Supplement

Traffic and Road Use Management
Volume 1 – Guide to Traffic Management

Part 6: Intersections, Interchanges and Crossings (2017)

March 2019

Queensland Government

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2.3.6-1 Warrants for BA, AU and CH turn treatments

Refer to the Transport and Main Roads' *Road Planning and Design Manual* Edition 2 Volume 3 Supplement to Austroads *Guide to Road Design* Part 4A: *Unsignalized and Signalized Intersections*.

2.5 Intersection performance

2.5.1 Safety

2.5.1-1 Safety at unsignalized intersections

Intersections involve traffic conflicts which lead to the risk of crashes. Measures such as denying movements, or the closure of an intersection may improve safety at an individual site, at the expense of factors such as local access, but it may result in relocation of a crash risk to another site. The nett effect may potentially reduce or not improve the total network safety performance. Intersection design must therefore appropriately balance the risk at the intersection and more broadly on the network.

The review of existing crash data will assist to identify repeated crash types which are most likely to recur. Crash types with potentially high severity outcome (for example, right angle or head-on) should be considered further. In particular, conflict points with high relative speeds between road users generally result in more severe crashes and, where pedestrians are involved, there is a high probability that crashes will be serious.

At roundabouts, the total number of crashes may be high but, in urban areas, there is generally a significant reduction in casualty crash rates because the severity of conflict angles is reduced by the removal of head-on and right-angle conflicts and the relative speeds are low.

Safety at intersections is considered to be a function of exposure, speed, and number of conflict points, sight distance and other factors that are site-specific. A high percentage of crashes involve some degree of human error by drivers.

The application of these safety principles at intersections results in the four general rules which follow. Safety principle(s) met are in brackets.

1) Reducing and separating the points of conflict (exposure control, injury control)

The reduction or minimisation of conflicts is particularly important. Refer to the *Austroads Guide to Road Design*, Commentary 8, for a discussion of the types of conflict.

An example of the number of conflicts under various intersection arrangements is given in Table 2.5.1-1 Points of conflict can be separated / reduced by various means – for example, the addition of deceleration lanes, realignment of the intersection. Figure 2.5.1-1(1) gives examples of conflict reduction.

The number and types of conflicts given in Table 2.5.1-1 are often used to explain why certain intersection types are safer than others; for example, a four-way roundabout is safer than a four-way unsignalized intersection because of the lower number of conflict points (eight as opposed to 32, respectively).

This comparison is very simplistic and should only be used as a general rule. It cannot explain how some intersection comparisons do not follow the indicated safety performance; for example, it cannot explain how a four-way roundabout under certain conditions can sometimes record a higher accident rate than four-way unsignalized and signalised intersections.

There are several reasons why some intersection comparisons do not follow this general rule. Some of these are as follows:

- Some of the major accident types occurring at intersections are not included in Table 2.5.1-1. For example, single vehicle accidents and rear-end vehicle accidents on the entry curve can be the predominant accident type at roundabouts in high speed areas. Table 2.5.1-1 does not consider such conflict types.

- Not all of the conflict points in Table 2.5.1-1 have the same exposure. Certain conflicts may involve low traffic volumes, thus being much less likely to record an accident.
- There are several other parameters that strongly influence crash rates that are not considered in Table 2.5.1-1 (for example, visibility and relative speed). The influence of these parameters can vary between conflict points and between intersection types. Some of these parameters are discussed in the following sections.
- Some of the conflict points only generate low severity crashes (that is, property damage only) and many of these crashes do not get reported to police.

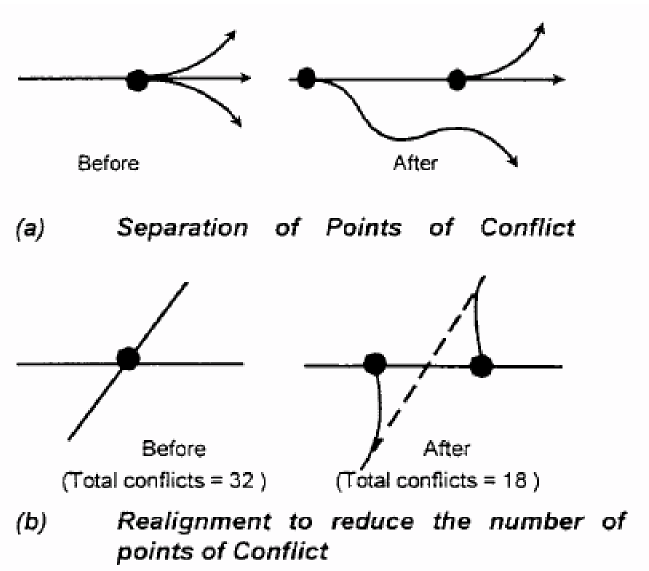
The Arndt (2004) study indicated that for a particular section of roadway, combining several low volume side intersections into a smaller number of intersections with higher side volumes would improve overall safety, subject to capacity and delay considerations. This also, in effect, reduces the total number of conflict points.

Table 2.5.1-1 – Number and types of conflicts

Intersection type	Method of control		
	No positive control	Signals*	Roundabout
3-way	3D, 3M, 3C, (9)	3D, 3M, 1C, (7)	3D, 3M or 3W, (9)
4-way	8D, 12M, 12C (32)	8D, 4M, 4C, (16)	4D, 4M or 4W (16)

D = diverge conflict M = merge conflict C = cross conflict W = weave () = Total conflicts
Note: Basis of assessment is two-phase operation; conflicts can be reduced or minimised under split phase operation.

Figure 2.5.1-1(1) – Examples of reducing the points of conflict at an intersection



2) Keeping it simple (exposure control, crash prevention)

Complicated intersections have poor accident records. A fundamental check is to imagine what a driver using the intersection for the first time would do. Two requirements are paramount:

- No driver should need special knowledge of how to negotiate the intersection.
- There should be a clear order of priority within the intersection.

Arndt (2004) found that those conflict points at unsignalised intersections with the highest driver workload recorded the highest accident rates. One of the causes of a higher driver workload was a greater number of legs (that is, drivers on a minor leg at a four-way intersection have to observe gaps in a greater number of traffic streams than drivers on the minor leg at a T-intersection).

3) Minimising the area of conflict (exposure control, crash prevention)

Minimising the area of conflict is achieved by reducing the area of pavement where conflict can occur by defining vehicle paths. Refer to *Austroads Guide to Traffic Management*, Part 6 *Intersections, Interchanges and Crossings* Section 2.5 *Intersection performance – Minimising potential for conflict* for further information on achieving this.

4) Controlling speed (exposure control, crash prevention, behaviour modification and injury control)

Alteration of approach alignment and channelisation can reduce approach speeds and the relative speed. A properly designed roundabout is a good example of this treatment. The improvement in relative speed is illustrated in Figure 2.5.1-1(2) and Figure 2.5.1-1(3). Arndt (2004) found that conflict points at unsignalised intersections with the highest relative speeds recorded the highest accident rates.

Figure 2.5.1-1(2) – Potential relative speed at intersections (source: Ogden and Bennett 1989)

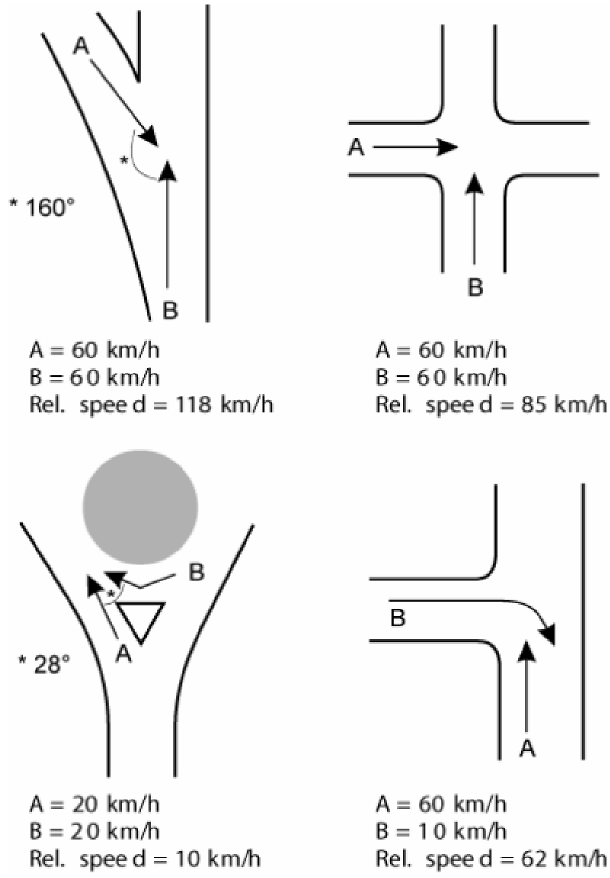
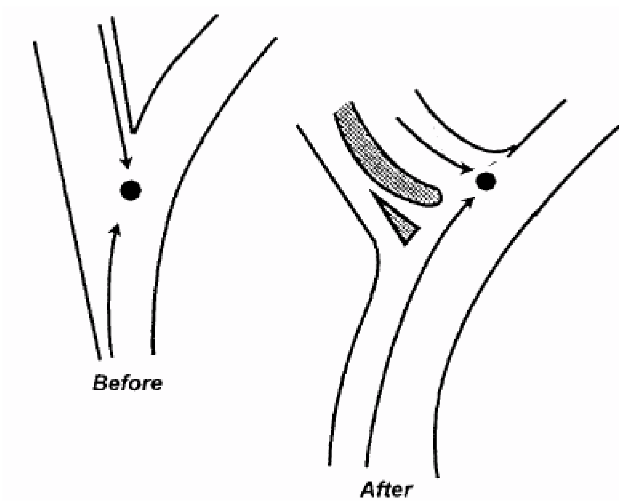


Figure 2.5.1-1(3) – Improvement in approach and relative speed by re-alignment and channelisation



3 Roundabouts

3.1 General

3.1-1 General

Refer to Transport and Main Roads Technical Note TN136 *Providing for cyclists on roundabouts* for further guidance.

8 Pedestrian and cyclist crossings of road

8.1 Introduction

8.1-1 Pedestrian crossing facility selection

This supplement provides guidance on the selection of appropriate pedestrian facilities on roads in Queensland. The guidance is intended to provide a rational, defensible mechanism for the implementation, replacement and upgrade of pedestrian facilities throughout the state.

Existing crossing facilities that do not conform with all technical requirements should not be removed without careful consideration. The desire line will still exist, and removal of the crossing may result in people crossing at even more substandard locations. The feasibility of modifying other road environment factors should be reviewed before considering the removal of a priority pedestrian crossing. The review may consider factors such as reducing speed environment, reducing the number of approach lanes or upgrading the crossing to signals.

1 Pedestrian crossing facility selection method

In the interests of national harmonisation, the Australasian pedestrian crossing facility selection tool ('the tool') is the preferred method for assessing crossing facility type on a known desire line.

Care must be taken to understand tool limitations and background assumptions when interpreting the output. The tool is an aid and does not replace professional planning or engineering judgement.

The tool and user guide can be accessed through the following link:

http://www.austroads.com.au/road-operations/network-operations/pedestrian-facility-selection-tool

It is strongly recommended that the Pedestrian Facility Selection Tool User Guide ('the user guide') be read before using the tool. In-depth details on the development of the tool are contained in Austroads report AP-R472-15.

2 Queensland specific guidelines for using the Australasian pedestrian crossing facility selection tool

2.1 Tool limitations

The tool does not assess feasibility of pedestrian (zebra) crossings on slip lanes. Slip lanes without pedestrian (zebra) crossings have been a source of disability discrimination claims from people with vision impairments. As such, pedestrian (zebra) crossings on slip lanes are feasible where approach speed conforms with MUTCD Part 10 and Approach Sight Distance (ASD) is achieved (refer AGRD4A), no other warrants are necessary.

The tool does not assess feasibility of pedestrian (zebra) crossings at intersections. This can be a valid treatment at intersections when designed in accordance with AGRD4 or Transport and Main Roads' Technical Note TN128 *Selection and design of cycle tracks*. The facility needs to be flagged as midblock in the tool to force an assessment.

The tool does not assess pedestrian (zebra) crossings on multi-lane roads; feasibility of shared zones (refer MUTCD Part 4 and Austroads *Guide to Traffic Management* Part 8) or children's' crossings (refer Transport and Main Roads' *Traffic and Road Use Management* manual (TRUM) Volume 2 Part 3 section 3.2-1).

The tool does not include an assessment of health benefits in the benefit-cost ratio (BCR) calculation. By installing crossing facilities and making walking a competitive mode choice in urban environments, some health benefit may be realised. The Australian Transport Assessment and Planning Guidelines: M4 Active Travel (available at https://atap.gov.au/mode-specific-guidance/active-travel/files/m4_active_travel.pdf) state the 2013 monetary value to the economy of the health benefits of walking is $2.77 per km.

2.2 Using the Tool in Queensland

2.2.1 Beginning the assessment

It is strongly recommended all blank fields are filled out when using the tool. If the tool has been used previously it is recommended that values are reset to the defaults. This is most easily done by clicking the 'Reset All' button in the save / load parameters section at the top right of the tool input form.

Default values given in the tool should be accepted unless noted following or site-specific reasons justify modification of the defaults. The reasons for using modified values should be recorded in project documentation.

2.2.2 Site information

Jurisdiction: should be set to Queensland.

2.2.3 Operational variables

Pedestrian volumes for sites without existing pedestrian provisions or with inadequate pedestrian provisions should allow for suppressed pedestrian demand. The amount of suppressed demand is highly site-specific. Any assumptions regarding allowances for suppressed demand should be clearly noted in the project documentation. Suppressed pedestrian demand should be considered where:

- pedestrians currently experience considerable difficulty crossing (LOS is D or worse)
- pedestrian attractors or trip generators such as schools, shops or train stations are in close proximity to the proposed crossing point, or
- on-street parking is being rationalised and crossing desire lines are expected to focus due to more crossings from side streets.

Where no current crossing facility exists, pedestrians crossing within 50 m of the proposed location should be included in the pedestrian volume input.

As cyclists can legitimately use pedestrian crossings in Queensland and, if present, should be added to the pedestrian non-sensitive volume. This requires site-specific judgement; a road crossing connecting off-road paths will be used by bicycle riders. On-road riders may use pedestrian refuges in order to benefit from a protected right turn.

2.2.4 Crash information

If there are no recorded crashes at the site, then select the crash 'Model' option.

Years of crash history: Number of years for which crash history is known. Typically, three to five years, a longer crash history may be appropriate if the infrastructure has been unchanged during that time period.

Number of pedestrian injury crashes: Pedestrian-related crashes within 50 m of the proposed crossing site are typically included.

Crashes unrelated to crossing manoeuvres should not be counted, such as run-off road crashes involving pedestrians on the footpath.

2.2.5 Model parameters

Evaluation days per annum: 250 is appropriate for a rural road that has little weekend / public holiday traffic. For urban roads that are used continuously, adopt 365.25.

Project lifetime: Depends on the likely useful life of the treatment, considering location and potential for growth. An assessment period of five years that results in a positive BCR may make a strong case for a short-term safety intervention. For longer assessment periods, whole-of-life maintenance costs may need to be considered in the construction cost estimate.

Discount rate: The 7% default is appropriate. If sensitivity analysis is required, the Australian Transport Assessment and Planning (ATAP) guidelines (available at https://atap.gov.au/) suggest using range between 4% and 10%.

2.2.6 Feasible facilities

Construction Cost: Should be an estimate to implement the crossing including all ancillary costs (for example, drainage, utility relocation, property acquisition, and so on). First pass option assessment costings do not need to be highly detailed. Once a facility is selected, the cost field should be revised with a detailed estimate for greater certainty in the BCR estimate.

2.3 Outputs

2.3.1 Facility assessment

Any option with a BCR >1 does not automatically warrant the installation of a pedestrian facility. Likewise, the option with the greatest BCR may not be the most appropriate facility to implement at the site being assessed. A network operation plan (refer AGTM4) applicable to the site can guide which output factors should take precedence in facility selection.

The options under consideration should be reviewed to ensure that:

- required sight distances are adequate
- adequate space is available to install a compliant facility (for example, the minimum refuge cut-through width is 2.4 m to ensure TGSI are compliant)
- impacts of the crossing facility on the road network are acceptable; for example, queuing of vehicles onto a motorway should not be tolerated, however, minor queues in other situations impacts may be appropriate and potentially assist crossing safety by reducing approach speed.

Alternative crossings less than 200 m apart may reduce the need for a new crossing; however, this is highly context sensitive. Demand for crossings less than 50m apart may indicate the road's status in the network hierarchy is in need of review to determine whether pedestrian access functions should be prioritised over the traffic carrying function.

It is strongly recommended that the Notes field be filled out detailing the decision whether a facility is viable, the proposed facility type, assumptions, data sources, impacts and other information relevant to the assessment. Completed assessments should be printed and stored in a document management system in case decisions are questioned in the future.

8.2 Mid-block crossings

8.2.1 General conditions for all road users

8.2.1-1 General considerations for all road users

Table 8.2.1-1(1) – Benefits of treatments: general crossing facilities

Objectives and priority	Application	Treatment	Benefits and considerations[1]
To increase the safety of pedestrians and cyclists by the use of physical aids within the roadway so as to: • reduce conflict between vehicles and both pedestrians and cyclists • simplify the decisions which drivers, pedestrians and cyclists have to make. Motorist has priority; non-motorised traffic must select an appropriate gap.	There are moderate volumes of crossing traffic. Pronounced desire line or cycle path route[2]. There is difficulty crossing full width of road in one stage due to: • long delays or unsafe gap selection • long crossing length or multiple lanes • high vehicle flows or speed • insufficient sight distance to enable a crossing length of both directions of traffic. Need exists to cater for people with disability or mobility difficulty. Pedestrian or cyclist priority crossings are not expected by motorists. There are poor crossing options at other locations, or best location to cross is unclear. There are crossings at numerous locations along short section of road.	Refuge island or median	• Improves accessibility for pedestrians and cyclists. • Users cross one direction of traffic at a time making gap selection easier. • Provides physical protection from vehicles.
		Kerb extension	• Reduces crossing distance and time. • Can reduce parking restrictions (refer MUTCD Part 10). • Must not create a squeeze point for cyclists.
		Road narrowing	• Can be used frequently along a length of road. • Merge to single lane where feasible.
		On-street parking	• Parking controls may be necessary to ensure adequate sight distance to pedestrians and cyclists. • Parking controls are low cost and can improve both traffic flow and safety. Allocation of kerbside space to cyclists improves pedestrian safety. • Many pedestrian crashes are related to people accessing a vehicle parked on-street. Parking off-road or on side streets can assist to direct pedestrians to safe crossing locations. • Indenting parking provides streetscape opportunities that can contribute to speed control.

Objectives and priority	Application	Treatment	Benefits and considerations[1]
		Staggered pedestrian crossing	• Staggered pedestrian crossing arrangement on multilane roads can provide assist two-way traffic signal coordination and provide the opportunity to double cycle the pedestrian crossing. • There is no evidence to support the theory that staggered refuges are safer than straight refuges. Pedestrian compliance appears to reduce the longer the stagger distance. • Queensland research has found an average pedestrian crossing signal compliance of: – 84% for a single stage crossing. – 69% compliance for the first leg of a two-stage crossing and 48% compliance for the second leg.
		Fence	• Only consider where pedestrian LOS is D or worse and all attempts to improve LOS and cater for pedestrian desire lines have proved infeasible. • Potential roadside hazard for motorcyclists. • Can be a target for vandalism. • Median corrals may increase the chance of stored path users becoming involved in an errant vehicle crash. • If anti-climb and well maintained, may redirect pedestrians and cyclists to a safe crossing point. • Must be designed to maintain inter-visibility between path users and drivers. • Refer to TRUM Volume 1, Part 5, Section 3.3-1 *Pedestrian Fencing*
		Holding rail	Consider at sites with a high number of elderly or people with a mobility disability (refer Figure 8.2.1-1). Potential roadside hazard for motorcyclists.

Objectives and priority	Application	Treatment	Benefits and considerations[1]
		Speed reduction	• Reduction in posted speed limit. • Speed platform, speed cushions or LATM to manage speed in the vicinity of untreated crossing points. • Improves driver compliance in give-way situations and reduces crash severity (rear end and path user-related)

1 See Part 4 of the *Guide to Road Design* (Austroads 2017a), AS 1742.9, AS 1742.10, NZTA (2009) and NZTA (2008b).

2 A desire line is the route naturally taken by pedestrians or cyclists, determined from a worn surface or observation.

Table 8.2.1-1(2) – Benefits of treatments: traffic controlled (time separation) facilities

Objectives and priority	Application	Treatment	Benefits and considerations[1]
To minimise conflict between path users crossing the road and vehicles travelling along the road. This is done by allotting appropriate time periods for use of a section of road by pedestrians and cyclists crossing the road, and also for vehicles travelling along the road. Pedestrians and cyclists have priority. Cyclists are not required to dismount. Improves accessibility for pedestrians and cyclists.	Regular crossings used by young or older pedestrians. May have pronounced peak crossing demand. Used for lower speed zones (for example, ≤ 40 km/h). Is suitable for crossing two-lane two-way, low-speed roads that have high volumes or insufficient gaps, and high entry angle left-turn slip lanes at arterial road intersections).	Pedestrian (Zebra) crossing	• Improves accessibility for people with a disability, children, elderly and cyclists. • Drivers are far more capable of making appropriate safety judgements than children or people with a disability. • Provides time separation from vehicles. • Additional controls should be considered to reduce motor vehicle approach speeds which improves driver compliance and reduces crash severity (rear end and path user related). • Not suitable on multilane roads. Measures such as merging to a single approach lane or signalisation should be considered.

Objectives and priority	Application	Treatment	Benefits and considerations[1]
		Children's crossing	• Part-time operation, crossing priority only when flags are in position. • Specific for children and youths, supervised. • Requires undertaking to manage flags. • Unless combined with another facility type reverts to mid-block where motorists not required to give way. • Ideally combined with other treatments to reduce motor vehicle speeds and crossing width.

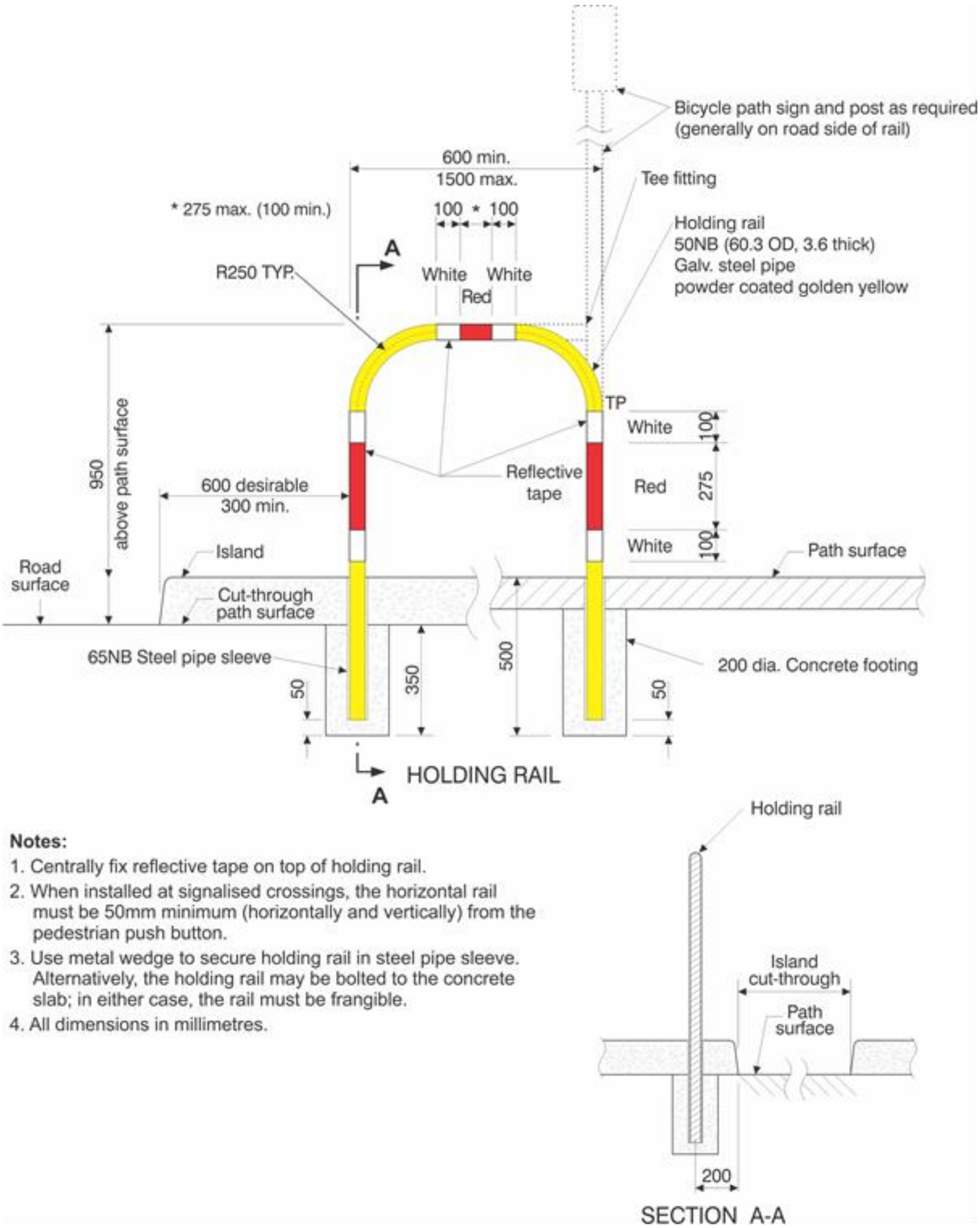
Objectives and priority	Application	Treatment	Benefits and considerations[1]
	Applicable for higher speed zones.	Pedestrian traffic signals[2]	• Provides greater guarantee of priority control. • Allows provision of audio and tactile cues. • Can be used where limited sight distance exists. • Single-stage pedestrian crossings on all legs is the recommended default provision at urban signalised intersections. • Pedestrian delay times should be minimised as far as possible. Queensland research has found pedestrian compliance is highest where the delay time is between 60 and 90 seconds. There is an almost 50% decrease in compliance for delay times exceeding this. • Signals incorporating pedestrian detection technology provides reduced delay to motorists, reduced cycle time and improved LOS for all. • Signalisation of single-lane slip lanes is not recommended due to inherent delay and non-compliance. • Consider bicycle detection on path approaches for reduced need to stop.

Objectives and priority	Application	Treatment	Benefits and considerations[1]
	Applicable at locations with: • One-way or two-lane roads • existing low-speed and low volumes • a need to reduce or control speeds • LATM schemes • high crossing use • good sight distance.	Pedestrian (Wombat) crossing	• Increases conspicuity. • Provides positive speed control. • Provides a low cost, permits landscaping. • Should form part of a traffic calming scheme. • May increase noise. Note: Wombat crossings are Pedestrian (Zebra) crossings placed on raised platforms of similar design to road humps.
	Applicable at locations with: • local streets intersecting frequently with cycle paths or cycle tracks • low proportion of commercial traffic • Low-speed environment • no more than two lanes • appropriate visibility.	Cyclist priority path crossing (refer AGRD4 and TMR TN128)	• Provides improved level of service to cyclists through continuity and directness of paths. • Cyclists are not required to dismount. • Improved safety by integrating with raised platform to reduce vehicle speeds at crossing point. • Locate and design to limit issues for motor vehicles near intersections. • Alternative to cul-de-sac of the street.

1 See Section 4, Part 9 of the *Guide to Traffic Management* (Austroads 2016c), Part 4 of the *Guide to Road Design* (Austroads 2017a), AS 1742.9, AS 1742.10, AS 1742.14, NZTA (2009) and NZTA (2008b).

2 For recent developments in the use of crossings at signalised facilities, see Section 8.2.3.

Figure 8.2.1-1 – Holding rail



8.2.2 Bicycle path terminal treatments at road crossings

8.2.2-1 Shared path and bicycle path termination treatments

Special termination treatments designed to slow cyclists must not introduce new hazards.

Figure 8.2.2-1 – Path with minimal termination treatment

It is clearly signed as a shared path which should be sufficient to deter illegal use by unauthorised motor vehicles. As the roadway is not physically defined by kerb and guttering, a GIVE WAY sign and linemarking has been added to improve legibility for the path users at the termination. The holding rail may or may not be used by riders, but it does provide extra definition of the path location for vehicles using the roadway. Canberra, ACT.

1 Purpose and scope

The purpose of this supplement is to provide operational and 'best practice' guidance on safe access management (vehicle restriction) treatments for bicycle paths and shared paths. Design guidance is provided in the Austroads *Guide to Road Design* Part 6A, Section 7.5 *Special Treatments for Intersections of Paths with Roads*.

1.1 Related documents

This supplement should be read in conjunction with the following:

- *Road Planning and Design Manual* Volume 3 Part 6A: *Pedestrian and Cyclist Paths*
- Austroads *Guide to Road Design* Part 6A: *Paths for Walking and Cycling*
- Austroads *Cycling Aspects of Austroads Guides*, Section 7.5.8 *Sight Distance*
- Queensland *Manual of Uniform Traffic Control Devices* Part 9: *Bicycle Facilities*
- *NSW Bicycle Guidelines* Roads and Maritime Services NSW.

1.2 Background

Historically, physical barriers in the form of terminal restriction devices ('banana bars'), bollards or U-rails have been included as standard terminal treatments for bicycle paths (and footpaths) when they connect with a road or another footpath. They have also been used as devices to slow cyclists on the approach to roads or in high conflict areas. This has often been done with no consideration of the requirement to manage vehicle access in terms of both the likelihood and consequences of vehicle access.

This has resulted in inappropriate application and overuse of these devices. These devices are an unnecessary expense to what is a relatively inexpensive piece of infrastructure. In some circumstances, they can also pose a crash hazard for cyclists.

Figure 8.2.2-1.1.2(1) – Excessive use of physical barriers to slow cyclists on approach to a blind corner

In this example, vehicles are already restricted by log fences, the need to slow cyclists on the curve could be better addressed by improving sightlines by trimming vegetation and marking a centreline. Kedron, QLD.

Figure 8.2.2-1.1.2(2) – Redundant path terminal barrier

This path terminal barrier is easily avoidable by both motor vehicles and cyclists. Ashgrove, QLD.

Figure 8.2.2-1.1.2(3) – Redundant U-rail type terminal barrier

This different style of path terminal barrier, a set of U-rails at the entry to a park, are also easily avoidable by both motorists and cyclists, as illustrated by the dirt track. Arana Hills, QLD.

Figure 8.2.2-1.1.2(4) – Redundant U-rail type barrier on a set of stairs

In this residential subdivision u-rails have been placed at both the top and bottom of a set of stairs which have a very low likelihood of illegal vehicle access. Everton Hills, QLD.

Figure 8.2.2-1.1.2(5) – Hazardous positioning of a path terminal barrier

This example is on a >10% grade leading to a road crossing. Note the signage would not be legible while crossing the street, the single entry, slope and sharp left turn. Wavell Heights QLD.

Figure 8.2.2-1.1.2(6) – Examples of easily avoidable and redundant physical barriers

Both of these examples show terminal restriction device that are redundant and inappropriate. Woolloongabba, QLD. Sippy Downs QLD.

Figure 8.2.2-1.1.2(7) – Hazardous path terminal device, limited visibility due to lack of contrast

This path termination is designed as a vehicle gate. It does not consider the safety, amenity of path users, the connectivity with the bikeway on the other side of the road or the lack of visual contrast. Arana Hills QLD.

2 Path terminal treatments

Refer to the department's *Road Planning and Design Manual* Volume 3, Part 6A, Part 10 for design details and specifics.

Under the Australian Road Rules, a bicycle path or shared path is terminated when it meets a road and cyclists and pedestrians have to give way to traffic before entering or crossing the roadway. Paths that continue on the other side of a roadway are considered crossings and are not covered by this supplement. Path crossings of roadways are covered in Austroads *Guide to Road Design*, Part 4 *Intersections and Crossings – General* Section 9 *Cyclist Crossings*.

2.1 Advising cyclists of a road ahead

Refer to the department's *Road Planning and Design Manual* Volume 3, Part 6A for design details and specifics.

Sight distance requirements are outlined in Austroads *Cycling Aspects of Austroads Guides*, Section 7.5.8. This Austroads document sets out the required information including minimum stopping sight distance for cyclists; lateral clearances on horizontal curves; and minimum length of crest vertical curves.

Warning devices typically include traffic control devices, such as signage and pavement markings. These should be used to warn cyclists of the road ahead and motorists to watch for cyclists and pedestrians and be installed so as to not form a hazard. This topic is addressed in the department's *Manual of Uniform Traffic Control Devices*; *A Guide to Signing Cycle Networks: Showing the way to more cycle trips*, and the Traffic and Road Use Management (TRUM) manual Volume 1 Part 4 section 3.6.3-1 *Traffic control signs*. These publications are available on the departmental website.

Figure 8.2.2-1.2.1 – Signs used for slowing cyclists and warning of a path termination

TC1592
For use on a shared path or bicycle path

TC1600
For use on a roadway to warn of a path termination

W6-8
For use on a shared path or bicycle path to warn of a path termination

R1-2*
For use on a bicycle path or shared path if the termination is not well defined or has inadequate sight lines

* This sign could also be applied as a pavement marking to reduce pole hazards

Signs are shown at their relative sizes.

2.2 Slowing cyclists

Refer to the department's *Road Planning and Design Manual* Volume 3, Part 6A for design details and specifics.

Crash data analysis performed by the department suggested that the frequency of crashes between pedestrians and cyclists on footpaths and bikeways is extremely low (compared with road crashes). Data analysis showed that the average speed of each (shared use path) facility at peak times approximates a reasonable design speed for each location. It is therefore posed that the cycling community is able to self-moderate speeds that are appropriate to the location (see footnote[1]).

[1] Lister, I (July / August 2007) Bicycle Queensland, *Queensland Cyclist* newsletter.

2.3 Restricting unauthorised vehicle access

Refer to the department's *Road Planning and Design Manual* Volume 3, Part 6A for design details and specifics.

Physical barriers placed at the termination of paths can pose a danger to cyclists presenting an obstacle at locations where cyclists typically need to be concentrating on ramps, footpaths, roads, motor traffic, other path users, and other hazards beyond or before the path.

In cases where paths through reserves are designed to be regularly used by park maintenance vehicles and a barrier is required, these should be designed to be removed to allow temporary vehicle access. Temporary barriers should not present a hazard to users when they are removed or the opened state with flush mounted footing covers and locking devices used.

3 Preferred treatment

This section provides detailed guidance on path terminal treatments using the three-stage assessment approach. This approach has been designed to provide escalating options to asset managers, when seeking to address this issue.

3.1 Stage 1 – Signage

The application of signage and pavement markings must be done in accordance with the *Manual of Uniform Control Devices* and Section 2.1 in this supplement. Figure 8.2.2-1.3.2(1) shows the various signs which may be used to mark path terminations in Queensland. Signs should be installed in conjunction with path linemarking in accordance with the *Manual of Uniform Traffic Control Devices* and the *Road Planning and Design Manual* Volume 3, Part 6A.

3.2 Stage 2 – Redesign terminal appearance

In some urban settings alongside major roads, signage can get lost in the 'urban clutter' and overlooked by road users who have reached cognitive limits in the amount of information that they can take in at any one time. In these instances, the redesign of the terminal appearance can be an effective method of access management without restricting legitimate users. This is often achieved through the use of pavement markings, different coloured concrete, kerbs, ramps, soft landscaping, and other visual cues. The intent of this treatment is to make it as intuitive as possible to anyone who sees it, that this is not a continuation of the road, but rather a 'transition' point from one environment to another.

Figure 8.2.2-1.3.2(1) – Examples of redesigned terminal appearances (USA)

In these two examples from the US, the colour contrast from the asphalt pavement and the design of the corner kerbing highlights that this is not a road. The kerb ramps in these examples are not standard width and regulatory signage has not yet been erected but legibility is good. Source Bicycle Path Access Control web-based resource. See footnote 6.

Figure 8.2.2-1.3.2(2) – Example of terminal appearance treatment using pavement markings

In this example, a yellow chevron marking has been used to clearly identify the bikeway entry. R8-1-A BICYCLES ONLY path sign and a pedestrian prohibition sign are located at the entry. A hold rail is provided for cyclists to assist with crossing and highlight the crossing to road users. There is no need for a terminal restrictor bar. A bicycle symbol pavement marking and green coloured surface treatment (as per TRUM Vol 1 Part 10) could also be an effective additional treatment for busier, more urban locations. Indooroopilly, QLD.

3.3 Stage 3 – Physical barriers

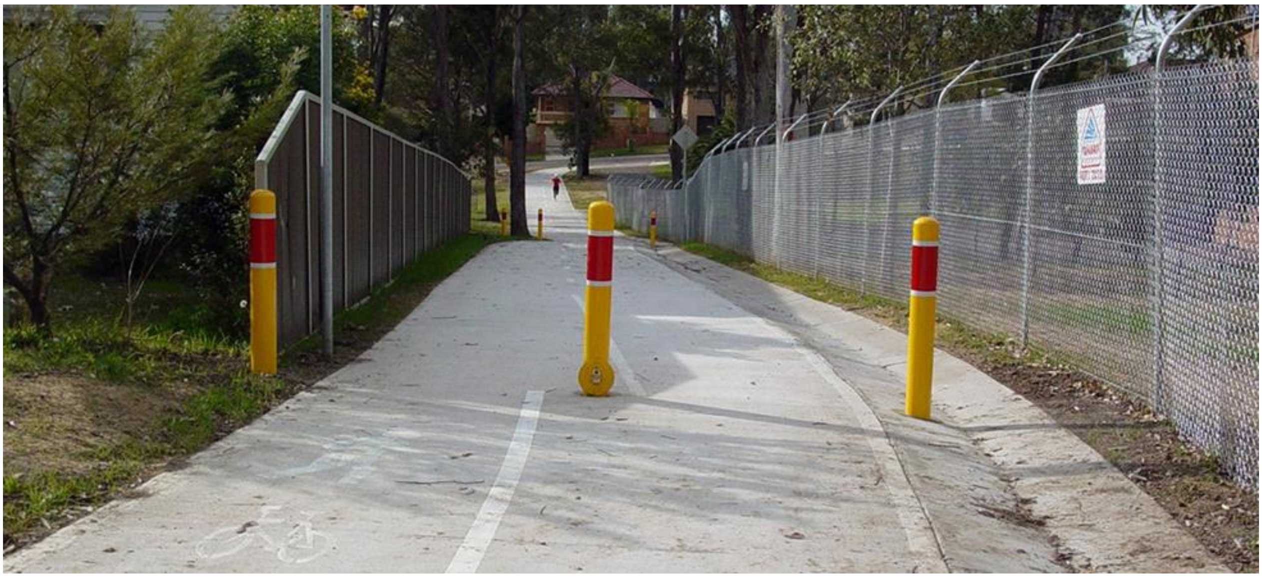
Physical barriers are the last option to be used and only after all other options (Stages 1 and 2) have been exhausted. They also pose the most danger to cyclists if not planned, designed and installed correctly when implementing Stage 3.

At the commencement of any work to install physical barriers, a road safety audit of the site must be undertaken to identify the risks to all path users in terms of likelihood and consequences.

The final design must also be signed off by a Registered Professional Engineer of Queensland (RPEQ) prior to construction.

Refer to the department's *Road Planning and Design Manual* Volume 3, Part 6A for design details and specifics.

Figure 8.2.2-1.3.3(1) – Maintenance vehicle access barrier on a shared path



This path is used on an ongoing basis by water supply authority vehicles on whose land the path is located. The two outside bollards are fixed while the centre bollard is removable. When the centre bollard is removed, a round flush fitting cover protects the hole and locking device. Although their height is lower than required, the bollards are finished in standard RMS NSW colour and reflectorized tape. Line marking has been used to 'direct' cyclists around the hazard caused by the low height of the bollard. Guildford NSW, photo: RMS.

Figure 8.2.2-1.3.3(2) – Examples of the use of bollards to protect an asset, with instructive text

These bollards protect an expensive bridge structure. The inset photo shows an enlargement of the plate on the centre fold-down bollard which places a load limit on maintenance vehicles accessing the path. Roma Street Parklands. Brisbane, QLD.

4 Operational issues

The remainder of this supplement will highlight the issues that need to be taken into consideration. These include:

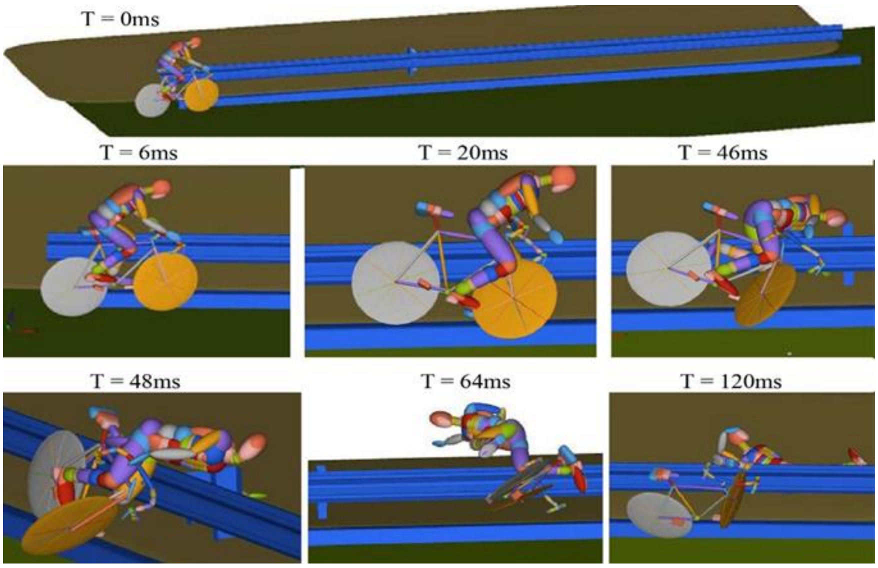
- crash risks with physical barriers
- path user capacity constraints
- preferred treatments – design guidelines, and
- preferred treatments – placement guidelines.

4.1 Crash risks with physical barriers

While it is easier for cyclists to negotiate a pole (or bollard) than a terminal restrictor bar, without crashing into it, the consequences of crashing into it are more serious than those of hitting the curved terminal restrictor bar ('banana bar'). As a result, bollards should be avoided, if possible. The curved terminal restrictor bar is designed to contact near a typical cyclist's centre of mass and keep the cyclist upright, not going either underneath or over the top resulting in additional injuries. It also incorporates a 'snag-free' design, so no part of the device will cause a cyclist to be caught or affected in any way.

A study carried out by University of New South Wales in 2008 used numerical analysis of real-world cyclist crashes to investigate speed, collision mechanism and movement trajectories where a cyclist lost control and collided with an Armco™ guardrail. This simulation provides an illustration of the types of crash forces involved when a cyclist collides with a low-height physical barrier, such as a bollard. The study showed that high speeds (such as a downhill slope) and hitting an object low to the ground (such as a bollard) are significant crash risk factors for cyclists. See Figure 8.2.2-1.4.1(1).

Figure 8.2.2-1.4.1(1) – MADYMO simulation of a rider losing control after striking a concrete kerb, followed by a steel guard rail



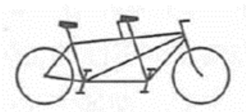
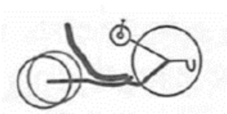
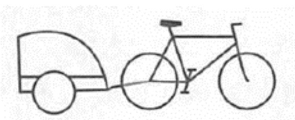
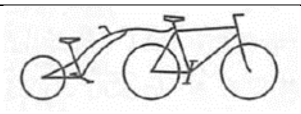
(Figure from the UNSW report referenced in Footnote 8.

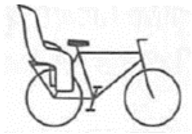
The simulation rebuilt the movement and position of rider during accident. The front tyre struck the kerb first (T=6 ms), then bicycle handle bar scraped along the guardrail (T=20 ms). After that, the victim was rotated (T=46 ms) and thrown over the guardrail (T=64 ms), hitting the ground (T=120 ms).

This led to severe brain injury with skull, rib and spinal fractures. According to the injuries suffered, it is likely that the accident occurred at speed of 35 km/h. This case is a very typical barrier crash scenario. The bicycle has high centre of gravity; thus, cyclists tend to be throw forward over barrier when front wheel hits the object. This is considered extremely dangerous; because there is no safety feature to hold the cyclist stable and the bike itself will lose balance the moment its momentum is eliminated.

Designers should anticipate the use of wheeled recreational devices, mobility aids, and non-standard cycles, particularly in areas with high levels of utility cycling, on recreation routes and on routes serving schools and day care centres –Austroads *Guide to Road Design* Part 6A, Commentary 2 includes information on typical requirements. Figure 8.2.2-1.4.1(2) provides supplementary guidance. A terminal restrictor bar at a height of 100 cm would be in the mid-range of average child's eye height and would be a greater hazard to inexperienced child cyclists, who would be more vulnerable given their lesser experience and cognitive ability than adult cyclists.

Figure 8.2.2-1.4.1(2) – Dimensions and eye heights of various types of bicycles

		Overall dimensions (cm)			**Eye height (cm)**	**Special features**
		Length	**Width**	**Height**		
Bicycle		165–180	40–75	90–110	140–185	
Childs bicycle		100–150	40–50	60–90	90–140	Small size
Tandem		275	40–75	90–110	140–185	Length + loaded weight
Adult tricycle		165–180	80	90–110	140–185	
Recumbent bicycle		165–200	40–75	110–130	110–130	Low eye height
Hand cycle		165–180	80	80–100	110–130	4 m turning radius
Bicycle + trailer		300	80	90–110	140–185	Length + loaded weight
Bicycle + trailer bike		300	40–75	90–110	140–185	Length + loaded weight

		Overall dimensions (cm)			Eye height (cm)	Special features
		Length	Width	Height		
Bicycle + child seat		165–180	40–75	120–140	140–185	Raised centre of gravity

Source Velo Quebec, Canada.

In accordance with the department's *Road Planning and Design Manual* Volume 3, Part 6 *Roadside Design, Safety and Barriers*, Section 6.5.2 *Pedestrians and cyclists*, where pedestrian facilities are incorporated behind a road safety barrier system, the desirable minimum height of the system is to be 1200 mm above the surface of the footway. Where provision for pedal cyclists is required, the desirable minimum height above the surface of the path should be 1400 mm. Refer to the *Road Planning and Design Manual* Volume 3, Part 6A for the recommended terminal restrictor bar heights.

4.2 Path user capacity constraints

Terminal restrictor bars require every through movement to be done when another path user is not trying to pass at the same time (staggered) – setting up a very uncertain 'right-of-way' situation that results in an increased crash risk to cyclists and a very poor level of service to other users (pedestrians, mobility aids, wheeled recreational devices). The obligation to come to a complete halt if someone is coming the other way should not be necessary. The scratch marks depicted at Figure 8.2.2-1.4.2(1) are common on many terminal restrictor bars and are evidence of a situation of insufficient width for the volume of path users (or misjudging a suitable location). The height is typically a snag hazard for handlebars.

Figure 8.2.2-1.4.2(1) – Damage which indicates evidence of insufficient passing width

The scratch marks on this terminal restrictor bars are commonplace and are evidence of insufficient passing width for a two-way path. Gold Coast, QLD.

In width-constrained areas such as bridges or embankments, the use of bollards can manage access without requiring additional width or protruding into the path user operating space. Refer to Figures 8.2.2-1.3.3(1), 8.2.2-1.3.3(2) and 8.2.2-1.4.3(3).

The department's *Road Planning and Design Manual* Volume 3, Part 6A requires the provision of an operating space of 1200 mm minimum for a person in a wheelchair. In order to meet the additional requirements for pedestrians using mobility aids, a typical clearance of 1400 mm through a single-entry point (the Austroads standard) will provide only enough room for a single wheelchair to pass through.

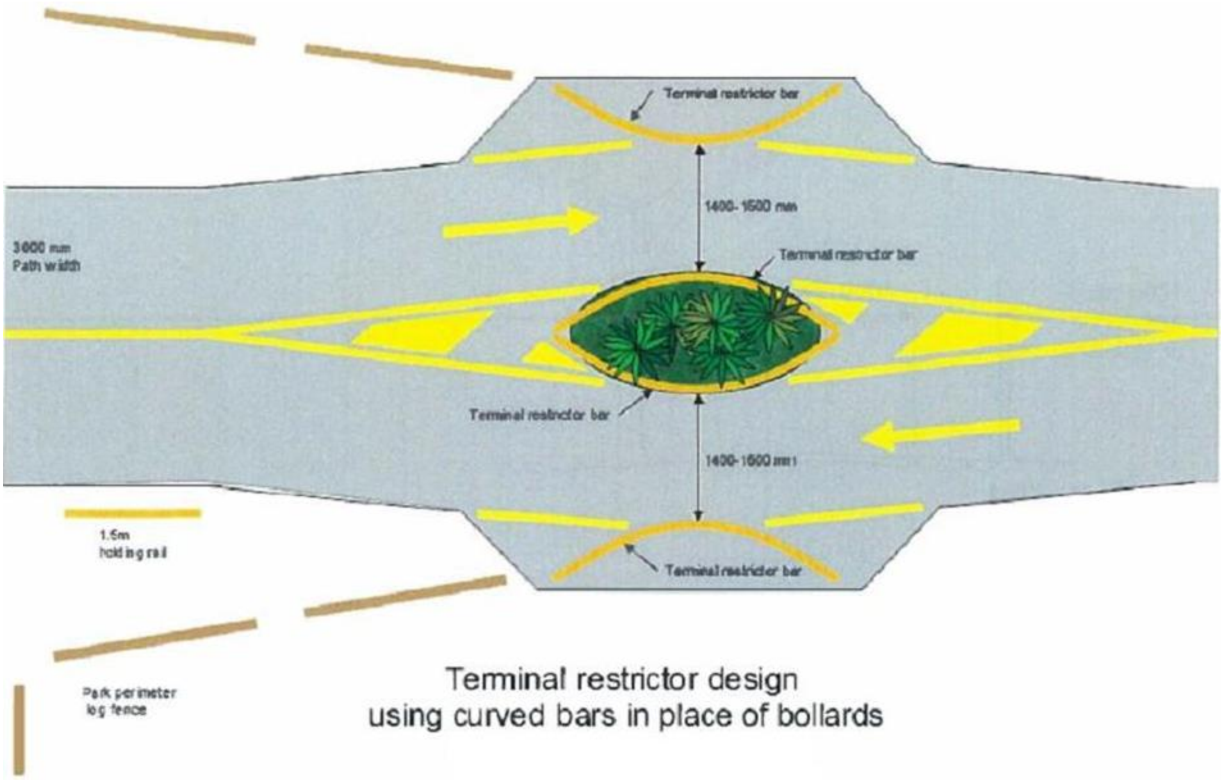
Having to stop can be difficult as following cyclists may not notice what is happening up front and may collide with those stopping – or a pedestrian may simply pause at the device, blocking it, without understanding the implications of his or her action. This increases the potential for path user conflict.

Passing width is an issue as terminal restrictor bars are required to leave a minimum clear opening between of 1.4 m and 1.6 m apart (as are bollards).

Refer to the department's *Road Planning and Design Manual* Volume 3, Part 6A for terminal device operating widths for entry and exit treatments.

The following diagrams illustrate 'best practice' where terminal restrictor bars have been duplicated to form two single direction paths to minimise cyclist and pedestrian conflict through the constrained space, as well as the risk of head-on collisions. Refer to the figures following and to the most recent versions of Brisbane City Council Standard Drawings (UMS) drawings which can be downloaded from www.brisbane.qld.gov.au by searching on 'UMS drawings'.

Figure 8.2.2-1.4.2(2) – Bicycle / shared path termination treatment with separated entry and exit: general layout

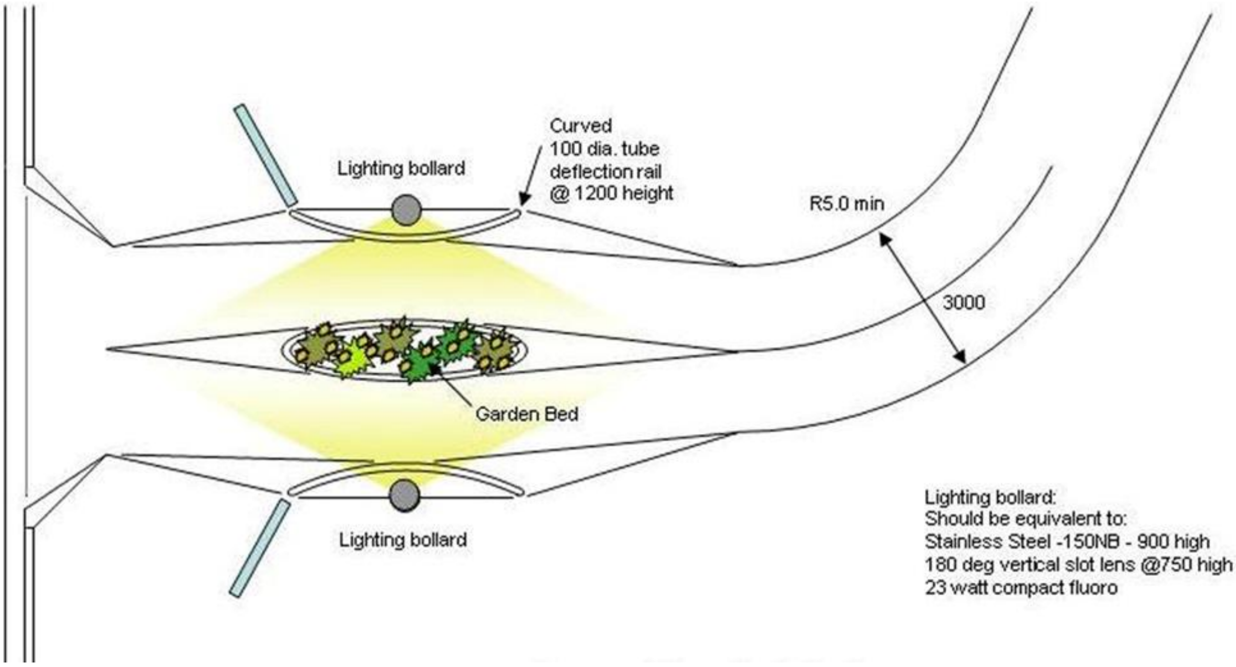


4.3 Preferred treatments – design guidelines

Figure 8.2.2-1.4.2(2) shows the general layout for a bicycle path or shared path with terminal restrictor with separate exit and entry paths. The use of narrowing side bollards can negate the need for centre bollards. A centre bollard may be installed while plants are growing, then removed once the central tree and ground cover are big enough. Lighting requirements are outlined in Figure 8.2.2-1.4.3(1). In this example, the central terminal restrictor bar has been replaced by a kerb raised garden bed.

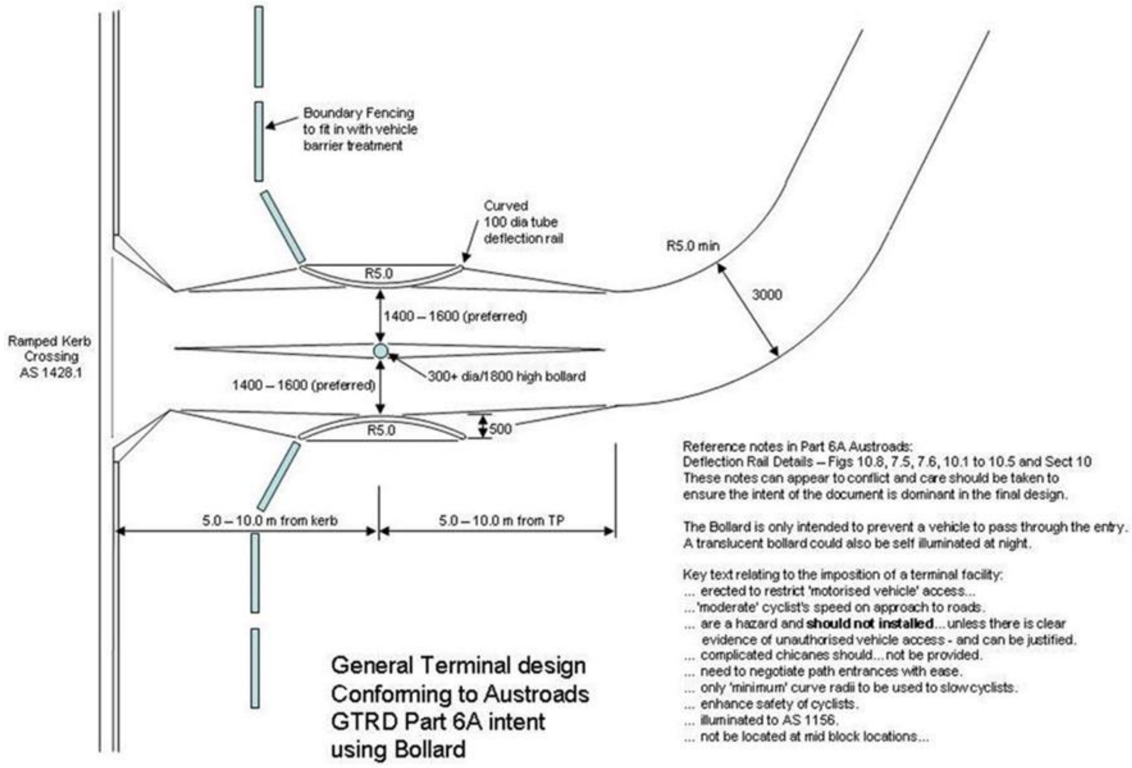
Entry requirements are illustrated in Figure 8.2.2-1.4.3(2). This example shows a terminal treatment for a more constrained site where the central deflection bars (used in the examples shown in Figures 8.2.2-1.4.2(2) and 8.2.2-1.4.3(1)) are replaced by a more compact arrangement using a central bollard.

Figure 8.2.2-1.4.3(1) – Bicycle / shared path termination treatment with separated entry and exit: lighting requirements



Lighting is provided at the path terminal from behind the curved deflection rail.

Figure 8.2.2-1.4.3(2) – Bicycle / shared path termination treatment with separated entry and exit: with bollard central separator



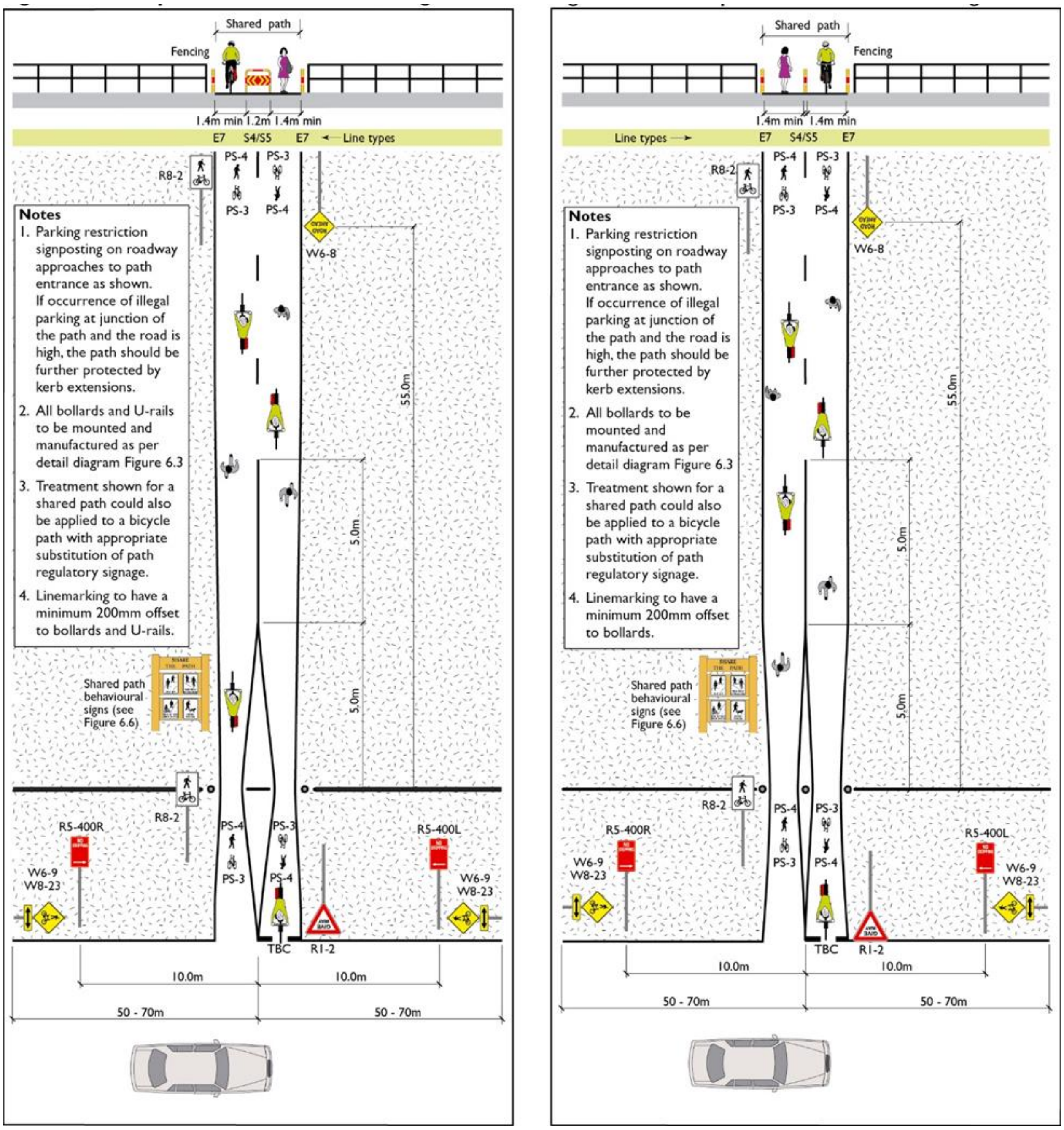
Every restrictive terminal device must be painted in high-visibility colours and retroreflective tape applied. The terminal devices should also have lighting. Lighting-specific issues and terminal device geometry are addressed in the department's *Road Planning and Design Manual* Volume 3, Part 6A *Pedestrian and Cyclist Paths*. There has been mixed success with 'glow in the dark' products; assessment should be made on a site-by-site basis as to the appropriateness of this option.

Raised garden beds allowing one-way movement on parallel paths will act the same way as a centre bollard if they have 250 mm high garden edging paths 1600 mm wide (a motorised vehicle cannot pass through such a facility). A garden should provide for a more forgiving fall than a bollard or terminal restriction bar, while still restricting access. The plantings should act as 'cushions' (thick ground cover) if a cyclist falls into a garden bed. The plantings should also be a species that is not likely to irritate or injure a person who happens to fall into a garden bed.

Note that the growth of garden beds will need to be monitored and maintained to ensure that it does not cause any restrictions in sight lines. Small children and people who use wheelchairs can be hidden from sight if plantings are permitted to grow higher than 500 mm above path height.

In instances where paths are designed to take maintenance vehicles, fixed bollards can be unlocked and temporarily removed to allow vehicles through the barrier (see Figures 8.2.2-1.3.3(1) and 8.2.2-1.3.3(2) and Figure 8.2.2-1.4.3(3), right hand side diagram following).

Figure 8.2.2-1.4.3(3) – Path termination advice from the NSW Bicycle Guidelines (RMS 2005)



The inverted U-rail in the left side illustration is designed to be removable to permit maintenance vehicle access. The bollards in in the diagram on the right-hand side are typically non-removable.

4.4 Preferred treatments – placement guidelines

Details of placement guidelines have been included in the department's *Road Planning and Design Manual* Part 6A.

Figure 8.2.2-1.4.4 – Illustration of cyclists 'lean into' corner turns, and the hazardous positioning of this terminal barrier

This image illustrates a path restriction device at the bottom of a steep gradient on a curve. Note how the cyclist must 'lean into' the curve at the constrained point, occupying the entire opening width of the terminal restriction device. The rider needs to navigate the horizontal curve, adjust for a curved floating hazard at handlebar height and also watch for oncoming path users. Eliminating the horizontal path curvature reduces the cognitive load and potential risks.

For further information on this supplement, please contact:

Vulnerable Road Users, Traffic Engineering Directorate
Road Operations, Engineering and Technology, Transport and Main Roads
Email: Cycle&PedTech@tmr.qld.gov.au

5 Transport and Main Roads assessment tool for vehicle access restriction

This assessment tool should be used for existing devices only.

Is the purpose of this device to restrict vehicle access?	No: Remove it	Yes: Continue to table following and make an assessment considering both the Bicycle Crash Risk Factors and the Motor Vehicle Access Management Factors listed.

Bicycle Crash Risk Factors	Yes	Partly	No	Considerations
Have there been complaints from cyclists?				• Can be an indicator of near misses • Allows for proactive investigation, there may be grounds for legal action if a complaint was not investigated • Can identify hazards before they cause a crash
Has there been a crash or serious injury?				If a crash or serious injury has already occurred the device **should be removed or relocated immediately**
Does the device have any sharp edges, exposed elements or corners?				• This can influence the consequences (severity) of a crash • Rounded edges will ‘deflect’ the crash forces and larger surface areas will ‘absorb’ impact forces
Does the device protrude into bicycle operating space?				• This can influence the **likelihood** of a crash • Protruding objects can be a ‘snag’ hazard for pedals and handlebars
Is the height of the device <1 m and perpendicular to the direction of travel (for example, gate, mid-path bollard or U-rail)?				• This can influence the **consequences** (severity) of a crash • As bicycles have a high centre of gravity they tend to be thrown forward and over a low-to-the-ground obstacle • Bollards must also be high enough to be visible from behind another cyclist (cyclists’ eye height is typically 1.4 m) – mid-path bollards are required to have a minimum height of 1.2 m with a desirable height of 1.8 m to ensure visibility
Does the device have a diameter <100 mm (for example, mid-path bollard or pole)?				• This can influence the **consequences** (severity) of a crash • Bollards with small diameters are considered ‘spearing’ or ‘impaling’ hazards for cyclists in the event of a crash • Bollards are required to have minimum diameter of 100 mm (and a flat or rounded top) and a desirable diameter of 300 mm to avoid being a hazard

Bicycle Crash Risk Factors	Yes	Partly	No	Considerations
Is the device at the bottom of a >4 % gradient slope?				• This can influence both the **likelihood and consequences** (severity) of a crash • Cyclists will naturally pick up speed at the bottom of a slope
Is the device on a horizontal curve <R40 m?				• This can influence the **likelihood** of a crash • On a horizontal curve the cyclist will have to 'lean into' the turn, occupying more space than remaining vertical (bicycles operate by both steering and balance) • Cyclists must be able to approach these devices 'straight on' to minimise risk
Is the device located at a mid-block location where bicycle speeds are likely to exceed 20 kph?				• This can influence both the **likelihood and consequences** (severity) of a crash • Cyclists will naturally pick up speed at mid-block on flat, straight, unimpeded sections of path
Is the device in a location with visibility restrictions on either approach?				This can influence the likelihood of a crash. Visibility may be improved by cutting back vegetation or removing obstructions (lowering fence heights, etc.)
Is there sufficient colour contrast and reflectivity on the device?				• This can influence the **likelihood** of a crash • Grey, black or stainless-steel colour will have insufficient contrast with concrete or asphalt • Green or black will have insufficient contrast with grass or tree foliage
Is the device sufficiently lit at night?				• This can influence the **likelihood** of a crash • If there is usage of the path at night, then lighting of the hazard is essential
Is the opening width adequate for the number of cyclists and pedestrians using the site?				• This can influence the **likelihood** of a head-on crash • Look for evidence of insufficient width, specifically: scratch marks at the narrowest point • Consider a separate entry and exit terminal (if needed at all), as most vehicles are min 1.8 m wide
Is the device <5 m to an intersection with closely-spaced conflict points or pedestrian activity?				• This can influence the **likelihood** of a crash • This is an indicator of the cognitive load placed on the cyclist: multiple consecutive conflict points or pedestrian activity will require greater concentration to navigate safely • Ideal setback of 5–10 m from an intersection or kerb

Motor Vehicle Access Management Factors	Yes	Partly	No	Considerations
Is the current device able to be easily bypassed by a motor vehicle?				• If yes, then removing the device will not have any impact on the likelihood of motor vehicle access • The device should be removed as it is not serving its intended purpose
Does the path create an attractive 'shortcut' for motor vehicles between two (or more) roads?				• This can influence the **likelihood** that if the device were removed motor vehicles would use the path • If no (and the path would take motor vehicles out of their way or parallel to an existing road), then the risk is minimal • If yes, consider relocating and upgrading the device (lighting, high visibility fluorescent colouring, reflective tape, and separate entry / exit terminals)
Is the likelihood high that, if a vehicle accessed this path, it would damage an expensive asset (for example, lightweight bridge)?				• This can influence the **consequences** of motor vehicle access if the device were removed • If no (and there are no assets that are vulnerable to damage), then reducing the danger to cyclists must be a higher priority • If yes, consider relocating and upgrading the device (lighting, high-visibility fluorescent colouring, reflective tape, and separate entry / exit terminals)
Is the likelihood high that if a vehicle accessed this path it would endanger vulnerable path users (children, disabled and elderly)?				• This can influence the **consequences** of motor vehicle access if the device were removed • If no (and there is no / minimal risk to vulnerable path users), then reducing the danger to cyclists must be a higher priority • If yes, consider relocating and upgrading the device (lighting, high-visibility fluorescent colouring, reflective tape, and separate entry / exit terminals)
Is there a recurrent issue with unauthorised vehicle access that cannot be resolved by other methods (for example, signage, lighting, CCTV, police enforcement, and so on)?				• This can influence the **likelihood** that, if the device were removed, motor vehicles would use the path • If no (in the event that other methods have not been attempted), these other methods must be attempted first • If yes, consider relocating and upgrading the device (lighting, high-visibility fluorescent colouring, reflective tape, and separate entry / exit terminals)

8.2.3-1 Traffic signal phasing arrangements for pedestrians

Information on Traffic Signal Phasing arrangements and options for special treatment of pedestrians at Traffic Signals can be found in TRUM Part 9 Section 6.4.