/kilometre	$0.71/kilometre	$0.72/kilometre	$0.72/kilometre
Average AdBlue Consumption Rate per Kilometre for the 5 Bus Types				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
2.1 litres/100km	3.9 litres/100km	2.8 litres/100km	3.2 litres/100km	3.2 litres/100km
$0.03/kilometre	$0.05/kilometre	$0.03/kilometre	$0.04/kilometre	$0.04/kilometre

2.6.2 Servicing and Maintenance Cost Rates

Routine garage kilometre based servicing activities include the following inspection, test and lubrication services:

- Brake roller and suspension shaker tests,
- Tyre wear inspection, rotation, rebalance, pressure checking and replacements,
- Chassis, suspension, axle and drive train greasing,
- Alternator, water pump, air conditioning compressor and radiator fan belt replacements,
- Engine, transmission, fuel, water, air conditioner and air system filter replacements,
- Engine, transmission, differential, steering box oil top-ups or replacements,
- Water additive, air conditioner refrigerant and hydraulic oil top-ups or replacements, and
- Door lubrication, operation and safety checks.

Regular garage kilometre based mechanical maintenance checks, diagnostics, replacements and repairs are undertaken for the:

- Tyres, wheels, shock absorbers and wheel alignments,
- Linings, drums, brake pads, discs, slack adjusters, etc,
- Compressor, air filter, air dryer, air bags, air valves, air hoses, etc,
- Brake and suspension compressed air tanks, valves and hoses,

- Water pump, radiator, intercooler, coolant hoses, thermostat, etc,
- Turbocharger, exhaust pipe(s), muffler and catalytic converter,
- Power steering, park brake and foot brake valves,
- Air conditioner compressor, evaporator, condenser, TX valve and fan motors,
- Driver seat suspension, door and wheelchair loader mechanisms,
- Vehicle road handling and stability tests,
- Injection pump, fuel lines and SCR mixer,
- Bus towing and on-road breakdown assistance, and
- Energy guidance system (articulated buses only).

Regular garage kilometre based electrical maintenance checks, diagnostics, replacements and repairs are undertaken for the:

- Alternator, starter motor, regulator, batteries and master switch contactor,
- CAN comms cable pairs, looms, harnesses, earths, power cables and connectors,
- Switches, fuses, circuit breakers, relays and protection devices,
- Driver instruments, LCD panels, audible alarms and visual indicators,
- Electric motors, solenoids, tachometers, senders and sensors,
- Lamps, LED lights, bulbs, CFLs, inverters, fluorescent tubes and ballasts,
- Windscreen wipers, washers and demisters,
- CAN, instrument cluster, gearbox, engine and ABS brake control modules,
- PLC, door, air conditioner, safety interlock and body control units,
- Mobile radio, air conditioner, destination sign(s), cameras, driver's video monitor and DVR,
- Turntable articulation control unit, angle/pressure sensors and proportional valve (articulated buses only), and
- *TransLink* smartcard DCU, PIM and door OBCIDs.

Regular garage kilometre based body maintenance checks, replacements and repairs are undertaken for:

- Body water leaks, structural rust, T-nut slippage and frame corrosion,
- Floor laminate rot and vinyl wear and tear damage,
- Cracked windscreens and glazing,
- Exterior panel damage fibreglass, bog, sand back and repaints,
- Exterior panel and FRP mould replacements and repaints,
- Bumper bar and dumb iron straightening and repaints,
- Rear view mirror, roof hatch, air conditioner pod, destination and rear numeral headers,
- Interior panel lifted fabric adherence and repaints,
- Graffiti removal and seat upholstery replacements,
- Hand grip, strap hanger, hand rail and stanchion tightening or replacements,
- Articulation bellows wear and tear (articulated buses only), and
- Driver and passenger seat cushion and squab replacements.

Present value bus servicing and maintenance cost rates per kilometre for the 5 bus types are given overleaf in Table 17.

Table 17: Average Servicing and Maintenance Cost Rates per Kilometre for the 5 Bus Types

Average Servicing and Maintenance Cost Rate per Kilometre				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
\$0.37/kilometre	\$0.51/kilometre	\$0.42/kilometre	\$0.47/kilometre	\$0.48/kilometre

2.6.3 Driver Labour Cost Rates

Notwithstanding that a driver is paid at an average 38 hour/week labour rate, labour cost per kilometre is needed to compute the cost of bus service(s) delivered on road. The mathematical relationship between the driver's average labour rate per hour and his/her average labour cost per kilometre is given by....

$$\text{Average labour cost per kilometre} = \frac{\text{Average labour rate per hour}}{\text{Average service speed}} \quad \begin{matrix}\text{(in dollars per hour)} \\ \text{(in kilometres per hour)}\end{matrix}$$

An average labour rate of \$33.94 per hour was calculated for an MR licensed bus driver to drive either a 12.5m or 14.5m rigid bus in Section 2.3.1; and \$35.96 per hour for a HR licensed bus driver to drive either a double deck or articulated bus in Section 2.3.2.

Table 18: Average Service Speeds for Different Route Lengths, Traffic Speeds and Stops per Trip

Comparison of Bus Types on 10 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	22	18	21	22	19
16	22	18	20	21	19
23	22	17	20	21	18
32	21	17	19	20	18
45 Kilometre/Hour Average Traffic Speed					
11	29	22	26	27	23
16	28	21	25	26	22
23	26	20	23	24	21
32	25	19	22	23	20
75 Kilometre/Hour Average Traffic Speed					
11	32	24	28	29	25

Comparison of Bus Types on 15 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	24	21	23	24	22
16	24	21	23	24	21
23	24	20	22	23	21
32	23	20	22	22	20
45 Kilometre/Hour Average Traffic Speed					
11	33	27	30	32	28
16	32	26	29	31	27
23	31	25	28	29	26
32	29	23	26	27	24
75 Kilometre/Hour Average Traffic Speed					
11	40	31	36	37	32
16	36	28	32	33	30

Comparison of Bus Types on 20 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	26	23	25	25	23
16	25	23	24	25	23
23	25	22	24	24	23
32	25	22	24	24	22
45 Kilometre/Hour Average Traffic Speed					
11	35	30	33	35	31
16	35	29	32	33	30
23	33	28	31	32	29
32	32	27	29	30	28
75 Kilometre/Hour Average Traffic Speed					
11	45	36	41	42	38
16	42	33	37	38	35
23	37	30	33	33	32

Comparison of Bus Types on 25 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	26	24	25	26	24
16	26	24	25	26	24
23	26	23	25	25	24
32	26	23	25	25	23
45 Kilometre/Hour Average Traffic Speed					
11	37	32	35	36	33
16	36	31	34	35	32
23	35	30	33	34	31
32	34	29	32	32	30
75 Kilometre/Hour Average Traffic Speed					
11	49	41	45	46	42
16	46	38	42	42	39
23	42	34	38	38	36
32	37	30	33	33	32

Average bus service speeds (and hence driver labour cost rates) vary markedly with route length, incident traffic speed, number of bus stops and number of passengers boarded at stops, and have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*. Table 18 above presents an extract from the performance evaluation report showing the average service speeds attained on route lengths of 10 to 25km with more than 10 stops at 3 typical Brisbane traffic speeds determined from the last *RACQ Brisbane City Travel Time Survey* conducted in October 2010:

- **30km/h Traffic Speed:** This was the typical 2010 peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional suburb substantially via local roads, then on a major city bound arterial or sub-arterial such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road. This traffic speed averaged the higher travel speeds achieved while still driving through the outer suburbs on local roads with the slower speeds later encountered during peak periods with traffic signals, congestion, stops and give-ways on the major arterial or sub-arterial roads.
- **45km/h Traffic Speed:** This was the typical 2010 peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb on a major highway such as the Bruce, Ipswich or Pacific Motorway. It was also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.
- **75km/h Traffic Speed:** This was the typical 2010 peak period traffic speed achieved on *TransLink* busways leading into the CBD and on major city bypass ring roads such as the Western, Gateway and Logan Motorways. It was also representative of the off-peak traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a city bound highway such as the Bruce, Ipswich or Pacific Motorway.

RACQ has not published a revised *Brisbane City Travel Time Survey* since 2010, but it has been observed from identical RACQ surveys conducted over the previous 7 years that average inbound and outbound traffic speeds along the city's main corridors, highways and motorways progressively fell at a rate of 2.5%/annum as a consequence of continuously increasing traffic congestion.

Assuming that most high capacity bus routes would be in the range of 10km to 20km with 10 or more bus stops, the average speed data listed in Table 18 can be reduced down to a two tail distribution mean speed with a variance of less than +/-12.5% at each of the 3 nominated road traffic speeds. Average current driver labour rates per kilometre appearing below in Table 19 have been calculated by dividing the applicable driver labour rates for each bus type by the 3 traffic speed distribution means, and decreasing the RACQ 2010 measured speeds for an additional 2 years @ 2.5%/annum to account for increased congestion since the last survey.

Table 19: Average Driver Labour Cost Rates per Kilometre for the 5 Bus Types

Average Driver Labour Rate per Kilometre at 30km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	**2 Door 12.5m Double Deck Bus**	**2 Door 14.5m Rigid Bus**	**2 Door 18m Articulated Bus**	**3 Door 18m Articulated Bus**
$1.51/kilometre	$1.87/kilometre	$1.60/kilometre	$1.65/kilometre	$1.82/kilometre
Average Driver Labour Rate per Kilometre at 45km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	**2 Door 12.5m Double Deck Bus**	**2 Door 14.5m Rigid Bus**	**2 Door 18m Articulated Bus**	**3 Door 18m Articulated Bus**
$1.16/kilometre	$1.52/kilometre	$1.28/kilometre	$1.30/kilometre	$1.47/kilometre
Average Driver Labour Rate per Kilometre at 75km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	**2 Door 12.5m Double Deck Bus**	**2 Door 14.5m Rigid Bus**	**2 Door 18m Articulated Bus**	**3 Door 18m Articulated Bus**
$0.92/kilometre	$1.25/kilometre	$1.03/kilometre	$1.07/kilometre	$1.18/kilometre

The estimates indicated in Table 19 assume each bus type will be loaded to its maximum carrying capacity and verify two key findings of the operational performance evaluation, namely that high capacity bus performance improves relative to both a standard 12.5m rigid bus and private motor vehicle with increasing traffic speed and route length.

2.6.4 Variable Operating Cost Rate Inflation Factors

The abovementioned variable operating cost rates inflate throughout each vehicle's service life. Inflation factors for the 4 identified variable operating cost rates have been determined as follows:

- **Diesel Consumption Cost Rate Inflation Factor:** In the 4 years since December 2008 following the global financial crisis, the Brisbane clean diesel price inclusive of federal excise, has inflated at an average of 6.34%/annum. The diesel consumption cost rate annual inflation factor has therefore been set at 1.0634. (Source: *FuelTrac Capital City Diesel Prices*).
- **AdBlue Consumption Cost Rate Inflation Factor:** In the 4 years since December 2008 following the global financial crisis, the Australian average AdBlue price has remained flat and not inflated, effectively falling in price against the *Brisbane All Groups CPI*. The AdBlue consumption cost rate annual inflation factor has therefore been set at unity. (Source: *GreenChem AdBlue International Index*).
- **Servicing and Maintenance Cost Rate Inflation Factor:** Over the past decade, the cost of Brisbane motor vehicle maintenance and repairs has inflated at an average of 3.39%/annum. The annual inflation factor for the bus servicing and maintenance cost rate has therefore been set at 1.0339 (Source: *ABS CPI A2711844F*).
- **Average Driver Labour Cost Rate Inflation Factor:** Over the past decade, the Queensland public and private wage CPI has inflated by an average of 4.2%/annum. The annual inflation factor for average driver labour rates has therefore been set at 1.042 (Source: *ABS CPI A2711844F*).

2.6.5 Total Variable Operating Costs

Because kilometres travelled per annum change in each year of vehicle service life, the total NPV of all bus variable operating costs has been computed by spreadsheet using the following calculations:

1) Kilometres travelled in each year of life were obtained from Table 1 for the bus at ages 1 to 21,
2) These were then multiplied by the cost rates for diesel, Adblue, servicing and maintenance and driver labour listed in Table 16 through Table 19 respectively,
3) The future value of each annual variable operating cost was computed by multiplying its annual cost by its compounding inflation factor using Eqt (iv),
4) Each future value was then backward converted to its present value using Eqt (i), and the
5) Present values were then summed for the 21 year service life to obtain their net present value.

Bus and driver total NPV variable operating costs are shown separately overleaf in Table 20 and Table **21** respectively, with breakdowns for the latter at the 3 typical road traffic speeds of 30km/h, 45km/h and 75km/h encountered on Brisbane roads and *TransLink* busways during peak and off-peak traffic periods.

Table 20: Total Variable Operating Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Total Variable Operating Cost (Dollars)	Relative Total Variable Operating Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,582,105	140.3%	112.6%	119.2%	119.3%

Table 21: Total Variable Operating Costs for Bus Driver at Different Brisbane Road Traffic Speeds

Bus Driver Variable Operating Costs at 30km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$2,092,395	$2,591,968	$2,211,407	$2,281,983	$2,520,007
Bus Driver Variable Operating Costs at 45km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,610,812	$2,110,385	$1,771,340	$1,797,633	$2,030,121
Bus Driver Variable Operating Costs at 75km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,275,918	$1,724,288	$1,430,910	$1,479,345	$1,634,337

3. Net Present Value Whole-of-Life Costs

3.1 Background

Bus ownership, fixed annual operating and variable operating costs for the 4 high capacity bus types relative to those of a standard two door 12.5m rigid route bus have been estimated in Part 2 of this study. In Part 3, the present values of all costs for the 5 bus types are summed to compare their net present values over whole-of-life, their average bus costs per kilometre and average bus costs per pax-kilometre.

The net present value of driver variable labour costs also calculated in Part 2 are then incorporated to assess whole-of-life average bus and driver costs per kilometre and per pax-kilometre at the 3 traffic speeds commonly encountered on Brisbane roads during peak and off-peak traffic periods.

3.2 Net Present Value of Bus Whole-of-Life Costs

Table 22 below summarises the net present values of all expenses and cost recoveries incurred by a bus operator over the whole-of-life of the 5 alternative bus types. Based on their relative whole-of-life costs per kilometre, the 5 bus types have been ranked as follows:

1. Two Door 12.5m Rigid Bus - $2.01/km
2. Two Door 14.5m Extended Rigid Bus - $2.30/km
3. Three Door 18m Articulated *Superbus* - $2.56/km
4. Two Door 18m Articulated Bus - $2.58/km
5. Two Door 12.5m Double Deck Bus - $2.88/km

Table 22: Total Net Present Value Whole-of-Life Bus Costs

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Bus Ownership Costs					
Bus Procurement Financial Costs	$538,610	$763,031	$628,378	$852,800	$864,020
Less Tax Deduction Recoveries	-$53,861	-$76,303	-$62,838	-$85,280	-$86,402
Less Resale Recoveries at Retirement	-$10,000	-$14,167	-$11,667	-$15,833	-$16,042
Depot Upgrade Costs Amortised to 5 Buses	$6,000	$23,000	$18,000	$18,000	$18,000
Major Bus Overhaul and Refurbishment Costs	$129,000	$150,000	$137,000	$142,000	$140,000
Total Ownership Costs	**$609,749**	**$845,561**	**$708,873**	**$911,687**	**$919,576**
Whole-of-Life Fixed Operating Costs					
Bus Statutory Compliance Costs	$122,464	$285,390	$153,712	$176,022	$147,661
Bus Insurance Costs	$68,562	$87,948	$86,687	$87,948	$87,948
Depot Bus Accommodation Costs	$35,578	$35,580	$40,851	$50,075	$50,075
Time Based Bus Servicing Costs	$57,732	$66,373	$57,731	$62,064	$62,064
Total Bus Fixed Operating Costs	**$284,336**	**$475,291**	**$338,981**	**$376,109**	**$347,748**
Whole-of-Life Variable Operating Costs					
Diesel Consumption Costs	$1,093,769	$1,526,189	$1,220,951	$1,246,387	$1,246,387
AdBlue Consumption Costs	$23,109	$42,918	$30,813	$35,215	$35,215
Distance Based Service & Maintenance Costs	$465,227	$650,043	$528,956	$604,157	$605,432
Total Bus Variable Operating Costs	**$1,582,105**	**$2,219,150**	**$1,780,720**	**$1,885,759**	**$1,887,034**
Total Whole-of-Life Bus Costs					
Total Bus Ownership + Fixed + Variable	**$2,476,190**	**$3,540,002**	**$2,828,574**	**$3,173,555**	**$3,154,358**
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	**$2.01/km**	**$2.88/km**	**$2.30/km**	**$2.58/km**	**$2.56/km**
Bus Ranking by Cost per Kilometre	**1**	**5**	**2**	**4**	**3**
Maximum Seated Plus Standing Capacity	75	116	92	90	110
Whole-of-Life Cost per Pax-Kilometre	**2.68¢/pax-km**	**2.48¢/pax-km**	**2.50¢/pax-km**	**2.87¢/pax-km**	**2.33¢/pax-km**
Bus Ranking by Cost per Pax-Kilometre	**4**	**2**	**3**	**5**	**1**

Based on their relative whole-of-life costs per pax-kilometre when carrying maximum passenger loads, the 5 bus types have however been ranked differently as follows:

1 Three Door 18m Articulated *Superbus* - 2.33¢/pax-km
2 Two Door 12.5m Double Deck Bus - 2.48¢/pax-km
3 Two Door 14.5m Extended Rigid Bus - 2.50¢/pax-km
4 Two Door 12.5m Rigid Bus – 2.68¢/pax-km
5 Two Door 18m Articulated Bus - $2.87¢/pax-km.

3.3 Net Present Value of Bus and Driver Whole-of-Life Costs

Driver variable labour rates and costs for the 5 bus types have been calculated in Part 2 and summarised in Table 19 and
Table **21** respectively for 30km/h, 45km/h and 75km/h traffic speed conditions. In this section, NPV whole-of-life bus and driver costs have been consolidated to assess their combined effects on the cost per kilometre and cost per pax-kilometre of operating services during typical peak and off-peak traffic speed periods. Combined whole-of-life bus and driver costs have also been used to evaluate the expected cost savings of substituting a high capacity bus in lieu of operating two standard 12.5 rigid buses to augment overloaded peak services.

3.3.1 Whole-of-Life Bus and Driver Costs in 30km/h Traffic Speed Conditions

Bus services operating in 30km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

Net present value whole-of-life bus and driver costs in 30km/hr traffic speed conditions have been consolidated below in Table 23. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 30km/h traffic speed conditions:

1 Two Door 12.5m Rigid Bus - $3.71/km
2 Two Door 14.5m Extended Rigid Bus - $4.10/km
3 Two Door 18m Articulated Bus - $4.43/km
4 Three Door 18m Articulated *Superbus* - $4.61/km
5 Two Door 12.5m Double Deck Bus - $4.98/km.

Table 23: Total Bus and Driver Costs Operating in 30km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 30km/h	$2,092,395	$2,591,968	$2,211,407	$2,281,983	$2,520,007
Total Bus and Driver Costs at 30km/h	**$4,568,585**	**$6,131,970**	**$5,039,981**	**$5,455,538**	**$5,674,365**
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	**$3.71/km**	**$4.98/km**	**$4.10/km**	**$4.43/km**	**$4.61/km**
Bus Ranking by Cost per Kilometre	**1**	**5**	**2**	**3**	**4**
Maximum Seated Plus Standing Capacity	75	116	92	90	110
Whole-of-Life Cost per Pax-Kilometre	**4.95¢/pax-km**	**4.30¢/pax-km**	**4.45¢/pax-km**	**4.93¢/pax-km**	**4.19¢/pax-km**
Bus Ranking by Cost per Pax-Kilometre	**5**	**2**	**3**	**4**	**1**

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 30km/h traffic speed conditions:

1 Three Door 18m Articulated *Superbus* - 4.19¢/pax-km
2 Two Door 12.5m Double Deck Bus - 4.30¢/pax-km
3 Two Door 14.5m Extended Rigid Bus – 4.45¢/pax-km
4 Two Door 18m Articulated Bus - $4.93¢/pax-km
5 Two Door 12.5m Rigid Bus – 4.95¢/pax-km.

3.3.2 Whole-of-Life Bus and Driver Costs in 45km/h Traffic Speed Conditions

<u>Bus services operating in 45km/h peak traffic speed conditions travel</u> between the CBD and an outer Brisbane or surrounding regional town/city suburb <u>substantially via a major highway</u> such as the Bruce, Ipswich or Pacific Motorway.

<u>Bus services operating in 45km/h off-peak traffic speed conditions travel</u> between the CBD and an outer Brisbane or surrounding regional suburb <u>via a combination of local and major arterial or sub-arterial roads</u> such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

Net present value whole-of-life bus and driver costs in 45km/hr traffic speed conditions have been consolidated below in Table 24. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 45km/h traffic speed conditions:

1 Two Door 12.5m Rigid Bus - $3.32/km
2 Two Door 14.5m Extended Rigid Bus - $3.74/km
3 Two Door 18m Articulated Bus - $4.04/km
4 Three Door 18m Articulated Superbus - $4.21/km
5 Two Door 12.5m Double Deck Bus - $4.59/km.

Table 24: Total Bus and Driver Costs Operating in 45km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 45km/h	$1,610,812	$2,110,385	$1,771,340	$1,797,633	$2,030,121
Total Bus and Driver Costs at 45km/h	**$4,087,002**	**$5,650,387**	**$4,599,914**	**$4,971,188**	**$5,184,479**
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	**$3.32/km**	**$4.59/km**	**$3.74/km**	**$4.04/km**	**$4.21/km**
Bus Ranking by Cost per Kilometre	1	5	2	3	4
Maximum Seated Plus Standing Capacity	75	116	92	90	110
Whole-of-Life Cost per Pax-Kilometre	4.43¢/pax-km	3.96¢/pax-km	4.06¢/pax-km	4.49¢/pax-km	3.83¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	4	2	3	5	1

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 45km/h traffic speed conditions:

1 Three Door 18m Articulated *Superbus* - 3.83¢/pax-km
2 Two Door 12.5m Double Deck Bus - 3.96¢/pax-km
3 Two Door 14.5m Extended Rigid Bus – 4.06¢/pax-km
4 Two Door 12.5m Rigid Bus – 4.43¢/pax-km
5 Two Door 18m Articulated Bus - $4.49¢/pax-km.

3.3.3 Whole-of-Life Bus and Driver Costs in 75km/h Traffic Speed Conditions

Bus services operating in 75km/h peak traffic speed conditions travel between the CBD and an outer Brisbane suburb substantially on a busway or bypass the CBD on a major ring road such as the Western, Gateway or Logan Motorway.

Bus services operating in 75km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Net present value whole-of-life bus and driver costs in 75km/hr traffic speed conditions have been consolidated below in Table 25. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 75km/h traffic speed conditions:

1. Two Door 12.5m Rigid Bus - $3.05/km
2. Two Door 14.5m Extended Rigid Bus - $3.46/km
3. Two Door 18m Articulated Bus - $3.78/km
4. Three Door 18m Articulated *Superbus* - $3.89/km
5. Two Door 12.5m Double Deck Bus - $4.28/km.

Table 25: Total Bus and Driver Costs Operating in 75km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 75km/h	$1,275,918	$1,724,288	$1,430,910	$1,479,345	$1,634,337
Total Bus and Driver Costs at 75km/h	**$3,752,108**	**$5,264,290**	**$4,259,484**	**$4,652,900**	**$4,788,695**
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	**$3.05/km**	**$4.28/km**	**$3.46/km**	**$3.78/km**	**$3.89/km**
Bus Ranking by Cost per Kilometre	**1**	**5**	**2**	**3**	**4**
Maximum Seated Plus Standing Capacity	75	116	92	90	110
Whole-of-Life Cost per Pax-Kilometre	**4.07¢/pax-km**	**3.69¢/pax-km**	**3.76¢/pax-km**	**4.20¢/pax-km**	**3.54¢/pax-km**
Bus Ranking by Cost per Pax-Kilometre	**4**	**2**	**3**	**5**	**1**

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 75km/h traffic speed conditions:

1. Three Door 18m Articulated *Superbus* – 3.54¢/pax-km
2. Two Door 12.5m Double Deck Bus – 3.69¢/pax-km
3. Two Door 14.5m Extended Rigid Bus – 3.76¢/pax-km
4. Two Door 12.5m Rigid Bus – 4.07¢/pax-km
5. Two Door 18m Articulated Bus - $4.20¢/pax-km.

3.3.4 High Capacity Bus and Driver Substitution Cost Savings on Overloaded Peak Services

The fundamental question for a bus operator who currently operates only standard capacity 12.5m route buses, is whether it is cheaper over the long run to augment an overloaded peak service with a second 12.5m rigid bus and driver or to subsitute a new high capacity bus and driver on the overloaded peak service?

The decision to either augment an overloaded peak service with an additional 12.5m rigid bus and driver or to step in a new high capacity bus and driver poses 3 additional flow-on considerations, namely:

- No operator should consider procuring a high capacity bus solely to augment an overloaded peak service which otherwise sits idle in the depot yard for most of its service life during the off-peaks.
- A second standard 12.5m rigid bus would increase the peak service frequency and complete its journey marginally faster than a substituted high capacity bus carrying more passengers at a slower average service speed. Thus the former option would appear at first sight to have a more likely prospect for improving patronage and ticket revenue over the long run than the latter option.

  (Note: The Stage 1 operational performance study has identified that the average service speed difference between a standard rigid bus and high capacity bus loaded to their respective maximum capacities falls exponentially to a neglible difference in 45km/h or higher traffic speed conditions on route lengths of 15km or longer).
- A second standard 12.5m rigid bus could be returned to depot after the overloaded peaks had passed but a substituted high capacity bus would have to continue operating off-peak services for the day. On off-peak services, the high capacity bus would effectively be underutilised and cost more to operate than a 12.5m rigid bus.

The following comparative cost assumptions have been applied to address the standard 12.5m rigid bus fleet operator's original question:

- We have assumed total passengers carried on the two 12.5m rigid buses would equal the total passengers carried by a substituted high capacity bus. The ticket revenues for both options are therefore equal, effectively cancel out, and do not enter into the net operating cost evaluation,
- Based on existing high capacity bus candidate HFP service timetables, a typical bus and driver would deliver peak weekday commuter and school service kilometres relative to off-peak weekday, weekend and public holiday service kilometres in the approximate ratio of 25% : 75%,
- Therefore 25% of whole-of-life bus variable operating costs and 100% of whole-of-life bus ownership and fixed operating costs for an additional 12.5m rigid bus would be avoided if a high capacity bus was to be substituted on the overloaded peak service,
- 25% of whole-of-life labour costs for an additional 12.5m rigid bus driver would also be avoided if a high capacity bus was to be substituted on the overloaded peak service, and
- The whole-of-life bus and driver total cost difference to operate all peak and off-peak services with a high capacity bus versus a 12.5m rigid bus would account for the added cost to operate off-peak services with the high capacity bus.

Because driver costs change with average traffic speed, the cost savings reaped by substituting a high capacity bus in lieu of operating a second 12.5m rigid bus on an overloaded peak service have been calculated at Brisbane road traffic speeds of 30km/h, 45km/h and 75km/h, and presented respectively in Table 26, Table 27 and Table 28.

Substitution of the 4 alternative high capacity bus types has been ranked by their net whole-of-life cost savings per kilometre as follows:

1. Two Door 14.5m Extended Rigid Bus
2. Two Door 18m Articulated Bus
3. Three Door 18m Articulated Superbus
4. Two Door 12.5m Double Deck Bus.

The results indicate cost savings will be realised under all traffic conditions, but the savings diminish with increasing traffic speed and vehicle passenger capacity underutilisation.

Table 26: Net Cost Saving for High Capacity Bus Substitution at 30km/h Traffic Speed

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
100% x Whole-of-Life Costs for One Bus and Driver at 30km/h	$4,568,585	$6,131,970	$5,039,981	$5,455,538	$5,674,365
100% x Whole-of-Life Bus Ownership Costs for One Extra Bus	$609,749				
100% x Whole-of-Life Fixed Operating Costs for One Extra Bus	$284,336				
25% x Whole-of-Life Variable Operating Costs for One Extra Bus	$395,527				
25% x Whole-of-Life Driver Costs for One Extra Bus at 30km/h	$523,099				
Total Bus and Driver Costs at 30km/h	**$6,381,296**	**$6,131,970**	**$5,039,981**	**$5,455,538**	**$5,674,365**
Net Whole-of-Life Cost Saving for High Capacity Bus Option		**-$249,326**	**-$1,341,315**	**-$925,758**	**-$706,931**
Whole-of-Life Travelled Kilometres		1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre		**-$0.20/km**	**-$1.09/km**	**-$0.75/km**	**-$0.57/km**
High Capacity Bus Ranking by Cost per Kilometre		**4**	**1**	**2**	**3**

Table 27: Net Cost Saving for High Capacity Bus Substitution at 45km/h Traffic Speed

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
100% x Whole-of-Life Costs for One Bus and Driver at 45km/h	$4,087,002	$5,650,387	$4,599,914	$4,971,188	$5,184,479
100% x Whole-of-Life Bus Ownership Costs for One Extra Bus	$609,749				
100% x Whole-of-Life Fixed Operating Costs for One Extra Bus	$284,336				
25% x Whole-of-Life Variable Operating Costs for One Extra Bus	$395,526				
25% x Whole-of-Life Driver Costs for One Extra Bus at 45km/h	$402,703				
Total Bus and Driver Costs at 45km/h	**$5,779,316**	**$5,650,387**	**$4,599,914**	**$4,971,188**	**$5,184,479**
Net Whole-of-Life Cost Saving for High Capacity Bus Option		**-$128,929**	**-$1,179,402**	**-$808,128**	**-$594,837**
Whole-of-Life Travelled Kilometres		1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre		**-$0.11/km**	**-$0.96/km**	**-$0.66/km**	**-$0.48/km**
High Capacity Bus Ranking by Cost per Kilometre		**4**	**1**	**2**	**3**

Table 28: Net Cost Saving for High Capacity Bus Substitution at 75km/h Traffic Speed

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
100% x Whole-of-Life Costs for One Bus and Driver at 75km/h	$3,752,108	$5,264,290	$4,259,484	$4,652,900	$4,788,695
100% x Whole-of-Life Bus Ownership Costs for One Extra Bus	$609,749				
100% x Whole-of-Life Fixed Operating Costs for One Extra Bus	$284,336				
25% x Whole-of-Life Variable Operating Costs for One Extra Bus	$395,526				
25% x Whole-of-Life Driver Costs for One Extra Bus at 75km/h	$318,980				
Total Bus and Driver Costs at 75km/h	**$5,360,699**	**$5,264,290**	**$4,259,484**	**$4,652,900**	**$4,788,695**
Net Whole-of-Life Cost Saving for High Capacity Bus Option		**-$96,409**	**-$1,101,215**	**-$707,799**	**-$572,004**
Whole-of-Life Travelled Kilometres		1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre		**-$0.08/km**	**-$0.89/km**	**-$0.58/km**	**-$0.47/km**
High Capacity Bus Ranking by Cost per Kilometre		**4**	**1**	**2**	**3**

3.4 Accounting for Ticket Revenue and Operator Subsidy

The whole-of-life cost evaluation analysis has not accounted for passenger ticket revenue or the cost of contract bus operator subsidy. All ticket revenue collected on SEQ bus services is returned to *TransLink* by its contract service providers, so from an operator's perspective, the cost analysis undertaken in this study accurately reflects the net present value of its whole-of-life costs for providing *TransLink* bus services using one of the 5 alternative bus types.

From *TransLink's* perspective however, the net cost of operating bus services also needs to include whole-of-life subsidies paid to the bus operator less ticket revenues collected to fully complete the net whole-of-life cost evaluation. It is possible to apply a simplified breakeven analysis to compare the average number of passengers needed to be loaded on a high capacity bus relative to a standard 12.5m rigid bus to just break even, because at this condition, total revenue must balance out total costs, including paid subsidies to bus operators.

Let...

OC_s = Total Whole-of-Life Bus Ownership Cost of a Standard 12.5m Rigid Bus (in dollars)
OC_h = Total Whole-of-Life Bus Ownership Cost of a High Capacity Bus (in dollars)
FC_s = Total Whole-of-Life Fixed Cost of a Standard 12.5m Rigid Bus (in dollars)
FC_h = Total Whole-of-Life Fixed Cost of a High Capacity Bus (in dollars)
VC_s = Total Whole-of-Life Variable Cost of a Standard 12.5m Rigid Bus (in dollars)
VC_h = Total Whole-of-Life Variable Cost of a High Capacity Bus (in dollars)
TR_s = Total Whole-of-Life Ticket Revenue Collected on the Standard 12.5m Rigid Bus (in dollars)
TR_h = Total Whole-of-Life Ticket Revenue Collected on the High Capacity Bus (in dollars)
v_s = Variable Cost per Kilometre for the Standard 12.5m Rigid Bus (in dollars/kilometre)
v_h = Variable Cost per Kilometre for the High Capacity Bus (in dollars/kilometre)
m = Margin paid to the Bus Operator (in percent)
f = *TransLink* Average Fare Collection Rate over the Vehicle's Service Life (in dollars/pax-kilometre)
p_s = Total Whole-of-Life Passengers Carried by the Standard 12.5m Rigid Bus (in pax)
p_h = Total Whole-of-Life Passengers Carried by the High Capacity Bus (in pax)
d = Total Whole-of-Life Distance Travelled by the Standard and High Capacity Buses (in kilometres).

For this simplified breakeven analysis, we assume that whole-of-life fare revenue collected on any bus type is proportional to both the total distance travelled and total passengers carried in each vehicle's service life, and define a constant of proportionality f as the average fare per pax-kilometre rate set by *TransLink* over the vehicle's service life. We then obtain the revenue collected by *TransLink* from each bus as...

$$TR_h = f\, p_h\, d$$
$$TR_s = f\, p_s\, d$$

These paired equations indicate that the ratio of the revenue expected to be collected on the high capacity bus relative to that collected on the standard 12.5m rigid bus should be proportional to the ratio of their average passenger loads, that is...

$$\frac{TR_h}{TR_s} = \frac{p_h}{p_s}$$

Now if the total whole-of-life costs for each vehicle just breaks even with the whole-of-life revenue collected and the operator's total costs plus paid profit margin m, the net subsidy paid by TransLink vanishes to zero at the breakeven points given by...

$$TR_h = f\, p_h\, d = (1 + m)\,(OC_h + FC_h + VC_h) = (1 + m)\,(OC_h + FC_h + v_h\, d)$$
$$TR_s = f\, p_s\, d = (1 + m)\,(OC_s + FC_s + VC_s) = (1 + m)\,(OC_s + FC_s + v_s\, d)$$

It will be noted from these paired breakeven equations that both the revenue and variable operating costs increase with travelled distance d, while total ownership and fixed annual costs remain constant for the whole-of-life of each vehicle type. Rearranging these equations provides an important insight into the effects of travelled distance d on the breakeven point for each bus type...

$$\frac{f\, p_h}{1 + m} = \frac{OC_h + FC_h}{d} + v_h$$

$$\frac{f\, p_s}{1 + m} = \frac{OC_s + FC_s}{d} + v_s$$

In these paired equations, the only variables remaining are the boarded passenger loads p_h and p_s which directly affect *TransLink's* revenue, and the travelled distance *d* which affects total operating cost and thereby both *TransLink* and the bus operator. So for any given average boarded passenger load carried by the bus, the breakeven point between the revenue collected and operating cost falls with increasing distance travelled.

To compare the high capacity bus with a standard 12.5m rigid bus for their whole-of-lives, the above equation for the former vehicle is divided by the equation for the latter vehicle giving...

$$\frac{TR_h}{TR_s} = \frac{p_h}{p_s} = \frac{OC_h + FC_h + VC_h}{OC_s + FC_s + VC_s}$$

If a new standard ultralow floor 12.5m rigid bus can be loaded to its maximum carrying capacity of 75 passengers, then the high capacity bus will return a higher expected revenue and breakeven point if its carrying capacity equals or exceeds...

$$p_h = 75 \frac{(OC_h + FC_h + VC_h)}{OC_s + FC_s + VC_s}$$

The following results are obtained by substituting the whole-of-life costs for each bus type from Table 22:

- **Two Door 12.5m Double Deck Bus:** Breaks even with a standard 12.5m rigid bus at a load of 107 passengers. Has an increased revenue potential of **8%** to load 9 additional passengers.
- **Two Door 14.5m Rigid Bus**: Breaks even with a standard 12.5m rigid bus at a load of 86 passengers. Has an increased revenue potential of **7%** to load 6 additional passengers.
- **Two Door 18m Articulated Bus:** Does not break even with a standard 12.5m rigid bus at the required minimum load of 96 passengers. Carries 6 less passengers and has a reduced revenue generation potential of **-6%** below that of the standard 12.5m rigid bus.
- **Three Door 18m Articulated *Superbus*:** Breaks even with a standard 12.5m rigid bus at a load of 96 passengers. Has an increased revenue potential of **15%** to load 14 additional passengers.

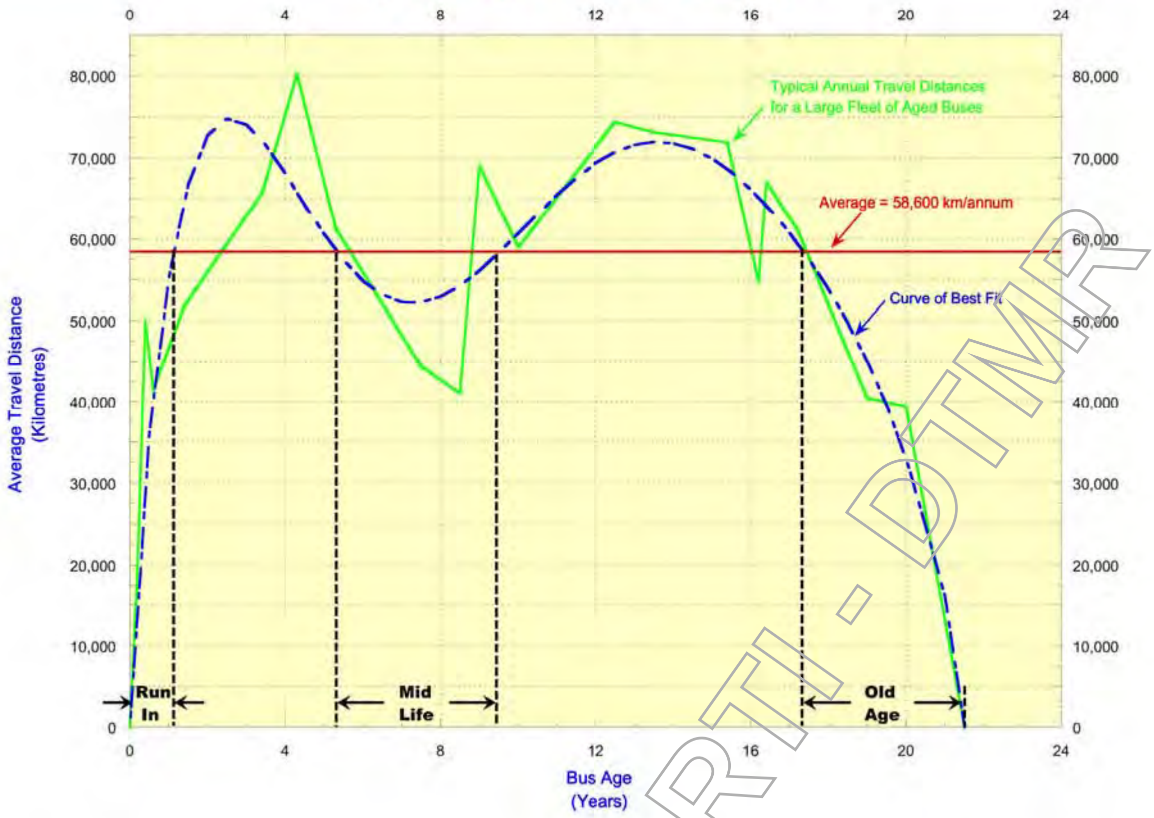
3.5 Retirement Age for Lowest Whole-of-Life Cost per Kilometre

The impact of travel distance on the breakeven point between collected ticket revenue and operating cost has been earlier highlighted in Section 3.4, but can best be appreciated by reference to the distance:age profile curve for a typical SEQ route bus earlier illustrated in Figure 1 and reproduced overleaf in Figure 2.

In the vehicle's normal life cycle, its first year of service commonly known as the run-in period, is beset with component infant mortality failures leading to repeated removal of the vehicle from service for warranty repairs causing its annual travel distance to drop below the whole-of-life average. The vehicle's mid-life is later plagued by a succession of unavoidable major mechanical and electrical overhauls and body refurbishments, which again act to reduce the vehicle's mid-life annual travel distance below the average.

Annual travel distances resurge following these typical life cycle events until the bus begins to reach its old age. In this last stage of its service life, the bus begins to lose its appeal against competing younger buses as the vehicle of choice for delivery of mainstream commuter services. This period in the vehicle's life cycle becomes one of constantly declining annual travel distance and increasing maintenance cost per kilometre as the vehicle's aging components fail more frequently after a sustained life of hard work, wear and tear.

Figure 2: Typical Route Bus Life Cycle



Old age is the period in a vehicle's life cycle when the breakeven point between fare revenue collected and operating cost grows exponentially with each passing year till retirement. It is also the period in the vehicle's life cycle when *TransLink* is heavily subsidising an aged and underutilised asset not owned by it, but by its contract bus operator.

Avoiding this cost can only realistically be achieved if the vehicle can be worked harder or sold off at an earlier age. Because the financial costs for its replacement are borne by the operator, its early retirement is resisted in an effort to improve the rate of return on the operator's sunken capital investment.

The ideal retirement age for minimum whole-of-life cost per kilometre occurs after the second crest on the distance:age profile curve in Figure 2. After passing the second crest, all costs of bus ownership, with the sole exception of resale price recovery have expired and become sunken costs. Beyond the crest age, only the vehicle's fixed annual and variable operating costs continue to be incurred by the bus operator until retirement is finally reached. The ideal retirement age occurs when the cumulative whole-of-life cost per kilometre reaches its minimum.

3.6 Ideal Age for Standard 12.5m Rigid Bus

PV annual total operating costs per kilometre and cumulative total costs per kilometre have been calculated in Table 29 overleaf for a standard 12.5m rigid bus between the ages of 14 and 21.

Beyond age 12, all operator capital investments in the vehicle have been completed and thereafter become sunken costs, so the cumulative cost per kilometre goes into a gradual decline. However, the annual kilometres travelled also begin to tail off above age 14 and the annual cost per kilometre rises exponentially from $1.58/km to $2.58/km by age 21. This causes the cumulative cost per kilometre to turn and begin rising beyond age 19, which is the bus operator's ideal retirement age for maximum whole-of-life return on investment.

Table 29: PV Annual and Cumulative Costs per Kilometre for Standard 12.5m Rigid Bus

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$538,610	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$53,861	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$36,309	-$30,201	-$25,120	-$20,894	-$17,379	-$14,455	-$12,023	-$10,000
Depot Upgrade Cost Amortised to 5 Buses		$6,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$129,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$619,749	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$5,803	$5,793	$5,783	$5,774	$5,764	$5,755	$5,745	$5,736
Bus Insurance Cost		$3,546	$3,671	$3,802	$3,937	$4,077	$4,222	$4,372	$4,527
Depot Bus Accommodation Cost		$1,786	$1,822	$1,859	$1,896	$1,934	$1,974	$2,013	$2,054
Time Based Bus Servicing Cost		$2,836	$2,868	$2,901	$2,933	$2,966	$3,000	$3,034	$3,068
Total Bus Fixed Operating Costs		**$13,970**	**$14,155**	**$14,345**	**$14,540**	**$14,742**	**$14,950**	**$15,164**	**$15,384**
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$70,569	$70,903	$69,214	$65,615	$60,043	$51,823	$39,066	$19,835
AdBlue Consumption Cost		$1,190	$1,124	$1,032	$920	$792	$643	$455	$217
Distance Based Service & Maintenance Cost		$27,483	$26,847	$25,481	$23,486	$20,895	$17,534	$12,851	$6,344
Total Bus Variable Operating Costs		**$99,242**	**$98,874**	**$95,726**	**$90,021**	**$81,730**	**$69,999**	**$52,373**	**$26,396**
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$113,212	$113,029	$110,071	$104,561	$96,472	$84,949	$67,536	$41,781
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		**$1.58**	**$1.62**	**$1.66**	**$1.72**	**$1.79**	**$1.89**	**$2.05**	**$2.58**
Cumulative Total Bus Cost at End of Year		$1,831,483	$1,950,620	$2,065,771	$2,174,559	$2,274,545	$2,362,418	$2,432,386	$2,476,189
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		**$2.067**	**$2.041**	**$2.022**	**$2.009**	**$2.001**	**$1.999**	**$2.003**	**$2.012**
Cost to Operator of Early/Late Retirement		**$530,935**	**$411,798**	**$296,646**	**$187,859**	**$87,873**	**$0**	**$69,968**	**$113,772**

Operators tend to relegate their aging buses to low profile services such as school, shopper and district runs, private school and community charters or to the menial rank of breakdown standby vehicle. Notwithstanding these arguably useful deployments for aging route buses, their sustained retention in the fleet on declining light duties after age 16 has to be subsidised by *TransLink* at lower revenue returns, and their reduced annual kilometres picked up by other younger buses in the operator's fleet.

Table 29 further shows the cost (in present dollar values) to the operator of retiring its standard 12.5m rigid bus before or after its ideal retirement age. Unfortunately, many bus operators do not fully appreciate the real costs of keeping aged buses in service, particularly when contemplating the high financial cost burden of their replacements, so the common misconception persists that it must be cheaper to keep aged buses running for as long as possible and simply place them on light service duties.

3.7 Ideal Retirement Age for High Capacity Buses

PV annual total operating costs per kilometre and cumulative total costs per kilometre have been calculated overleaf in Table 30 through Table 33 inclusive for the 4 high capacity buses between ages 14 and 21.

All 4 high capacity buses attain the same ideal retirement age of 19 calculated for the standard 12.5m rigid bus, but some 3 to 10 months later in the year due to their relatively higher procurement costs and resale values. While the underlying causes for declining cumulative cost per kilometre and increasing annual operating cost per kilometre are similar to those earlier explained for the standard rigid bus, the magnitudes of these costs and the penalty paid for premature or late retirement either side of the ideal age are significantly higher for all of the 4 high capacity vehicle types.

Two hidden risks arise for the high capacity buses which wouldn't normally apply to a standard 12.5m rigid route bus:

- **Unsuitability for Old Age Light Service Duties:** As earlier indicated, operators tend to allocate their aging standard 12.5m rigid buses on low profile menial assignments such as school, shopper and district runs, private school and community charters, and to breakdown standby duties.

  High capacity buses have road use restrictions such as over height limits for the double deck bus and road turning and under length bus stop limits for the 3 other high capacity bus types. They do not therefore satisfy the same universal "go anywhere" and "back up any service" functions which a standard 12.5m rigid bus traditionally affords during its old age.

- **Potential for Loss of Resale Value:** Aftermarket second hand route bus resale values are controlled by the market forces of supply and demand. Second hand route buses have traditionally been sold to small family business school, country bus service or tour operators from across Australia who can economically and legally operate old buses through to their maximum retirement age of 25.

  Aftermarket demand for second hand articulated buses previously sold by Brisbane Transport have fetched high prices but there was a notable difference in the number of bidders searching for these high capacity buses. Should a large number of SEQ bus operators choose to begin operating high capacity buses in their fleets, the anticipated downstream effect on their future aftermarket would be declining resale values.

These old age risks paint a very different future life cycle scenario for aging high capacity buses relative to a standard size route bus.

Unlike standard 12.5m rigid buses, high capacity buses will not be capable of being placed on universal light service duties in old age and will need to be worked hard for the whole of their service lives. The effect of this predicted high capacity vehicle life cycle scenario would be a shorter service life covering a similar total travel distance to the standard 12.5m rigid bus, but reaching ideal retirement around a year earlier at age 18.

Table 30: PV Annual and Cumulative Costs per Kilometre for Double Deck Bus

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$763,031	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$76,303	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$51,438	-$42,785	-$35,587	-$29,600	-$24,620	-$20,478	-$17,033	-$14,167
Depot Upgrade Cost Amortised to 5 Buses		$23,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$150,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$859,728	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$13,522	$13,500	$13,478	$13,455	$13,433	$13,411	$13,389	$13,367
Bus Insurance Cost		$4,548	$4,710	$4,877	$5,050	$5,229	$5,415	$5,608	$5,807
Depot Bus Accommodation Cost		$1,786	$1,822	$1,859	$1,896	$1,934	$1,974	$2,013	$2,054
Time Based Bus Servicing Cost		$3,261	$3,298	$3,335	$3,372	$3,410	$3,449	$3,488	$3,527
Total Bus Fixed Operating Costs		**$23,117**	**$23,329**	**$23,548**	**$23,774**	**$24,008**	**$24,249**	**$24,497**	**$24,754**
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$98,468	$98,934	$96,577	$91,556	$83,781	$72,311	$54,511	$27,677
AdBlue Consumption Cost		$2,210	$2,088	$1,916	$1,709	$1,470	$1,193	$846	$404
Distance Based Service & Maintenance Cost		$38,401	$37,512	$35,603	$32,816	$29,196	$24,500	$17,956	$8,864
Total Bus Variable Operating Costs		**$139,078**	**$138,534**	**$134,096**	**$126,080**	**$114,447**	**$98,003**	**$73,313**	**$36,945**
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$162,196	$161,863	$157,645	$149,854	$138,455	$122,252	$97,810	$61,699
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		**$2.26**	**$2.32**	**$2.38**	**$2.47**	**$2.57**	**$2.71**	**$2.97**	**$3.81**
Cumulative Total Bus Cost at End of Year		$2,613,151	$2,783,668	$2,948,510	$3,104,352	$3,247,786	$3,374,180	$3,475,435	$3,540,000
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		**$2.950**	**$2.913**	**$2.885**	**$2.867**	**$2.858**	**$2.856**	**$2.862**	**$2.877**
Cost to Operator of Early/Late Retirement		**$761,029**	**$590,512**	**$425,670**	**$269,828**	**$126,394**	**$0**	**$101,255**	**$165,820**

Table 31: PV Annual and Cumulative Costs per Kilometre for 14.5m Extended Rigid Bus

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$628,378	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$62,838	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$42,359	-$35,233	-$29,305	-$24,375	-$20,274	-$16,863	-$14,026	-$11,667
Depot Upgrade Cost Amortised to 5 Buses		$18,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$137,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$720,540	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$7,283	$7,271	$7,259	$7,247	$7,235	$7,223	$7,211	$7,199
Bus Insurance Cost		$4,483	$4,642	$4,807	$4,978	$5,155	$5,338	$5,527	$5,724
Depot Bus Accommodation Cost		$2,050	$2,092	$2,134	$2,177	$2,221	$2,266	$2,312	$2,358
Time Based Bus Servicing Cost		$2,836	$2,868	$2,901	$2,933	$2,966	$3,000	$3,034	$3,068
Total Bus Fixed Operating Costs		**$16,653**	**$16,873**	**$17,101**	**$17,335**	**$17,577**	**$17,826**	**$18,084**	**$18,349**
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$78,774	$79,147	$77,262	$73,245	$67,025	$57,848	$43,608	$22,141
AdBlue Consumption Cost		$1,586	$1,499	$1,376	$1,227	$1,056	$857	$607	$290
Distance Based Service & Maintenance Cost		$31,248	$30,525	$28,971	$26,703	$23,757	$19,936	$14,612	$7,213
Total Bus Variable Operating Costs		**$111,609**	**$111,171**	**$107,609**	**$101,174**	**$91,838**	**$78,641**	**$58,827**	**$29,644**
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$128,261	$128,044	$124,709	$118,510	$109,415	$96,468	$76,911	$47,993
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		**$1.79**	**$1.83**	**$1.89**	**$1.95**	**$2.03**	**$2.14**	**$2.34**	**$2.97**
Cumulative Total Bus Cost at End of Year		$2,095,832	$2,231,003	$2,361,639	$2,485,079	$2,598,595	$2,698,473	$2,778,221	$2,828,574
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		**$2.366**	**$2.334**	**$2.311**	**$2.295**	**$2.287**	**$2.284**	**$2.288**	**$2.299**
Cost to Operator of Early/Late Retirement		**$602,641**	**$467,471**	**$336,834**	**$213,394**	**$99,878**	**$0**	**$79,748**	**$130,101**

Table 32: PV Annual and Cumulative Costs per Kilometre for 2 Door Articulated Bus

Net Present Value Whole-of-Life Costs	Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs									
Bus Procurement Financial Cost		$852,800	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery		-$85,280	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement		-$57,485	-$47,814	-$39,770	-$33,079	-$27,514	-$22,885	-$19,035	-$15,833
Depot Upgrade Cost Amortised to 5 Buses		$18,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost		$142,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs		$927,520	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs									
Bus Statutory Compliance Cost		$8,340	$8,326	$8,313	$8,299	$8,285	$8,272	$8,258	$8,244
Bus Insurance Cost		$4,548	$4,710	$4,877	$5,050	$5,229	$5,415	$5,608	$5,807
Depot Bus Accommodation Cost		$2,513	$2,564	$2,616	$2,669	$2,723	$2,778	$2,834	$2,891
Time Based Bus Servicing Cost		$3,049	$3,084	$3,118	$3,153	$3,189	$3,225	$3,261	$3,298
Total Bus Fixed Operating Costs		**$18,451**	**$18,684**	**$18,924**	**$19,171**	**$19,426**	**$19,689**	**$19,960**	**$20,240**
Whole-of-Life Variable Operating Costs									
Diesel Consumption Cost		$80,415	$80,796	$78,871	$74,771	$68,421	$59,054	$44,517	$22,603
AdBlue Consumption Cost		$1,813	$1,713	$1,572	$1,402	$1,206	$979	$694	$331
Distance Based Service & Maintenance Cost		$35,690	$34,864	$33,090	$30,499	$27,135	$22,770	$16,689	$8,238
Total Bus Variable Operating Costs		**$117,919**	**$117,373**	**$113,534**	**$106,672**	**$96,762**	**$82,803**	**$61,900**	**$31,172**
Total Annual Operating Costs									
Total Fixed and Variable Costs This Year		$136,370	$136,057	$132,457	$125,843	$116,189	$102,492	$81,860	$51,412
Travelled Kilometres This Year		71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year		**$1.90**	**$1.95**	**$2.00**	**$2.07**	**$2.16**	**$2.28**	**$2.49**	**$3.18**
Cumulative Total Bus Cost at End of Year		$2,385,592	$2,531,320	$2,671,821	$2,804,355	$2,926,109	$3,033,230	$3,118,941	$3,173,555
Cumulative Kilometres at End of Year		885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year		**$2.693**	**$2.649**	**$2.615**	**$2.590**	**$2.575**	**$2.567**	**$2.568**	**$2.579**
Cost to Operator of Early/Late Retirement		**$647,639**	**$501,910**	**$361,409**	**$228,875**	**$107,121**	**$0**	**$85,710**	**$140,325**

3.8 Benefits of Reduced Seating on High Capacity Buses

Comparison of the total life cycle costs captured in Table 22 for the *2 Door 18m Articulated Bus* and *3 Door 18m Articulated Superbus* have demonstrated that reduced onboard seating can significantly improve high capacity bus economic performance, and previous Stage 1 high capacity vehicle studies have similarly indicated improved total passenger carrying capacity, bus stop dwell time, service speed, station/stop infrastructure utilisation and depot standard bus equivalent passenger capacities for the *Superbus*. The combined benefits of reduced onboard seating to the performance of a high capacity vehicle are such that we revisit here several key findings drawn from our earlier HCV evaluation studies to reinforce its critical importance.

Table 33: PV Annual and Cumulative Costs per Kilometre for 3 Door Articulated *Superbus*

Net Present Value Whole-of-Life Costs / Year Year No	2026 14	2027 15	2028 16	2029 17	2030 18	2031 19	2032 20	2033 21
Bus Ownership Costs								
Bus Procurement Financial Cost	$864,020	<== Sunken Cost at End of Year 12						
Less Tax Deduction Recovery	-$86,402	<== Sunken Recovery at End of Year 12						
Less Resale Recovery at Retirement	-$58,244	-$48,445	-$40,295	-$33,516	-$27,877	-$23,187	-$19,286	-$16,042
Depot Upgrade Cost Amortised to 5 Buses	$18,000	<== Sunken Cost at End of Year 12						
Major Bus Overhaul and Refurbishment Cost	$140,000	<== Sunken Cost at End of Year 12						
Total Ownership Costs	$935,618	<== Sunken Total Ownership Costs at End of Year 12						
Whole-of-Life Fixed Operating Costs								
Bus Statutory Compliance Cost	$6,996	$6,985	$6,973	$6,962	$6,950	$6,939	$6,927	$6,916
Bus Insurance Cost	$4,548	$4,710	$4,877	$5,050	$5,229	$5,415	$5,608	$5,807
Depot Bus Accommodation Cost	$2,513	$2,564	$2,616	$2,669	$2,723	$2,778	$2,834	$2,891
Time Based Bus Servicing Cost	$3,049	$3,084	$3,118	$3,153	$3,189	$3,225	$3,261	$3,298
Total Bus Fixed Operating Costs	**$17,107**	**$17,342**	**$17,585**	**$17,834**	**$18,091**	**$18,357**	**$18,630**	**$18,911**
Whole-of-Life Variable Operating Costs								
Diesel Consumption Cost	$80,415	$80,796	$78,871	$74,771	$68,421	$59,054	$44,517	$22,603
AdBlue Consumption Cost	$1,813	$1,713	$1,572	$1,402	$1,206	$979	$694	$331
Distance Based Service & Maintenance Cost	$35,766	$34,938	$33,160	$30,564	$27,192	$22,818	$16,724	$8,256
Total Bus Variable Operating Costs	**$117,994**	**$117,447**	**$113,603**	**$106,736**	**$96,820**	**$82,851**	**$61,935**	**$31,190**
Total Annual Operating Costs								
Total Fixed and Variable Costs This Year	$135,101	$134,789	$131,188	$124,570	$114,911	$101,208	$80,565	$50,101
Travelled Kilometres This Year	71,805	69,906	66,123	60,740	53,857	45,041	32,900	16,186
Total Operating Cost/Kilometre This Year	**$1.88**	**$1.93**	**$1.98**	**$2.05**	**$2.13**	**$2.25**	**$2.45**	**$3.10**
Cumulative Total Bus Cost at End of Year	$2,374,824	$2,519,412	$2,658,750	$2,790,099	$2,910,649	$3,016,546	$3,101,012	$3,154,358
Cumulative Kilometres at End of Year	885,847	955,753	1,021,876	1,082,616	1,136,473	1,181,514	1,214,414	1,230,600
Cumulative Cost/Kilometre at End of Year	**$2.681**	**$2.636**	**$2.602**	**$2.577**	**$2.561**	**$2.553**	**$2.554**	**$2.563**
Cost to Operator of Early/Late Retirement	**$641,723**	**$497,135**	**$357,796**	**$226,447**	**$105,898**	**$0**	**$84,466**	**$137,812**

Figure 3 below illustrates two different *2 Door 14.5m Extended Rigid Bus* cabin floor plans. There are currently around 130 of these high capacity buses operating in SEQ with the upper floor plan shown in Figure 3, and more have already been planned for construction. The upper floor plan has been specifically designed by the bus manufacturer for maximum onboard seating capacity at the bus operator's request.

Figure 3: Two Door 14.5m Rigid Bus Cabin Plans for Seat Maximisation vs Dwell Minimisation

The upper cabin floor plan incorporates no aisle circulation space between the front and rear doors, or a defined rear door storage space where passengers can queue, tag off their go cards and get ready to alight before reaching bus stops. Because the cabin design lacks aisle width for passenger circulation and a defined rear door storage area, it is also unsuitable for temporarily storage and spill out of boarding passengers if future all door boarding was to be implemented. Additionally, the rear door position has been placed to cram two additional rows of passenger seats into the rear saloon, but its positioning has resulted in 4 out of 5 boarded passengers alighting via the rear door, which would in effect prevent any potential stop dwell time saving ever being achieved through rear door boarding.

The lower cabin floor plan in Figure 3 has been redesigned for minimum bus stop dwell time using double width front to rear door aisle way passenger circulation, increased front door storage space adjacent to the wheelchair parking bays, and a defined rear door passenger queuing storage area. Its aftward relocated rear door also shifts passenger alighting preferences forward towards the front door, and the seating layout has been optimised for future all door boarding and alighting.

At the cost of just 3 passenger seats, the 14.5m bus with the lower cabin floor plan could legally carry 6 more passengers with increased standing capacity in the aisle ways, door storage areas and 2 wheelchair bays when unoccupied. With all door boarding, the modified vehicle's full load bus stop dwell time would be cut by 4 minutes per peak service trip, and its economic performance improved by the additional revenue collected from more boarded passengers and reduced paid time to the driver. These combined benefits significantly shift the peak service breakeven point towards the ticket revenue side, and consequently reduce *TransLink's* subsidy for the services this high capacity vehicle delivers.

The author asserts that the primary objectives when deploying high capacity buses on route services are to both increase the average number of passengers carried per trip <u>and to board and alight them as quickly as possible at bus stops</u>. It was revealed in the international research study for the Stage 1 *Operational Performance Evaluation* that very significant differences had been identified between mass transit high capacity bus operations overseas and contemporary high capacity bus services operated in South East Queensland. Bus station and bus stop dwell time minimisation was repeatedly identified from the international research as the central focus of best practice leading international mass transit authorities, and all door boarding, wider centre aisles, rear door passenger storage spaces and reduced onboard seating were the strategies typically implemented for rapid alighting and boarding of passengers at bus stations and stops.

The operational performance evaluation study further highlighted an entrenched mindset prevalent amongst both Australian and South East Queensland bus operators that cramming more passenger seats onto buses somehow equates to increased customer comfort, safety and satisfaction, but when applied to high capacity buses, the bus operator paradigm of maximised bus seating capacity is totally unsupported by the facts that:

- 56% to 75% of passenger seats presently go unoccupied in Brisbane on existing off-peak high capacity bus services, and over 40% on standard 12.5m rigid bus services. From our life cycle economic analyses, the cost of off-peak seat underutilisation translates to higher fuel consumption, higher bus maintenance, higher dead axle weight and lower combined bus seated plus standing capacity for 75 to 80% of the vehicle's travelled life cycle kilometres.
- All door boarding and improved passenger alighting/boarding efficiency are also totally incompatible with the doctrine of maximising seating capacity. Currently, some 6 to 11 minutes are consumed on every high capacity bus peak service just to board and alight passengers to full load capacity, and around 6 minutes on typical low floor 12.5m rigid bus peak services. All door boarding and improved passenger alighting/boarding efficiency could potentially cut bus stop dwell times by factors of 2 to 3, reducing driver labour costs,

increasing infrastructure stop capacity utilisation, preventing bus arrival clashes and offering the potential to increase service frequencies on HFP routes. But the most important benefit to peak services of a 200% or greater reduction in stop dwell time would be the increased competitiveness of high capacity bus services with the private motor vehicle.

- Every twin passenger seat installed in a bus cabin occupies approximately the same floor space as 4 standees. On peak services with highly crammed standing passenger loads, the price most often paid for 2 comfortably seated passengers is 4 very uncomfortable standees. Maximisation of seat capacity at the expense of aisle width does not consider the comfort needs of those less fortunate passengers still left standing.
- Average standing periods measured on some ten thousands of peak route services studied for the HCV operational performance evaluation showed that a typical standee endured uncomfortable crammed standing conditions for at least half the total trip time before finding a vacant seat to reoccupy. Throughout the time of standing, passengers had to shuffle back and forth and lean over seated passengers on exceptionally narrow aisle ways to let other passengers alight, and carry their personal belongings for most of the time to prevent trampling damage or tripping of other passengers.

It is arguably a total misnomer that adding more seats improves passenger satisfaction, comfort or safety on peak services with high standing loads, and bus operators need to be actively encouraged by *TransLink* to design their new high capacity vehicles for minimum stop dwell time.

3.9 High Capacity Bus Performance Benefit:Cost Ratios

In this last section, we compare the performance benefit to cost ratios for the 4 high capacity buses with respect to a standard 12.5m rigid bus. Operational performance, driving performance and road handling manoeuvrability, bus stop infrastructure compatibility and depot compatibility advantages/disadvantages for each vehicle type are compared using scores weighted by their relative importance. Data for the performance benefit to cost ratio evaluation have been sourced from our previous Stage 1 HCV technical studies.

The performance benefit to cost ratio analysis appears in Table 34. As a visual aid to its interpretation, we have colour coded the relative weighted scores, final assessment results and rankings as follows:

Highest Score for All Bus Types and High Capacity Buses Only
Second Highest Score for All Bus Types and High Capacity Buses Only
Second Lowest Score for All Bus Types and High Capacity Buses Only
Lowest Score for All Bus Types and High Capacity Buses Only

When taking into account vehicle operating performance, ease of driving and road manoeuvrability, compatibility with existing *TransLink* bus station and stop infrastructure and with existing operator bus depots, the conclusions drawn from the comparison of the performance benefit : cost ratio results were:

- On the basis of benefit to cost per kilometre, high capacity vehicle performance rankings have shifted relative to cost only rankings in favour of the smaller 90 passenger buses, but rankings within the 90 passenger and 110 passenger categories have remained unchanged. The shift in high capacity vehicle performance rankings by cost per kilometre relative to their cost only rankings has largely resulted from the shorter stop dwell times, faster operating speeds and superior driving performance of the 90 passenger buses compared to those of the 110 passenger buses.

Table 34: Performance Benefit:Cost Ratios for the 5 Bus Types

Performance and Compatibility Assessment Criteria	Relative Importance Weighting (1 to 10)	75 Passenger Ref Bus			90 Passenger High Capacity Buses						110 Passenger High Capacity Buses					
		2 Door 12.5m Standard Rigid Bus			2 Door 14.5m Extended Rigid Bus			2 Door 18m Articulated Bus			3 Door 18m Articulated Superbus			2 Door 12.5m Double Deck Bus		
		Measured Value	Relative Score	Weighted Score	Measured Value	Relative Score	Weighted Score	Measured Value	Relative Score	Weighted Score	Measured Value	Relative Score	Weighted Score	Measured Value	Relative Score	Weighted Score
Operating Performance																
Seated Carrying Capacity (passengers)	6	44	46%	2.8	56	58%	3.5	64	67%	4.0	52	54%	3.3	96	100%	6.0
Total Seated and Standee Carrying Capacity (passengers)**	9	75	65%	5.8	92	79%	7.1	90	78%	7.0	110	95%	8.5	116	100%	9.0
Total Journey Bus Stop Dwell Time - Fully Loaded, Front Door Boarding Only, Rear Door Alighting Only (minutes)	9	5.9	100%	9.0	7.8	76%	6.8	6.3	94%	8.4	10.6	56%	5.0	11.0	54%	4.8
Total Journey Bus Stop Dwell Time - Fully Loaded, Balanced All Door Boarding, Balanced All Door Alighting (minutes)	8	3.2	100%	8.0	3.9	82%	6.6	3.2	100%	8.0	3.5	91%	7.3	5.5	58%	4.7
Average Service Speed - Fully Loaded, Front Door Boarding, 10km Route, 8 Stops, 30km/h Traffic Speed (kilometres/hour)	8	22.7	100%	8.0	21.0	93%	7.4	22.1	97%	7.8	19.1	84%	6.7	18.7	82%	6.6
Average Service Speed - Fully Loaded, Front Door Boarding, 15km Route, 11 Stops, 45km/h Traffic Speed (kilometres/hour)	8	32.7	100%	8.0	30.1	92%	7.4	31.5	96%	7.7	27.6	84%	6.8	26.9	82%	6.6
Average Service Speed - Fully Loaded, Front Door Boarding, 20km Route, 16 Stops, 75km/h Traffic Speed (kilometres/hour)	8	41.7	100%	8.0	37.5	90%	7.2	38.0	91%	7.3	35.1	84%	6.7	33.5	80%	6.4
Driving Performance and Road Manoeuvrability																
Maximum Rate of Acceleration from Bus Stop (metres/second²)	8	1.1	100%	8.0	0.96	87%	7.0	0.89	81%	6.5	0.85	77%	6.2	0.76	69%	5.5
Maximum Service Speed (kilometres/hour)	7	95	97%	6.8	98	100%	7.0	92	94%	6.6	94	96%	6.7	92	94%	6.6
Road and Bridge Clearance Height Disadvantage (metres)	9	3.4	100%	9.0	3.4	100%	9.0	3.4	100%	9.0	3.4	100%	9.0	4.4	77%	7.0
15km/h Full Lock Turning Circle Disadvantage (metres)	8	14.98	100%	8.0	16.12	93%	7.4	15.96	94%	7.5	15.96	94%	7.5	16.46	91%	7.3
15km/h Full Lock Swept Path Width Disadvantage (metres)	8	4.38	100%	8.0	5.37	82%	6.5	5.19	84%	6.8	5.19	84%	6.8	5.74	76%	6.1
Pavement Damage Based on Gross Vehicle Mass Axle Load (tonne)	2	16	100%	2.0	29	80%	1.6	26	62%	1.2	26	62%	1.2	21	76%	1.5
Bus Station and Stop Infrastructure Compatibility																
Bus Stop Occupancy Space Disadvantage (metres)	9	12.5	100%	9.0	14.5	86%	7.8	18	69%	6.3	18	69%	6.3	12.5	100%	9.0
Bus Stop Rear Overhang Swing-In Disadvantage (metres)	3	3.24	64%	1.9	4.05	51%	1.5	3.33	62%	1.9	3.33	62%	1.9	2.08	100%	3.0
5km/h Bus Stop Full Lock Turn-Out Disadvantage (metres)	4	12.0	99%	6.0	12.11	98%	3.9	12.24	97%	3.9	12.24	97%	3.9	11.91	100%	4.0
5km/h Bus Stop Pull Out Swept Path Width Disadvantage (metres)	6	4.47	100%	8.0	5.86	76%	4.6	5.93	75%	4.5	5.93	75%	4.5	6.78	66%	4.0
Unobstructed Existing Bus Station & Park 'n Ride Accesses (percent)	8	100	100%	8.0	42	42%	3.4	42	42%	3.4	42	42%	3.4	82	82%	6.6
Accessible Existing Bus Station and Park 'n Ride Bus Stops (percent)	8	100	100%	8.0	55	55%	4.4	55	55%	4.4	42	42%	3.4	76	76%	6.1
Accessible Existing Roadside Bus Stops (percent)	8	100	100%	8.0	63	63%	5.0	63	63%	5.0	63	63%	5.0	100	100%	8.0
Bus Depot Compatibility																
Depot Accommodation Space Disadvantage (metres²/bus)	7	47.25	100%	7.0	54.25	87%	6.1	66.5	71%	5.0	66.5	71%	5.0	47.25	100%	7.0
Recommended Depot Fleet Service Life (years)	4	19	100%	4.0	18	95%	3.8	18	95%	3.8	18	95%	3.8	18	95%	3.8
Existing Depots Assessed Suitable with Minor Upgrades (number)	9	17	100%	9.0	17	100%	9.0	16	94%	8.5	16	94%	8.5	10	59%	5.3
Assessed Depot Equivalent Parking Capacity (12.5m buses)	7	2,319	100%	7.0	2,114	91%	6.4	2,107	91%	6.4	2,107	91%	6.4	2,216	96%	6.7
Assessed Depot Equivalent Passenger Carrying Capacity (std buses)	6	2,319	70%	4.2	2,322	70%	4.2	1,860	56%	3.4	2,210	67%	4.0	3,314	100%	6.0
Whole-of-Life Peformance Benefit:Cost Ratios																
Total Weighted Performance Score		171			145			144			138			147		
Whole-of Life Cost per Kilometre		$2.01/km			$2.30/km			$2.58/km			$2.56/km			$2.88/km		
Performance Benefit:Cost Ratio by Whole-of-Life Cost per Kilometre		85			63			56			54			51		
Ranking by Whole-of-Life Cost per Kilometre		1			2			3			4			5		
Whole-of Life Cost per Passenger-Kilometre		2.88¢/pax-km			2.50¢/pax-km			2.87¢/pax-km			2.33¢/pax-km			2.48¢/pax-km		
Performance Benefit:Cost Ratio by Whole-of-Life Cost per Pax-Kilometre		64			58			50			59			59		
Ranking by Whole-of-Life Cost per Pax-Kilometre		1			3			4			2			2		

- On the basis of benefit to cost per pax-kilometre, high capacity vehicle performance rankings have shifted relative to cost only rankings in favour of the larger 110 passenger buses, and the *2 Door 12.5m Double Deck Bus* has been pegged equally with the *3 Door 18m Articulated Superbus*. The shift in performance rankings by cost per pax-kilometre relative to cost only rankings for all high capacity buses has largely resulted from the superior compatibility of the double deck bus with existing bus station and roadside infrastructure, and the relatively high equivalent standard bus passenger and parking capacities in bus depots where double deck buses can readily be accommodated without major upgrades.
- The *2 Door 14.5m Extended Rigid Bus* had the highest performance benefit:cost ratio both in the 90 passenger category and between the 4 high capacity bus types. The *3 Door 18m Articulated Superbus* had the higher performance benefit:cost ratio in the 110 passenger category.
- The *2 Door 18m Articulated Bus* had the lowest performance benefit:cost ratio of all high capacity bus types.
- No high capacity vehicle outranked the *Standard 2 Door 12.5m Rigid Bus* on the like-for-like performance benefit to cost ratio evaluation. Notwithstanding it being the second dearest vehicle to operate based on cost per pax-kilometre, the standard bus significantly outperformed every high capacity bus and was fully compatible with all existing bus stations, stops and depots.

4. Key Findings

4.1 Key Findings from Whole-of-Life Cost Analyses

Bus ownership and operating costs are unaffected by road speed, but driver labour costs per kilometre have been shown to change markedly under different road traffic speed operating conditions. Driver labour costs have therefore been assessed in the study at 3 typical Brisbane road peak and off-peak traffic speeds:

(a) 30km/h Average Traffic Speed:

Bus services operating in 30km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

(b) 45km/h Average Traffic Speed:

Bus services operating in 45km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Bus services operating in 45km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

(c) 75km/h Average Traffic Speed:

Bus services operating in 75km/h peak traffic speed conditions travel between the CBD and an outer Brisbane suburb substantially on a busway or bypass the CBD on a major ring road such as the Western, Gateway or Logan Motorway.

Bus services operating in 75km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

The following findings were determined from a comparison of the net present values of all whole-of-life costs incurred by each high capacity bus relative to those incurred by a standard 12.5m rigid route bus under identical operating conditions.

1 **Two Door 14.5m Extended Rigid Bus:** This high capacity vehicle provided the best overall cost performance in the 90 passenger capacity category. It competes in this category with the 2 Door Articulated Bus.

At $2.30/km, this high capacity vehicle is 14% dearer to own and operate than a standard bus, but at 2.50¢/pax-km, is actually 7% cheaper in terms of its maximum 92 passenger carrying capacity. This bus breaks even with a standard bus at a load of 86 passengers, and has an increased future revenue generation potential of +7% when loaded with 6 additional passengers.

A standard bus MR licensed driver can legally drive this vehicle. It is 11% dearer at $4.10/km (30km/h), 12% dearer at $3.74/km (45km/h) and 13% dearer at $3.46km/h (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 11% cheaper at 4.45¢/pax-km (30km/h), 9% cheaper at 4.06¢/pax-km (45km/h) and 8% cheaper at 3.76¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life, this vehicle saves $1.341M (or $1.09/km) on 30km/h services, $1.179M (or $0.96/km) on 45km/h services and $1.101M (or $0.89/km) on 75km/h services, and is the best choice for any existing overloaded peak service only required to carry up to a maximum load of 92 passengers.

2 **Two Door 18m Articulated Bus:** **The cost performance of this high capacity vehicle has been relatively poor compared to a standard bus, and was assessed lowest for all high capacity buses.**

At $2.58/km, this high capacity vehicle is 28% dearer to own and operate than a standard bus, and at 2.87¢/pax-km, it remains 7% dearer to own and operate in terms of its maximum 90 passenger carrying capability. This bus does not break even with a standard bus at a comparable minimum load of 96 passengers. It carries 6 less passengers and therefore has a reduced future revenue generation potential -6% below that of the standard bus.

A HR licensed driver is needed to drive this vehicle. It is 19% dearer at $4.43/km (30km/h), 22% dearer at $4.04/km (45km/h) and 24% dearer at $3.78/km (75km/h) to operate than a standard bus and driver. At maximum passenger loads, it is 0.4% cheaper at $4.93¢/pax-km (30km/h), but 1% dearer at $4.49¢/pax-km (45km/h) and 3% dearer at $4.20¢/pax-km (75km/h) to operate than a standard bus and driver.

This vehicle could only be cost justified when substituted on an overloaded peak service in lieu of two standard buses and drivers. Over its whole-of-life, it saved $0.926M (or $0.75/km) on 30km/h services, $0.808M (or $0.66/km) on 45km/h services and $0.708M (or $0.58/km) on 75km/h services, but was ranked a poor second choice in the 90 passenger high capacity vehicle category, well behind the 14.5m extended rigid bus.

3 **Three Door Articulated *Superbus*:** **The cost performance of this high capacity vehicle was judged best in the 110 passenger capacity category. It competes in this category with the double deck bus, but carries only 52 seated passengers onboard, where the double deck bus carries 96 seated passengers. It is in effect identical to a 2 door 18m articulated bus with 12 less passenger seats and an extra door fitted, but its reduced seating capacity and tare weight has had a profound effect on its cost performance.**

At $2.56/km, this high capacity vehicle is 27% dearer to own and operate than a standard bus, but at 2.33¢/pax-km is 15% cheaper in terms of its maximum 110 passenger carrying capacity. This was the lowest cost per passenger-kilometre evaluated for all the high capacity buses. This bus breaks even with a standard bus at a load of 96 passengers, and has an increased future revenue generation potential of +15% when loaded with 14 additional passengers.

A HR licensed driver is needed to drive this vehicle. It is 24% dearer at $4.61/km (30km/h), 27% dearer at $4.21/km (45km/h) and 28% dearer at $3.89/km (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 18% cheaper at 4.19¢/pax-km (30km/h), 16% cheaper at 3.83¢/pax-km (45km/h) and 15% cheaper at 3.54¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life, this vehicle saves $0.707M (or $0.57/km) on 30km/h services, $0.595M (or $0.48/km) on 45km/h services and $0.572M (or $0.47/km) on 75km/h services, and is the preferred choice for any existing overloaded peak service required to carry a maximum load of up to 110 passengers.

4 **Two Door 12.5m Double Deck Bus:** The cost performance of this high capacity vehicle was also found to be satisfactory in the 110 passenger capacity category. It competes in this category with the 3 door articulated *Superbus,* but carries 96 seated passengers, where the *Superbus* only carries 52 seated passengers.

At $2.88/km, this high capacity vehicle is 43% dearer to own and operate than a standard bus. This was the highest cost per kilometre for all the high capacity vehicles assessed. At 2.48¢/pax-km, it was a distant runner up to the 18m articulated *Superbus,* but still 8% cheaper to own and operate than a standard bus in terms of its maximum 116 passenger carrying capacity. This bus breaks even with a standard bus at a load of 107 passengers, and has an increased future revenue generation potential of +8% when loaded with 9 additional passengers.

A HR licensed driver is needed to drive this vehicle. It is 34% dearer at $4.98/km (30km/h), 38% dearer at $4.59/km (45km/h) and 40% dearer at $4.28/km (75km/h) to operate than a standard bus and driver. With a maximum passenger load, it is however 15% cheaper at 4.30¢/pax-km (30km/h), 12% cheaper at 3.96¢/pax-km (45km/h) and 10% cheaper at 3.69¢/pax-km (75km/h) to operate than a standard bus and driver.

If substituted on an existing overloaded peak service in lieu of two standard buses and drivers, over its whole-of-life, this vehicle saves $0.249M (or $0.20/km) on 30km/h services, $0.129M (or $0.11/km) on 45km/h services and $0.096M (or $0.08/km) on 75km/h services, the lowest saving achieved by any of the high capacity buses. These relatively modest savings have been calculated at full load, a 21 year retirement age and 1.2306 million kilometre total service range. It is arguable whether substitution of a double deck bus would be cost justifiable against 2 rigid buses, given its known service limitations in Brisbane western and eastern suburbs with so many existing low clearance railway bridges.

5 **Ideal Retirement Age for a Standard 12.5m Rigid Bus:** Based on whole-of-life costs, the ideal retirement age for a new ultralow floor standard bus has been determined at 19 years. The detailed cost analysis has revealed that from age 14 to age 21, the annual total operating cost per kilometre for a typical SEQ standard route bus rises exponentially from $1.58/km to $2.58/km in present values, while its revenue/km declines proportionately in the negative direction. As a consequence, each year of service life after age 16 requires a higher *TransLink* subsidy to the bus operator to keep its aging standard buses in service.

6 **Ideal Retirement Age for All High Capacity Buses:** Based on their whole-of-life costs, the ideal retirement age for all 4 high capacity buses also fell at around age 19, but this was based on the assumption that aging high capacity buses could be deployed on school, shopper and district runs, private school and community charters, and breakdown standby bus duties, as is current practice for aging standard size route buses. It has been determined that the increase in annual operating cost per kilometre for a old age high capacity bus is much higher than for a standard bus, making it critical for *TransLink* that high capacity buses not be allowed to continue in service on light duties during the old age phase of their respective life cycles.

It has been further identified that high capacity buses have too many road use restrictions including over height limitations for the double deck bus, and restricted access, swept path/turning circle and bus stop length limitations for the 3 other single deck bus sizes. High capacity buses do not therefore appear to fill the same universal "go anywhere" and "back up any service" niche traditionally filled by standard 12.5m rigid buses during their old age.

A different future life cycle scenario has therefore been envisaged for high capacity buses in which they will need to be worked harder on normal commuter services in old age, and their retirements brought forward one year earlier to age 18.

7 **Maximum Seating vs Minimum Dwell Impact on High Capacity Bus Operating and Economic Performance:** Section 3.8 of the report has aptly demonstrated the high operating and whole-of-life economic benefits to TransLink of actively striving to trade seating capacity on high capacity buses for reduced dwell time at bus stops using bus cabin layouts with:

- Wider front to rear door aisle widths for improved passenger circulation and standee comfort,
- Wider, and on 110 passenger buses - second rear doors, for all door boarding and alighting,
- Rear door positions which encourage boarded passengers to alight in equal numbers through all doors, and
- Defined front and rear door passenger storage areas where alighting passengers can temporarily queue, tag off their go cards and get ready to alight before reaching bus stops; and where boarding passengers can then temporarily queue, tag on their go cards and spill out progressively to wide aisle ways and seats after leaving bus stops.

Operating benefits to high capacity buses of these bus cabin design reforms included:

- 200% to 300% reduction in average bus stop dwell time for all door balanced alighting and boarding,
- Higher legal total seated plus standing capacity,
- Reduced dead axle weight and fuel consumption,
- Greatly reduced simultaneous bus arrival clashes, particularly in single stop bay bus interchanges, park 'n rides and stations where arriving buses must circulate until allocated stop bays are cleared, at single bay roadside stops where arriving buses are forced to relocate off stop zones, and at busway stations where arriving bus queues force passengers to mobilise for long distances up platforms and delay service departures,
- Greatly improved utilisation of existing high cost bus stop infrastructure and bus depot equivalent standard bus parking space, and
- Improved service frequency and competitiveness with the private motor vehicle.

Over its whole-of-life, a 54¢ per pax-kilometre saving was realised by the *3 Door Articulated Superbus* relative to the *2 Door Articulated Bus* with 12 additional seats, but with future all door boarding and alighting, the total dwell time per peak trip would drop by 7 minutes for the former compared with only 3 minutes for the latter.

We have challenged the standing SEQ bus operator paradigm that more passenger seats on a high capacity bus equates to improved customer satisfaction, comfort and safety; and illustrated by example where all the above benefits could be realised on a current model *Two Door 14.5m Extended Rigid Bus* with as few as 3 less passenger seats. We have further highlighted that:

- 56% to 75% of passenger seats presently go unoccupied in Brisbane on existing off-peak high capacity bus services, and the cost of off-peak seat underutilisation translates to higher fuel consumption, bus maintenance, dead axle weight and lower combined bus seated plus standing capacity for 75 to 80% of a high capacity vehicle's travelled life cycle kilometres,
- Every extra twin passenger seat crammed into the bus cabin occupies approximately the same floor space as 4 standees. <u>On peak services with highly crammed standing passenger</u>

loads, the price paid for 2 comfortably seated passengers is 4 very uncomfortable standees. Maximisation of seat capacity at the expense of aisle width does not consider the customer satisfaction, comfort and safety needs of those passengers still left standing, and that

- Average standing periods measured on some ten thousands of peak route services studied for the HCV operational performance evaluation showed that a typical standee endured uncomfortable crammed standing conditions for at least half the total trip time before finding a vacant seat to reoccupy. Throughout the time of standing, passengers had to shuffle back and forth and lean over seated passengers on exceptionally narrow aisle ways to let other passengers alight, and carry their personal belongings for most of the time to prevent trampling damage or tripping of other passengers.

The combined benefits of designing and operating high capacity buses for minimum stop dwell time rather than maximum seating capacity pushes the peak service breakeven point significantly towards the ticket revenue side, and thereby significantly reduces *TransLink's* subsidy on services utilising buses specifically designed and operated for minimum dwell.

8 **Whole-of-Life High Capacity Bus Performance Benefit:Cost Assessments:** Operating performance, driving performance, road handling, bus stop infrastructure compatibility and depot compatibility have been compared for the 5 bus types using data from our previous Stage 1 HCV technical studies, and scores for assessed criterion weighted by their relative importance. Total weighted scores for each bus type were divided by their respective whole-of-life cost per kilometre and cost per pax-kilometre to obtain performance benefit:cost ratios and the ratios then ranked between the 5 bus types.

When taking into account vehicle operating performance, ease of driving and road manoeuvrability, compatibility with existing *TransLink* bus station and stop infrastructure, and compatibility with existing operator bus depots; the findings from the performance benefit : cost analysis were as follows:

- On the basis of benefit to cost per kilometre, high capacity vehicle performance rankings were shifted relative to cost only rankings in favour of the smaller 90 passenger buses, but relative rankings within the 90 passenger and 110 passenger categories remained unchanged. The shift in high capacity vehicle performance rankings by cost per kilometre relative to cost only rankings largely resulted from the shorter stop dwell times, faster operating speeds and superior driving performance of the 90 passenger buses compared with those of the 110 passenger buses.
- On the basis of benefit to cost per pax-kilometre, high capacity vehicle performance rankings shifted relative to cost only rankings in favour of the larger 110 passenger buses, and the *2 Door 12.5m Double Deck Bus* was pegged equally with the *3 Door 18m Articulated Superbus*. The shift in performance rankings by cost per pax-kilometre relative to cost only rankings largely resulted from the superior compatibility of the double deck bus with existing bus station and roadside stop infrastructure, and its very high equivalent standard bus passenger and parking capacities in those depots where double deck buses could readily be accommodated without major upgrades.
- The *2 Door 14.5m Extended Rigid Bus* attained the highest performance benefit:cost ratio both in the 90 passenger category and between all the high capacity bus types. The *3 Door 18m Articulated Superbus* attained the higher performance benefit:cost ratio in the 110 passenger category.
- The *2 Door 18m Articulated Bus* had the lowest performance benefit:cost ratio of all the high capacity bus types.

- No high capacity vehicle outranked the *Standard 2 Door 12.5m Rigid Bus* on the like-for-like performance benefit to cost evaluation. Notwithstanding it being the second dearest vehicle to operate on the basis of cost per pax-kilometre, the standard bus significantly outperformed every high capacity vehicle and was fully compatible with all existing bus stations, stops and depots.

Document Information

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1	Work-in-Progress Draft for Review	MF	BW, JV	LC	10/12/2012

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1. Introduction

1.1 Purpose of Report

MRCagney has been appointed by *TransLink Transit Authority (TransLink)* to undertake research and analysis of high capacity vehicle use within its South East Queensland network. The subject high capacity vehicle types nominated by *TransLink* for the study are already in service on its network and include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

This technical study evaluates and compares the costs of owning and operating each of the 4 high capacity vehicles relative to the costs of owning and operating a standard two door 12.5m rigid bus commonly deployed by most bus operators to *TransLink* route services in South East Queensland.

In Part 2, all relevant future value costs and cost recoveries have been estimated in Part 2 of the report for each vehicle type over its service life, backward converted to present value FY2012/13 dollars and summed to obtain a total whole-of-life net present value of its life cycle cash flows.

In Part 3 of the report, total (net present value) bus costs are compared and ranked for each vehicle type on a dollar per kilometre and dollar per passenger-kilometre basis. Total (net present value) driver labour costs are also determined over each vehicle's service life at typical peak and off-peak traffic speeds on Brisbane roads, and total (net present value) bus and driver operating costs compared and again ranked for each bus type on a dollar per kilometre and dollar per passenger-kilometre basis.

Total bus and driver operating costs are further examined to assess the economics of substituting a high capacity bus versus adding a second standard 12.5m bus on overloaded peak services.

Final conclusions drawn from the cost analysis have been consolidated with other relevant findings from earlier Stage 1 high capacity vehicle assessments in Part 4 of the report and a high capacity vehicle selection matrix has been developed.

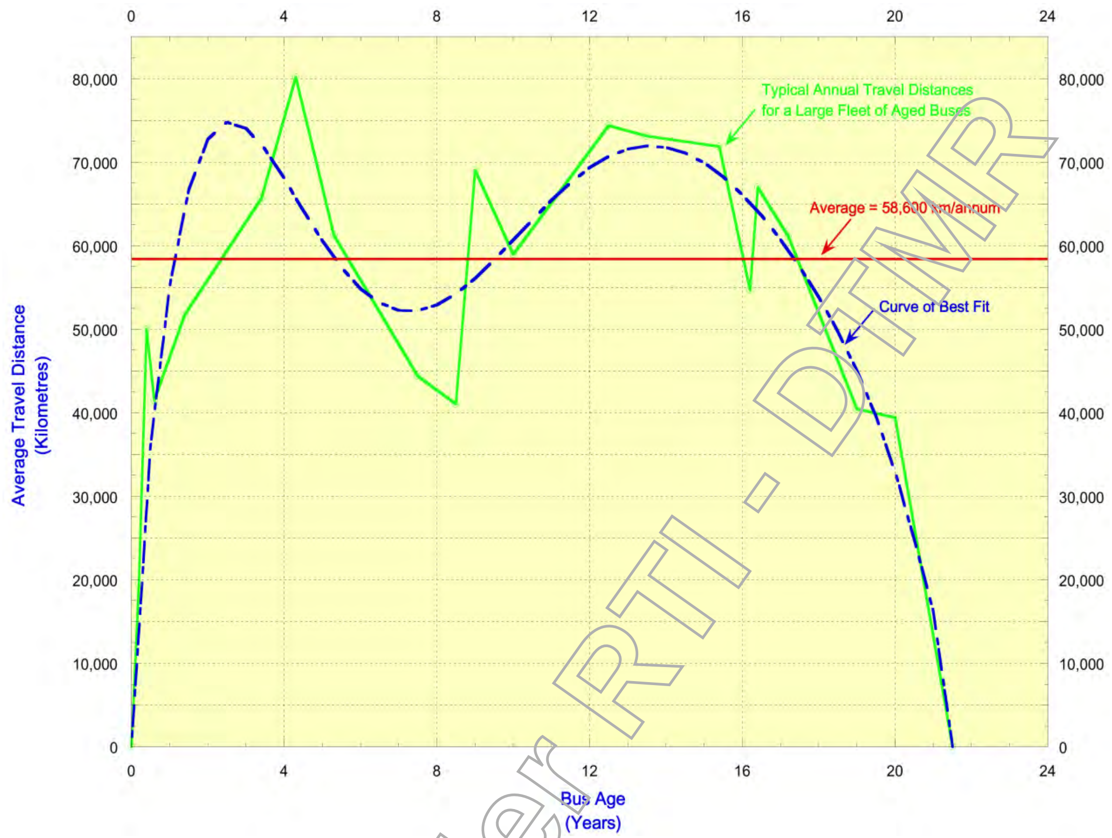
1.2 Key Assumptions Adopted in the Cost Analysis

The following assumptions have been adopted for this cost analysis:

- All quoted prices, costs, finance lease rates, *Consumer Price Indices*, annual inflation rates, fees, charges and other data obtained for cost calculations have been sourced in the second quarter of FY2012/13. Present values have therefore been provided throughout the report in FY2012/13 dollars.
- All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.
- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing overleaf. This curve was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have

been listed below in the table below the diagram, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.

Assumed Vehicle Travelled Distance vs Age Profile



Year Ending	Bus Age (years)	Travel Distance (kilometres)	Cumulative Odometer (kilometres)
2013	1	55,207	55,207
2014	2	72,781	127,988
2015	3	74,066	202,054
2016	4	68,080	270,134
2017	5	60,595	330,729
2018	6	54,863	385,592
2019	7	52,277	437,869
2020	8	52,932	490,801
2021	9	56,112	546,913
2022	10	60,695	607,608
2023	11	65,467	673,075
2024	12	69,360	742,435
2025	13	71,607	814,042
2026	14	71,805	885,847
2027	15	69,906	955,753
2028	16	66,123	1,021,876
2029	17	60,740	1,082,616
2030	18	53,857	1,136,473
2031	19	45,041	1,181,514
2032	20	32,900	1,214,414
2033	21	16,186	1,230,600

- New vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses at one existing bus depot.
- Capital expenditures other than for new bus procurements have been assumed to be funded out of business equity (i.e. from business cash reserves or savings accounts). This includes final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs per kilometre and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of operational cost evaluations, we have assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, loading of buses to their maximum legal seated plus standee carrying capacities and typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h. Average service speeds under these operating conditions have previously been accurately estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

1.3 Key Findings and Conclusions

To be completed once calculations are finalised and checked.

2. High Capacity Bus Cost Analysis

2.1 Background

This technical study investigates the costs of operating high capacity buses relative to those of a standard 12.5m rigid urban route bus. High capacity buses assessed in this technical study include the:

- Two Door 12.5m Double Deck Bus,
- Two Door 14.5m Rigid Bus,
- Two Door 18m Articulated Bus, and
- Three Door 18m Articulated *Superbus*.

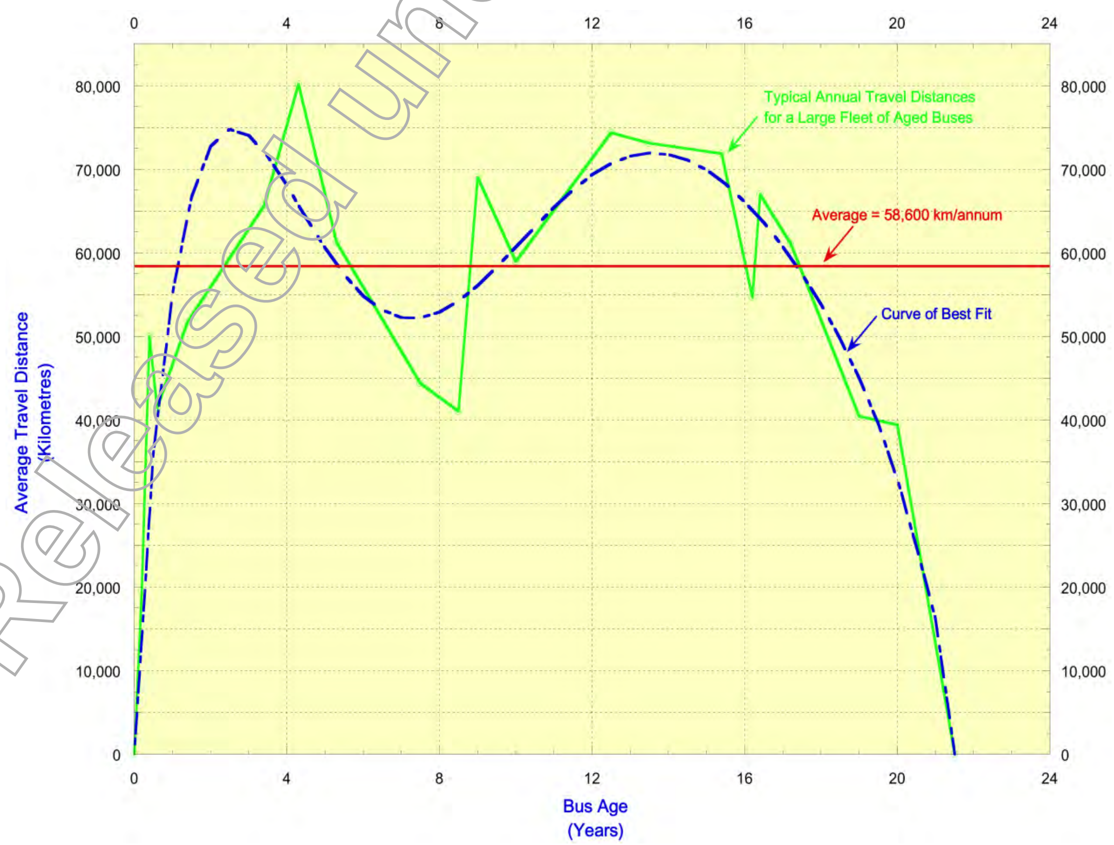
Part 2 of this report derives the ownership costs, fixed annual operating costs and variable operating costs for each bus type and explains where their reference cost data was sourced and how the present value of each cost element was calculated. Part 3 of the report summates the present values of all costs derived in Part 2 and compares the net present values for all bus types for their whole-of-life, both exclusive of, and inclusive of, bus driver operating costs.

2.1.1 Assumptions

The following assumptions have been adopted for this cost analysis:

- All quoted prices, costs, finance lease rates, *Consumer Price Indices*, annual inflation rates, fees, charges and other data obtained for cost calculations have been sourced in the second quarter of FY2012/13. Present values have therefore been provided in FY2012/13 dollars.

Figure 1: Assumed Vehicle Travelled Distance vs Age Profile



- All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.
- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing above in
- Figure 1The curve in Figure 1 was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses at one existing depot.
- Capital expenditures other than for new bus procurements have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or savings accounts). This includes the final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1: Assumed Travel Distances and Odometer Kilometres in Each Year of Bus Life

Year Ending	Bus Age (years)	Travel Distance (kilometres)	Cumulative Odometer (kilometres)
2013	1	55,207	55,207
2014	2	72,781	127,988
2015	3	74,066	202,054
2016	4	68,080	270,134
2017	5	60,595	330,729
2018	6	54,863	385,592
2019	7	52,277	437,869
2020	8	52,932	490,801
2021	9	56,112	546,913
2022	10	60,695	607,608
2023	11	65,467	673,075
2024	12	69,360	742,435
2025	13	71,607	814,042
2026	14	71,805	885,847
2027	15	69,906	955,753
2028	16	66,123	1,021,876
2029	17	60,740	1,082,616
2030	18	53,857	1,136,473
2031	19	45,041	1,181,514
2032	20	32,900	1,214,414

2033	21	16,186	1,230,600

2.2 Future to Present Value Conversion Formula

2.2.1 Present Value of a Future Single Expense or Revenue

The general equation for converting any future dollar value (*FV*) spent (+) or received (-) in future year *t* to its present dollar value (*PV*) today is given by..

$$PV = \frac{FV}{(1+q)^t} = \frac{FV}{(1.0304)^t} = \frac{FV}{c^t} \qquad \text{..........(i)}$$

where ...

FV = Future Value of the Single Expense (+) or Revenue (-) (in dollars)

PV = Present Value of the Future Single Expense (+) or Revenue (-) (in dollars)

q = *Brisbane Consumer Price Index – All Groups* for Decade Ending Q1, FY2012/13 = 3.04%/annum

c = Future to Present Value Conversion Factor = 1.0304

t = Elapsed Period from 1 January 2013 (in years).

2.2.2 Net Present Value of a Future Fixed Annuity Cash Flow

Let *a* = fixed annuity cash flow between year *1* and year *t*. The net (or total) present value of all successive annual cash flows between year *1* and year *t* becomes...

$$PV = a/c^1 + a/c^2 + a/c^3 + \ldots + a/c^t$$

Multiplying both sides of the equation by c^t gives...

$$c^t\, PV = a\,(c^0 + c^1 + c^2 + c^3 \ldots + c^{t-1}) = \frac{a\,(c^t - 1)}{c - 1}$$ for its standard form geometric series, then giving...

$$PV = \frac{a\,(c^t - 1)}{c^t\,(c - 1)} \qquad \text{..........(ii)}$$

Now let the fixed annuity cash flow start in year *n* and finish in year *m* which gives the general equation for the net present value of any future fixed annuity cash flow as:

$$PV = \frac{a\,(c^m - 1)}{c^m\,(c - 1)} - \frac{a\,(c^n - 1)}{c^n\,(c - 1)} = \frac{a\,\{(1 - c^{-m}) - (1 - c^{-n})\}}{c - 1}$$

$$PV = \frac{a\,(c^{-n} - c^{-m})}{c - 1} \qquad \text{..........(iii)}$$

where ...

a = Amount of a Fixed Future Expenditure (+) or Revenue (-) Annuity (in dollars)

PV = Net (or Total) Present Value of the Future Annuity Cash Flow (in dollars)

n = Elapsed Period from 1 January 2013 on which the Annuity Cash Flow Started (in years)

m = Elapsed Period from 1 January 2013 on which the Annuity Cash Flow Finished (in years)

c = Future to Present Value Conversion Factor = 1.0304.

2.2.3 Net Present Value of a Compounding Future Cash Flow

Let *p* = principal of a future cash flow compounding at interest rate *i* between year *1* and year *t*, and *r* = *1* + *i*, its annual compound growth rate. The net present value of all cash flows between year *1* and year *t* becomes...

$$PV = pr^1/c^1 + pr^2/c^2 + pr^3/c^3 + \ldots + pr^t/c^t = p(r/c)^1 + p(r/c)^2 + p(r/c)^3 + \ldots + p(r/c)^t$$

Letting *k* = *r/c* yields...

$PV = p\,(k^1 + k^2 + k^3 + \ldots + k^t)$

Dividing both sides of the equation by k then gives...

$\frac{PV}{k} = p\,(k^0 + k^1 + k^2 + k^3 \ldots + k^{t-1}) = \frac{p\,(k^t - 1)}{k - 1}$ for its standard form geometric series, finally giving...

$$PV = \frac{p\,k\,(k^t - 1)}{(k - 1)} \qquad \text{..........(iv)}$$

Now let the compounding cash flow start in year n and finish in year m which gives the general equation for the present value of any future compounding cash flow as:

$$PV = \frac{p\,k\,(k^m - 1)}{k - 1} - \frac{p\,k\,(k^n - 1)}{k - 1} = \frac{p\,k\,\{(k^m - 1) - (k^n - 1)\}}{k - 1}$$

$$PV = \frac{p\,k\,(k^m - k^n)}{k - 1} \qquad \text{..........(v)}$$

where ...

k = Future to Present Value Compound Conversion Factor = r/c
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Growth Rate = $1 + i$
c = Future to Present Value Conversion Factor = 1.0304
p = Investment Principal (in dollars)
PV = Net Present Value of the Compounding Future Cash Flow (in dollars)
n = Elapsed Period from 1 January 2013 on which the Compounding Cash Flow Started (in years)
m = Elapsed Period from 1 January 2013 on which the Compounding Cash Flow Finished (in years).

2.2.4 Instalment and Account Balance for a Compound Interest Loan

Let...

- p = principal of a commercial loan,
- i = fixed compound interest rate paid over the term of the loan between year 1 and year t,
- s = the fixed instalment paid annually on the loan,
- t = the term of the loan,
- b = the loan balance remaining at the end of each successive year of the loan term after all preceding fixed instalments have been paid, and
- $r = 1 + i$, the annual compound growth rate of the account principal and balance.

From Eqt (i), the future value of each fixed instalment is:

$FV = s\,c^t$

Hence from Eqt (ii), the total future value of all fixed instalment cash flows paid to the lender up to and including year t simplifies down to...

$$FV = \frac{s\,(r^t - 1)}{r - 1}$$

At the end of year t, the future value of the principal has grown from p to...

$FV = p\,r^t$ so the future value of the remaining balance at the end of year t becomes...

$$b = p\,r^t - \frac{s\,(r^t - 1)}{r - 1} \qquad \text{..........(vi)}$$

For commercial loans, no GST is paid to the lender, but instalments must continue until the account balance has reached $b = 0$. This yields the fixed instalment amount as...

$$s = \frac{p\, r^t (r - 1)}{r^t - 1} \qquad \text{..........(vii)}$$

where ...

s = Future Value of the Annual Instalment (in dollars)
p = Loan Principal (in dollars)
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Growth Rate = $1 + i$
t = Term of the Loan (in years).

The fixed instalments paid over the term of the loan represent a fixed expenditure cash flow which can be converted to a net present value using Eqt (iii) for a loan commencing in year n and terminating in year m. Substituting Eqt (iii) into Eqt (vii) gives...

$$PV = \frac{s\,(c^{-n} - c^{-m})}{c - 1} = \frac{p\, r^t (r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)}$$

Multiplying the numerator and denominator by c^m and substituting $t = m - n$ then gives the general equation for the net present value of any loan of term t ending in year m...

$$PV = \frac{p\, r^t (r - 1)\,(c^t - 1)}{c^m (c - 1)(r^t - 1)} \qquad \text{..........(viii)}$$

where ...

p = Loan Principal (in dollars)
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Growth Rate = $1 + i$
t = Term of the Loan (in years)
c = Future to Present Value Conversion Factor = 1.0304
m = Elapsed Period from 1 January 2013 on which the Loan Finishes (in years).

2.2.5 Instalment and Residual for a Compound Interest Finance Lease

A new vehicle procured by commercial loan becomes the property of the leasee (the bus operator) while the loan is being discharged. The new vehicle can be depreciated for tax purposes and the loan instalments attract no GST, but commercial loans contain no provision for a residual pay out upon termination.

A new vehicle procured under a finance lease becomes the property of the leasor until the lease has been fully discharged and its residual fully paid out. When a new vehicle is procured by finance lease, both the ongoing instalments and the residual left owing at termination of the lease attract GST. To determine the fixed instalment amount, the leasor and leasee must mutually agree upon the future value of the residual left to be paid out at the end of the lease, which is typically expressed as a percent of the principal, and has both a minimum and maximum dollar limit based on perceived risk. Residual percent limits are determined by the leasor in accordance with the amount borrowed, the term of the lease, the asset class and the credit worthiness of the leasee or its guarantor.

Let...

- p = principal of the finance lease, excluding GST,
- i = fixed compound interest rate paid over the term of the lease between year 1 and year t,
- s = the fixed instalments paid annually on the lease, excluding GST,
- t = the term of the finance lease,

- d = the residual remaining at the end of the term, excluding GST,
- j = the percentage future value of the residual to the principal, and
- $r = 1 + i$, the annual compound growth rate of the principal p.

The future value of the residual at the end of year t can be derived from Eqt (vi) by including the 10% GST applicable to both the ongoing instalments and the residual giving...

$$1.1\,d = p\,r^t - \frac{1.1\,s\,(r^t - 1)}{r - 1} \qquad \text{..........(ix)}$$

The ratio (in percent) of the residual to the principal is given by...

$$j = \frac{1.1\,d}{p} \qquad \text{..........(x)}$$

Therefore, an alternative form of Eqt (ix) for the future value of the residual is...

$$1.1\,d = j\,p = p\,r^t - \frac{1.1\,s\,(r^t - 1)}{r - 1} \qquad \text{..........(xi)}$$

Rearranging Eqt (xi) yields the future value of the ongoing fixed instalment (including GST) as...

$$1.1\,s = \frac{(p\,r^t - 1.1\,d)\,(r - 1)}{r^t - 1} = \frac{p\,(r^t - j)\,(r - 1)}{r^t - 1} \qquad \text{..........(xii)}$$

where ...

$1.1\,s$ = Future Value of the Annual Instalment, including GST (in dollars)
$1.1\,d$ = Future Value of the Residual, including GST (in dollars)
p = Finance Lease Principal, excluding GST (in dollars)
j = Percent Ratio of the Future Value of the Residual to the Principal (in percent),
i = Compound Interest Rate (in percent/annum)
r = Annual Compound Growth Rate = $1 + i$
t = Term of the Lease (in years).

The residual represents a fixed future lump sum expenditure paid at the end of the lease in year m, and its present value can be determined from Eqt (i) and Eqt (x) as...

$$PV = \frac{1.1\,d}{c^m} = \frac{j\,p}{c^m}$$

The fixed instalments paid over the term of the lease represent a fixed expenditure cash flow which can be converted to a net present value using Eqt (iii) for any lease commencing in year n and terminating in year m. Substituting Eqt (iii) into Eqt (xii) gives...

$$PV = \frac{(p\,r^t - 1.1\,d)\,(r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)} = \frac{p\,(r^t - j)\,(r - 1)\,(c^{-n} - c^{-m})}{(r^t - 1)\,(c - 1)}$$

Multiplying the numerator and denominator by c^m, substituting $t = m - n$, and adding the present value of the residual payout then gives the general equation for the net present value of both the instalments and residual for any lease of term t ending in year m as...

$$PV = \frac{(p\,r^t - 1.1\,d)\,(c^t - 1)\,(r - 1)}{c^m\,(c - 1)\,(r^t - 1)} + \frac{1.1\,d}{c^m} = \frac{p\,(r^t - j)\,(r - 1)\,(c^t - 1)\,(r - 1)}{c^m\,(c - 1)\,(r^t - 1)} + \frac{j\,p}{c^m} \qquad \text{..........(xiii)}$$

where ...

p = Future Value of Lease Principal (in dollars)
d = Future Value of the Residual, including GST (in dollars)
j = Percent Future Value of the Residual to the Principal (in percent),
i = Compound Interest Rate (in percent/annum)

r = Annual Compound Growth Rate = *1 + i*
t = Term of the Lease (in years)
c = Future to Present Value Conversion Factor = 1.0304
m = Elapsed Period from 1 January 2013 on which the Lease Finishes (in years).

2.2.6 Annually Reducing to Monthly Reducing Conversions

The compound interest equations (iv) through (xiii) above apply strictly to annual time periods only. Notwithstanding that financiers invariably quote interest rates in percent per annum, they seek repayment of instalments monthly and process account balances as monthly reducing, rather than annually reducing, which actually increases the amount repaid. The following conversions enable all the above equations to be used for monthly instalments paid on monthly reducing accounts:

- Substitute *i / 12* to convert annual interest rate *i* to monthly interest rate,
- Substitute *r + i / 12* to convert annual compound growth rate *r* to monthly growth rate,
- Substitute *c* = 1.0046376 to change the annual future to present conversion factor to a monthly future to present value conversion factor (as calculated to 7 decimal places using Eqt (ii)),
- Substitute *r + i / 12* to convert annual compound growth rate *r* to monthly growth rate, and
- Substitute *12 t, 12 m* and *12 n* to convert annual periods *t, m* and *n* to monthly periods.

2.2.7 Depreciated Book Value and Resale Value

The market resale value of a bus falls exponentially with age and whilst the resale price at any given time is driven by the economics of supply and demand, the book value can be modelled with reasonable accuracy from a knowledge of that point in time where there is no market resale demand for a second hand vehicle, at which point its book value has fallen to the scrap (or salvage) value only. For an old Queensland route bus, this occurs at age 25 and its future scrap metal salvage value is around 1% of the price of a new vehicle (in present value).

Let p = price of a new bus, v = its salvage value at age 25 and w = market book value. The exponential rate of depreciation in the vehicle's market book value can be calculated as...

$r = 1 - (v/p)^{1/25} = 1 - (0.01)^{0.04} = 16.8236\%$ per annum. Its future book value in any given year t of its service life then solves as...

$w = p\,(1 - r)^t = p\,(1 - 0.168236)^t = p\,0.831764^t$.

Hence on reaching retirement at age 21, the expected resale value of the vehicle would be around 2.09% of its replacement purchase price in present value.

2.3 Average Labour Rates

Direct labour costs are the largest single contributor to the overall cost of operating, servicing and maintaining a route bus fleet. The average labour rate per hour of a bus driver is needed to calculate the variable cost of operating a bus, the average labour rates of tradespersons and labourers (aka chassis cleaners, oiler-greasers and tyre repairers) to calculate the variable cost of maintaining the vehicle, and the average labour rate of cleaners (aka passenger services assistants, refuellers and yard persons) to calculate the annual cost of servicing the vehicle.

2.3.1 Average MR Licensed Bus Driver Labour Rate

Drivers holding an MR heavy vehicle licence can drive any standard 12.5m or extended 14.5m rigid bus. Their current award or certified agreement weekly rates vary markedly between bus operators in South East Queensland in the range of $638/week for a private bus operator up to $903/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $790/week.

An *Average MR Licensed Bus Driver Labour Rate = $33.94/hour* has been calculated from the cost and hours data appearing below in Table 2.

Table 2: Average Labour Rate Calculations for an MR Licensed Bus Driver

Annual Costs (Base = $790/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$41,080	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 17 hours/week over 6 shifts, including award night allowance rate	$22,865	Less 5 weeks/year for annual leave	-190 hours
Paid award allowances/year (training, meal and ticket/fare processing)	$2,416	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,697	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$3,037	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,936	Less an average of 3 days/year for compulsory authorised operator and driver training	-23 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$692	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Driver's uniform and accessories	$425	Less an average of 2.5 days/year for carer's, family and personal leave	-19 hours
Recruitment and training	$560	Less an average of 2.5 days/year for other paid leave (compassionate parental, bereavement, etc)	-19 hours
Total Labour Cost/Year	$76,708	Subtotal - Base Work Hours/Year	1563 hours (41 weeks)
Total Labour Costs/Year Total Work Hours/Year	$76,708 2,260	Plus overtime worked on shift penalty rates for an average of 17 hours/week for 41 weeks/year covering night services, weekend and public holiday services and fill-ins for other drivers	+697 hours
Average Labour Rate	$33.94	Total Work Hours/Year	2,260 hours

2.3.2 Average HR Licensed Bus Driver Labour Rate

Drivers holding a HR heavy vehicle licence can drive the heavier 12.5m double deck and 18m articulated buses. Their award or certified agreement weekly rates vary markedly between operators in South East

Queensland in the range of $653/week for a private bus operator up to $948/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $840/week.

An *Average HR Licensed Bus Driver Labour Rate = $35.96/hour* has been calculated from the cost and hours data appearing below in Table 3.

Table 3: Average Labour Rate Calculations for a HR Licensed Bus Driver

Annual Costs (Base = $840/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$43,680	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 17 hours/week over 6 shifts, including award night allowance rate	$24,240	Less 5 weeks/year for annual leave	-190 hours
Paid award allowances/year (training, meal and ticket/fare processing)	$2,416	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,931	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$3,226	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$2,057	Less an average of 3 days/year for compulsory authorised operator and driver training	-23 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$735	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Driver's uniform and accessories	$425	Less an average of 2.5 days/year for carer's, family and personal leave	-19 hours
Recruitment and training	$560	Less an average of 2.5 days/year for other paid leave (compassionate parental, bereavement, etc)	-19 hours
Total Labour Cost/Year	$81,270	Subtotal - Base Work Hours/Year	1563 hours (41 weeks)
Total Labour Costs/Year Total Work Hours/Year	$81,270 2,260	Plus overtime worked on shift penalty rates for an average of 17 hours/week for 41 weeks/year covering night services, weekend and public holiday services and fill-ins for other drivers	+697 hours
Average Labour Rate	$35.96	Total Work Hours/Year	2,260 hours

2.3.3 Average Bus Cleaner Labour Rate

Bus cleaners are employed in South East Queensland bus depots under various role specific job titles including chassis cleaner, oiler-greaser, tyre repairer, yard person, refueller and passenger services assistant. Their roles have become interchangeable in most depots over the past decade and those working for particular bus operators are employed under similar pay rates and conditions of employment.

Their award or certified agreement weekly rates vary markedly between operators in South East Queensland in the range of $603/week for a private bus operator up to $876/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $740/week. For industrial harmony, the majority of bus cleaners currently work rotational shifts to equalise their take home pays.

An *Average Bus Cleaner Labour Rate = $30.97/hour* has been calculated from the cost and hours data appearing overleaf in Average Tradesperson Labour Rate

Tradespersons employed in South East Queensland bus garages include motor mechanics, automotive electricians and motor body builders. They are covered by similar skills based C10 through C5 pay rates and conditions of employment. Trade award or certified agreement weekly rates vary markedly between operators in South East Queensland in the range of $833/week for a private bus operator up to $1,104/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $985/week.

An *Average Tradesperson Labour Rate = $39.89/hour* has been calculated from the cost and hours data appearing overleaf in Table 5.

2.4 Bus Ownership Costs

All dollar amounts listed in the tables that follow have been expressed in FY2012/13 dollar values. Future values of expenditures and revenues incurred during each vehicle's life have been backward converted to their equivalent present dollar values so that a like-for-like comparison can be made between the alternative bus types using dollar values today. Outgoing expenses have been assigned positive present values. Incoming revenues (or negative cost recoveries) have been assigned negative present values and illustrated in red text. Where abbreviated in the following analysis, "*PV*" means *Present Value*, "*NPV*" means *Net Present Value,* and "*FV*" means *Future Value*.

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Table 4: Average Labour Rate Calculations for a Bus Cleaner

Annual Costs (Base = $740/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$38,480	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime at shift penalty rates for 10 hours/week over 6 shifts, including award night allowance rate	$12,949	Less 5 weeks/year for annual leave	-190 hours
Paid meal allowance/year	$2,016	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$3,463	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$2,443	Less an average of 6 days/year for sick leave (ie 60% of maximum entitlement)	-46 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,557	Less an average of 1 day/year for compulsory authorised operator, fire, driving and safety training	-8 hours
Annual Leave Loading (17.5% of 5 weeks paid annual leave)	$648	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Safety vest, boots, goggles and raincoat	$125	Less an average of 2 days/year for carer's, family and personal leave	-15 hours
Recruitment and training	$200	Less an average of 2 days/year for other paid leave (compassionate parental, bereavement, etc)	-15 hours
Total Labour Cost/Year	$61,881	Subtotal - Base Work Hours/Year	1,578 hours (42 weeks)
Total Labour Costs/Year Total Work Hours/Year	$61,881 1,998	Plus overtime worked on shift penalty rates for an average of 10 hours/week for 42 weeks/year covering night, weekend and public holiday bus servicing and fill-ins for other cleaners	+420 hours
Average Labour Rate	$30.97	Total Work Hours/Year	1,998 hours

2.4.1 Average Tradesperson Labour Rate

Tradespersons employed in South East Queensland bus garages include motor mechanics, automotive electricians and motor body builders. They are covered by similar skills based C10 through C5 pay rates and conditions of employment. Trade award or certified agreement weekly rates vary markedly between operators in South East Queensland in the range of $833/week for a private bus operator up to $1,104/week for a public bus operator after 3 years continuous service. Their median weekly pay rate is around $985/week.

An *Average Tradesperson Labour Rate = $39.89/hour* has been calculated from the cost and hours data appearing overleaf in Table 5.

2.5 Bus Ownership Costs

All dollar amounts listed in the tables that follow have been expressed in FY2012/13 dollar values. Future values of expenditures and revenues incurred during each vehicle's life have been backward converted to their equivalent present dollar values so that a like-for-like comparison can be made between the alternative bus types using dollar values today. Outgoing expenses have been assigned positive present values. Incoming revenues (or negative cost recoveries) have been assigned negative present values and illustrated in red text. Where abbreviated in the following analysis, "*PV*" means *Present Value*, "*NPV*" means *Net Present Value,* and "*FV*" means *Future Value*.

Table 5: Average Labour Rate Calculations for a Tradesperson

Annual Costs (Base = $985/Week)		Annual Hours (Base = 38 Hours/Week)	
Paid base work hours and paid leave totalling 52 weeks/year	$51,220	Maximum base work hours at 52 weeks/year	1,976 hours
Paid overtime	$6,532	Less 4 weeks/year for annual leave	-152 hours
Paid tool, first aid and meal allowances/year	$1,052	Less 0.8667 weeks/year for accrued long service leave	-33 hours
Superannuation (9% of annual base rate)	$4,610	Less 10 days/year for Queensland public holidays	-76 hours
Queensland Payroll Tax (4.75% of total paid wages (i.e. base plus overtime)	$2,743	Less an average of 5 days/year for sick leave (ie 50% of maximum entitlement)	-38 hours
Queensland Worker's Compensation Insurance (2.753% of total paid wages plus GST)	$1,749	Less an average of 4 days/year for compulsory QA, trade skills, environmental and OHS training	-30 hours
Annual Leave Loading (17.5% of 4 weeks paid annual leave)	$690	Less an average of 2 days/year for community service leave (emergency services response assistance, etc)	-15 hours
Overalls, safety vest, boots, goggles, raincoat, hard hat and compensation for spectacles, hearing aids, tools and work clothing damaged on job	$500	Less an average of 2 days/year for carer's, family and personal leave	-15 hours
Recruitment and training	$1,500	Less an average of 2 days/year for other paid leave (compassionate parental, bereavement, etc)	-15 hours
Total Labour Cost/Year	$70,596	Subtotal - Base Work Hours/Year	1,602 hours (42 weeks)
Total Labour Costs/Year / Total Work Hours/Year	$70,596 / 1,770	Plus an average of 4 hours overtime at time and a half rates for 2 nights per week or Saturday mornings for 42 weeks/year	+168 hours
Average Labour Rate	$39.89	Total Work Hours/Year	1,770 hours

2.5.1 Bus Procurement Costs

Bus procurement costs cover a new vehicle's purchase price together with ancillary costs for axle weighing, ADR compliance certification, statutory on-road charges, insurance, delivery, operator pre-service quality inspections and minor fit-outs totalling approximately $7,500 per new vehicle.

New bus chassis and body manufacturer purchase prices vary significantly with production run lot sizes and this analysis has been based on an assumed minimum lot size of 5 new buses per production run. FY2012/13 average procurement costs for new high capacity buses relative to that of the reference two door 12.5m rigid bus are listed below in Table 6.

Table 6: Procurement Costs for New High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Procurement Cost (Dollars)	Relative Procurement Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$480,000	141.7%	116.7%	158.3%	160.4%

2.5.2 Bus Procurement Financial Costs

While bus procurement costs are a one-off capital expenditure incurred at the time of bus purchase, they are normally amortised in practice as future instalments on borrowing expenses and future residual payouts in the case of a finance lease. Bus operators typically fund new bus procurements through a mix of debt (commercial business loans or finance leases) and equity (cash downs, deposits and finance lease residual payouts). The weighted cost of capital will therefore vary from operator to operator in accordance with its preferred leveraging of debt to equity funding, the term of any commercial loan or finance lease entered into, its interest rate, and final residual payout if a lease.

For private bus operators, the cost of capital when funded by loan, can be offset through capital depreciation claimed back as BAS tax deductions, and any GST paid on finance lease instalments can similarly be recovered indirectly as an input tax credits by the lessor and as a BAS business operating expense claims by the lessee.

Whilst public bus operators similarly recognise capital depreciation for government accounting purposes, they have no recourse to depreciation cost recoveries through corporate taxation, but otherwise fully recoup their GST payments on finance loan instalments and obtain very low interest rates using finance leases sourced through the Queensland Treasury Corporation. To compare the cost of capital for all bus types and bus operators equitably, we have adopted the following assumptions for our bus life cost analysis:

- 100% of new bus procurement capital costs will be funded by a TransLink guaranteed finance lease entered into for a 10 year term with a 20% residual payout from operator equity falling due upon termination of the lease at the end of year 10.
- Cost of debt funding for new buses procured through the finance lease will be at a fixed interest rate of 7.25%/annum, the current finance industry median borrowing rate for long term truck and bus fleet finance leases effective as at Q2 FY2012/13, and the lease will be repaid in monthly reducing instalments.
- Capital depreciation for loans or GST tax deductions claimed for leases by private bus operators are considered comparable in value to GST recoveries obtained by public bus operators. To account for procurement cost offsets, the net cost of GST will be deducted from the net present value of the finance lease as an equivalent tax deduction recovery received by both private and public bus operators.

Table 7 below summarises the net present values of bus procurement financial costs for the 4 high capacity bus types relative to that of the reference two door 12.5m rigid bus. Amounts shown in the table have been calculated using Eqt (xiii) and verified by a spreadsheet confirmation of all monthly cash flows. Tax deductions indicated in Table 7 equal the net present value of all GST paid on the 120 monthly lease instalments and the residual payout at the end of year 10.

Table 7: Procurement Financial Costs for High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Procurement Financial Costs (Dollars)	Bus Procurement Financial Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$538,610 (Lease Repayments)	141.7%	116.7%	158.3%	160.4%
- $53,861 (Tax Deductions)	-141.7%	-116.7%	-158.3%	-160.4%

2.5.3 Bus Resale Recovery

The market value of a bus depreciates continuously throughout its service life until retirement, at which time the vehicle is either traded in, sold or salvaged to recover its remaining book value. Market resale values closely mirror the exponential decay characteristic of a reducing balance depreciation curve and from the analysis appearing in Section 2.2.7, the anticipated resale price for all bus types at a retirement age of 21 would be around 2.09% of their respective new replacement bus price when expressed in present dollar values. The respective book value recoveries in present value dollars are presented in Table 8 below.

Table 8: Resale Recovery for All Bus Types at a Retirement Age of 21

Reference 2 Door 12.5m Rigid Bus Resale Recovery (Dollars)	Relative Resale Recovery Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
-$10,000	-141.7%	-116.7%	-158.3%	-160.4%

2.5.4 Depot Costs for Initial High Capacity Bus Deployment

First-time deployment of longer, taller or wider swept path high capacity vehicles to an existing bus depot can potentially trigger significant major capital works for site modifications and other upgrades covering:

- Changed depot bus circulation paths,
- Dedicated HCV parking bays and/or lanes,
- Changed parking yard layouts and line remarking,
- Additional single post maintenance hoists or pit lengthening,
- Wheel brake and suspension shaker pit equipment modifications,
- Bus spray painting booth heightening or lengthening,
- Garage roller door and service shed widening or heightening,
- New bus roof access catwalks or tethered anti-fall personnel safety harnesses,
- Refuelling bay and washing machine modifications,
- AdBlue storage tank and dispenser hose installations in refuelling bays,
- Specialised HCV maintenance staff and driver orientation training sessions,
- Specialised HCV maintenance tools and test equipment procurements, and

- Specialised HCV spare parts procurements.

The *Depot Evaluation Technical Report* completed in Stage 1 of this study explored the likely impacts of deploying new high capacity vehicles to 16 existing bus depots in South East Queensland and concluded that specific high capacity bus types should be selected for each depot to obviate costly major building modifications for their initial accommodation.

During the course of the depot evaluation study, it was found that most private operators had not as yet installed AdBlue storage tanks and dispensers in their refuelling bays, but it was identified that such would become compulsory for any future new Australian Design Rule compliant buses entering service if fitted with SCR emission controlled diesel engines. We have therefore not included upgrade costs associated with retrofit refuelling bay AdBlue installations as such would occur irrespective of whether retiring standard 12.5m rigid buses were replaced by new 12.5m rigid buses or new high capacity buses.

Subject to an economically justifiable selective deployment of those high capacity bus types best suited to existing depot constraints, we have surmised for costing purposes that a typical depot should only require the following minor capital works and equipment upgrades:

- HCV parking bay creation and line remarking at those depots with existing perimeter bus parking bays **or** parking yard layout modifications and line remarking at those depots with existing nose-to-tail parking lanes,
- 4 additional new maintenance post hoists per garage,
- 1 additional bus roof anti-fall safety work harnesses per garage,
- 2 washing machine top rail and roller height extension modifications **or** 1 new mobile bus washing machine per garage (for double deck buses only),
- 1 set of specialised HCV spare parts per garage,
- 1 set of specialised HCV maintenance tools and test equipment per garage,
- 5 onsite HCV maintenance staff technical training sessions per garage, and
- 90 HV licensed driver high capacity bus orientation training sessions per depot.

Depot upgrade, new equipment/spares and staff training costs arise as once-off capital expenditures when any new bus type is first introduced into service at an existing depot, and the last 4 items listed above apply equally to the initial deployment of a new 12.5m rigid bus model. We have assumed for costing purposes that depot upgrade costs will be funded from the bus operator's business savings account but have apportioned the capital cost equally to the first lot of 5 new buses placed in service at a single existing depot. Depot upgrade costs applicable to the 5 new bus types are listed below in Table 9.

Table 9: Depot Upgrade Costs for 5 Initial High Capacity Bus Deployments to a Depot

Reference 2 Door 12.5m Rigid Bus Depot Upgrade Cost (Dollars)	Average Total Costs and Relative Cost Factors for Initial 5 Bus Deployment			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$30,000 (total)	$115,000 (total)	$90,000 (total)	$90,000 (total)	$90,000 (total)
$6,000 (per bus)	383%	300%	300%	300%

2.5.5 Major Overhaul and Refurbishment Costs

Major drive train overhauls and structural frame and body refurbishments incur significant capital costs during a vehicle's life. They are triggered either by elapse of time (bus age), but are not recurring fixed annual costs; or by travelled distance (bus odometer reading), but are not variable costs proportional to kilometres travelled.

A typical distance:age profile for a route bus life cycle has been presented in
Figure 1. The underlying reasons for the characteristic saddle shape of this curve are due in part to operator and driver preferences to operate young and middle age buses rather than old buses, and to major overhauls and refurbishments around the vehicle's mid-life which reduce its normal availability for service.

The area under the bus distance:age profile curve in each year of service is a measure of the kilometres travelled by the vehicle in that year, and the cumulative area under the curve up to the end of each year is a measure of the vehicle's accumulated odometer kilometres since first entering service. Travelled annual and cumulative odometer kilometres for each year of the assumed 21 year service life have been listed in All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing above in
- Figure 1The curve in Figure 1 was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses at one existing depot.
- Capital expenditures other than for new bus procurements have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or savings accounts). This includes the final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1, total 1,230,600 kilometres and average 58,600km/annum. This distance:age profile has been adopted to compare the relative costs of all 5 bus types under identical life cycle operating conditions.

Inspection of All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing above in
- Figure 1The curve in Figure 1 was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.

- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses at one existing depot.
- Capital expenditures other than for new bus procurements have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or savings accounts). This includes the final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1 reveals that the characteristic trough in the distance:age profile occurs around age 8 when the bus odometer reaches 500,000km. This is the point in the vehicle's life where most chassis manufacturers specify their major engine and gearbox overhauls, but new bus manufacturers today have managed to stretch this interval to 700,000km, which occurs later on All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing above in
- Figure 1The curve in Figure 1 was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses at one existing depot.
- Capital expenditures other than for new bus procurements have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or savings accounts). This includes the final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1 at around age 11 to 12. This 200,000km increase ensures that the engine on a typical bus only requires one major overhaul in its service life.

By age 9 to 10, bus frame structural fatigue and rust have typically begun, triggering the need for a major body frame refurbishment. Also around age 9 to 11, the cabin seat upholstery and floor vinyl also begin to look worn and deteriorated and the vehicle's finish could do with a fresh spray of 2 pack urethane. In the knowledge that the bus has attained its mid-life, the combined need for all these refurbishments forces a decision on the operator either to sell the bus or to give it a fresh makeover that would see it through to its retirement. The latter is invariably the cheaper option and the one most frequently chosen.

700,000km Major Engine Overhaul at Age 11 to 12

$48,000 for the 12.5m rigid bus, $52,000 for all other bus types. The indicated PV costs cover removal, major overhaul and refit of the engine to the vehicle. Labour has been costed for 140 hours at the average tradesperson rate of $39.89/hour calculated in Section 2.4.1. Material costs have been adjusted for a manufacturer's list price discount of 20% available to most large private operators and include GST. The tasks costed include overhaul of the starter motor, alternator, intercooler, radiator, water pump, power steering pump, air compressor, air conditioner compressor, turbocharger and radiator, plus replacement of the engine cylinder heads, liners, piston rings, filters, injectors, belts, hoses, oil and catalytic converter.

500,000km Major Gearbox and Retarder Overhaul at Age 8 to 10

$47,000 for all bus types. A similar model 5 speed automatic gearbox and retarder are installed on all bus types. The PV cost indicated covers removal, transport to and from the repairer, overhaul by the transmission repairer, and refit to the bus. Removal, transport and refit labour have been costed for 15 hours total at the average tradesperson rate. Automatic transmission repairs prove very costly and notwithstanding that gearbox manufacturers specify 500,000km for their major overhauls, operators will typically hold off mid-life overhauls for as long as possible to avoid having to do a repeat overhaul in the vehicle's old age.

Mid-Life Body Frame & Upholstery Refurbishment and Exterior Repaint at Age 9 to 10

$34,000 for a 12.5m rigid, $51,000 for a double deck bus, $38,000 for a 14.5m rigid bus, $43,000 for a 2 door articulated bus and $41,000 for a 3 door articulated bus. For most private operators, bus mid-life is actually reached at around age 9 to 10 based on odometer reading, and the cheapest way to complete the vehicle's mid-life makeover is to withdraw the bus entirely from service, send it to coach body repairers for competitive quotes, and raise an order to complete all the body refurbishments in a single pass.

While floor vinyl replacement, seat fabric re-upholstery and exterior repainting can be estimated with accuracy, structural cracks and rust in zincalum steel frames or weld fractures and T-nut slippages in aluminium frames can cause collateral damage to door frames and window pillars, bonded glazing, floor laminates, seat frame anchors and interior bulkheads.

We have assumed only minor frame deterioration and collateral body repairs to a total value of $10,000 + GST per bus, and priced replacement of worn floor vinyl along the cabin aisle ways only.

Summated PV overhaul and refurbishment costs for the 5 bus types appear below in Table 10. It has been assumed that these are fully funded by the operator without the need to borrow.

Table 10: Major Overhaul and Refurbishment Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Major Overhaul and Refurbishment Cost (Dollars)	Relative Major Overhaul and Refurbishment Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus

$129,000	116.3%	106.2%	110.1%	108.5%

2.6 Fixed Annual Operating Costs

In this analysis, fixed operating costs refer to expenses incurred annually by the operator to keep each bus registered, insured, clean and service ready. Fixed annual operating costs accrue in each year of the vehicle's life irrespective of the service kilometres actually travelled in any given year.

2.6.1 Annual Statutory Compliance Costs

All urban buses used to deliver public transport route services within TranLink's operating area require annual registration and Class 10B compulsory third party insurance, as well as two bi-annual Department of Transport and Main Roads *Programmed Vehicle Safety Audits.*

Annual Registration Fees

Bus registration fees depend on the vehicle type, its number of axles and the vehicle manufacturer's rated gross vehicle mass. State registration fees are currently $488/annum for all bus types other than the 2 door 12.5m double deck bus which is currently $2,429/annum because its front steer axle centres exceed the 1 metre maximum separation limit.

Compulsory Third Party Insurance Premium

Class 10B CTP insurance premiums vary quite markedly between the 5 bus types and depend on each vehicle's total passenger plus driver seating capacity. CTP insurance premiums range from $4740/annum for the standard 12.5m rigid bus with 45 total seats up to $10,700/annum for the 2 door 12.5m double deck bus with 97 total seats.

Programmed Vehicle Safety Audits

$710/annum for a 12.5m rigid or double deck bus, $850/annum for a 14.5m rigid bus and $1,015/annum for an articulated bus.

Compulsory bi-annual programmed vehicle safety audits are typically conducted on site in each bus depot. Visiting TMR safety auditors require that all vehicle undercarriages be pressure cleaned prior to inspection, every vehicle to be brake and shaker witness tested, then hoisted for a thorough chassis, steering, suspension, tyre wear and driveline inspection. Audits will also include cab interior and fire extinguisher safety checks, and may occasionally involve random road testing of vehicles upon request of the auditor.

A certificate of inspection is issued by the auditor for safety defect rectifications on each bus, and a second round of inspections conducted to confirm their timely completion. Maintenance work generated by safety rectifications has been separately costed under bus maintenance.

Total annual statutory compliance costs for the 5 bus types are summarised below in Table 11.

Table 11: Annual Statutory Compliance Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Statutory Compliance Cost (Dollars/Annum)	Relative Annual Statutory Compliance Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$5,938/annum	233%	125.5%	143.7%	120.6%

2.6.2 Annual Bus Insurance Costs

A range of insurance products is available for bus operators to manage their business risks, but the three most common policies taken up specifically for bus fleets are public liability, comprehensive commercial vehicle fleet insurance and depot insurance, the latter of which provides cover against theft, fire or flood damage sustained while buses are located in depots. As the legal owner of a leased bus, the two former policies will be stipulated by financiers to be kept current throughout the term of every finance lease.

Insurance brokers frequently bundle their offerings at discount premiums to cover every possible type of fleet insurance imaginable from CTP to depot insurance, business interruption protection, business income assurance, directors' and officers' legal liability, public liability and even worker's compensation. Discount bundle premiums per bus increase with reducing fleet size, increasing average fleet age and bus replacement price, the number of previous motor accident claims lodged by the fleet operator, and their total value.

With so many variables affecting discount annual insurance premiums, the following indicative costs would be typical of the average per unit unbundled premium rates for a large private bus operator with a fleet of 100 buses of 10 years average age with a moderate to good previous claim history.

Public Liability Insurance	\$1,160/annum for all bus types. Public liability insurance premiums are currently independent of bus passenger carrying capacity, but this may change over time when future SEQ bus fleets begin to incorporate increasing numbers of high capacity buses.
Comprehensive Commercial Vehicle Fleet Insurance	\$865/annum for a standard 12.5m rigid bus, \$1,440/annum for a 14.5m rigid bus and \$1,480/annum for a double deck or articulated bus. Comprehensive insurance premiums are affected by vehicle purchase price and road accident susceptibility. We have nominated per vehicle premium rates for a \$2,000 excess basic "no frills" comprehensive motor vehicle accident repair or replace and personal injury or death coverage capped to \$30 million. It should be noted however that fleet insurance premiums could be up to 3 times those indicated above for small bus operators with a poor claim history who elect full coverage for added "frills". Frills include options such as tow back to depot and to and from the vehicle's place of repair, refund of temporary bus repair costs, refund of passenger expenses to complete their journeys by taxi, refund of replacement bus hire charges, full passenger baggage damage cover and full replacement of vehicles under 12 months of age or pay out of their finance lease residual in the case of a total write off.
Depot Insurance	\$150/annum for all bus types. Depot insurance provides low cost insurance coverage for buses whilst located in depots and garages. Its main purpose is to insure vehicles against theft and catastrophes such as floods or fires, but not collisions or other accidents occasioned whilst buses are located in depots.

Total PV annual insurance costs for the 5 bus types are summated below in Table 12.

Table 12: Annual Insurance Costs for High Capacity Buses Relative to a 12.5m Rigid Bus

Reference 2 Door 12.5m Rigid Bus Annual Insurance Cost (Dollars/Annum)	Relative Annual Insurance Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
\$2,175	128.3%	126.4%	128.3%	128.3%

2.6.3 Annual Depot Bus Accommodation Cost

Many private bus operators around Australia choose to rent industrial properties to park and store their buses, enabling rental costs to be claimed back as BAS business expenses. Depot accommodation costs are in effect an accounting mechanism to apportion the annual cost of depot property amortisation, maintenance and upkeep, State land taxes and Council rates to the buses being accommodated.

For large operators who own their bus depots, depot building footprints are comparatively small in area relative to the garage, yard, temporary parking bays and circulation lanes provided for bus movements and parking, so the recurring annual costs of the entire depot site can reasonably be apportioned to each bus type by size and number as if the entire land parcel was being rented from a third party. Depot bus accommodation costs are a real fixed recurring annual cost to the operator, independent of the kilometres travelled by the buses actually being stabled and maintained at the depot.

Depot Bus Accommodation

$1,350/annum for a standard 12.5m rigid or double deck bus, $1,550/annum for a 14.5m rigid bus and $1,900/annum for an articulated bus. To cost depot bus accommodation, we have obtained long term annual rentals from realty agents for industrial properties located near, and similar in size, to existing bus depots in Brisbane, Redcliffe and the Gold Coast hinterland, averaged their rentals per unit area, and apportioned the rental per unit area to the parking space needed for each bus type as follows:

- 12.5m Rigid and Double Deck Bus Parking Space: (12.5m long + 1m clearance) x (2.5m wide + 1m clearance) = 47.25m^2 = 1 Standard Bus Space
- 14.5m Rigid Bus Parking Space: (14.5m length + 1m clearance) x (2.5m width + 1m clearance) = 54.25m^2 = 114.8% x Standard Bus Space
- 18m Articulated Bus: Parking Space: = (18m length + 1m clearance) x (2.5m width + 1m clearance) = 66.5m^2 = 140.7% x Standard Bus Space.

Table 13: Annual Depot Accommodation Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Depot Accommodation Cost (Dollars/Annum)	Relative Annual Depot Accommodation Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,350/annum	100%	114.8%	140.7%	140.7%

2.6.4 Annual Bus Refuelling, Fluid Top Up and Cleaning Costs

Bus servicing encompasses a broad range of routine refuelling, fluid top up, greasing, cleaning, inspection, testing and checking activities to maintain the vehicle in a state of service readiness, and are generally performed by unskilled cleaners or bus drivers. Bus servicing does not generally require accredited technical skills, fault diagnostics or dismantling of vehicle components; and may either be performed at fixed time or kilometre intervals. Fixed time based activities include the following:

Daily or Nightly Refuelling, AdBlue and Water Level Topping and Bus Exterior Lighting and Panel Damage Inspections

$1,065/annum for all bus types. Refuelling, AdBlue, demister and radiator water level top-ups may be undertaken by drivers when returning to depot or by rostered shift cleaners during day and late evening shifts. The 4 tasks take around 4 - 5 minutes per bus to complete and occur at an average frequency of 6 times per week. While tanks are being automatically topped, the bus exterior will typically be checked for signs of damage and if completed at night, operation of exterior lights (a legal requirement) will also be checked.

Consumables (viz. electricity and water) for these tasks amount to around $5 per

	bus per week. Because diesel and Adblue consumption costs increase with kilometres travelled, they are not included in the fixed annual costs of servicing the vehicle.
Daily or Bi-Daily Cab Interior Cleaning	$622/annum for a 12.5m or 14.5m rigid bus, $985/annum for a double deck bus, $804/annum for an articulated bus. Bus cabins need to be swept or vacuumed, and hand cleaned free of dust, spills and litter at least daily (6 times per week) or bi-daily (3 times per week). Interior cleaning takes around 3 minutes for a 12.5m or 14.5m rigid bus, 4.5 minutes for an 18m articulated bus and 6 minutes for a double deck bus, and is normally assigned to cleaners, but may in rare cases, be assigned to bus drivers. Operators who deploy 2 man cleaner teams at night will combine refuelling, fluid top-up inspections and cab cleaning as concurrent activities to avoid double handling of buses. Consumables (viz. detergent and water, glass cleaner and paper towels) amount to around $5 per bus per week.
Daily, Bi-Daily or Weekly Bus Exterior Washing and Tyre Pressure Checking	$738/annum for all bus types. Large bus operators who have installed automatic washing machines will combine drive-through exterior bus washing and tyre checking with their daily refuelling or bi-daily interior cleaning procedures to obviate double handling of buses. Small bus operators will typically wet detergent broom-wash their bus exteriors by hand on a weekly or fortnightly cycle. Our costing has been based on drive-through automatic machine washing by a cleaner 6 times per week at around 2 minutes per bus wash with a visual tyre pressure check, as large operators with washing machines are those more likely to deploy high capacity buses, and because hand washing of large buses is laborious, costly and inefficient. Consumables for automatic washing machines include electricity, water, water treatment and recycling chemicals, detergent and ongoing machine maintenance worth around $8 per bus per week for 6 washes.
Bi-Annual Chassis Pressure Cleaning	Bus chassis, engine bay and undercarriage pressure cleaning are required to remove the build up of road grime, dust and small stones which progressively accumulate in the vehicle's undercarriage, and the oil and distillate leak soaked dust residues which accumulate around and on top of the drive train components. The latter are a recognised bus fire safety hazard, and consequently bus undercarriage pressure cleaning cycles are synchronised by bus operators to take place before bi-annual TMR safety audits in the knowledge that the safety auditor will stop any vehicle found with a known fire safety hazard. We have consequently costed bi-annual chassis pressure cleans in with the costs of programmed safety audits previously discussed.

Total PV annual refuelling, fluid top-up and cleaning costs for the 5 bus types appear below in Table 14.

Table 14: Annual Refuelling, Fluid Top-up and Cleaning Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Annual Refuelling, Top-Up and Cleaning Cost (Dollars/Annum)	Relative Refuelling, Top-Up and Cleaning Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$2,425/annum	115%	100%	107.5%	107.5%

2.6.5 Fixed Annual Cost Inflation Factors

Fixed annual costs inflate annually throughout the vehicle's life. Inflation factors for the 4 identified fixed annual operating costs have been sourced as follows:

- Statutory Compliance Cost Inflation Factor: There are no motor industry price indices available which directly track annual increases in Queensland heavy vehicle registration and CTP charges, however Brisbane motor transport and private motoring costs have inflated at an average of 2.87%/annum over the past decade. The annual inflation factor for statutory charges has therefore been set at 1.0287 (Source: *ABS CPI A2326041L*).
- Bus Insurance Cost Inflation Factor: Over the past decade, the cost of Brisbane motor insurance premiums have increased at an average of 6.7%/annum. The annual inflation factor for bus insurance cost has therefore been set at 1.067 (Source: *ABS CPI A3602803R*).
- Depot Bus Accommodation Cost Inflation Factor: Over the past decade, the cost of Brisbane property rents have increased at an average of 5.12%/annum. The annual inflation factor for bus depot accommodation cost has therefore been set at 1.0512 (Source: *ABS CPI A2331846T*).
- Bus Servicing Cost Inflation Factor: Over the past decade, the Queensland public and private wage CPI has increased at an average of 4.2%/annum. The annual cost inflation factor for bus servicing by cleaners and drivers has therefore been set at 1.042 (Source: *ABS CPI A2711844F*).

2.6.6 Total Fixed Annual Operating Cost

The NPV of all vehicle fixed annual operating costs has been calculated using Eqt (v) and verified independently by spreadsheet. The calculated NPVs of all fixed annual operating costs for the 5 bus types are summarised below in Table 15.

Table 15: Total Fixed Annual Operating Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Total Fixed Annual Operating Cost (Dollars)	Relative Total Fixed Annual Operating Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$284,336	167.2%	119.2%	132.3%	122.3%

2.7 Variable Operating Costs

Variable operating costs are operating expenses which increase in proportion to the kilometres travelled while delivering bus services. Kilometres travelled vary from year by year with vehicle age as earlier illustrated by the distance:age profile in
Figure 1. The area under the distance:age profile curve in each year of its service life is a measure of the kilometres travelled in that year, and these have been listed in All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing above in
- Figure 1The curve in Figure 1 was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised

maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses at one existing depot.

- Capital expenditures other than for new bus procurements have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or savings accounts). This includes the final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

Table 1. The leading contributors to variable operating costs are diesel and AdBlue consumption, kilometre based bus servicing and maintenance and driver wages.

2.7.1 Diesel and AdBlue Consumption Cost Rates

Low sulphur clean diesel and AdBlue urea are the two primary consumables of a modern bus fitted with an SCR diesel engine complying with the exhaust emission standards defined by *Australian Design Rule ADR 80*. The federal diesel excise rebate previously available to public transport bus operators has now ceased and delivered prices for bulk clean diesel (inclusive of federal excise) and bulk AdBlue urea in 1,000 litre or larger drums are $1.47/litre and $1.20/litre respectively for large fleet operators.

PV average diesel and Adblue consumption cost rates per kilometre are summarised below in Table 16 for the 5 bus types.

Table 16: Average Diesel and AdBlue Consumption Rates per Kilometre for the 5 Bus Types

Average Diesel Consumption Rate per Kilometre for the 5 Bus Types				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
43 litres/100km	60 litres/100km	48 litres/100km	49 litres/100km	49 litres/100km
$0.63/kilometre	$0.88/kilometre	$0.71/kilometre	$0.72/kilometre	$0.72/kilometre
Average AdBlue Consumption Rate per Kilometre for the 5 Bus Types				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
2.1 litres/100km	3.9 litres/100km	2.8 litres/100km	3.2 litres/100km	3.2 litres/100km
$0.03/kilometre	$0.05/kilometre	$0.03/kilometre	$0.04/kilometre	$0.04/kilometre

2.7.2 Servicing and Maintenance Cost Rates

Routine garage kilometre based servicing activities include the following inspection, test and lubrication services:

- Brake roller and suspension shaker tests,
- Tyre wear inspection, rotation, rebalance, pressure checking and replacements,
- Chassis, suspension, axle and drive train greasing,
- Alternator, water pump, air conditioning compressor and radiator fan belt replacements,
- Engine, transmission, fuel, water, air conditioner and air system filter replacements,

- Engine, transmission, differential, steering box, etc. oil top-ups or replacements,
- Water additive, air conditioner refrigerant and hydraulic oil top-ups or replacements, and
- Door lubrication, operation and safety checks.

Regular garage kilometre based mechanical maintenance checks, diagnostics, replacements and repairs are undertaken for the:

- Tyres, wheels, shock absorbers and wheel alignments,
- Linings, drums, brake pads, discs, slack adjusters, etc,
- Compressor, air filter, air dryer, air bags, air valves, air hoses, etc,
- Brake and suspension compressed air tanks, valves and hoses,
- Water pump, radiator, intercooler, coolant hoses, thermostat, etc,
- Turbocharger, exhaust pipe(s), muffler and catalytic converter,
- Power steering, park brake and foot brake valves,
- Air conditioning compressor, evaporator, condenser, TX valve and fan motors,
- Driver seat suspension, door and wheelchair loader mechanisms,
- Vehicle road handling and stability tests,
- Injection pump, fuel lines and SCR mixer,
- Bus towing and on-road breakdown assistance, and
- Energy guidance system (articulated buses only).

Regular garage kilometre based electrical maintenance checks, diagnostics, replacements and repairs are undertaken for the:

- Alternator, starter motor, regulator, batteries and master switch contactor,
- CAN comms cable pairs, looms, harnesses, earths, power cables and connectors,
- Switches, fuses, circuit breakers, relays and protection devices,
- Driver instruments, LCD panels, audible alarms and visual indicators,
- Electric motors, solenoids, tachometers, senders and sensors,
- Lamps, LED lights, bulbs, CFLs, inverters, fluorescent tubes and ballasts,
- Windscreen wipers, washers and demisters,
- CAN, instrument cluster, gearbox, engine and ABS brake control units,
- PLC, door, air conditioner, safety interlock and body control units,
- Mobile radio, air conditioner, destination sign(s), cameras, driver's video monitor and DVR,
- Turntable articulation control unit, angle/pressure sensors and proportional valve (articulated buses only), and
- TransLink smartcard DCU, PIM and door OBCIDs.

Regular garage kilometre based body maintenance checks, replacements and repairs are undertaken for:

- Body water leaks, structural rust, T-nut slippage and frame corrosion,
- Floor laminate rot and vinyl wear and tear damage,
- Cracked windscreens and glazing,
- Exterior panel damage fibreglass, bog, sand and repaints,
- Exterior panel and FRP mould replacements and repaints,
- Bumper bar and dumb iron straightening and repaints,

- Rear view mirror, roof hatch, air conditioner pod, destination and rear numeral headers,
- Interior panel lifted fabric adherence and repaints,
- Graffiti removal and seat upholstery replacements,
- Hand grip, strap hanger, hand rail and stanchion tightening or replacements,
- Articulation bellows wear and tear (articulated buses only), and
- Driver and passenger seat cushion and squab replacements.

Present value bus servicing and maintenance cost rates per kilometre for the 5 bus types are given below in Table 17.

Table 17: Average Servicing and Maintenance Cost Rates per Kilometre for the 5 Bus Types

Average Servicing and Maintenance Cost Rate per Kilometre				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$0.37/kilometre	$0.51/kilometre	$0.42/kilometre	$0.47/kilometre	$0.48/kilometre

2.7.3 Driver Labour Cost Rates

Whilst a driver is paid at an average 38 hour/week labour rate, his or her labour cost per kilometre is needed to compute the cost of bus service(s) delivered on road. The mathematical relationship between the driver's average labour rate per hour and his/her average labour cost per kilometre is given by....

$$\text{Average labour cost per kilometre} = \frac{\text{Average labour rate per hour}}{\text{Average service speed}} \quad \begin{array}{l}\text{(in dollars per hour)}\\ \text{(in kilometres per hour)}\end{array}$$

An average labour rate of $33.94 per hour was calculated for an MR licensed bus driver to drive either a 12.5m or 14.5m rigid bus in Section 2.3.1; and $35.96 per hour for a HR licensed bus driver to drive either a double deck or articulated bus in Section 2.3.2.

Table 18: Average Service Speeds for Different Route Lengths, Traffic Speeds and Stops per Trip

Comparison of Bus Types on 10 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	22	18	21	22	19
16	22	18	20	21	19
23	22	17	20	21	18
32	21	17	19	20	18
45 Kilometre/Hour Average Traffic Speed					
11	29	22	26	27	23
16	28	21	25	26	22
23	26	20	23	24	21
32	25	19	22	23	20
75 Kilometre/Hour Average Traffic Speed					
11	32	24	28	29	25

Comparison of Bus Types on 15 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	24	21	23	24	22
16	24	21	23	24	21
23	24	20	22	23	21
32	23	20	22	22	20
45 Kilometre/Hour Average Traffic Speed					
11	33	27	30	32	28
16	32	26	29	31	27
23	31	25	28	29	26
32	29	23	26	27	24
75 Kilometre/Hour Average Traffic Speed					
11	40	31	36	37	32
16	36	28	32	33	30

Comparison of Bus Types on 20 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	26	23	25	25	23
16	25	23	24	25	23
23	25	22	24	24	23
32	25	22	24	24	22
45 Kilometre/Hour Average Traffic Speed					
11	35	30	33	35	31
16	35	29	32	33	30
23	33	28	31	32	29
32	32	27	29	30	28
75 Kilometre/Hour Average Traffic Speed					
11	45	36	41	42	38
16	42	33	37	38	35
23	37	30	33	33	32

Comparison of Bus Types on 25 Kilometre Bus Route					
Bus Stops Per Trip	Two Door 12.5m Standard Rigid Bus Ave Speed (km/h)	Two Door 12.5m Double Deck Bus Ave Speed (km/h)	Two Door 14.5m Extended Rigid Bus Ave Speed (km/h)	Two Door 18m Articulated Bus Ave Speed (km/h)	Three Door 18m Articulated Superbus Ave Speed (km/h)
30 Kilometre/Hour Average Traffic Speed					
11	26	24	25	26	24
16	26	24	25	26	24
23	26	23	25	25	24
32	26	23	25	25	23
45 Kilometre/Hour Average Traffic Speed					
11	37	32	35	36	33
16	36	31	34	35	32
23	35	30	33	34	31
32	34	29	32	32	30
75 Kilometre/Hour Average Traffic Speed					
11	49	41	45	46	42
16	46	38	42	42	39
23	42	34	38	38	36
32	37	30	33	33	32

Average bus service speeds (and hence driver labour cost rates) vary markedly with route length, incident traffic speed, number of bus stops and number of passengers boarded at stops, and have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*. Table 18 above presents an extract from the performance evaluation report showing the average service speeds attained on route lengths of 10 to 25km with more than 10 stops at 3 typical Brisbane traffic speeds determined from the last *RACQ Brisbane City Travel Time Survey* conducted in October 2010:

- 30km/h Traffic Speed: This was the typical 2010 peak period traffic speed achieved by a private motor vehicle travelling between the CBD and an outer Brisbane or surrounding regional suburb substantially via local roads, then on a major city bound arterial or sub-arterial such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road. This traffic speed averaged the higher travel speeds achieved while still driving through the outer suburbs on local roads with the slower speeds later encountered during peak periods with traffic signals, congestion, stops and give-ways on the major arterial or sub-arterial roads.
- 45km/h Traffic Speed: This was the typical 2010 peak period traffic speed achieved while travelling between the CBD and an outer Brisbane or surrounding regional town or city suburb on a major highway such as the Bruce, Ipswich or Pacific Motorway. It was also representative of the traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a mix of local, arterial or sub-arterial roads during the off-peak.

- **75km/h Traffic Speed:** This was the typical 2010 peak period traffic speed achieved on TransLink's busways leading into the CBD and on major city ring roads such as the Western, Gateway and Logan Motorways. It was also representative of the off-peak traffic speed achieved between the CBD and an outer Brisbane or surrounding regional town or city suburb using a city bound highway such as the Bruce, Ipswich or Pacific Motorway.

RACQ has not published a revised *Brisbane City Travel Time Survey* since 2010, but it has been observed from identical RACQ surveys conducted over the previous 7 years that average inbound and outbound traffic speeds along the city's main corridors, highways and motorways progressive fell at a rate of 2.5%/annum as a consequence of continuously increasing traffic congestion.

Assuming that most high capacity bus routes would be in the range of 10km to 20km with 10 or more bus stops, the average speed data listed in Table 18 can be reduced down to a two tail distribution mean speed with a variance of less than +/-12.5% for each of the 3 common traffic speeds. Average current driver labour rates per kilometre appearing below in Table 19 have been calculated by dividing the applicable driver labour rates for each bus type by the 3 traffic speed distribution means, and decreasing the RACQ 2010 measured speeds for an additional 2 years @ 2.5%/annum to account for increased congestion.

The estimates appearing in Table 19 assume each bus type will be loaded to its maximum carrying capacity based on the basic logic that increased carrying capacity was the primary justification for deploying a high capacity bus to the service. Estimates appearing in Table 19 verify two key findings of the operational performance evaluation, namely that high capacity bus performance improves significantly with increasing traffic speed and route length.

Table 19: Average Driver Labour Cost Rates per Kilometre for the 5 Bus Types

Average Driver Labour Rate per Kilometre at 30km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1.51/kilometre	$1.87/kilometre	$1.60/kilometre	$1.65/kilometre	$1.82/kilometre
Average Driver Labour Rate per Kilometre at 45km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1.16/kilometre	$1.52/kilometre	$1.28/kilometre	$1.30/kilometre	$1.47/kilometre
Average Driver Labour Rate per Kilometre at 75km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$0.92/kilometre	$1.25/kilometre	$1.03/kilometre	$1.07/kilometre	$1.18/kilometre

2.7.4 Variable Operating Cost Rate Inflation Factors

The abovementioned variable operating cost rates inflate throughout each vehicle's life. Inflation factors for the 4 identified variable operating cost rates have been determined as follows:

- **Diesel Consumption Cost Rate Inflation Factor:** In the 4 years since December 2008 following the global financial crisis, the Brisbane clean diesel price, inclusive of federal excise, has inflated at an average of 6.34%/annum. The diesel consumption cost rate annual inflation factor has therefore been set at 1.0634. (Source: *FuelTrac Capital City Diesel Prices*).
- **AdBlue Consumption Cost Rate Inflation Factor:** In the 4 years since December 2008 following the global financial crisis, the Australian average AdBlue price has remained flat and not inflated, effectively falling in price against the *Brisbane All Groups CPI*. The AdBlue consumption

cost rate annual inflation factor has therefore been set at unity. (Source: *GreenChem AdBlue International Index*).

- Servicing and Maintenance Cost Rate Inflation Factor: Over the past decade, the cost of Brisbane motor vehicle maintenance and repairs has inflated at an average of 3.39%/annum. The annual inflation factor for the bus servicing and maintenance cost rate has therefore been set at 1.0339 (Source: *ABS CPI A2711844F*).
- Average Driver Labour Cost Rate Inflation Factor: Over the past decade, the Queensland public and private wage CPI has inflated by an average of 4.2%/annum. The annual inflation factor for average driver labour rates has therefore been set at 1.042 (Source: *ABS CPI A2711844F*).

2.7.5 Total Variable Operating Costs

Because kilometres travelled per annum change in each year of service life, the total NPV of all bus variable operating costs had to be computed by spreadsheet using the following calculations:

1) The kilometres travelled in each year of life were obtained from All vehicle types have been assessed for an identical 21 year service life, assumed to commence on 1 January 2013 and terminate with the vehicle's retirement on 31 December 2033.

- Assumed travel distance per annum in each year of the vehicle's service life has been based on the statistical *Curve of Best Fit* appearing above in
- Figure 1The curve in Figure 1 was derived from a review of aged bus annual travel distances for an existing large bus fleet operating in South East Queensland. Life cycle annual travel distances and cumulative odometer kilometres for this service profile have been listed below in Table 1, average out at 58,600km/annum and total to 1,230,600km over the assumed 21 year service life.
- Vehicle capital costs have been based on an assumed initial lot procurement of 5 new buses. Once-only capital works needed to upgrade existing bus depots, procure specialised maintenance equipment and provide training sessions for the bus operator's staff have been apportioned equally to the assumed initial deployment of 5 new buses at one existing depot.
- Capital expenditures other than for new bus procurements have been assumed to be entirely funded out of business equity (i.e. from business cash reserves or savings accounts). This includes the final residual payouts on expiring bus finance leases.
- Average bus service speeds affect average driver labour costs and vary markedly with route length, incident traffic speed, number of bus stops and total number of passengers loaded at stops. For the purposes of cost evaluation, we have assumed typical route lengths of 10 to 25km, 10 or more bus stops per journey, typical Brisbane major road peak and off-peak traffic speeds of 30km/h, 45km/h and 75km/h and loading of buses to their maximum legal seated plus standee carrying capacities. Average service speeds under these operating conditions have previously been estimated for each bus type in the Stage 1 *Operational Performance Evaluation Report*.

2) Table 1 for bus ages 1 to 21,

3) These were then multiplied by the cost rates for diesel, Adblue, servicing and maintenance and driver labour listed in Table 16 through Table 19 respectively,

4) The future value of each annual variable operating cost was computed by multiplying the annual cost by its compounding inflation factor using Eqt (iv),

5) Each future value was then backward converted to its present value using Eqt (i), and the

6) Present values were summed for the 21 year service life to obtain their net present value.

Bus and driver total NPV variable operating costs are shown separately below in Table 20 and Table 21 respectively, with breakdowns for the latter at the 3 typical traffic speeds of 30km/h, 45km/h and 75km/h encountered on Brisbane roads and busways during peak and off-peak periods.

Table 20: Total Variable Operating Costs for the 5 Bus Types

Reference 2 Door 12.5m Rigid Bus Total Variable Operating Cost (Dollars)	Relative Total Variable Operating Cost Factors for High Capacity Buses			
	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,582,105	140.3%	112.6%	119.2%	119.3%

Table 21: Total Variable Operating Costs for Bus Driver at Different Brisbane Road Traffic Speeds

Bus Driver Variable Operating Costs at 30km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$2,092,395	$2,591,968	$2,211,407	$2,281,983	$2,520,007
Bus Driver Variable Operating Costs at 45km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,610,812	$2,110,385	$1,771,340	$1,797,633	$2,030,121
Bus Driver Variable Operating Costs at 75km/h Average Traffic Speed				
2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Bus
$1,275,918	$1,724,288	$1,430,910	$1,479,345	$1,634,337

3. Net Present Value Whole-of-Life Costs

3.1 Background

Part 2 of this report calculated the ownership, fixed annual operating and variable operating costs for the 4 high capacity bus types relative to those of a standard two door 12.5m rigid route bus. In this Part 3, the present values of all costs for the 5 bus types are summed to compare their net present values over whole-of-life, their average bus costs per kilometre and average bus costs per pax-kilometre.

The net present value of driver variable labour costs calculated in Part 2 are also re-examined to assess whole-ofl-life average bus and driver costs per kilometre and per pax-kilometre at 3 traffic speeds commonly encountered on Brisbane roads during peak and off-peak traffic periods.

3.2 Net Present Value of Bus Whole-of-Life Costs

Table 22 below summarises the net present values of all expenses and recoveries incurred by a bus operator over the whole-of-life of the 5 alternative bus types. Based on their relative whole-of-life costs per kilometre, the 5 bus types have been ranked as follows:

1. Two Door 12.5m Rigid Bus - $2.01/km
2. Two Door 14.5m Extended Rigid Bus - $2.30/km
3. Three Door 18m Articulated Superbus - $2.56/km
4. Two Door 18m Articulated Bus - $2.58/km
5. Two Door 12.5m Double Deck Bus - $2.88/km.

Table 22: Total Net Present Value Whole-of-Life Bus Costs

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Bus Ownership Costs					
Bus Procurement Financial Costs	$538,610	$763,031	$628,378	$852,800	$864,020
Less Tax Deduction Recoveries	-$53,861	-$76,303	-$62,838	-$85,280	-$86,402
Less Resale Recovies at Retirement	-$10,000	-$14,167	-$11,667	-$15,833	-$16,042
Depot Upgrade Costs Amortised to 5 Buses	$6,000	$23,000	$18,000	$18,000	$18,000
Major Bus Overhaul and Refurbishment Costs	$129,000	$150,000	$137,000	$142,000	$140,000
Total Ownership Costs	$609,749	$845,561	$708,873	$911,687	$919,576
Whole-of-Life Fixed Operating Costs					
Bus Statutory Compliance Costs	$122,464	$285,390	$153,712	$176,022	$147,661
Bus Insurance Costs	$68,562	$87,948	$86,687	$87,948	$87,948
Depot Bus Accommodation Costs	$35,578	$35,580	$40,851	$50,075	$50,075
Time Based Bus Servicing Costs	$57,732	$66,373	$57,731	$62,064	$62,064
Total Bus Fixed Operating Costs	$284,336	$475,291	$338,981	$376,109	$347,748
Whole-of-Life Variable Operating Costs					
Diesel Consumption Costs	$1,093,769	$1,526,189	$1,220,951	$1,246,387	$1,246,387
AdBlue Consumption Costs	$23,109	$42,918	$30,813	$35,215	$35,215
Distance Based Servicing & Maintenance Costs	$465,227	$650,043	$528,956	$604,157	$605,432
Total Bus Variable Operating Costs	$1,582,105	$2,219,150	$1,780,720	$1,885,759	$1,887,034
Total Whole-of-Life Bus Costs					
Total Bus Ownership + Fixed + Varable Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	$2.01/km	$2.88/km	$2.30/km	$2.58/km	$2.56/km
Bus Ranking by Cost per Kilometre	1	5	2	4	3
Maximum Seated Plus Standing Capacity	75	116	92	88	112
Whole-of-Life Cost per Pax-Kilometre	2.68¢/pax-km	2.48¢/pax-km	2.50¢/pax-km	2.93¢/pax-km	2.29¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	4	2	3	5	1

Based on their relative whole-of-life costs per pax-kilometre when carrying maximum passenger loads, the 5 bus types have however been ranked differently as follows:

1 Three Door 18m Articulated Superbus - 2.29¢/pax-km
2 Two Door 12.5m Double Deck Bus - 2.48¢/pax-km
3 Two Door 14.5m Extended Rigid Bus - 2.50¢/pax-km
4 Two Door 12.5m Rigid Bus – 2.68¢/pax-km
5 Two Door 18m Articulated Bus - $2.93¢/pax-km.

3.3 Net Present Value of Bus and Driver Whole-of-Life Costs

Driver variable labour rates and costs for the 5 bus types have been calculated in Part 2 and summarised in Table 19 and Table 21 respectively for 30km/h, 45km/h and 75km/h traffic speed conditions. In this section, NPV whole-of-life bus and driver costs have been consolidated to assess their combined effects on the cost per kilometre and cost per pax-kilometre of operating services in typical peak and off-peak traffic speed periods. Combined whole-of-life bus and driver costs have also been used to evaluate the expected savings of substituting a high capacity bus in lieu of operating two standard 12.5 rigid route buses to augment overloaded services.

3.3.1 Whole-of-Life Bus and Driver Costs in 30km/h Traffic Speed Conditions

Bus services operating in 30km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

Net present value whole-of-life bus and driver costs in 30km/hr traffic speed conditions have been consolidated below in Table 23. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 30km/h traffic speed conditions:

1 Two Door 12.5m Rigid Bus - $3.71/km
2 Two Door 14.5m Extended Rigid Bus - $4.10/km
3 Two Door 18m Articulated Bus - $4.43/km
4 Three Door 18m Articulated Superbus - $4.61/km
5 Two Door 12.5m Double Deck Bus - $4.98/km.

Table 23: Total Bus and Driver Costs Operating in 30km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 30km/h	$2,092,395	$2,591,968	$2,211,407	$2,281,983	$2,520,007
Total Bus and Driver Costs at 30km/h	**$4,568,585**	**$6,131,970**	**$5,039,981**	**$5,455,538**	**$5,674,365**
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	$3.71/km	$4.98/km	$4.10/km	$4.43/km	$4.61/km
Bus Ranking by Cost per Kilometre	1	5	2	3	4
Maximum Seated Plus Standing Capacity	75	116	92	88	112
Whole-of-Life Cost per Pax-Kilometre	4.95¢/pax-km	4.30¢/pax-km	4.45¢/pax-km	5.04¢/pax-km	4.12¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	4	2	3	5	1

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 30km/h traffic speed conditions:

1 Three Door 18m Articulated Superbus - 4.12¢/pax-km
2 Two Door 12.5m Double Deck Bus - 4.30¢/pax-km
3 Two Door 14.5m Extended Rigid Bus – 4.45¢/pax-km
4 Two Door 12.5m Rigid Bus – 4.95¢/pax-km
5 Two Door 18m Articulated Bus - $5.04¢/pax-km.

3.3.2 Whole-of-Life Bus and Driver Costs in 45km/h Traffic Speed Conditions

Bus services operating in 45km/h peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Bus services operating in 45km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional suburb via a combination of local and major arterial or sub-arterial roads such as Moggill, Beaudesert, Waterworks, Wynnum or Old Northern Road.

Net present value whole-of-life bus and driver costs in 45km/hr traffic speed conditions have been consolidated below in Table 24. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 45km/h traffic speed conditions:

1 Two Door 12.5m Rigid Bus - $3.32/km
2 Two Door 14.5m Extended Rigid Bus - $3.74/km
3 Two Door 18m Articulated Bus - $4.04/km
4 Three Door 18m Articulated Superbus - $4.21/km
5 Two Door 12.5m Double Deck Bus - $4.59/km.

Table 24: Total Bus and Driver Costs Operating in 45km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 45km/h	$1,610,812	$2,110,385	$1,771,340	$1,797,633	$2,030,121
Total Bus and Driver Costs at 45km/h	$4,087,002	$5,650,387	$4,599,914	$4,971,188	$5,184,479
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	$3.32/km	$4.59/km	$3.74/km	$4.04/km	$4.21/km
Bus Ranking by Cost per Kilometre	1	5	2	3	4
Maximum Seated Plus Standing Capacity	75	116	92	88	112
Whole-of-Life Cost per Pax-Kilometre	4.43¢/pax-km	3.96¢/pax-km	4.06¢/pax-km	4.59¢/pax-km	3.76¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	4	2	3	5	1

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 45km/h traffic speed conditions:

1 Three Door 18m Articulated Superbus - 3.76¢/pax-km
2 Two Door 12.5m Double Deck Bus - 3.96¢/pax-km
3 Two Door 14.5m Extended Rigid Bus – 4.06¢/pax-km
4 Two Door 12.5m Rigid Bus – 4.43¢/pax-km
5 Two Door 18m Articulated Bus - $4.59¢/pax-km.

3.3.3 Whole-of-Life Bus and Driver Costs in 75km/h Traffic Speed Conditions

Bus services operating in 75km/h peak traffic speed conditions travel between the CBD and an outer Brisbane suburb substantially on a busway or bypass the CBD on a major ring road such as the Western, Gateway and Logan Motorway.

Bus services operating in 75km/h off-peak traffic speed conditions travel between the CBD and an outer Brisbane or surrounding regional town/city suburb substantially via a major highway such as the Bruce, Ipswich or Pacific Motorway.

Net present value whole-of-life bus and driver costs in 75km/hr traffic speed conditions have been consolidated below in Table 25. The 5 bus types have been ranked as follows based on their relative whole-of-life bus and driver costs per kilometre in 75km/h traffic speed conditions:

1 Two Door 12.5m Rigid Bus - $3.05/km
2 Two Door 14.5m Extended Rigid Bus - $3.46/km
3 Two Door 18m Articulated Bus - $3.78/km
4 Three Door 18m Articulated Superbus - $3.89/km
5 Two Door 12.5m Double Deck Bus - $4.28/km.

Table 25: Total Bus and Driver Costs Operating in 75km/hr Traffic Speed Conditions

Net Present Value Whole-of-Life Costs	2 Door 12.5m Rigid Bus	2 Door 12.5m Double Deck Bus	2 Door 14.5m Extended Rigid Bus	2 Door 18m Articulated Bus	3 Door 18m Articulated Superbus
Total Whole-of-Life Bus Costs	$2,476,190	$3,540,002	$2,828,574	$3,173,555	$3,154,358
Total Whole-of-Life Driver Costs at 75km/h	$1,275,918	$1,724,288	$1,430,910	$1,479,345	$1,634,337
Total Bus and Driver Costs at 75km/h	$3,752,108	$5,264,290	$4,259,484	$4,652,900	$4,788,695
Whole-of-Life Travelled Kilometres	1,230,600	1,230,600	1,230,600	1,230,600	1,230,600
Whole-of-Life Cost per Kilometre	$3.05/km	$4.28/km	$3.46/km	$3.78/km	$3.89/km
Bus Ranking by Cost per Kilometre	1	5	2	3	4
Maximum Seated Plus Standing Capacity	75	116	92	88	112
Whole-of-Life Cost per Pax-Kilometre	4.07¢/pax-km	3.69¢/pax-km	3.76¢/pax-km	4.30¢/pax-km	3.47¢/pax-km
Bus Ranking by Cost per Pax-Kilometre	4	2	3	5	1

The 5 bus types have however been ranked differently based on their relative whole-of-life bus and driver costs per pax-kilometre when carrying maximum passenger loads in 75km/h traffic speed conditions:

1 Three Door 18m Articulated Superbus – 3.47¢/pax-km
2 Two Door 12.5m Double Deck Bus – 3.69¢/pax-km
3 Two Door 14.5m Extended Rigid Bus – 3.76¢/pax-km
4 Two Door 12.5m Rigid Bus – 4.07¢/pax-km
5 Two Door 18m Articulated Bus - $4.30¢/pax-km.

3.3.4 High Capacity Bus and Driver Substitution Cost Savings on Overloaded Services

A key question posed by a bus operator who currently operates only standard capacity 12.5m route buses, is whether it is cheaper to augment an overloaded peak service with a second bus and driver to increase its service frequency (and thereby carrying capacity) or to subsitute a high capacity bus and driver on the overloaded peak service?

The decision to either augment an overloaded peak service with an additional standard bus and driver or to step in a high capacity bus and driver has 3 flow-on considerations, namely:

- No operator would consider procuring a high capacity bus solely to augment overloaded peak services and to otherwise sit idle in the depot yard during the off-peaks.
- A second standard 12.5m rigid bus would increase the peak service frequency and complete its peak journey marginally faster than a substituted high capacity bus carrying more passengers at a slower average service speed. Thus the former option would be more likely to improve patronage and revenue over the long term than the latter option.

  (Note: The Stage 1 operational performance study has identified that the average service speed difference between a standard rigid bus and high capacity bus loaded to maximum capacity falls exponentially to a neglible difference in 45km/h or higher traffic speed conditions on route lengths of 15km or longer).
- A second standard 12.5m rigid bus can be returned to depot after the peak has passed but the substituted high capacity bus would need to continue operating off-peak services. On off-peak services, the high capacity bus would be underutilised and would cost more to operate than a standard 12.5m rigid bus.

The following assumptions have therefore been applied to resolve the question:

- Total passengers carried on 2 rigid buses equals total passengers carried one substituted high capacity bus. The ticket revenues for either option therefore cancel out and do not enter into the net operating cost assessment.
- Based on existing candidate HFP bus service timetables, a typical bus and driver will deliver peak weekday service kilometres to off-peak weekday, holiday and weekend service kilometres in the approximate ratio of 1:4,
- Whole-of-life costs of an additional 12.5m rigid bus will be avoided if a high capacity bus was substituted on the overloaded peak services,
- One quarter of the whole-of-life labour costs per kilometer of an additional 12.5m rigid bus driver would be avoided if a high capacity bus was substituted on the overloaded peak services, and
- Three quarters of the whole-of-life cost to operate off-peak services with a high capacity bus and driver in lieu of a 12.5m rigid bus and driver would be incurred if a high capacity bus was substituted on the overloaded peak services.

Final Project Summary Report

Research & Analysis of High Capacity Vehicle Use

TransLink Division

Department of Transport and Main Roads

Prepared by:

MRCagney Pty Ltd

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1. Introduction

1.1 Study Intention

MRCagney has been appointed by the TransLink Division of the Queensland Department of Transport and Main Roads (*TransLink Division*) to undertake research and analysis of the uses of high capacity vehicles within its South East Queensland bus network.

The intention of the study is to provide guidance to TransLink on the basic questions of:

- Based on network demand, when is it appropriate to acquire and use high capacity vehicles i.e. under what circumstances should a larger bus be used, rather than a second, smaller standard bus?
- If the use of a high capacity vehicle is warranted, what is the most appropriate vehicle type to use in a given situation?
- What are the issues and impacts relating to the use of high capacity vehicles, in terms of compatibility with existing infrastructure and current infrastructure design standards?
- What other constraints, in terms of legislation and policy, might influence the decision to use a high capacity vehicle?

1.2 Assessments Undertaken

The study has focussed its investigation on four types of high capacity vehicle (HCV) currently being used within the TransLink bus network, and comparing them against the standard specification of a modern two door, 12.5m rigid bus. The four types of HCV assessed were:

- Two Door 12.5m Double Deck Bus;
- Two Door 14.5m Rigid Bus;
- Two Door 18m Articulated Bus; and
- Three Door 18m Articulated '*Superbus*'.

One thing became clear during the study: any type of vehicle is only suitable for implementation if the corridor and infrastructure which it needs to use, can accommodate its specific geometrical requirements. The retrofitting of corridors and other infrastructure to accommodate larger vehicles may be too costly or impactful when compared to the benefits the larger vehicles may bring.

The areas of investigation covered by this study included:

- Characteristics of HCVs available in Australia and overseas;
- The legislation and government policies that relate to all buses, including HCVs;
- Assessment of key bus infrastructure to determine its ability to accommodate the dimensions, weight and manoeuvrability requirements of each vehicle type. This included:
  - Bus stations;
  - Busway stations;
  - Busway runningways;
  - Park'n'rides;
  - Roadside bus stops;
  - Bus depots;
  - Inter-modal services; and
  - Pavement impacts.

- Vehicle operational performance relating to:
  - Acceleration and deceleration rates, and travel speeds;
  - Passenger boarding and alighting rates;
  - Passenger alighting preferences (choice of door);
  - Impacts on effective station capacity; and
  - Peak and Off-peak capacity utilisation
- Whole-of-life vehicle costs incorporating:
  - Vehicle purchase cost;
  - Vehicle operational life;
  - Cleaning, maintenance and overhaul costs;
  - Financing costs;
  - End-of-life resale value;
  - Fuel costs;
  - Registration, compliance and insurance costs;
  - Labour costs for drivers and maintenance staff; and
  - Depot upgrades needed to accommodate larger vehicles.

2. Vehicle Types Assessed

This section provides an overview of the types of high capacity vehicles currently in operation in the TransLink network, along with the standard 12.5m rigid bus used as a basis for comparison. The assessment outcomes are summarised and compared in Table 2.1 below.

Table 2.1: Comparison of Vehicle Statistics and Assessment Outcomes

	Two Door Standard Rigid Bus	Two Door Double Deck Bus	Two Door Extended Rigid Bus		Two Door Articulated Bus	Three Door Articulated *Superbus*
Vehicle Overview						
Vehicle length	12.5m	12.5m	14.5m		18m	18m
Number of doors	2	2	2		2	3
Axles	2	3	3		3	3
Passenger capacity						
Seated	44	96	56		64 (LC)[1]	52
Standing	31	20	36		26 (LC)	60
Total	75	116	92		90 (LC)	110
Passengers per metre of bus length	6.00	9.28	6.34		5.00	6.11
Average purchase cost	$450,000	$700,000	$550,000		$750,000	$750,000
Loading Performance						
Measured average boarding time per pax	2.7s	3.1s	3.1s		3.5s (LC)[2] 2.6s (BT)	3.7s
Measured average alighting time per pax	2.0s	2.6s	2.0s		2.1s (LC) 1.7s (BT)	2.0s
Dwell time per pax (no standees)	2.5s	3.0s	2.5s		2.9s	2.9s
Dwell time per pax (with standees)	3.0s	undetermined	3.3s		3.1s	3.1s
Busway and Head of Bay Operation						
Gap between buses for independent pull out[3]	5m	5m	5m	8m	5m	5m
Buses per 55m busway platform	3	3	3	2	2	2
Pax per m of platform	4.29	6.63	4.72	4.09	3.91	4.78
Maximum theoretical full loads boarding per hour*	18.7	12.3	15.4	10.7	10.9	9.0
Maximum theoretical pax boardings per hour*	1401	1422	1412	985	985	991
Whole-of-life Costs						
Whole-of-life cost per kilometre	$2.01	$2.88	$2.30		$2.58	$2.56
Whole-of-life cost per pax-kilometre	$2.68	$2.48	$2.50		$2.87	$2.33

[1] For the 18m two-door articulated bus, Brisbane Transport and Logan City Bus Service operate vehicles with slightly different configurations. The LCBS version was used for assessment as it provides a slightly higher passenger capacity, and forms a better basis of comparison for the three-door articulated `Superbus' which only they operate.

2 The average boarding times for all LCBS services are influenced by the ability for passengers to top up their go card on board the bus, which is not permissible on BT services. This increases the average boarding time, average dwell time and average alighting time when the extended presence of a person interacting with the driver limits access to the front door. Analysis shows that on LCBS, there are 46 cash go card top-ups recorded for every 1000 boardings, meaning roughly 1 person in every 20 boarding a LCBS bus is doing so.

[3] For the 14.5m extended rigid vehicle, busway platform capacity is assessed both with a 5m and 8m gap between the vehicle in front. The larger gap allows safer exiting of the platform when the vehicle in front has not moved, and in the opinion of the authors, should inform future design standards.

Standard Rigid Bus

Length	12.5m
Number of doors	2
Axles	2
Passenger capacity:	
Seated	44
Standing	31
Total	**75**
Passengers per metre of bus length	6.00
Average purchase cost	$450,000

Loading Performance

Measured average boarding time per pax	2.7s
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.5s
Dwell time per pax (with standees)	3.0s

Vehicle Overview

The 12.5m rigid bus has been the mainstay of the Australian bus industry for several decades. Produced in large volumes, they are relatively easy to procure either from Australian bus builders or fully built imported vehicles.

The key variance between different models are the drivetrain (diesel or gas), door design and interior configuration. Depending on seating configurations, each bus can carry as many as 75 passengers (seated and standing), although the legal carrying capacity of the bus is governed by total axle loads, not physical internal space.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	3
Pax per m of platform	4.29
Maximum theoretical full loads boarding per hour [4]	18.7
Maximum theoretical pax boardings per hour	1401

Compatibility and Efficiency

A key advantage of the 12.5m rigid bus is that virtually all existing bus infrastructure can accommodate the size and manoeuvring of this vehicle, including stops, stations, busways and depots.

The ease of manoeuvring of a 12.5m bus usually allows drivers to pull up at bus stops so that both front and rear doors are closely aligned to the kerb, improving alighting efficiency.

Operational efficiency of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. The specification of narrow rear doors on buses of this type represents a limitation to achieving maximum operational efficiency at stops and stations.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.01
Whole-of-life cost per pax-kilometre	$2.68

Cost Effectiveness

As the least expensive vehicle type to procure, maintain and operate, the 12.5m rigid bus offers the lowest per km whole-of-life cost, though ranks less well on a whole-of-life cost per passenger kilometre basis.

Summary

Versatile in their operation, easy to procure and compatible with virtually all existing infrastructure, the 12.5m rigid bus is anticipated to remain the primary vehicle type in the TransLink bus fleet. Only the 12.5m standard rigid bus is universally useable, including being the only vehicle type that can be used on the 30 TMR identified, steep-incline Notified Roads.

It is recommended that TransLink take a more active role in working with their contracted operators to determine the most appropriate specifications for interior configuration, seating layout and door sizes, and encourage operators to procure vehicles that provide the maximum possible operational efficiency, rather than the maximum volume of seating.

[4] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

Double Deck Rigid Bus

Length	12.5m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	96
Standing	20
Total	**116**
Passengers per metre of bus length	9.28
Average purchase cost	$700,000

Loading Performance

Measured average boarding time per pax	3.1s
Measured average alighting time per pax	2.6s
Dwell time per pax (no standees)	3.0s
Dwell time per pax (with standees)	undetermined

Vehicle Overview

Double deck urban route buses are common in many parts of the world, including the UK and Hong Kong.

Although relatively uncommon in Australasia, double deck buses can be a cost effective high capacity vehicle. 12.5m double deck buses built locally by Bustech are currently being trialled in both Sydney and South East Queensland. Similar trials of Malaysian-built double deck city buses are now underway in Auckland.

Per metre of road or kerb space, double deck buses offer the highest passenger carrying capability, which is critical in congested networks.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	3
Pax per m of platform	6.63
Maximum theoretical full loads boarding per hour[5]	12.3
Maximum theoretical pax boardings per hour	1422

Compatibility and Efficiency

A key advantage of the 12.5m double deck bus is that it has the same manoeuvrability as a standard 12.5m rigid bus. Most existing infrastructure can accommodate the size and manoeuvring of this vehicle, though some concern exists about height clearances within the King George Square station, some depot workshops, building awnings and street trees. These buses are not able to enter the Myer Centre bus station, nor are they able to pass under the eight bridges that exist at locations in the TransLink bus network that may need to accommodate HCV services.

Operational efficiency of passenger boarding and alighting is impacted by the number and width of doors, internal seating configuration and staircase design. The concern that passenger movement between decks increases dwell times is offset in the busiest locations by the need for only one vehicle movement (compared to two smaller buses).

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.88
Whole-of-life cost per pax-kilometre	$2.48

Cost Effectiveness

Cheaper than an articulated bus and providing slightly more carrying capacity, the 12.5m double deck bus offers the highest per km whole-of-life cost, but ranks in the mid-range on a whole-of-life cost per passenger kilometre basis.

Summary

The only genuine reason identified why double deck buses should not be introduced into the TransLink network is where height restrictions limit their use. They use the same physical footprint as a 12.5m standard bus, yet load more passengers than an 18m articulated bus. At congested locations in the CBD or Cultural Centre, shorter bus lengths result in more buses able to access stops simultaneously.

Anecdotally, some passengers are attracted to the novelty of this bus type, and the elevated view available from the upper deck. This can increase patronage in the short-term, with long term benefits still to be assessed.

It is recommended that TransLink continue to investigate double decker buses for use in Queensland. Models by other manufacturers, or the revised design Bustech vehicles, may be provide superior performance to the vehicles on which this assessment has been based.

[5] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

Extended Rigid Bus

Length	14.5m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	56
Standing	36
Total	**92**
Passengers per metre of bus length	6.34
Average purchase cost	$550,000

Loading Performance

Measured average boarding time per pax	3.1s
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.5s
Dwell time per pax (with standees)	3.3s

Vehicle Overview

The use of 14.5m extended rigid buses has become increasingly common over the last decade, resulting from the adoption of tag steer rear tandem axles, which significantly improves manoeuvrability.

The additional 2m length of the 14.5m vehicle enables a higher total carrying capacity of up to 92 people. 14.5m buses can be built for a relatively low capital cost (approximately $550,000) which means they are cheaper on a per passenger carrying capacity basis than 12.5m standard rigid buses. Operating costs are also marginally higher than for 12.5m standard buses, but again lower when compared on a per passenger carrying capacity basis.

Busway Performance

Gap between buses for independent pull out	5m	8m
Buses per 55m busway platform	3	2
Pax per m of platform	4.72	4.09
Maximum theoretical full loads boarding per hour[6]	15.4	10.7
Maximum theoretical pax boardings per hour	1412	985

Compatibility and Efficiency

The biggest problem with the 14.5m extended rigid buses is that they have the poorest manoeuvrability of any bus type, requiring wider turning circles. At linear head-of-bay stops, they need an additional 3m between a bus in front of them to pull out without increasing the rear tail sweep beyond that of a 12.5m standard bus. This tail sweep issue regularly causes damage to kerbside street furniture, and poses a risk to passengers waiting at stops and platforms.

If this increased gap between buses were to be enforced at busway stations, it would reduce the number of buses that can simultaneously service a 55m platform from 3 to 2.

Operational efficiency in terms of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. The specification of wide rear doors on buses of this type is critical.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.30
Whole-of-life cost per pax-kilometre	$2.50

Cost Effectiveness

The extended rigid bus is the second-least expensive vehicle type to procure, maintain and operate on a per km whole-of-life cost, and ranks mid-range on a whole-of-life cost per passenger kilometre (roughly the same as a double deck bus).

Summary

The 14.5m extended rigid bus presents somewhat of a conundrum, purely due to their poor manoeuvrability. Where infrastructure - particularly stops and stations - has been designed to accommodate this type of bus, then they are a suitable choice for implementation.

However, in locations with geometrically constrained infrastructure, they represent a genuinely increased collision risk due to the large rear tail swing, when turning at full lock.

[6] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

Two-door Articulated Bus

Length	18.0m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	64
Standing	26
Total	**90**
Passengers per metre of bus length	5.00
Average purchase cost	$750,000

Minor variation exists between models owned by Brisbane Transport (BT) and Logan City Bus Service (LCBS), with a total capacity of 85 pax and 90 pax respectively. The LCBS configuration has been used for this comparison against their three-door articulated buses.

Loading Performance

Measured average boarding time per pax	3.5s (LC)[7] 2.6s (BT)
Measured average alighting time per pax	2.1s (LC) 1.7s (BT)
Dwell time per pax (no standees)	2.9s
Dwell time per pax (with standees)	3.1s

Vehicle Overview

18m articulated buses have been used in Australia for many years, rising to popularity in the 1980's. Two different configuration of articulated buses were assessed in this study, comparing the two-door and three-door models.

The two-door buses are designed to maximise the number of seats, at the expense of reduced total passenger load, poorer passenger circulation and slower alighting speeds.

The two-door configuration used by LCBS can carry up to 90 passengers, slightly more than the similarly configured BT buses.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	2
Pax per m of platform	3.91
Maximum theoretical full loads boarding per hour[8]	10.9
Maximum theoretical pax boardings per hour	985

Compatibility and Efficiency

A key advantage of the 18m articulated bus is that despite its length, it offers similar manoeuvrability to a 12.5m rigid bus. However, bus stops and layover bays need to be lengthened, and some existing depots would need to be modified to accommodate them.

Fortunately, the use of articulated buses was considered as part of the standard design of Brisbane's busways, and these buses are regularly used on the busway network. A common problem can be the difficulty for the rear half of the bus to move laterally close enough to the kerb to allow DDA compliant alighting from the rear door.

Operational efficiency in terms of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. These are the key differences between the two-door and three-door articulated buses.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.58
Whole-of-life cost per pax-kilometre	$2.87

Cost Effectiveness

Equally the most expensive vehicle type to procure, the two-door articulated bus offers a mid-range per km whole-of-life cost, but notably provides the worst outcome on a whole-of-life cost per passenger kilometre.

Summary

The two-door 18m articulated bus costs substantially more than the 14.5m extended rigid bus whilst carrying approximately the same total load. It also costs slightly more than the 12.5m double deck bus, yet offers 22% less passenger capacity.

The three-door versions of 18m articulated buses provide greater total capacity, improved alighting speeds and lower whole-of-life costs. Whilst TransLink is not able to mandate the specification of vehicle that their operators procure, it is recommended that TransLink work with their operators to discourage the procurement of two-door articulated buses.

[7] The average boarding times for all LCBS services are influenced by the ability for passengers to top up their go card on board the bus, which is not permissible on BT services.
[8] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

Three-door Articulated Bus (`Superbus')

Length	18.0m
Number of doors	3
Axles	3
Passenger capacity:	
Seated	52
Standing	60
Total	**110**
Passengers per metre of bus length	6.11
Average purchase cost	$750,000

Loading Performance

Measured average boarding time per pax	3.7s[9]
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.9s
Dwell time per pax (with standees)	3.1s

Vehicle Overview

Structurally and mechanically identical to a two-door articulated bus, the two `Superbus' three-door articulated buses being operated by LCBS are simply a standard specification used by Sydney Buses, and were sourced from Volgren as part of a Sydney Buses production run of around 150 buses.

The three-door configuration used can carry up to 110 passengers, 20 more than the two-door configuration (12 less seated passengers and 34 more standing passengers).

The interior design of this bus provides additional standing/circulation areas around the middle and rear doors, and a slightly wider entry area at the front door which improves boarding speeds.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	2
Pax per m of platform	4.78
Maximum theoretical full loads boarding per hour[10]	9.0
Maximum theoretical pax boardings per hour	991

Compatibility and Efficiency

Offering identical manoeuvrability as a two-door articulated bus, the only difference is the number of seats and the additional door. Alighting speeds are faster, and this is most pronounced where large loads of passengers alight at a single stop.

Observation of this vehicle design in operation in Sydney reveals an additional benefit of the modified front entry area, including the mounting locations of ticket readers. The entry design effectively allows two passengers to board at a time, with one using a ticket reader adjacent to the driver, and the other using another reader located approximately 2m along the aisle. This results in average boarding speeds in Sydney being notably faster than in Brisbane, despite still being reliant on magnetic stripe tickets.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.56
Whole-of-life cost per pax-kilometre	$2.33

Cost Effectiveness

Equally the most expensive vehicle type to procure, the three-door articulated bus offers a mid-range per km whole-of-life cost, but notably provides the best outcome on a whole-of-life cost per passenger kilometre.

Summary

The three-door 18m articulated `Superbus' costs 36% more than the 14.5m extended rigid bus whilst carrying 19% more passengers (and only 4 less seated passengers). It also costs slightly (7%) more than the 12.5m double deck bus, but offers 5% less passenger capacity (and 44 fewer seats).

It is recommended that if operators choose to continue to purchase articulated buses, they should be encouraged to consider three-door design, and preferably with reduced seating to improve passenger circulation, comfort and alighting speeds.

[9] The average boarding times for all LCBS services are influenced by the ability for passengers to top up their go card on board the bus, which is not permissible on BT services.
[10] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

3. When to Use a High Capacity Vehicle

3.1 Network Considerations

A key consideration that needs to be made in fleet procurement is when the use of High Capacity Vehicles becomes warranted.

Typically, a bus service operated by a standard 12.5m rigid bus has a capacity of 75 passengers. When the service reaches this capacity, operators are faced with two choices in order to accommodate additional patronage on that route at that time of day, either:

- Purchase a second 12.5m standard rigid bus; or
- Replace the existing bus with a HCV.

There are pros and cons with each choice, and the focus of this study has so far been on the operational and financial aspects of the different fleet options. However, whilst the procurement decision may seem to be based around the needs of the one extra passenger who cannot catch the existing, fully-loaded bus, it's a decision that needs to be made in the context of understanding exactly how it will affect the bus network overall.

There are two dimensions to this: the impact on frequency, and the impact on capacity. Both of these impacts need to be considered for the specific type of service which requires the additional capacity, namely peak express services, and high-frequency services.

Fundamentally, choosing to purchase a second 12.5m standard rigid bus presents the opportunity to increase the frequency of the bus service. Higher frequency services are more attractive to passengers and have the potential to generate additional patronage above the demand level that previously existed. This should not be overlooked, as high frequency routes (BUZ and CityGlider) carry 44% of all 340,000 passengers who use the BT network each weekday.

3.2 Impact on All-Day Services Operating at Peak Times

On regular, all-day services that may have a higher frequency in the peak hour, overloading of buses in the peak again provides the opportunity to increase frequency. A service that runs four times an hour in the peak can be increased to run five times an hour, potentially increasing its attractiveness. The continual increasing of frequency does have an upper limit in terms of increasing the attractiveness of the route, and the question now becomes *at what frequency of service do further improvements no longer attract additional patronage*?

It is generally accepted that a 15 minute headway is the *starting* point for a service to become attractive, allowing passengers the confidence that if they just miss their bus, the next one is a (debatably) acceptable wait away. In some jurisdictions, high-frequency service is defined at 10 minute headways. Improvements beyond 10 minute headways are still desirable, and in the author's view, 5 minute headways are the limit at which additional frequency no longer becomes noticeably more attractive.

This is supported by research by Nielsen and Lange (2007)[11] which suggested that the 'forget the timetable' effect starts at 10 minute headways. Headways of less than 5 minutes were reported to create significant issues with bus bunching, reducing network efficiency and exacerbating traffic congestion.

[11] Nielsen, G, and Lange, T, (2007) "Network Design For Public Transport Success – Theory And Examples", 10th International Conference on Competition and Ownership of Land Passenger. Transport ("Thredbo 10"),

It is thus suggested that TransLink and its operators *begin* to consider deploying HCVs into the network when the required peak frequency of 12.5m standard rigid buses increases beyond six buses an hour or more (10 minute headways or less).

At 10 minute headways, the hourly capacity is 450 pax using 12.5m standard rigid buses. Adding one additional 12.5m standard rigid bus per hour will increase capacity to 525 pax. Swapping the six buses for, say, six 14.5m extended rigid buses will increase the capacity to 552 pax per hour, resulting in a higher total capacity and a reduced whole-of-life per passenger cost.

Six buses an hour also represents a reasonably sized purchase order, allowing the peak fleet requirement for that route to be upgraded in one instance, rather than having a seemingly random mix of bus sizes that are present on some routes[12].

3.3 Impact on Peak-Only Services

On a peak-period-only service, often longer-distance express services, the deployment of a second bus provides increased travel choice.

If the service previously only had a single trip departing at 7:30am, deploying a second bus would allow, perhaps, a departure at 7:20am and another at 7:35am. This in itself should generate additional patronage demand by providing greater convenience and choice of travel time. The question becomes *how much additional demand will be generated by doing this*? This feeds into considerations around the impact on capacity.

Adding a second 12.5m standard rigid bus increases the capacity of the route from 75 passengers, to 150 passengers. In all likelihood, each of the two buses will now have happier, more comfortably seated medium passenger loads, but with some spare capacity.

Alternatively, the same outcome could be achieved by upgrading to a HCV. In this case, the service level would remain the same, and the opportunity to attract new patronage based on improved frequency would be lost. But the increase in available seats and reduced crowding will be attractive and may act to increase patronage, albeit to a lesser degree.

Whether the route in question should be upgraded to a HCV also depends on the operator, and their current fleet mix. If the operator already has HCVs in their fleet, then adding additional vehicles of the same or similar model is not usually seen as a problem.

In the instance that the operator only has 12.5m standard rigid buses, it can become both onerous and financially unattractive to add just one vehicle of a completely different type. Maintenance staff have to be retrained, additional spare parts may need to be kept and drivers may need to upgrade their licences - all just to enable one HCV to be purchased. The Stage 2 Report for this study assumed that HCVs would be procured at no less than five vehicles at a time, in order to gain the economies of scale needed to allow an upgrade to larger vehicles to realise its full benefits.

[12] The authors are aware of the highly complex nature of vehicle scheduling, and whilst in that context the upgrading of an entire route may seem like a gross oversimplification of the service delivery process, it should be seen as an aspiration to provide customers with a consistent product on which they can rely.

3.4 Impact on Traffic Congestion and Runningway Capacity

The impact of vehicle selection on the capacity of a runningway, such as a CBD street or a busway corridor, is often overlooked. The impact on stop capacity is the usual focus of capacity considerations, but each of the different vehicle types also has an impact on road capacity and traffic congestion.

Table 2.1 presented the statistic 'Passengers per metre of bus length', which is repeated below. This is effectively a measure of how efficient each bus type is in carrying passengers, based on the amount of road space that the vehicle utilises.

Table 3.1: Passenger Efficiency per Metre of Bus Length

	Two Door Standard Rigid Bus	Two Door Double Deck Bus	Two Door Extended Rigid Bus	Two Door Articulated Bus	Three Door Articulated *Superbus*
Passengers per metre of bus length	6.00	9.28	6.34	5.00	6.11

In congested traffic environments where buses seem to queue endlessly, such as Adelaide Street or the Victoria Bridge, it becomes highly desirable for the buses to use as little road space as possible so that they reduce their overall contribution to road congestion. This is also true where there are short distances between intersections and buses are unable to move forward at a green light when the road ahead is blocked by queued buses, such as Melbourne Street in South Brisbane approaching the busway entry.

The 12.5m standard rigid bus acts as a benchmark, accommodating 6.0 passengers per metre of length. The two-door articulated buses achieve a notably poorer score of 5.0 passengers per metre. This means that buses needed to carry 900 passengers would require 172 metres of road space if 12.5m standard rigid buses are used, but 198 metres of road space if two-door articulated buses are used (this assumes a two metre gap between each bus).

The three-door articulated bus and the 14.5m extended rigid bus both achieve a modest improvement over a 12.5m standard rigid bus. The 12.5m double deck bus is, however, a clear leader in the space efficiency aspect, benefitting from using the same footprint as a 12.5m standard rigid bus, but carrying over 50% more passengers.

4. Selection of High Capacity Vehicle Types

4.1 Initial Observations

This study has investigated the relative benefits of each vehicle type across a wide range of criteria. Of the five vehicle types investigated, four of them appear to be viable choices for implementation when the capacity of a 12.5m standard rigid bus is reached (the addition of a second 12.5m standard rigid bus is one of the four viable options).

It is clear that the use of two-door articulated buses is fundamentally flawed in a number of ways. This vehicle design, intended to maximise 'seats', then fails to deliver benefits in terms of total carrying capacity, operational efficiency, purchase cost or whole-of-life costs. This vehicle type should thus be excluded from consideration for future procurement, under any circumstances.

4.2 Vehicle Choice Methodology

An original intention of this study was to develop a decision making methodology in a flowchart format that would guide the determination of the most appropriate vehicle type to use in a given situation. Unfortunately, the complexity of the different contributing factors makes such a process more complicated than a simple flowchart can encapsulate.

Instead, we present a series of questions for each vehicle type that will either permit or exclude that vehicle for use. When multiple vehicle types are shown to be viable in a given situation, we present further factors that need to be considered in selecting a specific vehicle type.

One thing is clear:

Any type of vehicle is only suitable for implementation if the corridor and infrastructure which it needs to use, can accommodate its specific geometrical requirements.

In some existing instances where certain HCV types can be used, it is by coincidence, not by design. Infrastructure design standards need be updated to reflect the requirements of whichever types of fleet are the most suitable for a given route, corridor or network region.

Only the 12.5m standard rigid bus is universally useable, including being the only vehicle type that can be used on the 30 TMR identified, steep-incline *Notified Roads*.

Each of the three viable HCV types has its own inherent limitations. For example, a double decker bus won't fit under a low bridge, a 14.5m extended rigid bus won't manoeuvre around tight corners or into some bus stops, and articulated 18m buses won't fit into a workshop shed that was designed for shorter buses.

While roads, bridges and tunnels are harder and costly to retrofit to accommodate HCVs, bus stops are not. The deployment of HCVs based on bus stop capacity, should not preclude HCV deployment, if the bus stop can be retrofitted. State and Local Governments have dedicated funding programs to upgrade bus stops to meet DDA compliance standards by 2021. These funds should also be used to retrofit bus stops to accommodate HCVs.

4.3 Key Criteria for Assessing whether to Include or Exclude each Vehicle Type

The following series of questions for each HCV type to determine whether it *could* be used on a specific corridor or route.

It is inherently assumed that 12.5m standard rigid buses can be used on any existing corridor or route, and that all infrastructure can currently accommodate this vehicle type. Consequently, the use of a second vehicle of this type is a feasible solution for providing additional passenger capacity subject to adequate kerbside space and stop capacity.

4.3.1 Two Door Double Deck 12.5m Bus

Q1: Are there any low-clearance bridges (4.4m or lower) along the corridor that the buses need to pass beneath?
If *no*, proceed to Q2. If *yes*, then exclude this vehicle from further consideration.

Q2: Are there trees, building awnings or other structures (including at stops, stations and layovers) along the corridor that would conflict with the bus?
If *no*, proceed to Q3. If *yes*, proceed to Q2a.

Q2a: Can the conflicts with trees, building awnings or other structures be affordably trimmed or modified to remove conflict with the bus?
If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Are the depots at which the vehicle would be based able to handle the additional height and weight of a double deck bus? This includes hoists, roof heights, door heights, wash bays and fuelling facilities.
If *yes*, the 12.5m double deck bus can be considered a viable option for use on this corridor. If *no*, proceed to Q3a.

Q3a: Can the depot infrastructure be affordably modified to accommodate the double deck buses?
If *yes*, the 12.5m double deck bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.3.2 Two Door Extended Rigid 14.5m Bus

Q1: Are there any turns at intersections, or at access or egress points from bus stations, that the vehicle cannot safely complete without crossing centrelines, mounting kerbs etc?
If *no*, proceed to Q2. If *yes*, proceed to Q1a.

Q1a: Can these turning conflicts be affordably addressed, through physical modification of intersections, kerbs, medians, driveways etc?
If *yes*, proceed to Q2. If *no*, then exclude this vehicle from further consideration.

Q2: Do the on-road bus stops that the bus would serve provide adequate length for the vehicle to stop, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*? This includes providing adequate pull-out distance (10m minimum and 15m minimum for indented bays) so the vehicle can exit the stop without needing to be at full lock and prevent excessive rear tail swing over the kerb area.
If *yes*, proceed to Q3. If *no*, proceed to Q2a.

Q2a: Can the on-road bus stops be affordably modified to accommodate the manoeuvring needs of the bus?
If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Do the individual platforms or stops within the stations that the bus would serve provide adequate length for the vehicle to stop, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?
If *yes*, proceed to Q4. If *no*, proceed to Q3a.

Q3a: Can the individual platforms or stops within the stations be affordably modified to accommodate the manoeuvring needs of this type of bus?
If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q4: Do the layover locations provided within the network provide adequate space for the manoeuvrability and parking needs of this type of bus?
If *yes*, proceed to Q5. If *no*, proceed to Q4a.

Q4a: Can the layover locations be affordably modified, or alternative locations developed, to accommodate the manoeuvring and parking needs of this type of bus?
If *yes*, proceed to Q5. If *no*, then exclude this vehicle from further consideration.

Q5: Are the depots at which the vehicle would be based able to handle the additional length, weight and manoeuvrability requirements of a 14.5m extended rigid bus? This includes hoists, service pits, workshop building depths, wash bays and fuelling facilities.
If *yes*, the 14.5m extended rigid bus can be considered a viable option for use on this corridor. If *no*, proceed to Q5a.

Q5a: Can the depot infrastructure be affordably modified to accommodate the 14.5m extended rigid bus?
If *yes*, the 14.5m extended rigid bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.3.3 Three-Door Articulated 18m Bus

Q1: Are there any turns at intersections, or at access or egress points from bus stations, that the vehicle cannot safely complete without crossing centrelines, mounting kerbs etc?
If *no*, proceed to Q2. If *yes*, proceed to Q1a.

Q1a: Can these turning conflicts be affordably addressed, through physical modification of intersections, kerbs, medians, driveways etc?
If *yes*, proceed to Q2. If *no*, then exclude this vehicle from further consideration.

Q2: Do the on-road bus stops that the bus would serve provide adequate length for the vehicle to stop with the rear door closely located and parallel to the kerb, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?

If *yes*, proceed to Q3. If *no*, proceed to Q2a.

Q2a: Can the on-road bus stops be affordably modified to accommodate the manoeuvring needs of the bus?

If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Do the individual platforms or stops within the stations that the bus would serve provide adequate length for the vehicle to stop with the rear door closely located and parallel to the kerb, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?

If *yes*, proceed to Q4. If *no*, proceed to Q3a.

Q3a: Can the individual platforms or stops within the stations be affordably modified to accommodate the manoeuvring needs of this type of bus?

If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q4: At stations with physical barriers dividing passenger waiting areas from the runningway (e.g. King George Square), are the door or gate locations suitably located for each of the three bus doors?

If *yes*, proceed to Q5. If *no*, proceed to Q4a.

Q4a: Can the barrier door or gate locations be affordably modified to match the positions of all three bus doors?

If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q5: Do the layover locations provided within the network provide adequate space for the manoeuvrability and parking needs of this type of bus?

If *yes*, proceed to Q6. If *no*, proceed to Q5a.

Q5a: Can the layover locations be affordably modified, or alternative locations developed, to accommodate the manoeuvring and parking needs of this type of bus?

If *yes*, proceed to Q6. If *no*, then exclude this vehicle from further consideration.

Q6: Are the depots at which the vehicle would be based able to handle the additional length, weight and manoeuvrability requirements of an 18m articulated bus? This includes hoists, service pits, workshop building depths, wash bays and fuelling facilities.

If *yes*, the 18m articulated bus can be considered a viable option for use on this corridor. If *no*, proceed to Q6a.

Q6a: Can the depot infrastructure be affordably modified to accommodate the 18m articulated bus?

If *yes*, the 18m articulated bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.4 Choosing Between Viable Vehicle Types

After assessing each vehicle type, a list of viable alternatives will remain.

If none of the three HCV types are viable for use in the given corridor, or the delay in modifying infrastructure to allow their use would be too lengthy, then the use of a second 12.5m standard rigid bus is the appropriate outcome.

If one or more HCV types are viable, then the decision between vehicle types needs to be based on some practical issues relating to the operation of the network, and the procurement, operation and maintenance of the fleet.

The key issues that need to be considered include the following. Each issue could generate a different preferred vehicle type, resulting in the need for a holistic review of the issues in combination.

What vehicle types does the operator already have in their fleet?

It is far simpler and more cost effective for an operator to have large numbers of the same model of bus in their fleet, rather than small numbers of many different models. Consequently, there is a logical argument that if other factors are reasonably comparable, then operators should continue to procure the same types of vehicle they have previously.

For example, if an operator already has a fleet of 18m articulated buses (regardless of the number of doors) and no 14.5m extended rigid buses, it is logical for them to procure three-door articulated buses in the future as they can be immediately incorporated into the fleet.

An exception to this can be created when the number of new vehicles required is large enough to provide economies of scale to reduce their acquisition cost, and justify the investment in upgrading depot facilities, carrying additional spares inventory and retraining staff. This is also the case for an operator who currently does not operate any type of HCV - the acquisition of just one or two HCVs is likely to provide a poor overall outcome given the step change required in depot operations.

How much additional total capacity is needed or will be useful?

The following increases in passenger carrying capacity are offered by each bus type, in comparison to a 12.5m standard rigid bus:

- 14.5m extended rigid bus: 17 additional passengers (23%) including 12 additional seats.
- 18m three-door articulated bus: 35 additional passengers (47%) including 8 additional seats.
- 12.5m double deck bus: 41 additional passengers (55%) including 42 additional seats.
- Second 12.5m standard rigid bus: 75 additional passengers (100%) including 44 additional seats.

In the example of a high frequency route (6 buses per hour or higher) that requires additional capacity, the logical option is whichever bus type is listed highest above, and is suitable based on all other criteria.

The exception to this is if TransLink anticipates future patronage growth and believes that a larger vehicle may present a better long-term option to accommodate that growth.

What distances will passengers be travelling?

This is a fundamentally important issue when considering passenger comfort and resultant desire to catch public transport. The longer passengers need to travel, the greater the justification for increased seating levels.

The double deck bus and the three-door articulated bus have comparable total capacities, purchase costs and whole-of-life operational costs, but the double deck bus has 44 additional seats than the articulated bus.

The 14.5m extended rigid bus has four more seats than the three-door articulated bus, but with a lower total capacity, lower purchase cost and lower whole-of-life cost.

The use of an additional 12.5m standard rigid bus provides an increase in seated capacity similar to the use of a double decker, but at a higher purchase cost (when considering the cost of two buses versus one) and higher whole-of-life costs per passenger km, even if fully loaded.

If routes are long and passengers are travelling long distances, then the double deck and 14.5m extended rigid buses are the most logical choices. The double deck bus provides 32 more seats, but at a higher purchase cost. The decision on vehicle type here should be logically based on the total required capacity.

Do operator depots have the spare parking space required?

Using larger buses requires a larger physical area for the fleet to be parked overnight. Some depots are already at or near capacity in this regard, and deploying HCVs to these locations would trigger a need for additional depot space.

The need to increase depot capacity will need to be included in the economic assessment of any proposal to introduce 14.5m and 18m HCVs into depots that are currently at or near capacity, or if additional 12.5m standard rigid buses are purchased instead of replacing existing fleet with HCVs.

The exception to this is the double deck buses, which have the same footprint as a 12.5m standard rigid bus.

What value does the replaced vehicle represent?

By purchasing HCVs, existing 12.5m standard rigid buses could potentially become redundant. These redundant vehicles have the ability to provide value in any of the following ways:

- To accommodate overall network growth which will require a larger total fleet in the near future;
- If fleet growth is not required, the additional buses will allow the oldest fleet to be retired, reducing average fleet age; or
- If the fleet is relatively young and no buses are of an age at which they would normally be retired, the redundant buses could be sold, realising a financial benefit that will partly offset the purchase cost of the HCVs.

If the increase in passenger capacity is achieved through the use of an additional 12.5m standard rigid bus, no vehicles become redundant, though the number of unutilised vehicles in the off-peak may rise.

5. Summary of Recommendations

5.1 Gain Greater Control over Vehicle Specification

Irrespective of the type of vehicle used, poor decision making regarding basic bus design elements such as seating configuration, number of doors and width of doors has and will continue to result in buses that underperform compared to equivalent vehicles in other jurisdictions. An essential part of this process needs to be discontinuing the use of any form of KPI that reports 'new seats delivered', which encourages the simplistic maximisation of installed seats at the expense of developing operationally efficient and comfortable vehicles. While use of such a metric in the public domain might be more politically palatable and customer focused, compared to quoting total capacity, this should not prevent TransLink from specifying the latter in transport service contracts with its operators. Alternative KPIs could be developed to measure 'new passenger capacity'.

It was revealed in the international research study for the Stage 1 *Operational Performance Evaluation* that significant differences exist between high capacity bus operations overseas and contemporary high capacity bus services operated in South East Queensland. Bus station and bus stop dwell time minimisation was repeatedly identified from the international research as the central focus of best practice leading international mass transit authorities, and all door boarding, wider centre aisles, rear door passenger storage spaces and reduced seating were the strategies typically implemented to achieve rapid alighting and boarding of passengers at bus stations and stops.

To highlight the difference in approaches between Australia and Europe, during a period when Brisbane Transport continued to procure two-door 18.0m articulated buses, the *European Bus System of the Future (EBSF)* project developed and deployed an 18.7m five-door articulated bus into operation in Budapest[13].

It is strongly recommended that TransLink takes a greater and proactive role in specifying the design of the vehicles that they subsidise each operator to purchase and use in the TransLink network. This may extend to working directly with manufacturers to develop a TransLink Vehicle Specification, for each of the available bus sizes, that will detail the requirements needed to achieve operationally efficient outcomes. Development of such specifications would be greatly assisted by the wealth of research undertaken by this study and the EBSF project[14].

5.2 Discontinue the Procurement of Two-Door Articulated Buses

Aside from providing a large number of installed seats, the two-door articulated bus provides no benefit to the TransLink network, and seriously impacts the efficiency and performance of the bus services the vehicles are used on, and the stop infrastructure they access.

It is strongly recommended that TransLink negotiate with its operators to discontinue the procurement of these vehicles.

Additionally, it may be technically feasible and financially viable to modify existing two-door articulated buses to add a third door, modifying seating arrangements at the same time.

[13] http://www.uitp.org/news/pics/pdf/Budapest%20Press%20Release%2002.11.2011.pdf
[14] http://www.ebsf.eu and http://www.ebsf.eu/images/stories/documents/EBSF-DEMONSTRATIONS-Leaflet.pdf

5.3 Continue to Investigate the Use of Double Deck Buses

Inarguably, double deck buses pose an obvious height clearance issue on some routes, whether it be low bridges, overhanging trees, building awnings or incompatible station infrastructure. However, many of the routes on which HCVs may need to operate travel along major roads where numerous heavy vehicles, with the same height constraints also travel, suggesting that double decks buses could be used.

The trial use of the double deck buses by Hornibrook Buslines on Route 315 is a conceptually good example of where double deck buses can be useful. Any route that carries a large load of passengers a relatively long distance is a viable candidate, assuming vertical height clearance is acceptable. High patronage services from Browns Plains, Logan and Redland Bay could also be potential candidates for double deck bus deployment.

Double deck buses also have an undeniable novelty value, making them more attractive to some passengers. The opportunity to travel on the upper deck on a long journey and enjoying the view is an attractor to these buses worldwide. In a time of declining public transport patronage in the TransLink network, the attractiveness to passengers of these buses should not be underestimated.

It is important to note that the Bustech double deck vehicles trialled by TransLink are prototypes, and had inherent flaws that affected their reliability, possibly diminishing their acceptance by the industry. This needs to be acknowledged as a flaw in the *vehicle*, not the vehicle *type*. It is worth noting that the Bustech double deck vehicle design has gone through two further stages of redesign and refinement, with the buses they are now producing for the Sydney market being markedly different to the prototypes.

The new double deck buses being procured for deployment in Auckland in March 2013 are manufactured in Malaysia and are an existing "off-the-shelf" design. Designs used overseas also offer distinctively different features, optimised around efficient passenger loading on high-turnover routes. For example, the double-decker buses in Berlin (MAN Lion's City DD model) have dual staircases and three doors, with a bus length of 13.7m and a total passenger capacity of 121 (83 seated and 38 standing[15]).

Whilst the Australian bus industry is to be commended for developing new double deck bus designs, bus procurers should be encouraged to look further afield in order to obtain the best vehicles available, especially considering equivalent buses built in the United Kingdom are more than one third cheaper than Australian-built buses[16]. This is particularly true with HCVs as they are typically procured in smaller volumes, and with few competing models manufactured in Australia there is little in the way of economies of scale or market price competitiveness.

A clear caveat to this is the logical desire for operators to have a consistent fleet to maximise efficiencies in areas such as scheduled maintenance and spare parts inventory. The procurement of fleet from overseas would need to comprise a sizeable order from a well-established manufacturer, who is able to commit to providing ongoing support and an efficient supply chain to the Australian market.

[15] Sourced from http://www.postauto.ch/en/pag-startseite/pag-ueberuns/pag-portrait/pag-fahrzeugflotte/pag-fahrzeugflotte-fahrzeuge/pag-fahrzeugflotte-fahrzeuge-doppelstock.htm

[16] It is the opinion of the author that exceptionally high-standard, high-capacity vehicles could be built in the United Kingdom to a TransLink specification that meets Australian design regulations. The purchase price of an 18m articulated bus in the UK is approximately $300,000 to $350,000 AUD - less than half that of an Australian manufactured bus. Considering that these buses use the same drivetrains and componentry as Australian models, there is a strong financial argument in support of importing HCV buses rather buying locally. Even after shipping costs, import duties and compliance checks, imported HCVs could still be priced as low as half of the Australian models ($750,000). A hybrid model exists where UK manufacturers ship HCV buses in kit-form, for local assembly.

5.4 Innovate

We refer repeatedly to emerging best practices identified overseas, particularly in Europe. One observation is that vehicle lengths can be far more varied than the 12.5m, 14.5m and 18.0m lengths used as a standard in Australia.

It is noted Kangaroo Bus Lines operate a small number of 13.5m extended rigid buses. This length of bus is rarely seen in Australia, but is quite common in New Zealand and is the standard vehicle length used in Auckland. The additional metre increases passenger capacity by at least 6 passengers. As the vehicles are one metre shorter than the 14.5m extended rigid vehicles used in Queensland, they have better manoeuvrability and would most likely be more compatible with existing infrastructure than the other HCV vehicles assessed.

5.5 Update Standard Infrastructure Designs to Accommodate HCVs

It is noted that current infrastructure design guidelines and manuals do not detail the requirements of 14.5m buses, or double deck buses. This means that infrastructure is currently being designed and constructed that may not accommodate these bus types.

It is recommended that all bus infrastructure design guidelines and manuals be updated to reflect the specific geometric needs of each HCV type.

5.6 Reconsider the Need for High Capacity Vehicles

No HCV outranked the Standard 12.5m Rigid Bus on the like-for-like performance benefit to cost ratio evaluation. Notwithstanding it being the second dearest vehicle to operate based on cost per pax-kilometre, the standard bus significantly outperformed every high capacity bus and was fully compatible with all existing bus stations, stops and depots.

These buses have the greatest flexibility in use, particularly in off-peak services when higher capacity vehicles are less likely to be needed.

Adding a second standard 12.5m rigid bus to the network will provide improved service frequency, creating a more attractive network and potentially increasing patronage. Swapping to a larger bus but retaining the same frequency has far less potential to attract new patronage.

It is suggested that only when a service's frequency needs to increase beyond six buses an hour, that HCVs be automatically considered as a measure to address overcrowding.

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1. Introduction

1.1 Study Intention

MRCagney has been appointed by the TransLink Division of the Queensland Department of Transport and Main Roads (*TransLink Division*) to undertake research and analysis of the uses of high capacity vehicles within its South East Queensland bus network.

The intention of the study is to provide guidance to TransLink on the basic questions of:

- Based on network demand, when is it appropriate to acquire and use high capacity vehicles i.e. under what circumstances should a larger bus be used, rather than a second smaller, standard bus?
- If the use of a high capacity vehicle is warranted, what is the most appropriate vehicle type to use in a given situation?
- What are the issues and impacts relating to the use of high capacity vehicles, in terms of compatibility with existing infrastructure and current infrastructure design standards?
- What other constraints, in terms of legislation and policy, might influence the decision to use a high capacity vehicle?

1.2 Assessments Undertaken

The study has focussed its investigation on four types of high capacity vehicle (HCV) currently being used within the TransLink bus network, and comparing them against the standard specification of a modern two door, 12.5m rigid bus. The four types of HCV assessed were:

- Two Door 12.5m Double Deck Bus;,
- Two Door 14.5m Rigid Bus;
- Two Door 18m Articulated Bus; and
- Three Door 18m Articulated '*Superbus*'.

The areas of investigation covered by this study included:

- Characteristics of HCVs available in Australia and overseas;
- The legislation and government policies that relate to all buses, including HCVs;
- Assessment of key bus infrastructure to determine its ability to accommodate the dimensions, weight and manoeuvrability requirements of each vehicle type. This included:
  - Bus stations;
  - Busway stations;
  - Busway runningways;
  - Park'n'rides;
  - Roadside bus stops;
  - Bus depots;
  - Inter-modal services; and
  - Pavement impacts.
- Vehicle operational performance relating to:
  - Acceleration and deceleration rates, and travel speeds;
  - Passenger boarding and alighting rates;

  - o Passenger alighting preferences (choice of door);
  - o Impacts on effective station capacity; and
  - o Peak and Off-peak capacity utilisation

- Whole-of-life vehicle costs incorporating:
  - o Vehicle purchase cost;
  - o Vehicle operational life;
  - o Cleaning, maintenance and overhaul costs;
  - o Financing costs;
  - o End-of-life resale value;
  - o Fuel costs;
  - o Registration, compliance and insurance costs;
  - o Labour costs for drivers and maintenance staff; and
  - o Depot upgrades needed to accommodate larger vehicles.

2. Vehicle Types Assessed

This section provides an overview of the types of high capacity vehicles currently in operation in the TransLink network, along with the standard 12.5m rigid bus used as a basis for comparison. The assessment outcomes are summarised and compared in Table 2.1 below.

Table 2.1: Comparison of Vehicle Statistics and Assessment Outcomes

	Two Door Standard Rigid Bus	Two Door Double Deck Bus	Two Door Extended Rigid Bus		Two Door Articulated Bus	Three Door Articulated *Superbus*
Vehicle Overview						
Vehicle length	12.5m	12.5m	14.5m		18m	18m
Number of doors	2	2	2		2	3
Axles	2	3	3		3	3
Passenger capacity						
Seated	44	96	56		64 (LC)	52
Standing	31	20	36		26 (LC)	60
Total	75	116	92		90 (LC)	110
Passengers per metre of bus length	6.00	9.28	6.34		5.00	6.11
Purchase cost	$450,000	$700,000	$550,000		$750,000	$750,000
Loading Performance						
Measured average boarding time per pax	2.7s	3.1s	3.1s		3.5s (LC) 2.6s (BT)	3.7s
Measured average alighting time per pax	2.0s	2.6s	2.0s		2.1s (LC) 1.7s (BT)	2.0s
Dwell time per pax (no standees)	2.5s	3.0s	2.5s		2.9s	2.9s
Dwell time per pax (with standees)	3.0s	undetermined	3.3s		3.1s	3.1s
Busway and Head of Bay Operation						
Gap between buses for independent pull out	5m	5m	8m	5m	5m	5m
Buses per 55m busway platform	3	3	3	2	2	2
Pax per m of platform	4.29	6.63	4.72	4.09	3.91	4.78
Maximum theoretical full loads boarding per hour*	18.7	12.3	15.4	10.7	10.9	9.0
Maximum theoretical pax boardings per hour*	1401	1422	1412	985	985	991
Whole-of-life Costs						
Whole-of-life cost per kilometre	$2.01	$2.88	$2.30		$2.58	$2.56
Whole-of-life cost per pax-kilometre	$2.68	$2.48	$2.50		$2.87	$2.33

Notes:

- For the 14.5m extended rigid vehicle, busway platform capacity is assessed both with a 5m and 8m gap between the vehicle in front. The larger gap allows safer exiting of the platform when the vehicle in front has not moved, and in the opinion of the authors, should inform future design standards.
- For the 18m two-door articulated bus, Brisbane Transport and Logan City Bus Service operate vehicles with slightly different configurations. The LCBS version has been used for assessment as it provides a slightly higher passenger capacity, and forms a better basis of comparison for the three-door articulated 'Superbus' which only they operate.

Standard Rigid Bus

Length	12.5m
Number of doors	2
Axles	2
Passenger capacity:	
Seated	44
Standing	31
Total	**75**
Passengers per metre of bus length	6.00
Purchase cost	$450,000

Loading Performance

Measured average boarding time per pax	2.7s
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.5s
Dwell time per pax (with standees)	3.0s

Vehicle Overview

The 12.5m rigid bus has been the mainstay of the Australian bus industry for several decades. Produced in large volumes, they are relatively easy to procure either from Australian bus builders or fully built imported vehicles.

The key variance between different models are the drivetrain (diesel or gas), door design and interior configuration. Depending on seating configurations, each bus can carry as many as 75 passengers (seated and standing), although the legal carrying capacity of the bus is governed by total axle loads, not physical internal space.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	3
Pax per m of platform	4.29
Maximum theoretical full loads boarding per hour*	18.7
Maximum theoretical pax boardings per hour*	1401

Compatibility and Efficiency

A key advantage of the 12.5m rigid bus is that virtually all existing bus infrastructure can accommodate the size and manoeuvring of this vehicle, including stops, stations, busways and depots.

The ease of manoeuvring of a 12.5m bus usually allows drivers to pull up at bus stops so that both front and rear doors are closely aligned to the kerb, improving alighting efficiency.

Operational efficiency of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. The specification of narrow rear doors on buses of this type represents a limitation to achieving maximum operational efficiency at stops and stations.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.01
Whole-of-life cost per pax-kilometre	$2.68

Cost Effectiveness

As the least expensive vehicle type to procure, maintain and operate, the 12.5m rigid bus offers the lowest per km whole-of-life cost, though ranks less well on a whole-of-life cost per passenger kilometre basis.

Summary

Versatile in their operation, easy to procure and compatible with virtually all existing infrastructure, the 12.5m rigid bus is anticipated to remain the primary vehicle type in the TransLink bus fleet.

It is recommended that TransLink take a more active role in the specification of interior configuration and door sizes, to ensure that vehicles procured provide the maximum possible operational efficiency.

* note: for comparison purposes, a averaged passenger boarding speed of 3.0s has been assumed.

Double Deck Rigid Bus

Length	12.5m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	96
Standing	20
Total	**116**
Passengers per metre of bus length	9.28
Purchase cost	$700,000

Loading Performance

Measured average boarding time per pax	3.1s
Measured average alighting time per pax	2.6s
Dwell time per pax (no standees)	3.0s
Dwell time per pax (with standees)	undetermined

Vehicle Overview

Double deck urban route buses are common in many parts of the world, including the UK and Hong Kong. The London Routemaster double deck bus is arguably the most iconic bus design of all time.

Although relatively uncommon in Australasia, double deck buses can be a cost effective high capacity vehicle. 12.5m double deck buses built locally by Bustech are currently being trialled in both Sydney and South East Queensland. Similar trials of Malaysian-built double deck city buses are now underway in Auckland.

Per metre of road or kerb space, double deck buses offer the highest passenger carrying capability, which is critical in congested networks.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	3
Pax per m of platform	6.63
Maximum theoretical full loads boarding per hour	12.3
Maximum theoretical pax boardings per hour	1422

Compatibility and Efficiency

A key advantage of the 12.5m double deck bus is that it has the same manoeuvrability as a standard 12.5m rigid bus. Most existing infrastructure can accommodate the size and manoeuvring of this vehicle, though some concern exists about height clearances within the King George Square busway station, some depot workshops, building awnings and street trees. These buses are not able to enter the Myer Centre bus station. Eight bridges exist at locations in the TransLink bus network that would prevent double deck buses from operating on potential HCV routes.

Operational efficiency of passenger boarding and alighting is impacted by the number and width of doors, internal seating configuration and staircase design. The commonly expressed concern that passenger movement between decks causes increased dwell times is offset in the busiest locations by the need for only one vehicle movement (compared to two smaller buses).

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.88
Whole-of-life cost per pax-kilometre	$2.48

Cost Effectiveness

Cheaper than an articulated bus and providing slightly more carrying capacity, the 12.5m double deck bus offers the highest per km whole-of-life cost, but ranks in the mid-range on a whole-of-life cost per passenger kilometre basis.

Summary

The only genuine reason identified why double deck buses should not be introduced into the TransLink network is where height restrictions limit their use. Their key benefit is the ability to use the same physical footprint as a 12.5m standard bus, yet load or unload more passengers than an 18m articulated bus. At congested locations in the CBD or Cultural Centre, shorter bus lengths result in more buses able to access stops simultaneously.

It is recommended that TransLink continue to investigate double decker buses for use in Queensland. Models by other manufacturers may be provide superior performance to the vehicles on which this assessment has been based.

* note: for comparison purposes, a averaged passenger boarding speed of 3.0s has been assumed.

Extended Rigid Bus

Length	14.5m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	56
Standing	36
Total	**92**
Passengers per metre of bus length	6.34
Purchase cost	$550,000

Loading Performance

Measured average boarding time per pax	3.1s
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.5s
Dwell time per pax (with standees)	3.3s

Vehicle Overview

The us of 14.5m extended rigid buses has become increasingly common over the last decade, resulting from the adoption of tag steer rear tandem axles, which significantly improves manoeuvrability.

The additional 2m length of the 14.5m vehicle enables a higher total carrying capacity of up to 92 people. 14.5m buses can be built for a relatively low capital cost (approximately $550,000) which means they are cheaper on a per passenger carrying capacity basis than 12.5m standard rigid buses. Operating costs are also marginally higher than for 12.5m standard buses, but again lower when compared on a per passenger carrying capacity basis.

Busway Performance

Gap between buses for independent pull out	5m	8m
Buses per 55m busway platform	3	2
Pax per m of platform	4.72	4.09
Maximum theoretical full loads boarding per hour	15.4	10.7
Maximum theoretical pax boardings per hour	1412	985

Compatibility and Efficiency

The biggest problem with the 14.5m extended rigid buses is that they have the poorest manoeuvrability of any bus type, requiring wider turning circles. At linear head-of-bay stops, they need an additional 3m between a bus in front of them to pull out without increasing the rear tail sweep beyond that of a 12.5m standard bus. This tail sweep issue regularly causes damage to kerbside street furniture, and poses a risk to passengers waiting at stops and platforms.

If this increased gap between buses were to be enforced at busway stations, it would reduce the number of buses that can simultaneously service a 55m platform from 3 to 2.

Operational efficiency in terms of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. The specification of wide rear doors on buses of this type is critical.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.30
Whole-of-life cost per pax-kilometre	$2.50

Cost Effectiveness

The extended rigid bus is the second-least expensive vehicle type to procure, maintain and operate on a per km whole-of-life cost, and ranks mid-range on a whole-of-life cost per passenger kilometre (roughly the same as a double deck bus).

Summary

The 14.5m extended rigid bus presents somewhat of a conundrum, purely due to their poor manoeuvrability. Where infrastructure - particularly stops and stations - has been designed to accommodate this type of bus, then they are a suitable choice for implementation.

However, in locations with geometrically constrained infrastructure, they represent a genuinely increased collision risk due to the large rear tail swing, when turning at full lock.

* note: for comparison purposes, a averaged passenger boarding speed of 3.0s has been assumed.

Two-door Articulated Bus

Length	18.0m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	64
Standing	26
Total	**90**
Passengers per metre of bus length	5.00
Purchase cost	$750,000

Minor variation exists between models owned by Brisbane Transport (BT) and Logan City Bus Service (LCBS), with a total capacity of 85 pax and 90 pax respectively. The LCBS configuration has been used for this comparison against their three-door articulated buses.

Loading Performance

Measured average boarding time per pax	3.5s (LC) 2.6s (BT)
Measured average alighting time per pax	2.1s (LC) 1.7s (BT)
Dwell time per pax (no standees)	2.9s
Dwell time per pax (with standees)	3.1s

Vehicle Overview

18m articulated buses have been used in Australia for many years, rising to popularity in the 1980's. Two different configuration of articulated buses were assessed in this study, comparing the two-door and three-door models.

The two-door buses are designed to maximise the number of seats, at the expense of reduced total passenger load, poorer passenger circulation and slower alighting speeds.

The two-door configuration used by LCBS can carry up to 90 passengers, slightly more than the similarly configured BT buses.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	2
Pax per m of platform	3.91
Maximum theoretical full loads boarding per hour	10.9
Maximum theoretical pax boardings per hour	985

Compatibility and Efficiency

A key advantage of the 18m articulated bus is that despite its length, it offers similar manoeuvrability to a 12.5m rigid bus. However, bus stops and layover bays need to be lengthened to accommodate the buses, and some existing depots would need to be modified to accommodate them.

Fortunately, the use of articulated buses was considered as part of the standard design of Brisbane's busways, and these buses are regularly used on the busway network. However, a common problem can be the difficulty for the rear half of the bus to move laterally close enough to the kerb to allow DDA compliant alighting from the rear door.

Operational efficiency in terms of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. These are the key differences between the two-door and three-door articulated buses.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.58
Whole-of-life cost per pax-kilometre	$2.87

Cost Effectiveness

Equally the most expensive vehicle type to procure, the two-door articulated bus offers a mid-range per km whole-of-life cost, but notably provides the worst outcome on a whole-of-life cost per passenger kilometre.

Summary

The two-door 18m articulated bus costs substantially more than the 14.5m extended rigid bus whilst carrying approximately the same total load. It also costs slightly more than the 12.5m double deck bus, yet offers 22% less passenger capacity.

Given that the three-door versions of 18m articulated buses provide greater carrying capacity, improved alighting speeds and lower whole-of-life costs, it is recommended that TransLink operators immediately cease procuring two-door articulated buses.

* note: for comparison purposes, a averaged passenger boarding speed of 3.0s has been assumed.

Three-door Articulated Bus (`Superbus')

Length	18.0m
Number of doors	3
Axles	3
Passenger capacity:	
Seated	52
Standing	60
Total	**110**
Passengers per metre of bus length	6.11
Purchase cost	$750,000

Loading Performance

Measured average boarding time per pax	3.7s
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.9s
Dwell time per pax (with standees)	3.1s

Vehicle Overview

Structurally and mechanically identical to a two-door articulated bus, the two `Superbus' three-door articulated buses being operated by LCBS are simply a standard specification used by Sydney Buses, and were sourced from Volgren as part of a Sydney Buses production run of around 150 buses.

The three-door configuration used can carry up to 110 passengers, 20 more than the two-door configuration (12 less seated passengers and 34 more standing passengers).

The interior design of this bus provides additional standing/circulation areas around the middle and rear doors, and a slightly wider entry area at the front door which improves boarding speeds.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	2
Pax per m of platform	4.78
Maximum theoretical full loads boarding per hour	9.0
Maximum theoretical pax boardings per hour	991

Compatibility and Efficiency

Offering identical manoeuvrability as a two-door articulated bus, the only difference is the number of seats and the additional door. Alighting speeds are faster, and this is most pronounced where large loads of passengers alight at a single stop.

Observation of this vehicle design in operation in Sydney reveals an additional benefit of the modified front entry area, including the mounting locations of ticket readers. The entry design effectively allows two passengers to board at a time, with one using a ticket reader adjacent to the driver, and the other using another reader located approximately 2m along the aisle. This results in average boarding speeds in Sydney being notably faster than in Brisbane, despite still being reliant on magnetic stripe tickets.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.56
Whole-of-life cost per pax-kilometre	$2.33

Cost Effectiveness

Equally the most expensive vehicle type to procure, the three-door articulated bus offers a mid-range per km whole-of-life cost, but notably provides the best outcome on a whole-of-life cost per passenger kilometre.

Summary

The three-door 18m articulated `Superbus' costs 36% more than the 14.5m extended rigid bus whilst carrying 19% more passengers (and only 4 less seated passengers). It also costs slightly (7%) more than the 12.5m double deck bus, but offers 5% less passenger capacity (and 44 fewer seats).

It is recommended that if TransLink allows its operators to continue to purchase articulated buses, they should all be of three-door design, and preferably with reduced seating to improve passenger circulation, comfort and alighting speeds.

* note: for comparison purposes, a averaged passenger boarding speed of 3.0s has been assumed.

3. When to Use a High Capacity Vehicle

3.1 Network Considerations

A key consideration that needs to be made in fleet procurement is when the use of High Capacity Vehicles becomes warranted.

Typically, a bus service operated by a standard 12.5m rigid bus has a capacity of 75 passengers. When the service reaches this capacity, operators are faced with two choices in order to accommodate additional patronage on that route at that time of day, either:

- Purchase a second 12.5m standard rigid bus; or
- Replace the existing bus with a HCV.

There are pros and cons with each choice, and the focus of this study has so far been on the operational and financial aspects of the different fleet options. However, whilst the procurement decision may seem to be based around the needs of the one extra passenger who cannot catch the existing, fully-loaded bus, it's a decision that needs to be made in the context of understanding exactly how it will affect the bus network overall.

There are two dimensions to this: the impact on frequency, and the impact on capacity. Both of these impacts need to be considered for the specific type of service which requires the additional capacity, namely peak express services, and high-frequency services.

Fundamentally, choosing to purchase a second 12.5m standard rigid bus presents the opportunity to increase the frequency of the bus service. Higher frequency services are more attractive to passengers and have the potential to generate additional patronage above the demand level that previously existed. This should not be overlooked, as high frequency routes (BUZ and CityGlider) carry 44% of all 340,000 passengers who use the BT network each weekday.

3.2 Impact on All-Day Services Operating at Peak Times

On regular, all-day services that may have a higher frequency in the peak hour, overloading of buses in the peak again provides the opportunity to increase frequency. A service that runs four times an hour in the peak can be increased to run five times an hour, potentially increasing its attractiveness. The continual increasing of frequency does have an upper limit in terms of increasing the attractiveness of the route, and the question now becomes *at what frequency of service do further improvements no longer attract additional patronage*?

It is generally accepted that a 15 minute headway is the *starting* point for a service to become attractive, allowing passengers the confidence that if they just miss their bus, the next one is a (debatably) acceptable wait away. In some jurisdictions, high-frequency service is defined at 10 minute headways. Improvements beyond 10 minute headways are still desirable, and in the author's view, 5 minute headways are the limit at which additional frequency no longer becomes noticeably more attractive.

This is supported by research by Nielsen and Lange (2007)[1] which suggested that the 'forget the timetable' effect starts at 10 minute headways. Headways of less than 5 minutes were reported to create significant issues with bus bunching, reducing network efficiency and exacerbating traffic congestion.

It is thus suggested that TransLink and its operators *begin* to consider deploying HCVs into the network when the required peak frequency of 12.5m standard rigid buses increases beyond six buses an hour or more (10 minute headways or less).

At 10 minute headways, the hourly capacity is 450 pax using 12.5m standard rigid buses. Adding one additional 12.5m standard rigid bus per hour will increase capacity to 525 pax. Swapping the six buses for, say, six 14.5m extended rigid buses will increase the capacity to 552 pax per hour, resulting in a higher total capacity and a reduced whole-of-life per passenger cost.

Six buses an hour also represents a reasonably sized purchase order, allowing the peak fleet requirement for that route to be upgraded in one instance, rather than having a seemingly random mix of bus sizes that are present on some routes[2].

3.3 Impact on Peak-Only Services

On a peak-period-only service, often longer-distance express services, the deployment of a second bus provides increased travel choice.

If the service previously only had a single trip departing at 7:30am, deploying a second bus would allow, perhaps, a departure at 7:20am and another at 7:35am. This in itself should generate additional patronage demand by providing greater convenience and choice of travel time. The question becomes *how much additional demand will be generated by doing this*? This feeds into considerations around the impact on capacity.

Adding a second 12.5m standard rigid bus increases the capacity of the route from 75 passengers, to 150 passengers. In all likelihood, each of the two buses will now have happier, more comfortably seated medium passenger loads, but with some spare capacity.

Alternatively, the same outcome could be achieved by upgrading to a HCV. In this case, the service level would remain the same, and the opportunity to attract new patronage based on improved frequency would be lost. But the increase in available seats and reduced crowding will be attractive and may act to increase patronage, albeit to a lesser degree.

Whether the route in question should be upgraded to a HCV also depends on the operator, and their current fleet mix. If the operator already has HCVs in their fleet, then adding additional vehicles of the same or similar model is not usually seen as a problem.

In the instance that the operator only has 12.5m standard rigid buses, it can become both onerous and financially unattractive to add just one vehicle of a completely different type. Maintenance staff have to be retrained, additional spare parts may need to be kept and drivers may need to upgrade their licences - all just to enable one HCV to be purchased. The Stage 2 Report for this study assumed that HCVs would be procured at no less than five vehicles at a time, in order to gain the economies of scale needed to allow an upgrade to larger vehicles to realise its full benefits.

[1] Nielsen, G, and Lange, T, (2007) "Network Design For Public Transport Success – Theory And Examples", 10th International Conference on Competition and Ownership of Land Passenger. Transport ("Thredbo 10"),

[2] The authors are aware of the highly complex nature of vehicle scheduling, and whilst in that context the upgrading of an entire route may seem like a gross oversimplification of the service delivery process, it should be seen as an aspiration to provide customers with a consistent product on which they can rely.

3.4 Impact on Traffic Congestion and Runningway Capacity

The impact of vehicle selection on the capacity of a runningway, such as a CBD street or a busway corridor, is often overlooked. The impact on stop capacity is the usual focus of capacity considerations, but each of the different vehicle types also has an impact on road capacity and traffic congestion.

Table 2.1 presented the statistic 'Passengers per metre of bus length', which is repeated below. This is effectively a measure of how efficient each bus type is in carrying passengers, based on the amount of road space that the vehicle utilises.

Table 3.1: Passenger Efficiency per Metre of Bus Length

	Two Door Standard Rigid Bus	Two Door Double Deck Bus	Two Door Extended Rigid Bus	Two Door Articulated Bus	Three Door Articulated *Superbus*
Passengers per metre of bus length	6.00	9.28	6.34	5.00	6.11

In congested traffic environments where buses seem to queue endlessly, such as Adelaide Street or the Victoria Bridge, it becomes highly desirable for the buses to use as little road space as possible so that they reduce their overall contribution to road congestion. This is also true where there are short distances between intersections and buses are unable to move forward at a green light when the road ahead is blocked by queued buses, such as Melbourne Street in South Brisbane approaching the busway entry.

The 12.5m standard rigid bus acts as a benchmark, accommodating 6.0 passengers per metre of length. The two-door articulated buses achieve a notably poorer score of 5.0 passengers per metre. This means that buses needed to carry 900 passengers would require 172 metres of road space if 12.5m standard rigid buses are used, but 198 metres of road space if two-door articulated buses are used (this assumes a two metre gap between each bus).

The three-door articulated bus and the 14.5m extended rigid bus both achieve a modest improvement over a 12.5m standard rigid bus. The 12.5m double deck bus is, however, a clear leader in the space efficiency aspect, benefitting from using the same footprint as a 12.5m standard rigid bus, but carrying over 50% more passengers.

4. Selection of High Capacity Vehicle Types

4.1 Initial Observations

This study has investigated the relative benefits of each vehicle type across a wide range of criteria. Of the five vehicle types investigated, four of them appear to be viable choices for implementation when the capacity of a 12.5m standard rigid bus is reached (the addition of a second 12.5m standard rigid bus is one of the four viable options).

It is clear that the use of two-door articulated buses is fundamentally flawed in a number of ways. This vehicle design, intended to maximise 'seats', then fails to deliver benefits in terms of total carrying capacity, operational efficiency, purchase cost or whole-of-life costs. This vehicle type should thus be excluded from consideration for future procurement, under any circumstances.

4.2 Vehicle Choice Methodology

An original intention of this study was to develop a decision making methodology in a flowchart format that would guide the determination of the most appropriate vehicle type to use in a given situation. Unfortunately, the complexity of the different contributing factors makes such a process more complicated than a simple flowchart can encapsulate.

Instead, we present a series of questions for each vehicle type that will either permit or exclude that vehicle for use. When multiple vehicle types are shown to be viable in a given situation, we present further factors that need to be considered in selecting a specific vehicle type.

One thing is clear:

Any type of vehicle is only suitable for implementation if the corridor and infrastructure which it needs to use, can accommodate its specific geometrical requirements.

In some existing instances where certain HCV types can be used, it is by coincidence, not by design. Infrastructure design standards need be updated to reflect the requirements of whichever types of fleet are the most suitable for a given route, corridor or network region.

Only the 12.5m standard rigid bus is universally useable, including being the only vehicle type that can be used on the 30 TMR identified, steep-incline *Notified Roads*.

Each of the three viable HCV types has its own inherent limitations. For example, a double decker bus won't fit under a low bridge, a 14.5m extended rigid bus won't manoeuvre around tight corners or into some bus stops, and articulated 18m buses won't fit into a workshop shed that was designed for shorter buses.

While roads, bridges and tunnels are harder and costly to retrofit to accommodate HCVs, bus stops are not. The deployment of HCVs based on bus stop capacity, should not preclude HCV deployment, if the bus stop can be retrofitted. State and Local Governments have dedicated funding programs to upgrade bus stops to meet DDA compliance standards by 2021. These funds should also be used to retrofit bus stops to accommodate HCVs.

4.3 Key Criteria for Assessing whether to Include or Exclude each Vehicle Type

The following series of questions for each HCV type to determine whether it *could* be used on a specific corridor or route.

It is inherently assumed that 12.5m standard rigid buses can be used on any existing corridor or route, and that all infrastructure can currently accommodate this vehicle type. Consequently, the use of a second vehicle of this type is a feasible solution for providing additional capacity.

4.3.1 Two Door Double Deck 12.5m Bus

Q1: Are there any low-clearance bridges (4.4m or lower) along the corridor that the buses need to pass beneath?
If *no*, proceed to Q2. If *yes*, then exclude this vehicle from further consideration.

Q2: Are there trees, building awnings or other structures (including at stops, stations and layovers) along the corridor that would conflict with the bus?
If *no*, proceed to Q3. If *yes*, proceed to Q2a.

Q2a: Can the conflicts with trees, building awnings or other structures be affordably trimmed or modified to remove conflict with the bus?
If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Are the depots at which the vehicle would be based able to handle the additional height and weight of a double deck bus? This includes hoists, roof heights, door heights, wash bays and fuelling facilities.
If *yes*, the 12.5m double deck bus can be considered a viable option for use on this corridor. If *no*, proceed to Q3a.

Q3a: Can the depot infrastructure be affordably modified to accommodate the double deck buses?
If *yes*, the 12.5m double deck bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.3.2 Two Door Extended Rigid 14.5m Bus

Q1: Are there any turns at intersections, or at access or egress points from bus stations, that the vehicle cannot safely complete without crossing centrelines, mounting kerbs etc?
If *no*, proceed to Q2. If *yes*, proceed to Q1a.

Q1a: Can these turning conflicts be affordably addressed, through physical modification of intersections, kerbs, medians, driveways etc?
If *yes*, proceed to Q2. If *no*, then exclude this vehicle from further consideration.

Q2: Do the on-road bus stops that the bus would serve provide adequate length for the vehicle to stop, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*? This includes providing adequate pull-out distance (10m minimum and 15m minimum for indented bays) so the vehicle can exit the stop without needing to be at full lock and prevent excessive rear tail swing over the kerb area.
If *yes*, proceed to Q3. If *no*, proceed to Q2a.

Q2a: Can the on-road bus stops be affordably modified to accommodate the manoeuvring needs of the bus?
If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Do the individual platforms or stops within the stations that the bus would serve provide adequate length for the vehicle to stop, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?
If *yes*, proceed to Q4. If *no*, proceed to Q3a.

Q3a: Can the individual platforms or stops within the stations be affordably modified to accommodate the manoeuvring needs of this type of bus?
If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q4: Do the layover locations provided within the network provide adequate space for the manoeuvrability and parking needs of this type of bus?
If *yes*, proceed to Q5. If *no*, proceed to Q4a.

Q4a: Can the layover locations be affordably modified, or alternative locations developed, to accommodate the manoeuvring and parking needs of this type of bus?
If *yes*, proceed to Q5. If *no*, then exclude this vehicle from further consideration.

Q5: Are the depots at which the vehicle would be based able to handle the additional length, weight and manoeuvrability requirements of a 14.5m extended rigid bus? This includes hoists, service pits, workshop building depths, wash bays and fuelling facilities.
If *yes*, the 14.5m extended rigid bus can be considered a viable option for use on this corridor. If *no*, proceed to Q5a.

Q5a: Can the depot infrastructure be affordably modified to accommodate the 14.5m extended rigid bus?
If *yes*, the 14.5m extended rigid bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.3.3 Three-Door Articulated 18m Bus

Q1: Are there any turns at intersections, or at access or egress points from bus stations, that the vehicle cannot safely complete without crossing centrelines, mounting kerbs etc?
If *no*, proceed to Q2. If *yes*, proceed to Q1a.

Q1a: Can these turning conflicts be affordably addressed, through physical modification of intersections, kerbs, medians, driveways etc?
If *yes*, proceed to Q2. If *no*, then exclude this vehicle from further consideration.

Q2: Do the on-road bus stops that the bus would serve provide adequate length for the vehicle to stop with the rear door closely located and parallel to the kerb, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?
If *yes*, proceed to Q3. If *no*, proceed to Q2a.

Q2a: Can the on-road bus stops be affordably modified to accommodate the manoeuvring needs of the bus?
If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Do the individual platforms or stops within the stations that the bus would serve provide adequate length for the vehicle to stop with the rear door closely located and parallel to the kerb, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?
If *yes*, proceed to Q4. If *no*, proceed to Q3a.

Q3a: Can the individual platforms or stops within the stations be affordably modified to accommodate the manoeuvring needs of this type of bus?
If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q4: At stations with physical barriers dividing passenger waiting areas from the runningway (e.g. King George Square), are the door or gate locations suitably located for each of the three bus doors?
If *yes*, proceed to Q5. If *no*, proceed to Q4a.

Q4a: Can the barrier door or gate locations be affordably modified to match the positions of all three bus doors?
If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q5: Do the layover locations provided within the network provide adequate space for the manoeuvrability and parking needs of this type of bus?
If *yes*, proceed to Q6. If *no*, proceed to Q5a.

Q5a: Can the layover locations be affordably modified, or alternative locations developed, to accommodate the manoeuvring and parking needs of this type of bus?
If *yes*, proceed to Q6. If *no*, then exclude this vehicle from further consideration.

Q6: Are the depots at which the vehicle would be based able to handle the additional length, weight and manoeuvrability requirements of an 18m articulate bus? This includes hoists, service pits, workshop building depths, wash bays and fuelling facilities.
If *yes*, the 18m extended rigid bus can be considered a viable option for use on this corridor. If *no*, proceed to Q6a.

Q6a: Can the depot infrastructure be affordably modified to accommodate the 14.5m extended rigid bus?
If *yes*, the 14.5m extended rigid bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.4 Choosing Between Viable Vehicle Types

After assessing each vehicle type, a list of viable alternatives will remain.

If none of the three HCV types are viable for use in the given corridor, or the delay in modifying infrastructure to allow their use would be too lengthy, then the use of a second 12.5m standard rigid bus is the appropriate outcome.

If one or more HCV types are viable, then the decision between vehicle types needs to be based on some practical issues relating to the operation of the network, and the procurement, operation and maintenance of the fleet.

The key issues that need to be considered include the following. Each issue could generate a different preferred vehicle type, resulting in the need for a holistic review of the issues in combination.

What vehicle types does the operator already have in their fleet?
It is far simpler and more cost effective for an operator to have large numbers of the same model of bus in their fleet, rather than small numbers of many different models. Consequently, there is a logical argument that if other factors are reasonably comparable, then operators should continue to procure the same types of vehicle they have previously.

For example, if an operator already has a fleet of 18m articulated buses (regardless of the number of doors) and no 14.5m extended rigid buses, it is logical for them to procure three-door articulated buses in the future as they can be immediately incorporated into the fleet.

An exception to this can be created when the number of new vehicles required is large enough to provide economies of scale to reduce their acquisition cost, and justify the investment in upgrading depot facilities, carrying additional spares inventory and retraining staff. This is also the case for an operator who currently does not operate any type of HCV - the acquisition of just one or two HCVs is likely to provide a poor overall outcome given the step change required in depot operations.

How much additional total capacity is needed or will be useful?
The following increases in passenger carrying capacity are offered by each bus type, in comparison to a 12.5m standard rigid bus:

- 14.5m extended rigid bus: 17 additional passengers (23%) including 12 additional seats.
- 18m three-door articulated bus: 35 additional passengers (47%) including 8 additional seats.
- 12.5m double deck bus: 41 additional passengers (55%) including 42 additional seats.
- Second 12.5m standard rigid bus: 75 additional passengers (100%) including 44 additional seats.

In the example of a high frequency route (6 buses per hour or higher) that requires additional capacity, the logical option is whichever bus type is listed highest above, and is suitable based on all other criteria.

The exception to this is if TransLink anticipates future patronage growth and believes that a larger vehicle may present a better long-term option to accommodate that growth.

What distances will passengers be travelling?
This is a fundamentally important issue when considering passenger comfort and resultant desire to catch public transport. The longer passengers need to travel, the greater the justification for increased seating levels.

The double deck bus and the three-door articulated bus have comparable total capacities, purchase costs and whole-of-life operational costs, but the double deck bus has 44 additional seats than the articulated bus.

The 14.5m extended rigid bus has four more seats than the articulated bus, but with a lower total capacity, lower purchase cost and lower whole-of-life cost.

The use of an additional 12.5m standard rigid bus provides an increase in seated capacity similar to the use of a double decker, but at a higher purchase cost (when considering the cost of two buses versus one) and higher whole-of-life costs per passenger km, even if fully loaded.

If routes are long and passengers are travelling long distances, then the double deck and 14.5m extended rigid buses are the most logical choices. The double deck bus provides 32 more seats, but at a higher purchase cost. The decision on vehicle type here should be logically based on the total required capacity.

Do operator depots have the spare parking space required?

Using larger buses requires a larger physical area for the fleet to be parked overnight. Some depots are already at or near capacity in this regard, and deploying HCVs to these locations would trigger a need for additional depot space.

The need to increase depot capacity will need to be included in the economic assessment of any proposal to introduce 14.5m and 18m HCVs into depots that are currently at or near capacity, or if additional 12.5m standard rigid buses are purchased instead of replacing existing fleet with HCVs.

The exception to this is the double deck buses, which have the same footprint as a 12.5m standard rigid bus.

What value does the replaced vehicle represent?

By purchasing HCVs, existing 12.5m standard rigid buses could potentially become redundant. These redundant vehicles have the ability to provide value in any of the following ways:

- To accommodate overall network growth which will require a larger total fleet in the near future;
- If fleet growth is not required, the additional buses will allow the oldest fleet to be retired, reducing average fleet age; or
- If the fleet is relatively young and no buses are of an age at which they would normally be retired, the redundant buses could be sold, realising a financial benefit that will partly offset the purchase cost of the HCVs.

If the increase in passenger capacity is achieved through the use of an additional 12.5m standard rigid bus, no vehicles become redundant, though the number of unutilised vehicles in the off-peak may rise.

5. Summary of Recommendations

5.1 Gain Greater Control over Vehicle Specification

Irrespective of the type of vehicle used, poor decision making regarding basic bus design elements such as seating configuration, number of doors and width of doors has and will continue to result in buses that underperform compared to equivalent vehicles in other jurisdictions. An essential part of this process needs to be discontinuing the use of any form of KPI that reports 'new seats delivered', which encourages the simplistic maximisation of installed seats at the expense of developing operationally efficient and comfortable vehicles. While use of such a metric in the public domain might be more politically palatable and customer focused, compared to quoting total capacity, this should not prevent TransLink from specifying the latter in transport service contracts with its operators. Alternative KPIs could be developed to measure 'new passenger capacity'.

It was revealed in the international research study for the Stage 1 *Operational Performance Evaluation* that significant differences exist between high capacity bus operations overseas and contemporary high capacity bus services operated in South East Queensland. Bus station and bus stop dwell time minimisation was repeatedly identified from the international research as the central focus of best practice leading international mass transit authorities, and all door boarding, wider centre aisles, rear door passenger storage spaces and reduced seating were the strategies typically implemented to achieve rapid alighting and boarding of passengers at bus stations and stops.

To highlight the difference in approaches between Australia and Europe, during a period when Brisbane Transport continued to procure two-door 18.0m articulated buses, the *European Bus System of the Future (EBSF)* project developed and deployed an 18.7m five-door articulated bus into operation in Budapest[3].

It is strongly recommended that TransLink takes a greater and proactive role in specifying the design of the vehicles that they subsidise each operator to purchase and use in the TransLink network. This may extend to working directly with manufacturers to develop a TransLink Vehicle Specification, for each of the available bus sizes, that will detail the requirements needed to achieve operationally efficient outcomes. Development of such specifications would be greatly assisted by the wealth of research undertaken by this study and the EBSF project[4].

5.2 Discontinue the Procurement of Two-Door Articulated Buses

Aside from providing a large number of installed seats, the two-door articulated bus provides no benefit to the TransLink network, and seriously impacts the efficiency and performance of the bus services the vehicles are used on, and the stop infrastructure they access.

It is strongly recommended that TransLink negotiate with its operators to discontinue the procurement of these vehicles.

Additionally, it may be technically feasible and financially viable to modify existing two-door articulated buses to add a third door, modifying seating arrangements at the same time.

[3] http://www.uitp.org/news/pics/pdf/Budapest%20Press%20Release%2002.11.2011.pdf
[4] http://www.ebsf.eu and http://www.ebsf.eu/images/stories/documents/EBSF-DEMONSTRATIONS-Leaflet.pdf

5.3 Discontinue the Use of CNG Vehicles

Brisbane Transport has put on hold any new orders for CNG buses due to safety concerns resulting from recent gas explosions at Garden City and Virginia depots. This matter aside, CNG buses are slower to accelerate from a stopping position which in turn increases bus dwell times and travel times.

It is also understood a standard CNG bus must be refuelled every 250km and a CNG articulated bus must be refuelled every 220km, resulting in CNG buses having to be refuelled twice a day. CNG buses must also rest for 30 minutes after refuelling before being allowed back into service. Any propulsion system that unnecessarily slows a bus down or unnecessarily takes it out of service for activities like refuelling indirectly reduces the capacity of the entire fleet, in that more CNG buses are required to operate a network schedule compared to a diesel bus. This in turn contributes to bus congestion, reduced system capacity and increased government subsidy.

5.4 Continue to Investigate the Use of Double Deck Buses

Inarguably, double deck buses pose an obvious height clearance issue on some routes, whether it be low bridges, overhanging trees, building awnings or incompatible station infrastructure. However, many of the routes on which HCVs may need to operate travel along major roads where numerous heavy vehicles, with the same height constraints also travel, suggesting that double decks buses could be used.

The trial use of the double deck buses by Hornibrook Buslines on Route 315 is a conceptually good example of where double deck buses can be useful. Any route that carries a large load of passengers a relatively long distance is a viable candidate, assuming vertical height clearance is acceptable. High patronage services from Browns Plains, Logan and Redland Bay could also be potential candidates for double deck bus deployment.

Double deck buses also have an undeniable novelty value, making them more attractive to some passengers. The opportunity to travel on the upper deck on a long journey and enjoying the view is an attractor to these buses worldwide. In a time of declining public transport patronage in the TransLink network, the attractiveness to passengers of these buses should not be underestimated.

It is important to note that the Bustech double deck vehicles trialled by TransLink are prototypes, and had inherent flaws that affected their reliability, possibly diminishing their acceptance by the industry. This needs to be acknowledged as a flaw in the *vehicle*, not the vehicle *type*. It is worth noting that the Bustech double deck vehicle design has gone through two further stages of redesign and refinement, with the buses they are now producing for the Sydney market markedly different to the prototypes.

The new double deck buses being procured for deployment in Auckland in March 2013 are manufactured in Malaysia and are an existing "off-the-shelf" design. Whilst the Australian bus industry is to be commended for developing new double deck bus designs, bus procurers must be willing to look further afield in order to obtain the best vehicles available, especially considering equivalent buses built in the United Kingdom are more than one third cheaper than Australian-built buses[5]. This is particularly true with HCVs as they are typically procured in smaller volumes, and with few competing models manufactured in Australia, there is little in the way of economies of scale or market price competitiveness.

[5] It is the opinion of the author that exceptionally high-standard, high-capacity vehicles could be built in the United Kingdom to a TransLink specification that meets Australian design regulations. The purchase price of an 18m articulated bus in the UK is approximately $300,000 to $350,000 AUD - less than half that of an Australian manufactured bus. Considering that these buses use the same drivetrains and componentry as Australian models, there is a strong financial argument in support of importing HCV buses rather buying locally. Even after shipping costs, import duties and compliance checks, imported HCVs could still be priced as low as half of the Australian models ($750,000). A hybrid model exists where UK manufacturers ship HCV buses in kit-form, for local assembly.

Designs used overseas also offer distinctively different features, optimised around efficient passenger loading on high-turnover routes. For example, the double-decker buses in Berlin (MAN Lion's City DD model) have dual staircases and three doors, with a bus length of 13.7m and a total passenger capacity of 121 (83 seated and 38 standing[6]).

5.5 Innovate

We refer repeatedly to emerging best practices identified overseas, particularly in Europe. One observation is that vehicle lengths can be far more varied than the 12.5m, 14.5m and 18.0m lengths used as a standard in Australia.

It is noted Kangaroo Bus Lines operate a small number of 13.5m extended rigid buses. This length of bus is rarely seen in Australia, but is quite common in New Zealand and is the standard vehicle length used in Auckland. The additional metre increases passenger capacity by at least 6 passengers. As the vehicles are one metre shorter than the 14.5m extended rigid vehicles used in Queensland, they have better manoeuvrability and would most likely be more compatible with existing infrastructure than the other HCV vehicles assessed.

5.6 Update Standard Infrastructure Designs to Accommodate HCVs

It is noted that current infrastructure design guidelines and manuals do not detail the requirements of 14.5m buses, or double deck buses. This means that infrastructure is currently being designed and constructed that may not accommodate these bus types.

It is recommended that all bus infrastructure design guidelines and manuals be updated to reflect the specific geometric needs of each HCV type.

5.7 Reconsider the Need for High Capacity Vehicles

No HCV outranked the Standard 12.5m Rigid Bus on the like-for-like performance benefit to cost ratio evaluation. Notwithstanding it being the second dearest vehicle to operate based on cost per pax-kilometre, the standard bus significantly outperformed every high capacity bus and was fully compatible with all existing bus stations, stops and depots.

These buses have the greatest flexibility in use, particularly in off-peak services when higher capacity vehicles are less likely to be needed.

Adding a second standard 12.5m rigid bus to the network will provide improved service frequency, creating a more attractive network and potentially increasing patronage. Swapping to a larger bus but retaining the same frequency has far less potential to attract new patronage.

It is suggested that only when a service's frequency needs to increase beyond six buses an hour, that HCVs be automatically considered as a measure to address overcrowding.

[6] Sourced from http://www.postauto.ch/en/pag-startseite/pag-ueberuns/pag-portrait/pag-fahrzeugflotte/pag-fahrzeugflotte-fahrzeuge/pag-fahrzeugflotte-fahrzeuge-doppelstock.htm

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1. Introduction

1.1 Study Intention

MRCagney has been appointed by the TransLink Division of the Queensland Department of Transport and Main Roads (*TransLink Division*) to undertake research and analysis of the uses of high capacity vehicles within its South East Queensland bus network.

The intention of the study is to provide guidance to TransLink on the basic questions of:

- Based on network demand, when is it appropriate to acquire and use high capacity vehicles i.e. under what circumstances should a larger bus be used, rather than a second smaller, standard bus?
- If the use of a high capacity vehicle is warranted, what is the most appropriate vehicle type to use in a given situation?
- What are the issues and impacts relating to the use of high capacity vehicles, in terms of compatibility with existing infrastructure and current infrastructure design standards?
- What other constraints, in terms of legislation and policy, might influence the decision to use a high capacity vehicle?

1.2 Assessments Undertaken

The study has focussed its investigation on four types of high capacity vehicle (HCV) currently being used within the TransLink bus network, and comparing them against the standard specification of a modern two door, 12.5m rigid bus. The four types of HCV assessed were:

- Two Door 12.5m Double Deck Bus;
- Two Door 14.5m Rigid Bus;
- Two Door 18m Articulated Bus; and
- Three Door 18m Articulated '*Superbus*'.

One thing became clear during the study: any type of vehicle is only suitable for implementation if the corridor and infrastructure which it needs to use, can accommodate its specific geometrical requirements. The retrofitting of corridors and other infrastructure to accommodate larger vehicles may be too costly or impactful when compared to the benefits the larger vehicles may bring.

The areas of investigation covered by this study included:

- Characteristics of HCVs available in Australia and overseas;
- The legislation and government policies that relate to all buses, including HCVs;
- Assessment of key bus infrastructure to determine its ability to accommodate the dimensions, weight and manoeuvrability requirements of each vehicle type. This included:
  - Bus stations;
  - Busway stations;
  - Busway runningways;
  - Park'n'rides;
  - Roadside bus stops;
  - Bus depots;
  - Inter-modal services; and

  - Pavement impacts.
- Vehicle operational performance relating to:
  - Acceleration and deceleration rates, and travel speeds;
  - Passenger boarding and alighting rates;
  - Passenger alighting preferences (choice of door);
  - Impacts on effective station capacity; and
  - Peak and Off-peak capacity utilisation
- Whole-of-life vehicle costs incorporating:
  - Vehicle purchase cost;
  - Vehicle operational life;
  - Cleaning, maintenance and overhaul costs;
  - Financing costs;
  - End-of-life resale value;
  - Fuel costs;
  - Registration, compliance and insurance costs;
  - Labour costs for drivers and maintenance staff; and
  - Depot upgrades needed to accommodate larger vehicles.

2. Vehicle Types Assessed

This section provides an overview of the types of high capacity vehicles currently in operation in the TransLink network, along with the standard 12.5m rigid bus used as a basis for comparison. The assessment outcomes are summarised and compared in Table 2.1 below.

Table 2.1: Comparison of Vehicle Statistics and Assessment Outcomes

	Two Door Standard Rigid Bus	Two Door Double Deck Bus	Two Door Extended Rigid Bus		Two Door Articulated Bus	Three Door Articulated *Superbus*
Vehicle Overview						
Vehicle length	12.5m	12.5m	14.5m		18m	18m
Number of doors	2	2	2		2	3
Axles	2	3	3		3	3
Passenger capacity						
Seated	44	96	56		64 (LC)[1]	52
Standing	31	20	36		26 (LC)	60
Total	75	116	92		90 (LC)	110
Passengers per metre of bus length	6.00	9.28	6.34		5.00	6.11
Average purchase cost	$450,000	$700,000	$550,000		$750,000	$750,000
Loading Performance						
Measured average boarding time per pax	2.7s	3.1s	3.1s		3.5s (LC)[2] 2.6s (BT)	3.7s
Measured average alighting time per pax	2.0s	2.6s	2.0s		2.1s (LC) 1.7s (BT)	2.0s
Dwell time per pax (no standees)	2.5s	3.0s	2.5s		2.9s	2.9s
Dwell time per pax (with standees)	3.0s	undetermined	3.3s		3.1s	3.1s
Busway and Head of Bay Operation						
Gap between buses for independent pull out[3]	5m	5m	8m	5m	5m	5m
Buses per 55m busway platform	3	3	3	2	2	2
Pax per m of platform	4.29	6.63	4.72	4.09	3.91	4.78
Maximum theoretical full loads boarding per hour*	18.7	12.3	15.4	10.7	10.9	9.0
Maximum theoretical pax boardings per hour*	1401	1422	1412	985	985	991
Whole-of-life Costs						
Whole-of-life cost per kilometre	$2.01	$2.88	$2.30		$2.58	$2.56
Whole-of-life cost per pax-kilometre	$2.68	$2.48	$2.50		$2.87	$2.33

[1] For the 18m two-door articulated bus, Brisbane Transport and Logan City Bus Service operate vehicles with slightly different configurations. The LCBS version was used for assessment as it provides a slightly higher passenger capacity, and forms a better basis of comparison for the three-door articulated `Superbus' which only they operate.

2 The average boarding times for all LCBS services are influenced by the ability for passengers to top up their go card on board the bus, which is not permissible on BT services. This increases the average boarding time, average dwell time and average alighting time when the extended presence of a person interacting with the driver limits access to the front door. Analysis shows that on LCBS, there are 46 cash go card top-ups recorded for every 1000 boardings, meaning roughly 1 person in every 20 boarding a LCBS bus is doing so.

[3] For the 14.5m extended rigid vehicle, busway platform capacity is assessed both with a 5m and 8m gap between the vehicle in front. The larger gap allows safer exiting of the platform when the vehicle in front has not moved, and in the opinion of the authors, should inform future design standards.

Standard Rigid Bus

Length	12.5m
Number of doors	2
Axles	2
Passenger capacity:	
Seated	44
Standing	31
Total	**75**
Passengers per metre of bus length	6.00
Average purchase cost	$450,000

Loading Performance

Measured average boarding time per pax	2.7s
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.5s
Dwell time per pax (with standees)	3.0s

Vehicle Overview

The 12.5m rigid bus has been the mainstay of the Australian bus industry for several decades. Produced in large volumes, they are relatively easy to procure either from Australian bus builders or fully built imported vehicles.

The key variance between different models are the drivetrain (diesel or gas), door design and interior configuration. Depending on seating configurations, each bus can carry as many as 75 passengers (seated and standing), although the legal carrying capacity of the bus is governed by total axle loads, not physical internal space.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	3
Pax per m of platform	4.29
Maximum theoretical full loads boarding per hour [4]	18.7
Maximum theoretical pax boardings per hour	1401

Compatibility and Efficiency

A key advantage of the 12.5m rigid bus is that virtually all existing bus infrastructure can accommodate the size and manoeuvring of this vehicle, including stops, stations, busways and depots.

The ease of manoeuvring of a 12.5m bus usually allows drivers to pull up at bus stops so that both front and rear doors are closely aligned to the kerb, improving alighting efficiency.

Operational efficiency of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. The specification of narrow rear doors on buses of this type represents a limitation to achieving maximum operational efficiency at stops and stations.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.01
Whole-of-life cost per pax-kilometre	$2.68

Cost Effectiveness

As the least expensive vehicle type to procure, maintain and operate, the 12.5m rigid bus offers the lowest per km whole-of-life cost, though ranks less well on a whole-of-life cost per passenger kilometre basis.

Summary

Versatile in their operation, easy to procure and compatible with virtually all existing infrastructure, the 12.5m rigid bus is anticipated to remain the primary vehicle type in the TransLink bus fleet. Only the 12.5m standard rigid bus is universally useable, including being the only vehicle type that can be used on the 30 TMR identified, steep-incline Notified Roads.

It is recommended that TransLink take a more active role in working with their contracted operators to determine the most appropriate specifications for interior configuration, seating layout and door sizes, and encourage operators to procure vehicles that provide the maximum possible operational efficiency, rather than the maximum volume of seating.

[4] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

Double Deck Rigid Bus

Length	12.5m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	96
Standing	20
Total	**116**
Passengers per metre of bus length	9.28
Average purchase cost	$700,000

Loading Performance

Measured average boarding time per pax	3.1s
Measured average alighting time per pax	2.6s
Dwell time per pax (no standees)	3.0s
Dwell time per pax (with standees)	undetermined

Vehicle Overview

Double deck urban route buses are common in many parts of the world, including the UK and Hong Kong.

Although relatively uncommon in Australasia, double deck buses can be a cost effective high capacity vehicle. 12.5m double deck buses built locally by Bustech are currently being trialled in both Sydney and South East Queensland. Similar trials of Malaysian-built double deck city buses are now underway in Auckland.

Per metre of road or kerb space, double deck buses offer the highest passenger carrying capability, which is critical in congested networks.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	3
Pax per m of platform	6.63
Maximum theoretical full loads boarding per hour[5]	12.3
Maximum theoretical pax boardings per hour	1422

Compatibility and Efficiency

A key advantage of the 12.5m double deck bus is that it has the same manoeuvrability as a standard 12.5m rigid bus. Most existing infrastructure can accommodate the size and manoeuvring of this vehicle, though some concern exists about height clearances within the King George Square station, some depot workshops, building awnings and street trees. These buses are not able to enter the Myer Centre bus station, nor are they able to pass under the eight bridges that exist at locations in the TransLink bus network that may need to accommodate HCV services.

Operational efficiency of passenger boarding and alighting is impacted by the number and width of doors, internal seating configuration and staircase design. The concern that passenger movement between decks increases dwell times is offset in the busiest locations by the need for only one vehicle movement (compared to two smaller buses).

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.88
Whole-of-life cost per pax-kilometre	$2.48

Cost Effectiveness

Cheaper than an articulated bus and providing slightly more carrying capacity, the 12.5m double deck bus offers the highest per km whole-of-life cost, but ranks in the mid-range on a whole-of-life cost per passenger kilometre basis.

Summary

The only genuine reason identified why double deck buses should not be introduced into the TransLink network is where height restrictions limit their use. They use the same physical footprint as a 12.5m standard bus, yet load more passengers than an 18m articulated bus. At congested locations in the CBD or Cultural Centre, shorter bus lengths result in more buses able to access stops simultaneously.

Anecdotally, some passengers are attracted to the novelty of this bus type, and the elevated view available from the upper deck. This can increase patronage in the short-term, with long term benefits still to be assessed.

It is recommended that TransLink continue to investigate double decker buses for use in Queensland. Models by other manufacturers, or the revised design Bustech vehicles, may be provide superior performance to the vehicles on which this assessment has been based.

[5] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

Extended Rigid Bus

Length	14.5m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	56
Standing	36
Total	**92**
Passengers per metre of bus length	6.34
Average purchase cost	$550,000

Loading Performance

Measured average boarding time per pax	3.1s
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.5s
Dwell time per pax (with standees)	3.3s

Vehicle Overview

The use of 14.5m extended rigid buses has become increasingly common over the last decade, resulting from the adoption of tag steer rear tandem axles, which significantly improves manoeuvrability.

The additional 2m length of the 14.5m vehicle enables a higher total carrying capacity of up to 92 people. 14.5m buses can be built for a relatively low capital cost (approximately $550,000) which means they are cheaper on a per passenger carrying capacity basis than 12.5m standard rigid buses. Operating costs are also marginally higher than for 12.5m standard buses, but again lower when compared on a per passenger carrying capacity basis.

Busway Performance

Gap between buses for independent pull out	5m	8m
Buses per 55m busway platform	3	2
Pax per m of platform	4.72	4.09
Maximum theoretical full loads boarding per hour[6]	15.4	10.7
Maximum theoretical pax boardings per hour	1412	985

Compatibility and Efficiency

The biggest problem with the 14.5m extended rigid buses is that they have the poorest manoeuvrability of any bus type, requiring wider turning circles. At linear head-of-bay stops, they need an additional 3m between a bus in front of them to pull out without increasing the rear tail sweep beyond that of a 12.5m standard bus. This tail sweep issue regularly causes damage to kerbside street furniture, and poses a risk to passengers waiting at stops and platforms.

If this increased gap between buses were to be enforced at busway stations, it would reduce the number of buses that can simultaneously service a 55m platform from 3 to 2.

Operational efficiency in terms of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. The specification of wide rear doors on buses of this type is critical.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.30
Whole-of-life cost per pax-kilometre	$2.50

Cost Effectiveness

The extended rigid bus is the second-least expensive vehicle type to procure, maintain and operate on a per km whole-of-life cost, and ranks mid-range on a whole-of-life cost per passenger kilometre (roughly the same as a double deck bus).

Summary

The 14.5m extended rigid bus presents somewhat of a conundrum, purely due to their poor manoeuvrability. Where infrastructure - particularly stops and stations - has been designed to accommodate this type of bus, then they are a suitable choice for implementation.

However, in locations with geometrically constrained infrastructure, they represent a genuinely increased collision risk due to the large rear tail swing, when turning at full lock.

[6] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

Two-door Articulated Bus

Length	18.0m
Number of doors	2
Axles	3
Passenger capacity:	
Seated	64
Standing	26
Total	**90**
Passengers per metre of bus length	5.00
Average purchase cost	$750,000

Minor variation exists between models owned by Brisbane Transport (BT) and Logan City Bus Service (LCBS), with a total capacity of 85 pax and 90 pax respectively. The LCBS configuration has been used for this comparison against their three-door articulated buses.

Loading Performance

Measured average boarding time per pax	3.5s (LC)[7] 2.6s (BT)
Measured average alighting time per pax	2.1s (LC) 1.7s (BT)
Dwell time per pax (no standees)	2.9s
Dwell time per pax (with standees)	3.1s

Vehicle Overview

18m articulated buses have been used in Australia for many years, rising to popularity in the 1980's. Two different configuration of articulated buses were assessed in this study, comparing the two-door and three-door models.

The two-door buses are designed to maximise the number of seats, at the expense of reduced total passenger load, poorer passenger circulation and slower alighting speeds.

The two-door configuration used by LCBS can carry up to 90 passengers, slightly more than the similarly configured BT buses.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	2
Pax per m of platform	3.91
Maximum theoretical full loads boarding per hour[8]	10.9
Maximum theoretical pax boardings per hour	985

Compatibility and Efficiency

A key advantage of the 18m articulated bus is that despite its length, it offers similar manoeuvrability to a 12.5m rigid bus. However, bus stops and layover bays need to be lengthened, and some existing depots would need to be modified to accommodate them.

Fortunately, the use of articulated buses was considered as part of the standard design of Brisbane's busways, and these buses are regularly used on the busway network. A common problem can be the difficulty for the rear half of the bus to move laterally close enough to the kerb to allow DDA compliant alighting from the rear door.

Operational efficiency in terms of passenger boarding and alighting is impacted by the number and width of doors, and internal seating configuration, both of which influence in-vehicle passenger circulation. These are the key differences between the two-door and three-door articulated buses.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.58
Whole-of-life cost per pax-kilometre	$2.87

Cost Effectiveness

Equally the most expensive vehicle type to procure, the two-door articulated bus offers a mid-range per km whole-of-life cost, but notably provides the worst outcome on a whole-of-life cost per passenger kilometre.

Summary

The two-door 18m articulated bus costs substantially more than the 14.5m extended rigid bus whilst carrying approximately the same total load. It also costs slightly more than the 12.5m double deck bus, yet offers 22% less passenger capacity.

The three-door versions of 18m articulated buses provide greater total capacity, improved alighting speeds and lower whole-of-life costs. Whilst TransLink is not able to mandate the specification of vehicle that their operators procure, it is recommended that TransLink work with their operators to discourage the procurement of two-door articulated buses.

[7] The average boarding times for all LCBS services are influenced by the ability for passengers to top up their go card on board the bus, which is not permissible on BT services.
[8] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

Three-door Articulated Bus (`Superbus')

Length	18.0m
Number of doors	3
Axles	3
Passenger capacity:	
Seated	52
Standing	60
Total	**110**
Passengers per metre of bus length	6.11
Average purchase cost	$750,000

Loading Performance

Measured average boarding time per pax	3.7s[9]
Measured average alighting time per pax	2.0s
Dwell time per pax (no standees)	2.9s
Dwell time per pax (with standees)	3.1s

Vehicle Overview

Structurally and mechanically identical to a two-door articulated bus, the two `Superbus' three-door articulated buses being operated by LCBS are simply a standard specification used by Sydney Buses, and were sourced from Volgren as part of a Sydney Buses production run of around 150 buses.

The three-door configuration used can carry up to 110 passengers, 20 more than the two-door configuration (12 less seated passengers and 34 more standing passengers).

The interior design of this bus provides additional standing/circulation areas around the middle and rear doors, and a slightly wider entry area at the front door which improves boarding speeds.

Busway Performance

Gap between buses for independent pull out	5m
Buses per 55m busway platform	2
Pax per m of platform	4.78
Maximum theoretical full loads boarding per hour[10]	9.0
Maximum theoretical pax boardings per hour	991

Compatibility and Efficiency

Offering identical manoeuvrability as a two-door articulated bus, the only difference is the number of seats and the additional door. Alighting speeds are faster, and this is most pronounced where large loads of passengers alight at a single stop.

Observation of this vehicle design in operation in Sydney reveals an additional benefit of the modified front entry area, including the mounting locations of ticket readers. The entry design effectively allows two passengers to board at a time, with one using a ticket reader adjacent to the driver, and the other using another reader located approximately 2m along the aisle. This results in average boarding speeds in Sydney being notably faster than in Brisbane, despite still being reliant on magnetic stripe tickets.

Whole-of-Life Costs

Whole-of-life cost per kilometre	$2.56
Whole-of-life cost per pax-kilometre	$2.33

Cost Effectiveness

Equally the most expensive vehicle type to procure, the three-door articulated bus offers a mid-range per km whole-of-life cost, but notably provides the best outcome on a whole-of-life cost per passenger kilometre.

Summary

The three-door 18m articulated `Superbus' costs 36% more than the 14.5m extended rigid bus whilst carrying 19% more passengers (and only 4 less seated passengers). It also costs slightly (7%) more than the 12.5m double deck bus, but offers 5% less passenger capacity (and 44 fewer seats).

It is recommended that if operators choose to continue to purchase articulated buses, they should be encouraged to consider three-door design, and preferably with reduced seating to improve passenger circulation, comfort and alighting speeds.

[9] The average boarding times for all LCBS services are influenced by the ability for passengers to top up their go card on board the bus, which is not permissible on BT services.
[10] For comparison purposes, an averaged passenger boarding speed of 3.0s has been assumed.

3. When to Use a High Capacity Vehicle

3.1 Network Considerations

A key consideration that needs to be made in fleet procurement is when the use of High Capacity Vehicles becomes warranted.

Typically, a bus service operated by a standard 12.5m rigid bus has a capacity of 75 passengers. When the service reaches this capacity, operators are faced with two choices in order to accommodate additional patronage on that route at that time of day, either:

- Purchase a second 12.5m standard rigid bus; or
- Replace the existing bus with a HCV.

There are pros and cons with each choice, and the focus of this study has so far been on the operational and financial aspects of the different fleet options. However, whilst the procurement decision may seem to be based around the needs of the one extra passenger who cannot catch the existing, fully-loaded bus, it's a decision that needs to be made in the context of understanding exactly how it will affect the bus network overall.

There are two dimensions to this: the impact on frequency, and the impact on capacity. Both of these impacts need to be considered for the specific type of service which requires the additional capacity, namely peak express services, and high-frequency services.

Fundamentally, choosing to purchase a second 12.5m standard rigid bus presents the opportunity to increase the frequency of the bus service. Higher frequency services are more attractive to passengers and have the potential to generate additional patronage above the demand level that previously existed. This should not be overlooked, as high frequency routes (BUZ and CityGlider) carry 44% of all 340,000 passengers who use the BT network each weekday.

3.2 Impact on All-Day Services Operating at Peak Times

On regular, all-day services that may have a higher frequency in the peak hour, overloading of buses in the peak again provides the opportunity to increase frequency. A service that runs four times an hour in the peak can be increased to run five times an hour, potentially increasing its attractiveness. The continual increasing of frequency does have an upper limit in terms of increasing the attractiveness of the route, and the question now becomes *at what frequency of service do further improvements no longer attract additional patronage*?

It is generally accepted that a 15 minute headway is the *starting* point for a service to become attractive, allowing passengers the confidence that if they just miss their bus, the next one is a (debatably) acceptable wait away. In some jurisdictions, high-frequency service is defined at 10 minute headways. Improvements beyond 10 minute headways are still desirable, and in the author's view, 5 minute headways are the limit at which additional frequency no longer becomes noticeably more attractive.

This is supported by research by Nielsen and Lange (2007)[11] which suggested that the 'forget the timetable' effect starts at 10 minute headways. Headways of less than 5 minutes were reported to create significant issues with bus bunching, reducing network efficiency and exacerbating traffic congestion.

[11] Nielsen, G, and Lange, T, (2007) "Network Design For Public Transport Success – Theory And Examples", 10th International Conference on Competition and Ownership of Land Passenger. Transport ("Thredbo 10"),

It is thus suggested that TransLink and its operators *begin* to consider deploying HCVs into the network when the required peak frequency of 12.5m standard rigid buses increases beyond six buses an hour or more (10 minute headways or less).

At 10 minute headways, the hourly capacity is 450 pax using 12.5m standard rigid buses. Adding one additional 12.5m standard rigid bus per hour will increase capacity to 525 pax. Swapping the six buses for, say, six 14.5m extended rigid buses will increase the capacity to 552 pax per hour, resulting in a higher total capacity and a reduced whole-of-life per passenger cost.

Six buses an hour also represents a reasonably sized purchase order, allowing the peak fleet requirement for that route to be upgraded in one instance, rather than having a seemingly random mix of bus sizes that are present on some routes[12].

3.3 Impact on Peak-Only Services

On a peak-period-only service, often longer-distance express services, the deployment of a second bus provides increased travel choice.

If the service previously only had a single trip departing at 7:30am, deploying a second bus would allow, perhaps, a departure at 7:20am and another at 7:35am. This in itself should generate additional patronage demand by providing greater convenience and choice of travel time. The question becomes *how much additional demand will be generated by doing this*? This feeds into considerations around the impact on capacity.

Adding a second 12.5m standard rigid bus increases the capacity of the route from 75 passengers, to 150 passengers. In all likelihood, each of the two buses will now have happier, more comfortably seated medium passenger loads, but with some spare capacity.

Alternatively, the same outcome could be achieved by upgrading to a HCV. In this case, the service level would remain the same, and the opportunity to attract new patronage based on improved frequency would be lost. But the increase in available seats and reduced crowding will be attractive and may act to increase patronage, albeit to a lesser degree.

Whether the route in question should be upgraded to a HCV also depends on the operator, and their current fleet mix. If the operator already has HCVs in their fleet, then adding additional vehicles of the same or similar model is not usually seen as a problem.

In the instance that the operator only has 12.5m standard rigid buses, it can become both onerous and financially unattractive to add just one vehicle of a completely different type. Maintenance staff have to be retrained, additional spare parts may need to be kept and drivers may need to upgrade their licences - all just to enable one HCV to be purchased. The Stage 2 Report for this study assumed that HCVs would be procured at no less than five vehicles at a time, in order to gain the economies of scale needed to allow an upgrade to larger vehicles to realise its full benefits.

[12] The authors are aware of the highly complex nature of vehicle scheduling, and whilst in that context the upgrading of an entire route may seem like a gross oversimplification of the service delivery process, it should be seen as an aspiration to provide customers with a consistent product on which they can rely.

3.4 Impact on Traffic Congestion and Runningway Capacity

The impact of vehicle selection on the capacity of a runningway, such as a CBD street or a busway corridor, is often overlooked. The impact on stop capacity is the usual focus of capacity considerations, but each of the different vehicle types also has an impact on road capacity and traffic congestion.

Table 2.1 presented the statistic 'Passengers per metre of bus length', which is repeated below. This is effectively a measure of how efficient each bus type is in carrying passengers, based on the amount of road space that the vehicle utilises.

Table 3.1: Passenger Efficiency per Metre of Bus Length

	Two Door Standard Rigid Bus	Two Door Double Deck Bus	Two Door Extended Rigid Bus	Two Door Articulated Bus	Three Door Articulated *Superbus*
Passengers per metre of bus length	6.00	9.28	6.34	5.00	6.11

In congested traffic environments where buses seem to queue endlessly, such as Adelaide Street or the Victoria Bridge, it becomes highly desirable for the buses to use as little road space as possible so that they reduce their overall contribution to road congestion. This is also true where there are short distances between intersections and buses are unable to move forward at a green light when the road ahead is blocked by queued buses, such as Melbourne Street in South Brisbane approaching the busway entry.

The 12.5m standard rigid bus acts as a benchmark, accommodating 6.0 passengers per metre of length. The two-door articulated buses achieve a notably poorer score of 5.0 passengers per metre. This means that buses needed to carry 900 passengers would require 172 metres of road space if 12.5m standard rigid buses are used, but 198 metres of road space if two-door articulated buses are used (this assumes a two metre gap between each bus).

The three-door articulated bus and the 14.5m extended rigid bus both achieve a modest improvement over a 12.5m standard rigid bus. The 12.5m double deck bus is, however, a clear leader in the space efficiency aspect, benefitting from using the same footprint as a 12.5m standard rigid bus, but carrying over 50% more passengers.

4. Selection of High Capacity Vehicle Types

4.1 Initial Observations

This study has investigated the relative benefits of each vehicle type across a wide range of criteria. Of the five vehicle types investigated, four of them appear to be viable choices for implementation when the capacity of a 12.5m standard rigid bus is reached (the addition of a second 12.5m standard rigid bus is one of the four viable options).

It is clear that the use of two-door articulated buses is fundamentally flawed in a number of ways. This vehicle design, intended to maximise 'seats', then fails to deliver benefits in terms of total carrying capacity, operational efficiency, purchase cost or whole-of-life costs. This vehicle type should thus be excluded from consideration for future procurement, under any circumstances.

4.2 Vehicle Choice Methodology

An original intention of this study was to develop a decision making methodology in a flowchart format that would guide the determination of the most appropriate vehicle type to use in a given situation. Unfortunately, the complexity of the different contributing factors makes such a process more complicated than a simple flowchart can encapsulate.

Instead, we present a series of questions for each vehicle type that will either permit or exclude that vehicle for use. When multiple vehicle types are shown to be viable in a given situation, we present further factors that need to be considered in selecting a specific vehicle type.

One thing is clear:

Any type of vehicle is only suitable for implementation if the corridor and infrastructure which it needs to use, can accommodate its specific geometrical requirements.

In some existing instances where certain HCV types can be used, it is by coincidence, not by design. Infrastructure design standards need be updated to reflect the requirements of whichever types of fleet are the most suitable for a given route, corridor or network region.

Only the 12.5m standard rigid bus is universally useable, including being the only vehicle type that can be used on the 30 TMR identified, steep-incline *Notified Roads*.

Each of the three viable HCV types has its own inherent limitations. For example, a double decker bus won't fit under a low bridge, a 14.5m extended rigid bus won't manoeuvre around tight corners or into some bus stops, and articulated 18m buses won't fit into a workshop shed that was designed for shorter buses.

While roads, bridges and tunnels are harder and costly to retrofit to accommodate HCVs, bus stops are not. The deployment of HCVs based on bus stop capacity, should not preclude HCV deployment, if the bus stop can be retrofitted. State and Local Governments have dedicated funding programs to upgrade bus stops to meet DDA compliance standards by 2021. These funds should also be used to retrofit bus stops to accommodate HCVs.

4.3 Key Criteria for Assessing whether to Include or Exclude each Vehicle Type

The following series of questions for each HCV type to determine whether it *could* be used on a specific corridor or route.

It is inherently assumed that 12.5m standard rigid buses can be used on any existing corridor or route, and that all infrastructure can currently accommodate this vehicle type. Consequently, the use of a second vehicle of this type is a feasible solution for providing additional passenger capacity subject to adequate kerbside space and stop capacity.

4.3.1 Two Door Double Deck 12.5m Bus

Q1: Are there any low-clearance bridges (4.4m or lower) along the corridor that the buses need to pass beneath?
If *no*, proceed to Q2. If *yes*, then exclude this vehicle from further consideration.

Q2: Are there trees, building awnings or other structures (including at stops, stations and layovers) along the corridor that would conflict with the bus?
If *no*, proceed to Q3. If *yes*, proceed to Q2a.

Q2a: Can the conflicts with trees, building awnings or other structures be affordably trimmed or modified to remove conflict with the bus?
If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Are the depots at which the vehicle would be based able to handle the additional height and weight of a double deck bus? This includes hoists, roof heights, door heights, wash bays and fuelling facilities.
If *yes*, the 12.5m double deck bus can be considered a viable option for use on this corridor. If *no*, proceed to Q3a.

Q3a: Can the depot infrastructure be affordably modified to accommodate the double deck buses?
If *yes*, the 12.5m double deck bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.3.2 Two Door Extended Rigid 14.5m Bus

Q1: Are there any turns at intersections, or at access or egress points from bus stations, that the vehicle cannot safely complete without crossing centrelines, mounting kerbs etc?
If *no*, proceed to Q2. If *yes*, proceed to Q1a.

Q1a: Can these turning conflicts be affordably addressed, through physical modification of intersections, kerbs, medians, driveways etc?
If *yes*, proceed to Q2. If *no*, then exclude this vehicle from further consideration.

Q2: Do the on-road bus stops that the bus would serve provide adequate length for the vehicle to stop, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*? This includes providing adequate pull-out distance (10m minimum and 15m minimum for indented bays) so the vehicle can exit the stop without needing to be at full lock and prevent excessive rear tail swing over the kerb area.
If *yes*, proceed to Q3. If *no*, proceed to Q2a.

Q2a: Can the on-road bus stops be affordably modified to accommodate the manoeuvring needs of the bus?
If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Do the individual platforms or stops within the stations that the bus would serve provide adequate length for the vehicle to stop, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?
If *yes*, proceed to Q4. If *no*, proceed to Q3a.

Q3a: Can the individual platforms or stops within the stations be affordably modified to accommodate the manoeuvring needs of this type of bus?
If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q4: Do the layover locations provided within the network provide adequate space for the manoeuvrability and parking needs of this type of bus?
If *yes*, proceed to Q5. If *no*, proceed to Q4a.

Q4a: Can the layover locations be affordably modified, or alternative locations developed, to accommodate the manoeuvring and parking needs of this type of bus?
If *yes*, proceed to Q5. If *no*, then exclude this vehicle from further consideration.

Q5: Are the depots at which the vehicle would be based able to handle the additional length, weight and manoeuvrability requirements of a 14.5m extended rigid bus? This includes hoists, service pits, workshop building depths, wash bays and fuelling facilities.
If *yes*, the 14.5m extended rigid bus can be considered a viable option for use on this corridor. If *no*, proceed to Q5a.

Q5a: Can the depot infrastructure be affordably modified to accommodate the 14.5m extended rigid bus?
If *yes*, the 14.5m extended rigid bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.3.3 Three-Door Articulated 18m Bus

Q1: Are there any turns at intersections, or at access or egress points from bus stations, that the vehicle cannot safely complete without crossing centrelines, mounting kerbs etc?
If *no*, proceed to Q2. If *yes*, proceed to Q1a.

Q1a: Can these turning conflicts be affordably addressed, through physical modification of intersections, kerbs, medians, driveways etc?
If *yes*, proceed to Q2. If *no*, then exclude this vehicle from further consideration.

Q2: Do the on-road bus stops that the bus would serve provide adequate length for the vehicle to stop with the rear door closely located and parallel to the kerb, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?
If *yes*, proceed to Q3. If *no*, proceed to Q2a.

Q2a: Can the on-road bus stops be affordably modified to accommodate the manoeuvring needs of the bus?
If *yes*, proceed to Q3. If *no*, then exclude this vehicle from further consideration.

Q3: Do the individual platforms or stops within the stations that the bus would serve provide adequate length for the vehicle to stop with the rear door closely located and parallel to the kerb, and adequate pull in and pull out distance to allow the vehicle to manoeuvre safely into and out of the stop, in accordance with the TransLink *Public Transport Infrastructure Manual*?
If *yes*, proceed to Q4. If *no*, proceed to Q3a.

Q3a: Can the individual platforms or stops within the stations be affordably modified to accommodate the manoeuvring needs of this type of bus?
If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q4: At stations with physical barriers dividing passenger waiting areas from the runningway (e.g. King George Square), are the door or gate locations suitably located for each of the three bus doors?
If *yes*, proceed to Q5. If *no*, proceed to Q4a.

Q4a: Can the barrier door or gate locations be affordably modified to match the positions of all three bus doors?
If *yes*, proceed to Q4. If *no*, then exclude this vehicle from further consideration.

Q5: Do the layover locations provided within the network provide adequate space for the manoeuvrability and parking needs of this type of bus?
If *yes*, proceed to Q6. If *no*, proceed to Q5a.

Q5a: Can the layover locations be affordably modified, or alternative locations developed, to accommodate the manoeuvring and parking needs of this type of bus?
If *yes*, proceed to Q6. If *no*, then exclude this vehicle from further consideration.

Q6: Are the depots at which the vehicle would be based able to handle the additional length, weight and manoeuvrability requirements of an 18m articulated bus? This includes hoists, service pits, workshop building depths, wash bays and fuelling facilities.
If *yes*, the 18m articulated bus can be considered a viable option for use on this corridor. If *no*, proceed to Q6a.

Q6a: Can the depot infrastructure be affordably modified to accommodate the 18m articulated bus?
If *yes*, the 18m articulated bus can be considered a viable option for use on this corridor. If *no*, then exclude this vehicle from further consideration.

4.4 Choosing Between Viable Vehicle Types

After assessing each vehicle type, a list of viable alternatives will remain.

If none of the three HCV types are viable for use in the given corridor, or the delay in modifying infrastructure to allow their use would be too lengthy, then the use of a second 12.5m standard rigid bus is the appropriate outcome.

If one or more HCV types are viable, then the decision between vehicle types needs to be based on some practical issues relating to the operation of the network, and the procurement, operation and maintenance of the fleet.

The key issues that need to be considered include the following. Each issue could generate a different preferred vehicle type, resulting in the need for a holistic review of the issues in combination.

What vehicle types does the operator already have in their fleet?

It is far simpler and more cost effective for an operator to have large numbers of the same model of bus in their fleet, rather than small numbers of many different models. Consequently, there is a logical argument that if other factors are reasonably comparable, then operators should continue to procure the same types of vehicle they have previously.

For example, if an operator already has a fleet of 18m articulated buses (regardless of the number of doors) and no 14.5m extended rigid buses, it is logical for them to procure three-door articulated buses in the future as they can be immediately incorporated into the fleet.

An exception to this can be created when the number of new vehicles required is large enough to provide economies of scale to reduce their acquisition cost, and justify the investment in upgrading depot facilities, carrying additional spares inventory and retraining staff. This is also the case for an operator who currently does not operate any type of HCV - the acquisition of just one or two HCVs is likely to provide a poor overall outcome given the step change required in depot operations.

How much additional total capacity is needed or will be useful?

The following increases in passenger carrying capacity are offered by each bus type, in comparison to a 12.5m standard rigid bus:

- 14.5m extended rigid bus: 17 additional passengers (23%) including 12 additional seats.
- 18m three-door articulated bus: 35 additional passengers (47%) including 8 additional seats.
- 12.5m double deck bus: 41 additional passengers (55%) including 42 additional seats.
- Second 12.5m standard rigid bus: 75 additional passengers (100%) including 44 additional seats.

In the example of a high frequency route (6 buses per hour or higher) that requires additional capacity, the logical option is whichever bus type is listed highest above, and is suitable based on all other criteria.

The exception to this is if TransLink anticipates future patronage growth and believes that a larger vehicle may present a better long-term option to accommodate that growth.

What distances will passengers be travelling?

This is a fundamentally important issue when considering passenger comfort and resultant desire to catch public transport. The longer passengers need to travel, the greater the justification for increased seating levels.

The double deck bus and the three-door articulated bus have comparable total capacities, purchase costs and whole-of-life operational costs, but the double deck bus has 44 additional seats than the articulated bus.

The 14.5m extended rigid bus has four more seats than the three-door articulated bus, but with a lower total capacity, lower purchase cost and lower whole-of-life cost.

The use of an additional 12.5m standard rigid bus provides an increase in seated capacity similar to the use of a double decker, but at a higher purchase cost (when considering the cost of two buses versus one) and higher whole-of-life costs per passenger km, even if fully loaded.

If routes are long and passengers are travelling long distances, then the double deck and 14.5m extended rigid buses are the most logical choices. The double deck bus provides 32 more seats, but at a higher purchase cost. The decision on vehicle type here should be logically based on the total required capacity.

Do operator depots have the spare parking space required?

Using larger buses requires a larger physical area for the fleet to be parked overnight. Some depots are already at or near capacity in this regard, and deploying HCVs to these locations would trigger a need for additional depot space.

The need to increase depot capacity will need to be included in the economic assessment of any proposal to introduce 14.5m and 18m HCVs into depots that are currently at or near capacity, or if additional 12.5m standard rigid buses are purchased instead of replacing existing fleet with HCVs.

The exception to this is the double deck buses, which have the same footprint as a 12.5m standard rigid bus.

What value does the replaced vehicle represent?

By purchasing HCVs, existing 12.5m standard rigid buses could potentially become redundant. These redundant vehicles have the ability to provide value in any of the following ways:

- To accommodate overall network growth which will require a larger total fleet in the near future;
- If fleet growth is not required, the additional buses will allow the oldest fleet to be retired, reducing average fleet age; or
- If the fleet is relatively young and no buses are of an age at which they would normally be retired, the redundant buses could be sold, realising a financial benefit that will partly offset the purchase cost of the HCVs.

If the increase in passenger capacity is achieved through the use of an additional 12.5m standard rigid bus, no vehicles become redundant, though the number of unutilised vehicles in the off-peak may rise.

5. Summary of Recommendations

5.1 Gain Greater Control over Vehicle Specification

Irrespective of the type of vehicle used, poor decision making regarding basic bus design elements such as seating configuration, number of doors and width of doors has and will continue to result in buses that underperform compared to equivalent vehicles in other jurisdictions. An essential part of this process needs to be discontinuing the use of any form of KPI that reports 'new seats delivered', which encourages the simplistic maximisation of installed seats at the expense of developing operationally efficient and comfortable vehicles. While use of such a metric in the public domain might be more politically palatable and customer focused, compared to quoting total capacity, this should not prevent TransLink from specifying the latter in transport service contracts with its operators. Alternative KPIs could be developed to measure 'new passenger capacity'.

It was revealed in the international research study for the Stage 1 *Operational Performance Evaluation* that significant differences exist between high capacity bus operations overseas and contemporary high capacity bus services operated in South East Queensland. Bus station and bus stop dwell time minimisation was repeatedly identified from the international research as the central focus of best practice leading international mass transit authorities, and all door boarding, wider centre aisles, rear door passenger storage spaces and reduced seating were the strategies typically implemented to achieve rapid alighting and boarding of passengers at bus stations and stops.

To highlight the difference in approaches between Australia and Europe, during a period when Brisbane Transport continued to procure two-door 18.0m articulated buses, the *European Bus System of the Future (EBSF)* project developed and deployed an 18.7m five-door articulated bus into operation in Budapest[13].

It is strongly recommended that TransLink takes a greater and proactive role in specifying the design of the vehicles that they subsidise each operator to purchase and use in the TransLink network. This may extend to working directly with manufacturers to develop a TransLink Vehicle Specification, for each of the available bus sizes, that will detail the requirements needed to achieve operationally efficient outcomes. Development of such specifications would be greatly assisted by the wealth of research undertaken by this study and the EBSF project[14].

5.2 Discontinue the Procurement of Two-Door Articulated Buses

Aside from providing a large number of installed seats, the two-door articulated bus provides no benefit to the TransLink network, and seriously impacts the efficiency and performance of the bus services the vehicles are used on, and the stop infrastructure they access.

It is strongly recommended that TransLink negotiate with its operators to discontinue the procurement of these vehicles.

Additionally, it may be technically feasible and financially viable to modify existing two-door articulated buses to add a third door, modifying seating arrangements at the same time.

[13] http://www.uitp.org/news/pics/pdf/Budapest%20Press%20Release%2002.11.2011.pdf
[14] http://www.ebsf.eu and http://www.ebsf.eu/images/stories/documents/EBSF-DEMONSTRATIONS-Leaflet.pdf

5.3 Continue to Investigate the Use of Double Deck Buses

Inarguably, double deck buses pose an obvious height clearance issue on some routes, whether it be low bridges, overhanging trees, building awnings or incompatible station infrastructure. However, many of the routes on which HCVs may need to operate travel along major roads where numerous heavy vehicles, with the same height constraints also travel, suggesting that double decks buses could be used.

The trial use of the double deck buses by Hornibrook Buslines on Route 315 is a conceptually good example of where double deck buses can be useful. Any route that carries a large load of passengers a relatively long distance is a viable candidate, assuming vertical height clearance is acceptable. High patronage services from Browns Plains, Logan and Redland Bay could also be potential candidates for double deck bus deployment.

Double deck buses also have an undeniable novelty value, making them more attractive to some passengers. The opportunity to travel on the upper deck on a long journey and enjoying the view is an attractor to these buses worldwide. In a time of declining public transport patronage in the TransLink network, the attractiveness to passengers of these buses should not be underestimated.

It is important to note that the Bustech double deck vehicles trialled by TransLink are prototypes, and had inherent flaws that affected their reliability, possibly diminishing their acceptance by the industry. This needs to be acknowledged as a flaw in the *vehicle*, not the vehicle *type*. It is worth noting that the Bustech double deck vehicle design has gone through two further stages of redesign and refinement, with the buses they are now producing for the Sydney market being markedly different to the prototypes.

The new double deck buses being procured for deployment in Auckland in March 2013 are manufactured in Malaysia and are an existing "off-the-shelf" design. Designs used overseas also offer distinctively different features, optimised around efficient passenger loading on high-turnover routes. For example, the double-decker buses in Berlin (MAN Lion's City DD model) have dual staircases and three doors, with a bus length of 13.7m and a total passenger capacity of 121 (83 seated and 38 standing[15]).

Whilst the Australian bus industry is to be commended for developing new double deck bus designs, bus procurers should be encouraged to look further afield in order to obtain the best vehicles available, especially considering equivalent buses built in the United Kingdom are more than one third cheaper than Australian-built buses[16]. This is particularly true with HCVs as they are typically procured in smaller volumes, and with few competing models manufactured in Australia there is little in the way of economies of scale or market price competitiveness.

A clear caveat to this is the logical desire for operators to have a consistent fleet to maximise efficiencies in areas such as scheduled maintenance and spare parts inventory. The procurement of fleet from overseas would need to comprise a sizeable order from a well-established manufacturer, who is able to commit to providing ongoing support and an efficient supply chain to the Australian market.

[15] Sourced from http://www.postauto.ch/en/pag-startseite/pag-ueberuns/pag-portrait/pag-fahrzeugflotte/pag-fahrzeugflotte-fahrzeuge/pag-fahrzeugflotte-fahrzeuge-doppelstock.htm

[16] It is the opinion of the author that exceptionally high-standard, high-capacity vehicles could be built in the United Kingdom to a TransLink specification that meets Australian design regulations. The purchase price of an 18m articulated bus in the UK is approximately $300,000 to $350,000 AUD - less than half that of an Australian manufactured bus. Considering that these buses use the same drivetrains and componentry as Australian models, there is a strong financial argument in support of importing HCV buses rather buying locally. Even after shipping costs, import duties and compliance checks, imported HCVs could still be priced as low as half of the Australian models ($750,000). A hybrid model exists where UK manufacturers ship HCV buses in kit-form, for local assembly.

5.4 Innovate

We refer repeatedly to emerging best practices identified overseas, particularly in Europe. One observation is that vehicle lengths can be far more varied than the 12.5m, 14.5m and 18.0m lengths used as a standard in Australia.

It is noted Kangaroo Bus Lines operate a small number of 13.5m extended rigid buses. This length of bus is rarely seen in Australia, but is quite common in New Zealand and is the standard vehicle length used in Auckland. The additional metre increases passenger capacity by at least 6 passengers. As the vehicles are one metre shorter than the 14.5m extended rigid vehicles used in Queensland, they have better manoeuvrability and would most likely be more compatible with existing infrastructure than the other HCV vehicles assessed.

5.5 Update Standard Infrastructure Designs to Accommodate HCVs

It is noted that current infrastructure design guidelines and manuals do not detail the requirements of 14.5m buses, or double deck buses. This means that infrastructure is currently being designed and constructed that may not accommodate these bus types.

It is recommended that all bus infrastructure design guidelines and manuals be updated to reflect the specific geometric needs of each HCV type.

5.6 Reconsider the Need for High Capacity Vehicles

No HCV outranked the Standard 12.5m Rigid Bus on the like-for-like performance benefit to cost ratio evaluation. Notwithstanding it being the second dearest vehicle to operate based on cost per pax-kilometre, the standard bus significantly outperformed every high capacity bus and was fully compatible with all existing bus stations, stops and depots.

These buses have the greatest flexibility in use, particularly in off-peak services when higher capacity vehicles are less likely to be needed.

Adding a second standard 12.5m rigid bus to the network will provide improved service frequency, creating a more attractive network and potentially increasing patronage. Swapping to a larger bus but retaining the same frequency has far less potential to attract new patronage.

It is suggested that only when a service's frequency needs to increase beyond six buses an hour, that HCVs be automatically considered as a measure to address overcrowding.

QUEENSLAND GOVERNMENT

TransLink Division Briefing Note

Our ref TRIM DOC13/6434
Your ref
Date 22 February 2013

To Stephen Banaghan, General Manager (Passenger Transport Services)

Copy to Michael McGee, Executive Director (Bus, Ferry, Coach & Air)

Subject **Superbus Review and Analysis Project | Finalisation of MRCagney's Analysis**

Background

- MRCagney were engaged as expert consultants in January 2012 to undertake a review and analysis of high capacity vehicles (HCVs). The project's first phase examined the performance of HCVs on TransLink's network; the second phase focuses on the infrastructure issues associated with HCVs. The broader scope was intended to inform a number of TransLink strategies including depots, fleet and infrastructure to support analysis of HCV options.

Comment

- MRCagney's analysis project was split into two phases for practical reasons, not financial. This mid-way review provided an opportunity for key stakeholders to consider the Phase 1 findings and re-scope Phase 2 as necessary.
- Phase 1 focused on evaluating the performance of HCVs on TransLink's network, reviewing and analysing related infrastructure, and analysing current depot configurations and their suitability/capacity to house and maintain HCVs.
- MRCagney delivered a finalised Phase 1 Report in December 2012. In finalising this phase, feedback was sought from the (former) Bus & Ferry, Infrastructure & Investment and Strategy & Planning directorates and their comments were incorporated in the finalised report.
- Phase 2 focused on the capital and operational (running) cost impacts of procuring and operating HCVs and the depot and network infrastructure improvements associated with the deployment of HCVs on TransLink's network.

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- MRCagney delivered their draft Phase 2 Report which raised only a few queries from the SEQ Bus Contracts Team. Feedback was also sought from the Passenger Transport Integration Branch.
- Attached to this brief are the queries raised with MRCagney and their corresponding response.
- MRCagney have today presented their finalised Phase 2 report. Additional Phase 2 supporting documentation is expected to be finalised and received by end February 2013.
- Upon receipt of the finalised supporting documentation, a further brief will be prepared summarising MRCagney's review and analysis. At your discretion, it may then be appropriate to brief the TransLink Operations Panel or Leadership Team.

Recommendation

It is recommended that you note the next steps:

- Preparation of a further brief upon finalisation of MRCagney's Phase 2 report and supporting documentation;
- Presentation/briefing to the TransLink Operations Panel and/or Leadership Team.

Lisa Parker
Director (SEQ Bus Contracts)
TransLink Division
Department of Transport and Main Roads

Comments:

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Responses to TransLink HCV Phase 2 Operating Cost Evaluation Feedback

Please find below our responses to the feedback received from ***TMR TransLink Division*** via email dated 18 January 2013 relating to Issue 2 of the ***HCV Stage 2 Operating Cost Evaluation Report***.

Edits referred to in the responses below have been incorporated in the final version of the report - Issue 3 dated 27 January 2013.

Responses:

C1 Your analysis was based on a 5 bus procurement (page 5, 3rd dot point). This is not necessarily likely for all our operators. Can you please provide some commentary on why calculations were made on this basis, and what the effect on outcomes would be if only 1 bus was purchased?

R1 In Stage 1 of the HCV study, MRCagney and TransLink representatives identified a list of SEQ bus operators considered most likely to deploy high capacity vehicles in the near future, and our Stage 1 stakeholder interviews, Stage 1 technical reports and Stage 2 ***Operating Cost Evaluation*** were subsequently focussed on this target group, their depots and existing bus stop infrastructure in their respective contract operating areas. The 6 operators targeted for stakeholder interviews and HCV deployment evaluations were, with the exception of Hornibrook Bus lines, all large fleet operators with 120 or more TransLink route buses and included:

- Brisbane Transport,
- Surfside Buslines,
- Clarks Logan City Bus Service,
- Veolia Transdev Queensland,
- Park Ridge Transit, and
- Hornibrook Bus Lines.

From our experience, large fleet operators such as these strive to avoid procuring small fleet subgroups of 1 or 2 buses and to exploit their buying power with bus chassis and body manufacturers to obtain the best prices for new bus procurements. By rule of thumb, the average fleet renewal rate for a large fleet operator is equal to its bus fleet strength divided by its preferred bus retirement age. So to avoid a Queensland 21 year full body structural refurbishment, operators with 120 or more standard route buses should theoretically at least be purchasing new replacement standard buses at an average rate of at least 6 or more vehicles per annum. Because high capacity buses are dearer than standard buses, we selected 5 buses as an indicative lot size on which to base our cost estimates and to amortise other ownership capital costs. Our bus procurement, finance lease, capital tax deduction, resale price, insurance and depot upgrade capital estimates have all been based on the procurement of 5 buses at volume production prices.

Per bus cost estimates would not be greatly affected for say a smaller economic lot procurement of 3 or more similar high capacity buses but would be significantly impacted for a one-off procurement of a custom built high capacity bus unless it were piggy backed onto another bus operator's bus build contract. This strategy was adopted for instance to procure the 2 Logan City articulated ***Superbuses*** which we understand were sourced off a then existing Sydney Buses articulated bus build production line.

The cost of gearing up a special HCV body build for a single custom built 14.5m rigid or 18m articulated bus would likely result in procurement costs at least 10-15% dearer than the estimated procurement costs appearing in Table 6 of our report, unless the operator deliberately chose to piggy back off an existing large bus operator production run with minor variations, to procure a fully built stock production bus from a mainstream Australian bus builder such as Custom Coaches, Denning or Volgren, or alternatively imported a fully built stock production bus from an international supplier such as Daewoo or Higer (which is not SEQ operator contemporary procurement practice).

Our procurement and financial cost estimates could be used for these 3 alternative options, but other cost estimates in our report for items such as depot modifications, spare parts, garage equipment upgrades, finance lease terms and insurance that have been amortised over 5 similar high capacity buses would no longer hold true. These in turn would ripple through most of the calculations and findings in our report requiring significant rework. We believe our current assumptions are representative of those applicable to TransLink's larger operators.

C2 Regarding overall fleet size, can you provide some commentary about at what point do the number of HCVs in a fleet become saturated in terms of realised savings on maintenance, etc?

R2 Ironically, TransLink is a victim of SEQ population growth and its own success at attracting ever more passengers onto public transport during the commuter peaks through initiatives already implemented including more reliable, more frequent, faster and coordinated PT services, fleet modernisation and upgraded PT infrastructure. Put simply, passenger demand on peak commuter services is creeping ever upward to the maximum carrying capacity of a standard route bus and is being experienced in ever Australian capital city.

As and when standard bus overloading occurs, the options facing TransLink are to either increase fares to dampen growth, permit random minor overloading to occur, increase existing affected service frequencies (ie by deploying more standard 12.5m buses and bus drivers) to meet the demand, or increase vehicle carrying capacities. If a low floor 75pax standard bus service has to be augmented by an additional service (ie an additional bus and driver), the service capacity jumps a quantum leap from 75pax to 150pax resulting in two underutilised buses and the surplus capacity cannot be economically utilised during the off-peaks.

For the reasons explained in our Stage 1 reports, we do not advocate deployment of high capacity buses on every ad hoc service reported as overloaded by drivers or operators, and numerous other factors such as existing stop lengths, road widths, bridge clearances, depot garage constraints, parking yard capacities and circulation will determine on what routes HCV's can ultimately be deployed. Tables 23 to 25 in our ***Cost Evaluation Report*** have shown that, inclusive of driver wages, all HCV's are dearer to operate than standard rigid 12.5m buses and only reap significant savings when they can board high passenger loads. The cut over point at which one high capacity bus and driver becomes more economical to operate than 2 standard 12.5m buses and 2 drivers in the peak has also been evaluated in Tables 26 to 28. The latter tables take into account the added cost of continuing to operate underutilised HCV's during off-peak periods and demonstrate realisable savings for all HCV bus types other than perhaps the double deck bus which achieves only marginal savings.

Thus in conditions where population, urban sprawl and passenger demand continue to grow, HCV's can be readily cost justified, and no point of saturation is reached based solely on HCV ownership, maintenance or operating costs. From on our earlier Stage 1 studies, where routes can continue to be found with bus station/interchange and roadside stop infrastructure suitable for HCV deployment, depot parking yard capacity would most likely limit the continued growth of the longer single deck HCV buses.

C3 ***Section 2.4.2: Bus Procurement Financial Costs*** (page 23, 1st dot point) – "...funded by a TransLink guaranteed finance lease...." – this assumption needs clarification. TransLink funds buses through our 3G contract arrangements. We do not however fund every bus at 100%. This is determined bus by bus, through agreement with the operator. The operator is responsible for leasing arrangements. TransLink does not guarantee any lease.

R3 Our references both to a "TransLink guaranteed finance lease" in Section 2.4.2 and implied as a lease "guarantor" in Section 2.2.5, have been deleted from the Issue 3 final version report. This assumption was originally included in our write-up because we were advised by fleet lease financiers that their lease conditions covering the maximum term, interest rate and minimum residual percentage for route bus fleet assets were set differently for different operators according to the operator's perceived financial risk. Because the leasor retains ownership of its leased vehicles until the lease has expired and the residual has been fully paid out, lease conditions are based on the operator's established credit history and business continuity risk. Existence of a long term TransLink 3G operating contract is taken into account by financiers when assessing the operator's business continuity risk.

C4 The analysis is based on full bus loads (assuming this has to be the case otherwise there would be no differentials between vehicle types). However the reality is that on average, buses are nowhere near full loads. Are there some comments needed to reflect this? In effect, we are building peak capacity with bigger buses, but like most PT, that peak capacity is underutilised for most of the day.

R4 We concur with the points made in this comment and have attempted in 2 sections of the report to provide some answers to the concerns raised. The key focus of the study was to evaluate the relative costs of owning, operating, maintaining and servicing the 4 alternative high capacity buses relative to the costs of owning, operating, maintaining and servicing standard 12.5m rigid buses under identical life cycle and operating conditions.

<u>Maximum bus passenger loading has been assumed throughout the cost report but only for the purposes of including its effects on operating costs, not on operating revenues.</u>

We have captured the cost of bus passenger loading by its effect on the total dwell time spent at bus stops to board and alight the full complement of passengers applicable to each particular bus type. The original detailed analysis for stop dwell time was undertaken in the Stage 1 operational performance report and its results, which included average times lost decelerating and accelerating at stops, were translated into average service speeds for different combinations of route length and number of stops per trip at 3 typical incident traffic speeds. An extract from the Stage 1 report has been included in our cost evaluation report at Table 18. By dividing the driver's paid hourly rate by the average service speed applicable at the 3 typical Brisbane road traffic speeds (ie 30km/h, 45km/h and 75km/h), we have been able to calculate the cost of increased passenger loading for the 5 bus types and include it in the driver's wages.

We have not attempted in the study to examine the broader impacts of average boarded passenger loads, fares and zone crossings on TransLink's collected ticket revenue. Section 3.4 of our study has however examined the breakeven relationship between ticket revenue, operating cost and operator subsidy using a simplified linear model in which operator subsidy was zeroed out and ticket revenue was set equal to each vehicle type's life cycle operating cost plus operator profit margin and assumed proportional to the pax-kilometres travelled. This analysis yielded the passenger loads needed to board a high capacity bus relative to those boarded by a standard bus, to just break even. By assuming a 75 pax maximum passenger load for the standard bus, we could then identify the corresponding break even passenger loads needed for each of the HCV bus types.

Calculating the real impacts of average passenger loadings on ticket revenues would prove to be a very difficult and complex undertaking. It requires a detailed knowledge of passenger origins and destinations, ticketing, zone based fare structures and zone crossings for each particular HCV service being operated. Over the 20 year plus life cycle of a bus, all these revenue related variables are constantly changing so the task of modelling such would be somewhat difficult.

Our approach to resolving the contentious issue of HCV capacity underutilisation during the off-peaks in the absence of revenue data has been addressed in Section 3.3.4 of the report. Here we consider the real life case of an existing peak commuter service whose passenger demand can no longer be satisfied by a standard bus capacity, and compare the relative costs of the option to either increase the frequency by stepping in a second standard bus and driver with the option to simply replace the standard bus with a higher capacity bus. We have assumed in this case study that the passengers carried by either option remain unchanged. Therefore the revenue collected using either option remains the same and nulls out in the overall comparative net cost evaluation. We highlighted the caveats to this revenue assumption, noting particularly that increased frequency would be likely to attract more passengers and a thereby higher revenue over the long term.

We have included in this evaluation the added marginal cost of operating the underutilised HCV on off-peak services for 75% of its service life kilometres in lieu of a better utilised standard bus, and have deducted the savings accrued by one less standard bus and one less part-time driver needed to operate overloaded services during the peaks, assumed to make up only 25% of the HCV service life kilometres. The results of this analysis appear in Tables 26 through 28 and show that provided the HCV has the capacity to board the standard bus overload, every HCV is cheaper to operate with one driver, but the double deck bus is only marginally cheaper than the two standard bus option.

Based on our Brisbane Transport interviews and on capital city route bus operations experience right across Australia; increasing population growth, urban sprawl and peak commuter service passenger demand is progressively outstripping the carrying capacity of standard route buses and while this continuing growth persists, so too will the demand for more HCV's. As BT learnt in the 1990's, it is uneconomical to only operate high capacity buses during the peaks, dead run them back to depot, substitute standard buses and drivers back onto off-peak services, and let HCVs sit idle during the off-peaks. HCV's can only be economically justified if they are used both during the peaks and off-peaks (including late night, weekend and public holiday services), albeit with underutilised capacity in the latter case.

C5 I like key finding Point 7 – Illuminating and well made + Section 3.8 too.

R5 We are delighted that this key finding has been noted by TransLink because we are keenly aware from our Stage 1 analyses of the adverse impacts caused by designing HCV buses for maximum seating versus better cabin circulation and minimum stop dwell. We would recommend the commenter also review our other key findings from the Stage 1 operational evaluation, particularly the greatly improved infrastructure utilisation and dwell time savings being achieved overseas from balanced all door boarding and onboard go card processing in door queuing areas when HCV buses are still in motion. HCV buses benefit greatly from initiatives that reduce stop dwell to a minimum.

Because our brief was to focus on existing HCV buses in SEQ, we did not mention that there are other smaller classes of HCV bus, namely standard 12.5m rigid buses fitted with less seats to increase their legal carrying capacity, and 13.5m rigid buses with reduced seating which can legally carry more passengers than current generation SEQ 14.5m rigid buses.

C6 Page 11, 1st bullet – Don't the 90 & 110 passenger artics have the same manoeuvrability? Shouldn't this point be more specific?

R6 Yes, the 90 pax two door and 110 pax 3 door articulated buses have identical full lock turning circles and bus stop manoeuvrabilities, but have slightly different bus stop deceleration/acceleration rates and maximum service speeds in live service. Table 34 in Section 3.9 of the report summarises all the operational, bus depot and stop infrastructure compatibility data gathered during our Stage 1 investigations for the 5 bus types, and compares their relative weighted performance scores line-by-line, as well as deriving their total weighted benefit to cost ratios. To organise the data comparisons in Table 34, driving performance and road manoeuvrability were logically grouped together into a single assessment category, and each row in the table was colour coded for ease of interpretation and visual comparison.

The objective for including Section 3.9 and Table 34 in our report was to determine if the relative rankings of the 5 bus types changed materially when assessed by their operational performance benefit/cost ratios relative to their rankings earlier derived from life cycle costs per kilometre and pax-kilometre in Part 3. It was not our intention in the bullet point nominated in the comment to provide a detailed discussion of all the performance data appearing in Table 34, but to provide a one paragraph overview as to where and why the rankings had changed when operational benefits and disadvantages were taken into account. The 110pax double deck bus scored poorly in the category of driving performance and manoeuvrability and that is why the general reference to manoeuvrability appeared in our bullet point. This reference has now been removed in the final version report to avoid further confusion.

C7 The data doesn't appear to be sourced. Where has it all come from? Very impressive amount of data mind you.

R7 We were instructed by TransLink in November/December 2012 not to contact or request any cost information from its SEQ contract bus operators or their bus manufacturers, and have therefore deliberately not contacted these parties or disclosed our confidential data sources in the report. Prior to receipt of Translink's instruction, some cost data had already been voluntarily furnished to MRCagney during the Stage 1 stakeholder interviews by 4 of the earlier mentioned operators and 2 of their bus manufacturers, and this data has been used in the HCV cost evaluation.

Because we were constrained by TransLink's request not to contact its operators, commercial-in-confidence data was obtained and used in our report from 2 other Australian PT authorities and 2 NSW/Victorian bus builders with whom we maintain ongoing business contacts. We also obtained confidential private bus contract pricing data from Tasmania and NSW where bus industry/government agreed bus operating costs and annual indices are applied when revising operating contracts similar to TransLink's 3G operator contracts. We also sourced some limited operating cost data for STA buses from the IPART and STA/RTA (NSW) websites.

Insurance, commercial loan, fleet finance lease, industrial property rental, HCV garage equipment and spares, washing machine maintenance, bus towing, aftermarket bus resale values, gearbox/engine overhaul, bus repaint, bus body frame refurbishment, diesel and Adblue costs were obtained simply by ringing/ emailing commercial suppliers and coach repairers and requesting their indicative budget costs, charges and rates.

Driver, bus cleaner and tradesperson labour rates were obtained from publically registered awards and certified agreements. Electricity rates, CTP, ADR compliance, bus registration charges and ABS cost inflators were obtained from government websites. Our knowledge of typical bus servicing times, TMR inspection routines and labour rates were used to calculate time based bus auditing, inspection and servicing costs. Kilometre based maintenance costs were obtained from public operator and bus industry sources. We reviewed several MRCagney bus maintenance studies and 2 large maintenance cost databases previously received from a large Queensland bus operator and local government authority to obtain indicative bus equipment maintenance intervals, parts and labour costs.

We can disclose with confidence that all the data appearing in the report has been adjusted to FY2012/13 current values, is valid, verifiable and accurate. We prefer not to nominate the public and private sources of this data as this would constitute a breach of our confidentiality agreements.

While every effort has been taken to keep our sources anonymous, specific bus operators and bus manufacturers might recognise some of their own confidential data in our cost evaluation report (for example, the fleet distance : age profile in Figure 1, the 14.5m bus floor plan in Figure 3, the bus procurement prices, maintenance rates and intervals appearing in several tables, etc). We would request therefore that the report not be disseminated to bus operators and manufacturers or published to the web.

C8 So at what point does it make sense to invest in HCV's? When the frequency of a route using 12.5's is so high that you can't manage the schedule? I guess I'm still not clear at what point in the Brisbane context do you switch to HCV's? Very few routes achieve close to maximum capacity all day. Therefore, does this mean we will never obtain economic benefits from HCV's until we have routes that are running at near capacity all day?

R8 These questions have been partially addressed in Responses R2 and R4 above, but there are other complicating factors described in our earlier Stage 1 reports which must be taken into account before deciding whether to deploy HCV buses on overloaded services. These factors include:

- Determination by TransLink planners as to whether the overload condition being reported by an operator and/or its drivers actually exists and warrants service augmentation. For instance, a reported standard bus overload may be seasonal, of short duration/transient, or could be occurring on a HFP route, arterial road or busway section where missed passengers at stops would normally be picked up by other following buses within a few minutes. Deciding whether augmentation is warranted requires a detailed analysis of the route, other services sharing the route, and stop-by-stop boarding and alighting counts on the alleged overloaded service to calculate the total boarded passengers in each route section over a representative period of some weeks. We understand TransLink has, or is already in the process of developing, its own in-house ticketing analysis software to do this stop-by-stop route section load analysis.
- Determination as to whether the route and existing bus stop infrastructure are suitable for deployment of HCV's. The best value-for-money substitute 90 pax HCV is the 14.5m rigid bus, but this vehicle can only be deployed on (TMR, or in the future, national Heavy Vehicle Regulator declared) concessional access roads. The best value-for-money substitute 110 pax HCV is the 18m articulated ***Superbus*** but most existing bus stations, interchanges and roadside stops in Brisbane north of the river are unsuitable for 18m articulated buses. While double deck buses can use most existing stops (but not all suburban stations/interchanges) on both sides of the river, their economic and turning circle performance are poor, they can't be accommodated in most existing Brisbane operator depots without major building or bus wash modifications, and numerous existing low railway bridge clearances to the west of the CBD prevent their route deployment.
- Determination as to whether the applicable service operator has HCV's it could deploy to operate the overloaded service. Brisbane Transport has a substantial and still growing fleet of 14.5m rigid buses and 30 two door articulated buses, but the latter are the poorest value for money HCV to use because they have been deliberately built to maximise seating capacity rather than to maximise total carrying capacity and minimise total stop dwell time. Current BT articulated buses are CNG fuelled. Their range is limited to 450km and depots where they can be stationed on the northside are limited to just one, viz the Virginia Bus Depot. Apart from BT, the only other operators with HCV buses operating in Brisbane are Hornibrook Bus Lines, Veolia and Clarks Logan City Bus Service, and as explained, there is no inducement for operators to deploy larger buses.
- Determination as to whether the HCV bus, once deployed, can be cost-effectively utilised during the off-peak periods. Ideally a HCV would continue to operate the same route experiencing peak period overloads all day, as well as on weekends and public holidays. It would simply be uneconomical for a HCV to spend the greatest portion of its working life otherwise parked in depot. The cost per kilometre to operate any bus falls exponentially with increasing average annual kilometres. As for standard buses, HCV buses also need to clock up high average annual kilometres to economically recoup their fixed annual, ownership and sunken investment costs.

We can state unequivocally that it is less costly to operate an overloaded peak service with one HCV and one driver than to augment the overloaded service with a second standard bus and driver. The recurring concern in the comments appears to be that a HCV if deployed, remains under loaded and underutilised for the remainder of the day. What seems to have been forgotten is what happens to every extra standard bus the operator has had to purchase, service and maintain, and extra part-time driver the operator has had to employ for overloaded peak service(s) when the alternative augmentation option is pursued. The extra standard bus has to be dead run to and from its home depot to complete the augmented service, then sit idle in the depot until the next overloaded service occurs, and the driver has to be sent home and return back to depot.

Even if the returned bus and driver could be reallocated to other work on off-peak services, they would still essentially be surplus underutilised assets because there would normally be plenty of other standard buses and full-time drivers available at the home depot during the off-peak periods. Deliberately transferring off-peak kilometres from existing buses and drivers to surplus buses and part time drivers does not reduce operating costs, it simply redistributes the costs over the fleet and all drivers as a whole. The cost reduction trick is to reduce the maximum peak bus demand, and maximise the annual kilometres travelled by every bus and every driver.

We have looked at typical peak patronage counts and weekly timetables for a mix of routes on which BT and Logan City Bus Service currently deploy their HCV's, and have determined that their HCV's are being substantially loaded for 20% to 30% of weekly operating hours, primarily during the AM and PM commuter peaks, but often including the late AM and early PM overlaps for school, college and Uni services, and in particular cases, for late night shopping and recreational peaks. We concluded that the capacity of these HCV buses was being substantially utilised for around 25% of weekly operating hours on average, and underutilised for the remaining 75% of their whole-of-week off-peak service hours. Our case study in Section 3.3.4 proved that peak overload augmentation by HCV's was cost justified relative to augmentation with additional standard buses and part-time drivers.

From our reasoning, if a 10km or longer service is proven by TransLink to be consistently overloaded and its route and stop infrastructure are suitable for HCV buses, the best <u>long term</u> economic option is to deploy a HCV bus on the overloaded service(s) rather than to continue adding more underutilised standard 12.5m rigid buses and drivers. Increasing population, urban sprawl and passenger demand virtually guarantee that eventually more and more bus services must begin to reach the point of overload and this has been observed in every Australian capital city where retiring standard buses are being progressively replaced by HCV buses.

Every extra standard bus currently procured for augmenting existing SEQ services has a 20 year payback period left to recover. By continuing to unnecessarily augment overloaded services with standard buses, TransLink and its operators are effectively locking in a long term scenario where average standard bus kilometres must fall and homogenous standard bus fleets incapable of meeting long term future peak demands. Continued growth of standard bus fleet and driver establishments may well suit bus operator business plans, but ultimately it will be the State who must subsidise an ever growing tally of unnecessary augmented standard bus services. Without a concerted policy change, we foresee that there is simply no inducement for private operators to switch to more cost efficient larger buses to meet projected passenger growth demands.

We conclude by restating that contemporary ultralow floor standard and HCV buses are being inappropriately designed and built for maximum seating rather than maximum capacity and minimum stop dwell time. With the added axle weight concessions afforded by State and Federal regulators to ultralow floor buses, higher capacity utilisation could be obtained on all bus types including SEQ standard 12.5m buses, and the relative costs of operating the two door and three door articulated buses have verified this important finding. We think there needs to be a shift in thinking to the future viability of the homogenous standard size bus fleets currently being locked in for 20 years by most private operators and to providing mass transit services rather than conventional small city route services. In relation to HCV buses, all door boarding, wider aisles and dedicated passenger storage areas at doors would reap very significant cost savings and improved utilisation of existing station/stop infrastructure.

C9 Overall, this is a great report. Stacks of data, well thought through and the analysis has been taken to its logical conclusions.

R9 We appreciate the comment.

C10 There are a lot of duplicate/repeated paragraphs, misplaced headings etc. in the copy we were sent – by now these may have been picked up and corrected by your team. Let me know if you want me to run through these.

R10 We have fully reviewed the original Word and Adobe .pdf versions of the Stage 2 report and found that every Word cross-reference to either Figure 1 or Table 1 was pasting identical blocks of text into the pdf printout. We have traced this weird error to the ***Style*** settings embedded in our Word report template, and have removed the Style and reference links that were causing the error. Thank you for drawing this to our attention.

Transport and Main Roads

Superbus Project

Research and Analysis of High Capacity Vehicle Use - Recommendations and Project Closure

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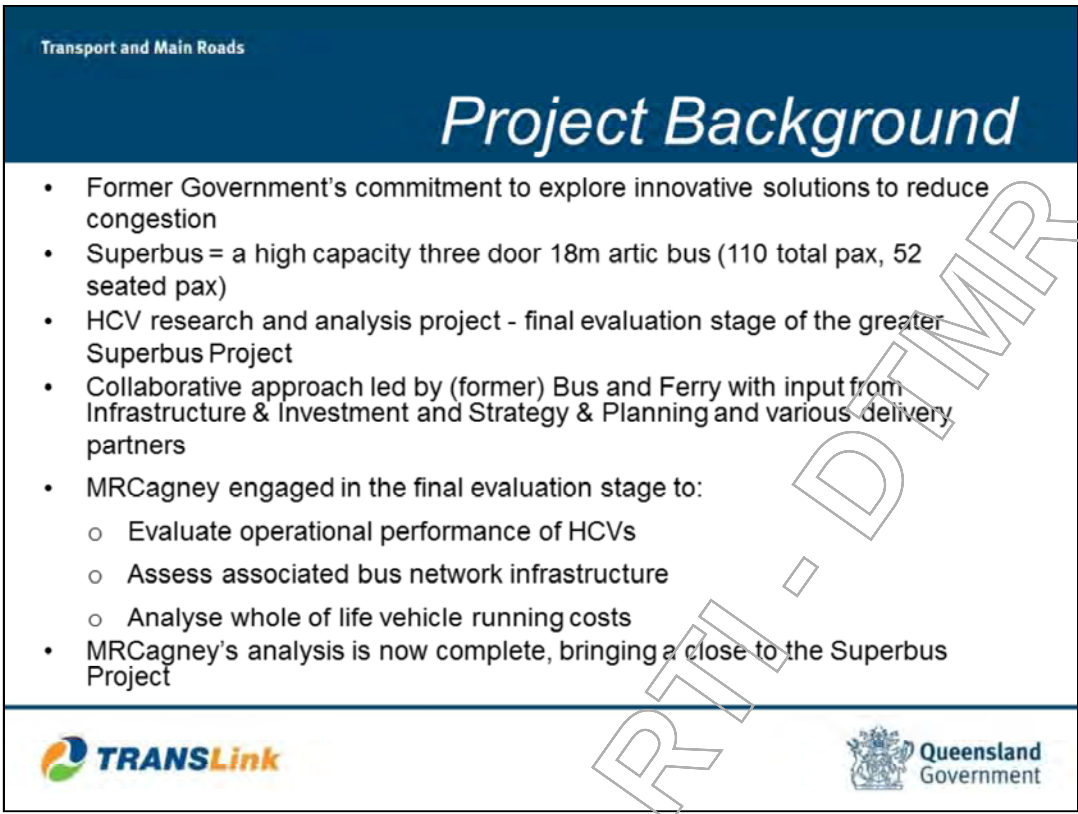


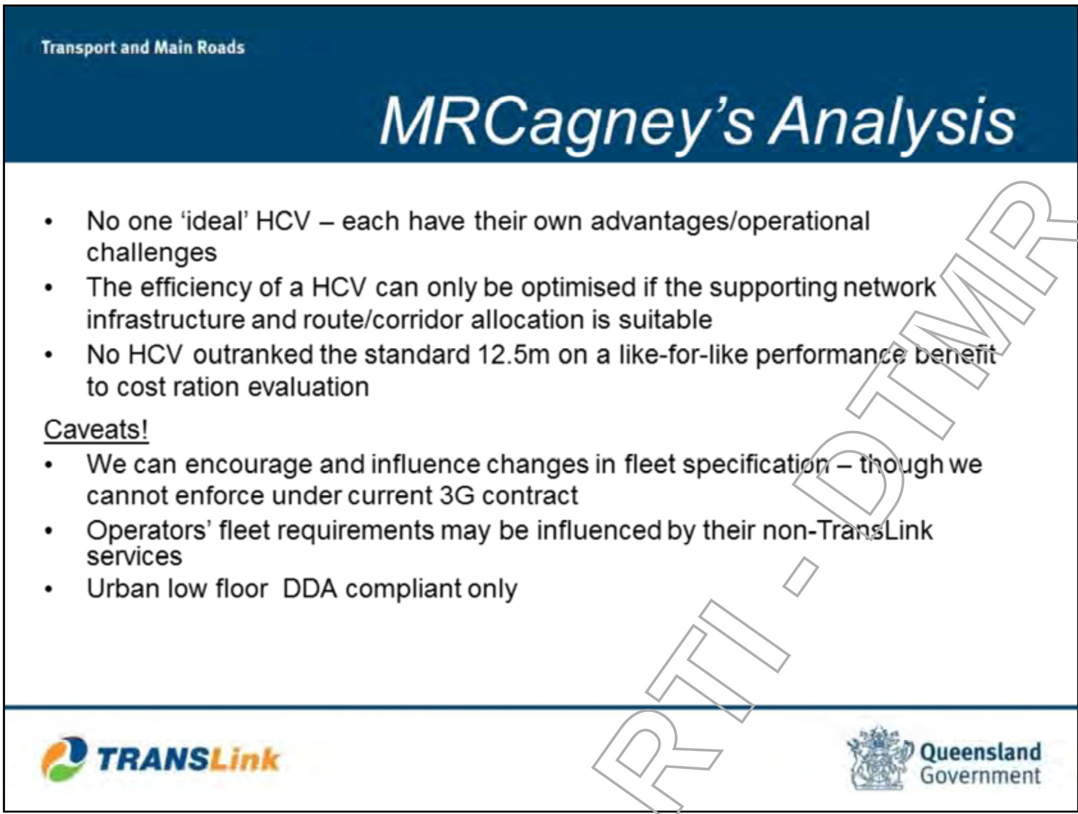
CBRC approval was given and funding received (2008/09 to 2011/12) via TMR's Congestion Management Office (CMO) to procure two superbuses (originally 6) and evaluate their performance.

Superbuses are now owned by Clarks Logan City and operate on the high frequency 555 route (Loganholme to Brisbane CBD).

Analysis phase re-scoped to include all HCVs operating on TransLink's network, not just superbus.

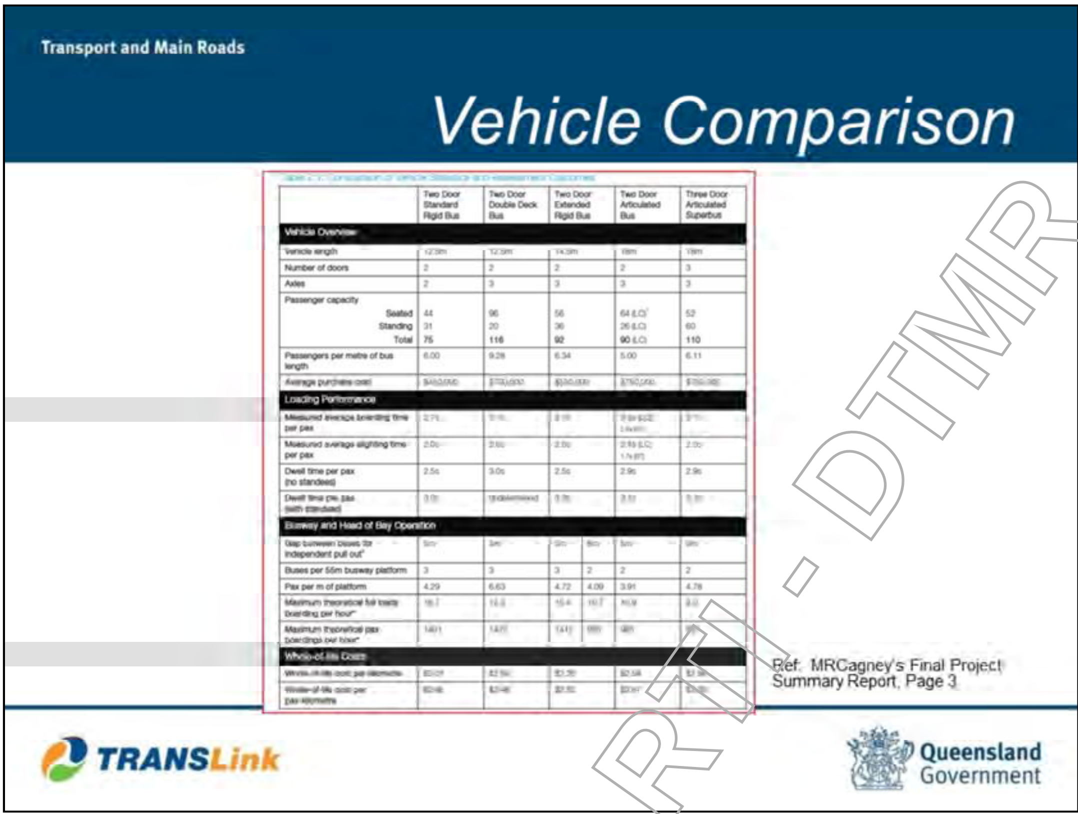
Two stage approach to analysis phase – operational performance, infrastructure assessment, then costings .

HCVs assessed include 14.5 rigid, double decker, 18m artic and superbus (benchmarked against 12.5m standard bus).



Two detailed analysis reports have been finalised, together with an Exec Summary (copy provided).

Common adoption of 12.5m buses has seen bus network infrastructure built to accommodate (and maximise) the 12.5m's.



	Two Door Standard Rigid Bus	Two Door Double Deck Bus	Two Door Extended Rigid Bus		Two Door Articulated Bus	Three Door Articulated Superbus
Vehicle Overview						
Vehicle length	12.5m	12.5m	14.5m		18m	18m
Number of doors	2	2	2		2	3
Axles	2	3	3		3	3
Passenger capacity Seated	44	96	56		64 (LC)	52
Standing	31	20	36		26 (LC)	60
Total	75	116	92		90 (LC)	110
Passengers per metre of bus length	6.00	9.28	6.34		5.00	6.11
Average purchase cost	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
Loading Performance						
Measured average boarding time per pax	2.7s	[illegible]	[illegible]		[illegible]	[illegible]
Measured average alighting time per pax	2.0s	2.6s	2.0s		2.5s (LC) 1.7s (IT)	2.0s
Dwell time per pax (no standees)	2.5s	3.0s	2.5s		2.9s	2.9s
Dwell time per pax (with standees)	3.0s	Undetermined	[illegible]		[illegible]	[illegible]
Busway and Head of Bay Operation						
Gap between buses for independent pull out	5m	5m	5m	8m	5m	5m
Buses per 55m busway platform	3	3	3	2	2	2
Pax per m of platform	4.29	6.63	4.72	4.09	3.91	4.78
Maximum theoretical full loads boarding per hour	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maximum theoretical pax boardings per hour	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Whole-of-life Costs						
Whole-of-life cost per kilometre	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
Whole-of-life cost per pax kilometre	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]

Impacts of go card top ups on loading performance

Tail swing of 14.5m rigid – how busway capacity is affected if 'safe' distance between buses is enforced (5m vs 8m gap between buses)

Verbal walk through of Exec Summary Pages 4 to 8 (vehicle type summaries)

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Infrastructure Considerations

- Two thirds of surveys stops cannot be lengthened to safely accommodate 14.5m or 18m buses
- Need to consider adequate passenger waiting/disembarking areas serviced by HCVs
- Pavement deterioration at bus stops is impacted by load frequency (axle weight loading and route/service frequency) and pavement quality – all bus types will have an impact (regardless of whether HCV or not)
- Relevant infrastructure manuals should be updated to take into account different HCVs operated to influence infrastructure build specs (these are currently being updated)
- Tail swing of 14.5m rigid is a challenge – 8m gap between buses at stations reduces tail swing to that of a 12.5m standard, but reduces the station capacity (3 to 2 buses on a 55m busway platform)
    - Increase platform to 60m
    - Mark a clear/safety zone 700mm from kerb
    - Both strategies would allow three 14.5m buses

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Operational Assessment

- Higher boarding times over alighting times were evidenced on all bus types
- All door boarding could improve dwell times, though single width doors may negate any benefit all door boarding brings (CityGlider)
- Slow boarding times can negate the benefit of double width alighting doors
- Superbus fleet spec provided the least conflict between boarding and alighting passengers
- On board *go* card top ups can affect boarding / dwell times on all bus types
- Cabin layout is a contributing factor to dwell times - how can we influence passenger preferences with targeted cabin layout?
  - 90% passenger seats/standing areas for a 14.5m are closer to rear door
  - Passengers were observed disembarking single file through double width rear doors on the double decker
  - # Seats vs total passengers #
  - 2% to 7% of high capacity weekday peak services carried standing passengers – could afford to reduce seating capacity (thus increasing total pax capacity) to improve boarding, alighting and dwell times

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When to Procure a HCV?

- Extra 12.5m vs replace current 12.5m with a HCV
- Need to consider impact on frequency and impact on capacity
- Extra 12.5m presents opportunity to increase frequency/travel choice for passengers (which to a point can increase patronage)
- Can the route corridor accommodate additional buses? Can the route corridor accommodate a HCV?
- How much additional capacity is needed?
    - 14.5m rigid – 23% additional capacity
    - 18m artic – 47% additional capacity
    - 12m double decker - 55% additional capacity
    - Additional 12.5m standard – 100% additional capacity

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Report provides 2 'cheat sheets'

Refer pages 9, 10 and 11 exec summary

Refer page 16 exec summary report

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Operator Considerations

- Current fleet make up
- Maintenance facilities
- Driver/maintenance staff training and qualifications
- Depot configuration
- Local terrain
- Business model (charter)

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MRCagney's Recommendations

- Greater control over vehicle specifications
- Discontinue procurement of two door 18m artics
- Investigate use of double deckers
- Innovate
- Update standard infrastructure design specs
- Reconsider need for HCVs

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Next Steps

Recommendation	Action Owner
Update standard infrastructure designs to accommodate HCVs	Infrastructure *(in conjunction with TMR busways/interchange/road builders and designers); guide future infrastructure builds (senior user)*
Continue to investigate use of double deck buses	Network Strategy *(with input from Network Planning, Bus Contracts and Infrastructure)*
Discontinue the procurement of two-door articulated buses	Bus Contracts *(SEQ and Regional to influence/manage as their contracts allow)*
Innovate	Bus Contracts (SEQ and Regional *to manage noting budget constraints*)
Greater control of vehicle specifications	4G Bus Reform *(in conjunction with Bus Contracts and Network Planning)*
Costing analysis	Finance *(review MRCagney's costing analysis to inform adoption (or not) of further HCV procurement)*

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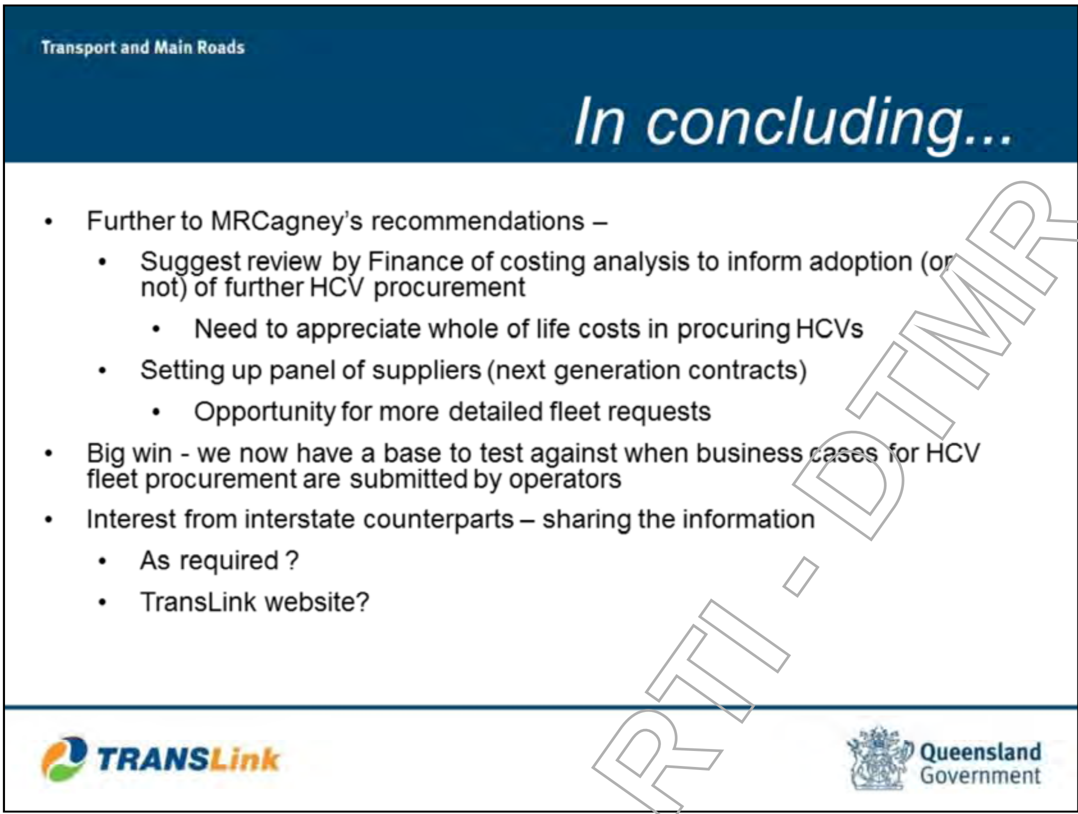

New double decker opportunity on Gold Coast