Guideline

Providing for people walking and riding bikes at roundabouts

August 2020

Queensland Government

Translating and interpreting assistance

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Feedback

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1 Introduction

This guideline helps designers improve the safety of people walking and riding bikes at existing roundabouts. Roundabouts represent about four percent of all intersections on the Queensland state-controlled road network and approximately 15% of all bicycle social crash costs at intersections on state-controlled roads. In 2013, the Queensland road network contained over 3400 roundabouts. This number appears to be growing.

The advice contained in this guideline is targeted at brownfield sites; however, some of the treatments may be applicable to greenfield roundabout projects.

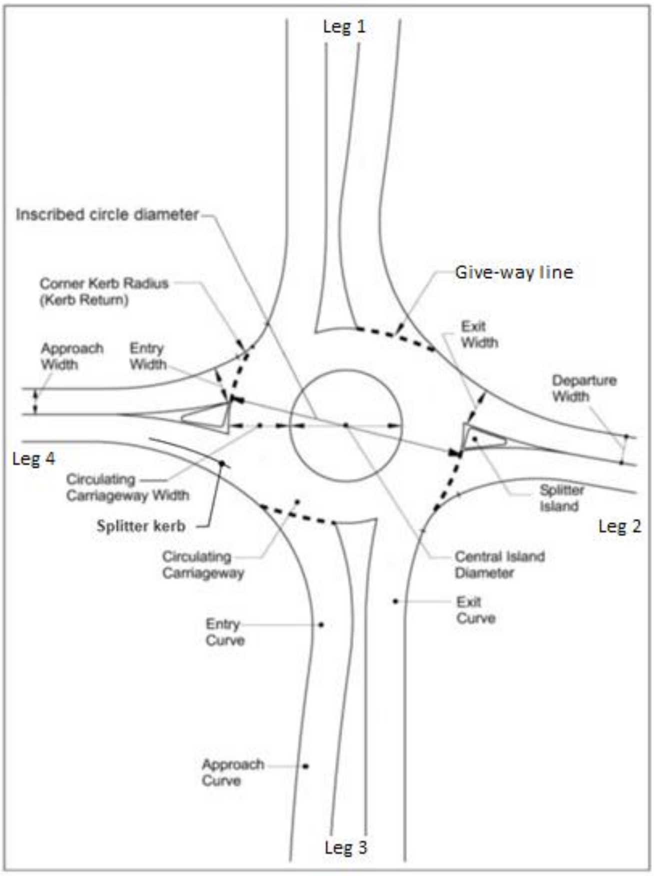
In many situations, optimal solutions may not be practicable in the short term. Some suggested treatments have not been implemented in Queensland previously and should be trialled and evaluated.

This guideline supports the Department of Transport and Main Roads *Cycling Infrastructure Policy* and *Queensland Cycle Strategy 2017–2027*. These documents aim to make bike riding safer and more convenient so more Queenslanders can use this sustainable and enjoyable mode of travel.

Unless specifically noted, all content is supplementary to the Department of Transport and Main Roads *Road Planning and Design Manual* and *Manual of Uniform Traffic Control Devices* (MUTCD) and Austroads guides.

Figure 1 details specific terminology associated with roundabouts.

Figure 1 – Roundabout feature terminology



Definitions are listed in Table 1.

Table 1 – Definitions

Term or acronym	Definition
ASD	Approach Sight Distance. Distance it takes a driver to see a pavement marking and stop before the marking.
Bicycle facility	Any type of explicit bicycle infrastructure provision including bicycle path, bicycle lane, or cycle track.
Bicycle lane	An on-road special purpose lane for the exclusive use of bicycles.
Bicycle path / Exclusive bicycle path	A dedicated two-way facility for bicycle riders that is considered road-related area under the *Australian Road Rules*.
Bicycle route	A route may comprise a number of different types of bicycle facilities or route signage to connect key origins and destinations.
Compact (radial) geometry	Approach geometry that is largely radial to the central island and includes entry / exit curve radii around 15–20m.
CPTED	Crime Prevention through Environmental Design.
CRF	Crash Reduction Factor. Estimated influence a treatment may have in reducing the number of crashes. Usually only relevant to one or two specific crash types.
Cycle track	A bicycle path, physically separated from people walking and motor vehicles that provides priority at intersections with roads.
Cycle track (one way)	A bicycle path that only permits one-way movements. Defined as road-related area under QRR (see following for definition).
Cycle track (two way)	A bicycle path that permits two-way movements. Defined as road-related area under QRR.
Danger reduction	Reduce the danger that is present; Reduce the likelihood of a crash occurring; Reduce the consequences if a crash does occur.
DCA	Definitions for Coding Accidents. A system of classifying crashes, using 'collision diagrams' based on the traffic movements leading up to the crash. Participant intent, as well as actual movement, can be used in determining the DCA crash type; however, the relative fault of the participants is not relevant. Refer Austroads' *Guide to Road Safety Part 8 Figure 5.1*
DCA101	Through vehicle collision with another through vehicle. At a roundabout, an entering vehicle collision with circulating vehicle.
ICD	Inscribed Circle Diameter. Diameter of the outer edge of the circulating roadway of a roundabout.
Intersection	Without altering the QRR definition, this guideline also defines an intersection as the meeting of one path with at least one other road, path or driveway.
MUTCD	*Manual of Uniform Traffic Control Devices*.
Off-road	A path located outside the road corridor, possibly through a park, reserve, easement, within a public transport corridor or other public or private land not open to motor vehicle traffic.
On-road	Where bicycles are operated in a general purpose traffic lane, special purpose lane, auxiliary lane, a lane shared with parked cars or road shoulder.
PCNPs	Principal Cycle Network Plans
QRR	*Queensland Road Rules*.

Term or acronym	Definition
Road	As per the definition in Schedule 4 of the *Transport Operations (Road Use Management) Act 1995*.
Road-related area	As per Section 13 of the Transport Operations (Road Use Management Road Rules) Regulation 2009.
Separator	An area that divides a bicycle facility or path from the footpath, nature strip or roadway.
Shared path	A pedestrian and bicycle facility that gives people walking priority under QRR.
Tangential geometry	Entry geometry designed to direct vehicles into the roundabout circulation tangential to the central island.
TGSI	Tactile Ground Surface Indicator
Transition	A bicycle path connection, possibly a ramp, between road and road related area (or vice versa), such as a bend in transition.
TRUM	Traffic and Road Use Management Manual.

2 Referenced documents

The *Active transport guidelines references* lists documents of interest to readers of this guideline.

Table 2 – Referenced documents

Author	Title
Austroads	*Guide to Road Design Part 3*
	Guide to Road Design Part 4A
	Guide to Road Design Part 4B.
	Guide to Road Design Part 6
	Guide to Road Design Part 6A.
	Guide to Road Safety Part 8.
	Guide to Traffic Management Part 6.
	Guide to Traffic Management Part 8.
Qld Government	Transport Operations (Road Use Management Road Rules) Regulation 2009
Queensland Police Service	*Crime Prevention through Environmental Design guidelines*
Transport and Main Roads	*Bridge design and assessment criteria*
	Queensland *Manual of Uniform Traffic Control Devices*
	Policy – Reduction of risk from objects thrown from overpass structures onto roads
	Road Planning and Design manual 2nd edition
	Selection and design of cycle tracks guideline
	Traffic and Road Use Management (TRUM) manual Vol. 1 Part 10

3 Background

Roundabouts have been shown to be effective in reducing the frequency and severity of motor vehicle crashes; however, the safety of roundabouts for bicycle riders remains a source of concern.

3.1 Layout considerations

Roundabout designs depend on the road environment where they will be installed. Roundabout geometric dimensions are governed by the selection of design vehicle, approach speed and traffic volume.

Entering speed is a key factor influencing roundabout safety. Entering speed influences both the time available to perceive and react to other users, and the severity of any resulting crash.

The selection and operation of the design vehicle can influence light vehicle speeds. Treatments such as aprons and mountable central islands may be required for heavy vehicle access while keeping speeds safe. The frequency of use by heavy vehicles may govern appropriateness of mountable elements. The influence of mountable elements on heavy vehicle stability and underbody clearance, as well as motorcycle safety, must be considered.

There are two schools of roundabout geometry design which are known as either tangential or compact (also known as radial) geometry. The primary difference is the radius of entry and exit curves. Compact geometry supports priority crossings for people walking and riding bikes as it requires lower approach and exit speeds.

The two approaches to roundabout design differ in their focus. Capacity is the primary focus of tangential roundabouts (named after the design road entry and exit geometry), minimising the delay to motor vehicles. Compact roundabouts focus on speed reduction and safety. English-speaking countries (United States, Australia and New Zealand) typically use tangential roundabouts, while countries from continental Europe (Sweden, Denmark, Germany, and Netherlands) use compact roundabouts. United Kingdom guidelines permit both types of geometry, recommending their most appropriate contexts.

3.2 Bicycle operation at roundabouts

Guidelines on the provisions for people riding bikes are similar among jurisdictions. Most expect people riding bikes on-road to act as a vehicle in single-lane, typically low-speed, roundabouts. Some jurisdictions do not permit people riding bikes to travel on multi-lane roundabouts and recommend segregated off-road cycle paths. Other jurisdictions do allow for the use of bicycle lanes in the circulating area, but caution against positioning people riding bikes at the edge of the road.

3.3 Effect on road safety (crash risk)

Worldwide, the conversion of signalised and unsignalised intersections to roundabouts has improved overall safety outcomes. The reductions in injury crashes vary between jurisdictions, and probably reflect different design guidelines and road user expectations. Overall, the conversion to roundabouts reduces all crashes by 36%. Fatal crashes are reduced by 66%, and injury crashes are reduced by 46%. There is a small increase in crashes involving only property damage. While there have been overall improvements in road safety, the effect has not been positive for all road user groups, and lower vehicle approach speeds should reduce the risk of crashes and injuries occurring at roundabouts for all users. Attaining appropriate entry speed can be achieve through horizontal curvature on approach, vertical speed control treatments such as road humps, lower posted speed limits or perceptual countermeasures. Australian jurisdictions have not evaluated lower posted speed limits approaching roundabouts; however, lower posted speed limits have been found to be effective at several Queensland high-speed intersections. Perceptual countermeasures have reduced vehicle speeds by 5–10 km/h and roundabout crashes on approach to roundabouts by about 60%.

3.4 Bicycle safety at roundabouts

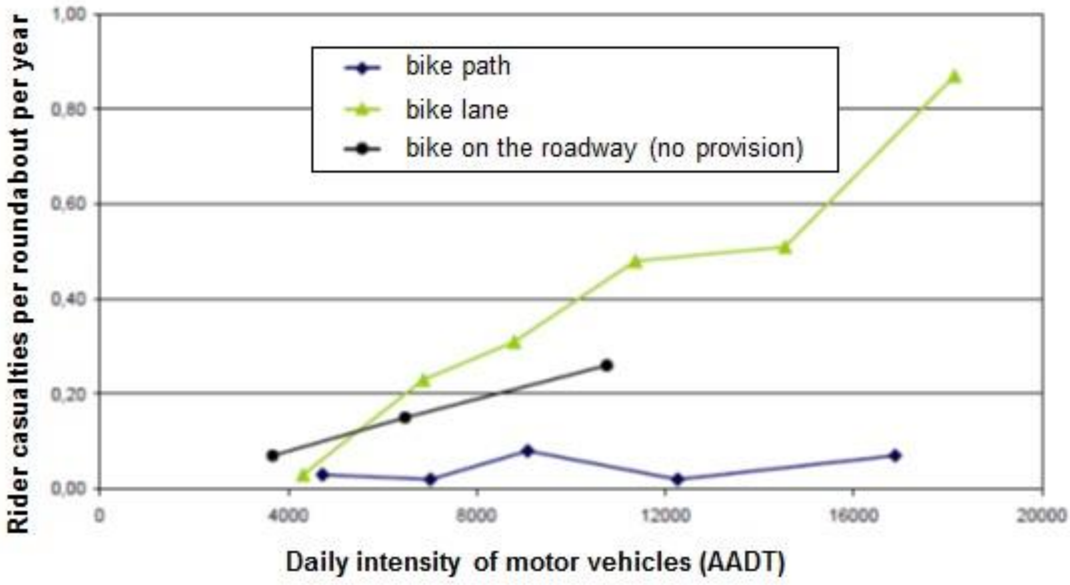
People riding bikes are vulnerable compared to occupants of motorised vehicles, due to their relative lack of occupant protection, slower speeds and smaller size. While roundabouts have increased the safety for motor vehicle occupants, compared with other junctions, the same cannot be said for people riding bikes. Traffic signals provide more protection to vulnerable road users than roundabouts. In Queensland, roundabouts represent about 4% of all intersections on state-controlled roads and approximately 15% of bicycle social crash costs at intersections.

People riding bikes in different countries perceive the risk of roundabouts differently. Those who ride in the United Kingdom perceive roundabouts to be very risky, whereas people riding bikes in continental Europe view low-speed urban roundabouts in a more positive light.

There are several factors that may influence safety for people riding bikes at roundabouts. One issue is the tendency for people riding bikes to position themselves on the outside edge of the circulating roadway when travelling through the roundabout, even if no bicycle lane is provided. Travelling on the outer edge of the roadway may reduce the likelihood a driver will perceive the bike rider and limits potential crash avoidance manoeuvres possible with a greater buffer distance. This relates to the most common crash (25–40% of total crashes) involving people riding bikes at roundabouts, involving a driver entering the roundabout who fails to yield to an already circulating bike rider.

Geometric features may influence bicycle crash rates at intersections. Compact roundabouts reduce bicycle–vehicle crashes, while crash rates at two-lane roundabouts are higher than expected. Roundabouts with bicycle lanes are riskier for people riding bikes, even compared to roundabouts with no provision for bicycle riders. Roundabouts with segregated bicycle facilities have the lowest crash ratings for people riding bikes, refer Figure 3.4.

Figure 3.4 – Rider casualties, traffic intensity and bicycle facility types



Source: Dykstra, 2004

While segregated bike paths at roundabouts in operation overseas reduce bike rider crashes, different priority rules at crossing points make comparisons with Australian roundabouts difficult. In Sweden, vehicles do not have priority when exiting. Traffic regulations in the Netherlands also require larger vehicles to take more care when interacting with more vulnerable road users. In Australia, the road rules do not require drivers to give way to people walking or people riding bikes crossing the road near a roundabout; however, path users can be prioritised by implementing various forms of priority crossings. Priority crossings support bicycle network continuity and foster appropriate driver expectations. Priority crossing selection and design is discussed in Section 6.

People who ride bicycles are not a homogenous group; there are different types of bike riders, riding for different reasons, with differing perceptions of risk, using different types of roundabouts, in different ways. A roundabout design that is well-accepted by sports or commuting bike riders may be daunting and potentially unsafe for children and their parents.

The perceived safety of bike riding is a significant barrier to more people taking up bike riding as a regular transport mode; 'interested but concerned' is the term coined for the majority of the population who could cycle but do not due to safety concerns. This is a key target market to engage to achieve *Queensland Cycle Strategy* growth targets.

3.5 Mixed traffic vs bicycle lanes

Mixed traffic roundabouts are usually safe and appropriate in low speed, low volume environments. In The Netherlands, design advice for mixed traffic roundabout is for volumes up to 6000 vehicles per day in the roundabout, typically with entering speeds of 30 km/h. Between 6000 and 10,000 vehicles per day is advised for mixed traffic if none of the approach roads provides bicycle paths.

Austroads *Research Report AP-R461-14* suggests design entry speeds around 25–30 km/h are 'equitable' for people riding bikes to share the lane comfortably with motor vehicles.

Circulation bicycle lanes are inappropriate as they may lead to unsafe positioning of people riding bikes closest to entering traffic and drivers sweep through approach bicycle lanes using the entry width to optimise their entry speed. Splitter kerbs have been used in many locations to separate cars and bicycles until equitable speeds are attained.

The termination of a bicycle lane does not mean people riding bikes must depart the road. Unless alternatives reduce delays, many bike riders will remain on-road. Treatments that maintain cyclist network continuity and help drivers anticipate the actions of people riding bikes are important safety considerations, particularly in mixed traffic environments. American Association of State Highway and Transportation Officials (AASHTO) states 'motorist reaction times (are) 35% higher when processing unexpected events' and 'reinforced expectancies help drivers respond rapidly and correctly'. Treatments that maintain bicycle conspicuity and network continuity will reduce driver surprise by unexpected manoeuvres by bike riders and improve safety.

4 Roundabout retrofitting rationale

The detailed retrofit treatments in this guideline's modular data sheet format assist targeted safety treatments and retrofit specific problems. What works in one context may not work in another.

Table 4(a) presents the basic geometric groups. Section 6 presents data sheets that list the problems people riding bikes may encounter at these roundabout types and suggests possible retrofit treatments.

Table 4(b) presents a series of treatments grouped into treatment toolboxes presented in Section 7 to improve bicycle safety at roundabouts. These treatments can be used in isolation or in combination. It may be appropriate to begin with few treatments and implement additional controls as needed.

Roadside objects (such as signage landscaping or artwork) should be reviewed for safety. Flexible signs may improve vulnerable user safety and reduce maintenance costs from errant vehicle damage.

Steel access lids should supply sufficient friction, particularly where turning, acceleration or deceleration is taking place. Concrete infill lids are one possible option for a durable friction treatment.

Existing or innovative treatments not listed here should not automatically be considered unsafe. Engineering judgement should prevail until trial, monitoring and evaluation can assist with evidence-based decision making.

Table 4(a) – Basic geometric groups

Single lane approaches	Multiple lane approaches
B1 – Tangential geometry	B2 – Tangential geometry

Table 4(b) – Toolbox treatments

Awareness Toolbox	Speed Management Toolbox
A1 – Bicycle awareness zone	S1 – Approach speed limit
A2 – Setback give-way line	S2 – Perceptual treatments
A3 – Bicycle activated warning sign	S3 – Compact geometry S4 – Convert multi lane to single lane S5 – Convert multi lane to C-Roundabout S6 – Central island apron S7 – Outside Aprons S8 – Speed cushion with splitter kerb S9 – Splitter kerb S10 – Raised crossing
Transition Toolbox	Conflict Management Toolbox
T1 – Path following kerb line	C1 – Alternative route
T2 – Path on own alignment	C2 – Eliminate left turn slip lane
T3 – On-road-off-road transition	C3 – Non-priority crossing C4 – Unsignalised at-grade priority crossing C5 – Mid-block signals C6 – Replace the Roundabout with a signalised intersection C7 – Signalise the roundabout C8 – Grade Separation (Underpass) C9 – Grade Separation (Overpass)

5 Retrofit process

This section steps out the process to:

- identify candidate treatment sites
- select appropriate treatments
- prioritise and implement, and
- monitor and evaluate,

5.1 Identify candidate treatment sites

Table 5.1 provides an overview of risk identification methods. Proactive methods may highlight safety issues prior to a crash occurring. Reactive methods rely on crash history.

Table 5.1 – Proactive and reactive risk identification methods

Proactive	Complaints from bicycle users Safety audit Crash prediction model
Reactive	Bicycle crash history All user crash history (car-based proxy)

A crash prediction model for bicycles at roundabouts has been calibrated for Queensland and is presented in Appendix B. The model is most suited for a first pass proactive assessment of the expected average bicycle crash rate at a roundabout. As the model does not include factors for geometric elements some engineering judgement may be required to determine features that may modify expected risks. Some effort is required by the practitioner to determine user volumes and turning movements for each roundabout. Roundabout safety should be investigated if:

- more than two bicycle crashes have been recorded in a five-year period,
- the crash prediction model indicates more than 0.2 crashes are expected annually (an average of one crash every five years), or
- other methods highlight significant risks.

5.2 Select appropriate treatments

At sites with a pre-existing crash history, reviewing the detailed crash reports may provide insights on the effectiveness of infrastructure treatments in reducing crash occurrence. Austroads' *Guide to Road Safety* Part 8 presents a complete discussion on crash analysis and treatment.

Table 5.2 suggests infrastructure treatments to improve bicycle safety in the context of the bicycle network and road environment. These suggestions are not definitive and engineering judgement is required in selection of treatments appropriate to the site being investigated. Bicycle lanes within the circulation of the roundabout have been excluded as an unvalidated treatment.

A roundabout is a system. Changes to one aspect of the roundabout affect other elements of the system. Each roundabout is different, and a choice made for one location does not necessarily suit another. Decisions should be based on thorough data collection, analysis and consideration of local conditions and context for all users.

Site visits and consultation with local users, formal bicycle user groups, road racing groups, triathlon groups, walking volunteers, local aged care centres, schools, disability advocates and so on can help provide a thorough understanding of existing operating conditions and concerns. If bicycle volumes need to be determined accurately, a manual traffic count should be undertaken as it more likely to represent the number of actual users.

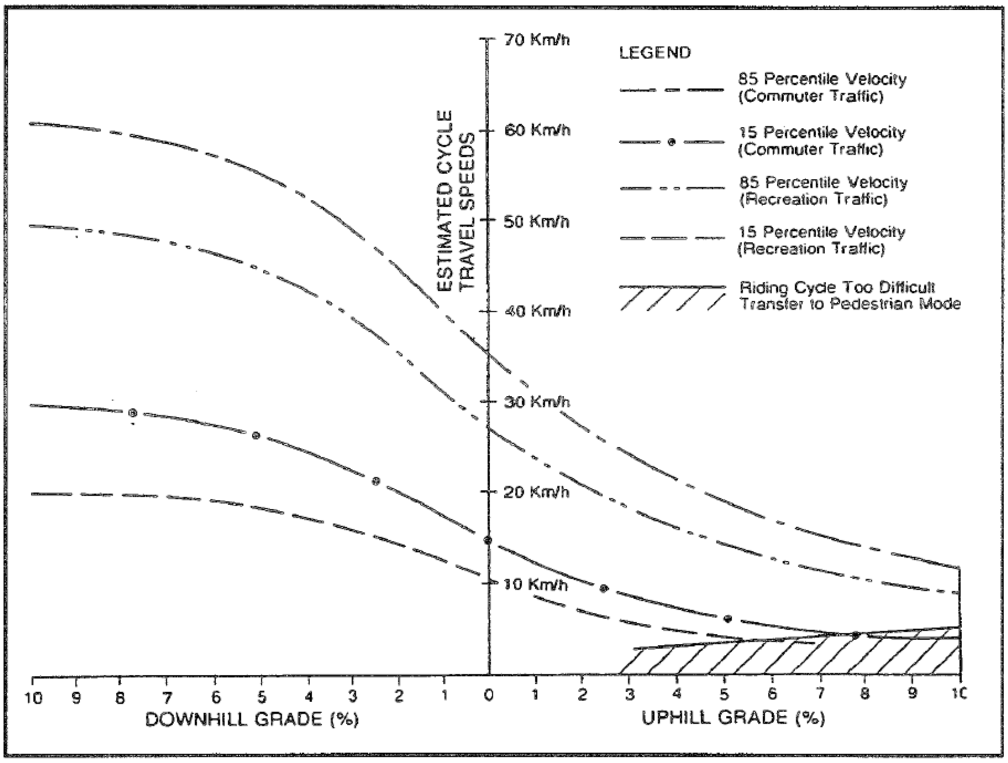
Bicycle speeds can be significantly reduced when travelling uphill; bicycle speed on gradients may be approximated using Figure 5.2.

Note that downhill speeds are terminal speeds, a coasting bicycle (no rider power input) may take up to one kilometre of downhill gradient to achieve terminal speed. Contact cyclepedtech@tmr.qld.gov.au for operational speed assessment for bikes.

Table 5.2 – Suggested treatments given traffic environment and bicycle network context

	Low volume single lane – Entry speed <40km/h	**Medium volume multi lane – Entry speed <40km/h**	**High volume multi lane – Entry speed ≥40km/h**
Principal cycle network	S3 – Compact geometry S6 – Central island apron S7 – Outside aprons S8 – Speed cushion with splitter kerb S9 – Splitter kerbs S10 – Raised crossing T2 – Path on own alignment T3 – On-road-off-road transition C3 – Unsignalised priority crossing	A3 – Bicycle activated warning sign S4 – Convert multi-lane to single lane S5 – Convert multi-lane to C-Roundabout S6 – Central island apron S7 – Outside aprons S8 – Speed cushion with splitter kerb S9 – Splitter kerbs T1 – Path following kerb line T3 – On-road-off-road transition C1 – Alternative route C3 – Non-priority crossing C5 – Mid-block signals C6 – Replace the roundabout with a signalised intersection C7 – Signalise the roundabout C8 – Grade separation (underpass) C9 – Grade separation (overpass)	A3 – Bicycle activated warning sign S6 – Central island apron S7 – Outside aprons S9 – Splitter kerbs T1 – Path following kerb line T3 – On-road-off-road transition C1 – Alternative route C3 – Non-priority crossing C5 – Mid-block signals C6 – Replace the roundabout with a signalised intersection C7 – Signalise the roundabout C8 – Grade separation (underpass) C9 – Grade separation (overpass)
Not on principal cycle network	S3 – Compact geometry S6 – Central island apron S7 – Outside aprons S8 – Speed cushion with splitter kerb S9 – Splitter kerbs C2 – Non-priority crossing C4 – Unsignalised at-grade priority crossing	S4 – Convert multi-lane to single lane S5 – Convert multi-lane to C-Roundabout S6 – Central island apron S7 – Outside aprons S8 – Speed cushion with splitter kerb S9 – Splitter kerbs T1 – Path following kerb line T3 – On-road-off-road transition C1 – Alternative route C3 – Non-priority crossing C5 – Mid-block signals C6 – Replace the roundabout with a signalised intersection C7 – Signalise the roundabout C8 – Grade separation (underpass) C9 – Grade separation (overpass)	S6 – Central island apron S7 – Outside aprons S9 – Splitter kerbs T1 – Path following kerb line T3 – On-road-off-road transition C1 – Alternative route C3 – Non-priority crossing C5 – Mid-block signals C6 – Replace the roundabout with a signalised intersection C7 – Signalise the roundabout C8 – Grade separation (underpass) C9 – Grade separation (overpass)
Generic – for all situations	S1 – Approach speed limit S2 – Perceptual treatments A1 – Bicycle awareness zone A2 – Setback give-way line C2 – Eliminate left turn slip lane Review roadside objects (remove, relocate, replace with more forgiving alternative)		

Figure 5.2 – Bicycle operating speeds



(Source: Austroads' *Guide to Road Design* Part 3)

5.3 Prioritise and implement

Treat the 'worst first' but seek opportunistic integration of roundabout safety treatments with other works such as resurfacing.

Risks to bicycle riders are likely to be higher on roundabouts where:

- motor vehicle speeds significantly exceed on-road bicycle speeds (>20 km/h speed differential)
- motor vehicle volumes are higher (annual average daily traffic (AADT))
- motor vehicles frequently sweep across lanes (observed via site visits or aerial photography)
- bicycle numbers are higher (exposure)
- the roundabout is in close proximity to a school (<1 km), and
- alternative routes for bicycles are non-existent or not desirable.

Risks are likely to be higher, particularly where a number of these conditions exists in combination.

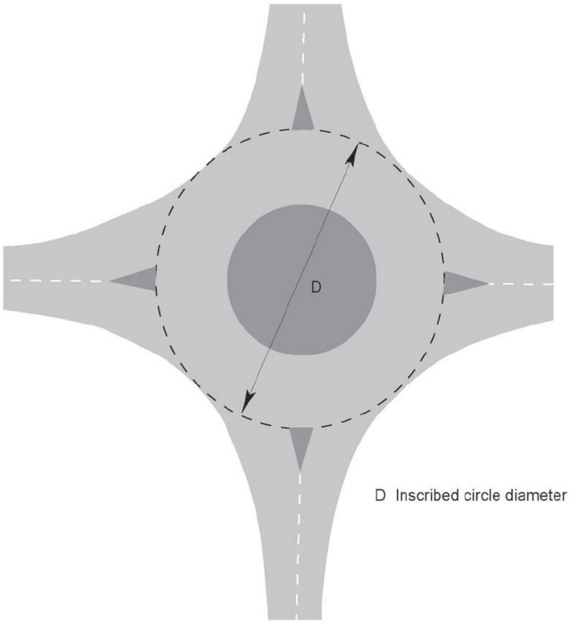
Funding for improvements may be available through capital works programs or grants programs such as *Blackspot* or *Safer Roads Sooner*. Other projects compete for funding and priority.

5.4 Monitor and evaluate

It is important for each project to include a monitoring and evaluation plan, particularly where the treatment may be innovative or new to the locality. This plan should initiate the collection and analysis of appropriate before / after data on traffic and safety patterns. Some relevant information for a before / after analysis would include entering speed, traffic volumes, bicycle volumes, lateral positioning and detailed crash records. Similar information may need to be collected at a nearby control site to rule out other systemic changes occurring over time.

6 Basic geometric groups

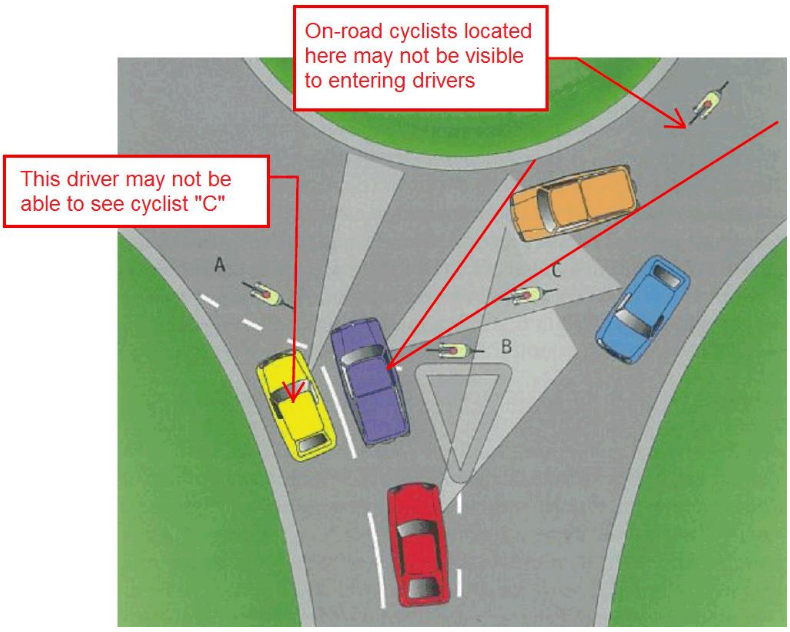
B1 – Single lane approaches (tangential geometry)



Guidelines	*Road Planning and Design Manual*.
Consider bicycle treatments where	• combined AADT of all approaches exceeds 6000, and • approach speed limit exceeds 40 km/h.
Avoid	• in urban areas near schools • locations frequented by the elderly or people with disability, and • elliptical central islands.
Advantages	• Low angle of incidence reduces motor vehicle collision severity. • Five metre-wide approach lanes can allow people riding bikes to queue jump during congested periods.
Disadvantages	• Limited motor vehicle speed control at crossing conflict points, speeds greater than 50 km/h result in high probability of a fatal crash if a vulnerable road user is involved. • Lane width flare at entry can be difficult for people riding bikes to claim the lane. • Late motor vehicle deceleration can prohibit bike riders' integration on approach. • Entering driver attention may be focused on vehicles about to enter on the adjacent approach if they expect high-speed, potentially conflicting vehicles; bike riders present on the circulation lane may be overlooked when driver attention is focused elsewhere. • Drivers may misjudge the speed of people riding bikes or perceive there is enough road width available to push past.

Other considerations	• Early acceleration allowed by generous exit geometry enables drivers to attain their desired speed quickly but reinforces driver expectation that the intersection has ended, just when path users are about to cross. • This expectation might increase the probability of rear-end crashes associated with a downstream priority crossing and reduce driver likelihood of giving way.
Possible retrofit treatments	• Refer Table 5.2 for suggested treatments by context. • Apply selected facilities from the *Awareness Toolbox*. • Apply selected facilities from the *Speed Management Toolbox*. • Apply selected facilities from the *Transition Toolbox*. • Apply selected facilities from the *Conflict Management Toolbox*. • Bicycle lanes should be terminated on approach at a point where equitable car–bicycle speeds are achieved.
Additional references	• Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 6.

B2 – Multiple lane approaches (tangential geometry)



Typical arcs of concentration or drivers entering a roundabout (modified to show potential dynamic visibility obstructions)

Source: Franklin Cyclecraft

Guidelines	*Road Planning and Design Manual*.
Consider bicycle treatments where	• people walking and bike riding are known to use the roundabout.
Avoid	• in urban areas near schools • locations frequented by the elderly or people with disability • on principal bicycle network, and • elliptical central islands.
Advantages	• Reduced need to stop for motor vehicles. • Low angle of incidence reduces motor vehicle collision severity.
Disadvantages	• Permits vehicular speeds at conflict points above threshold for human crash tolerance. • Drivers can sweep across lanes to compromise intended geometric speed control. • Lane width flare at entry can be difficult for on-road bike riders to claim the lane. • It can be difficult to cross the road, particularly for children, elderly and people with a vision impairment. • Drivers look for gaps in circulation traffic and high-speed vehicles about to enter on adjacent approach, drivers not focused on bicycles are less likely to perceive them. • People riding bikes are potentially overlooked in a busy traffic environment. • People riding bikes are potentially obscured from sight by other vehicles (multiple threat).

Possible retrofit treatments	• Refer Table 5.2 for suggested treatments by context. • Apply selected facilities from the *Awareness Toolbox*. • Apply selected facilities from the *Speed Management Toolbox*. • Apply selected facilities from the *Transition Toolbox*. • Apply selected facilities from the *Conflict Management Toolbox*. • Bicycle lanes should be terminated on approach at a point where equitable car–bicycle speeds are achieved.
Additional references	• Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 6.

7 Treatment details

7.1 *Awareness Toolbox*

A1 – Bicycle awareness zone

River Street, Mackay, Queensland

Edited photo: Mark McDonald

Guidelines	*Traffic and Road Use Management (TRUM) Volume 1 Part 10.*
Use:	• on approaches and within the circulation of roundabouts with mixed traffic, and • at the transition zones on approaches to roundabouts. • Symbol must be located in the centre of the lane.
Avoid:	• as a standalone treatment, and • locating the symbol near the left-hand edge.
Advantages	• Drivers are reminded of the presence of bike riders in queue and circulation. • Entering lane width does not increased, helping control motor vehicle entering speed.
Disadvantages	• Pavement markings may be obscured by queued vehicles. • 'Interested but concerned' user groups may not find the treatment appealing.
Other considerations	• People do not see what they are not looking for: treatments to raise driver awareness and expectations should support safety. • Symbols located in the centre of the lane may receive less wheel wear and last longer.
Additional references	• Austroads *Guide to Traffic Management* Part 6.

A2 – Set back GIVE WAY line

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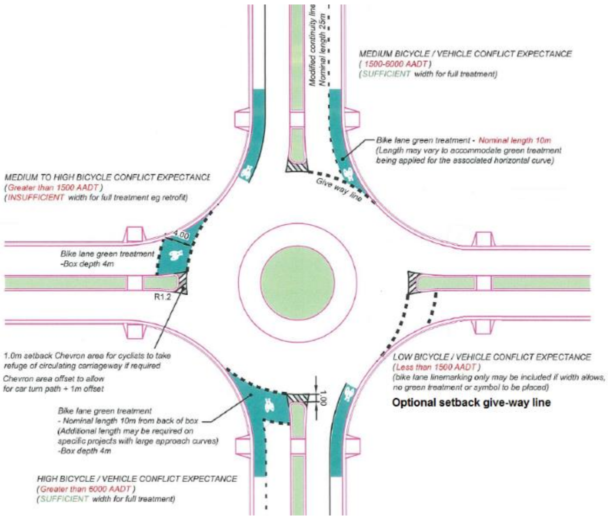


Source: Sunshine Coast Council Standard Plans LM20 to LM22 (modified)
</td><td>

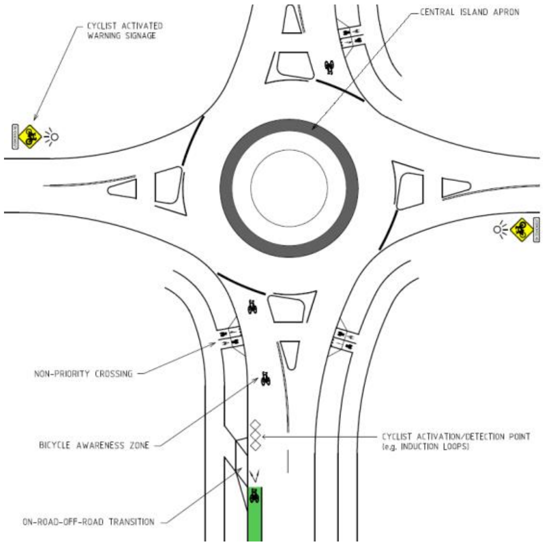
David Low Way at Mahogany Dr
Photo: Departmental aerial imagery
</td></tr>
<tr><td colspan="3">Innovative treatment: SHOULD be monitored and evaluated if installed.</td></tr>
<tr><td>Use:</td><td colspan="2">
• where higher-order treatments are unwarranted or unsuitable
• on identified sport and commuter routes, including pelotons
• where there is demand for right-turn cycle movement
• where roundabout is known to be difficult for people riding bikes to negotiate
• on identified cycle routes to support driver awareness of the presence of people riding bikes
• where sight distance criteria for roundabouts can be maintained, and
• where the speed limit is 60 km/h or less on all approaches.
</td></tr>
<tr><td>Avoid:</td><td colspan="2">
• as a standalone treatment (for example, provide alternative options and traffic speed mitigating treatments for less experienced bike riders).
</td></tr>
<tr><td>Advantages</td><td colspan="2">
• Hold line is set back from circulation, potentially reducing DCA101 crashes.
• People riding bikes attain good road position.
• Pavement marking will not be obscured by queued vehicles.
• Drivers are reminded of the presence of people riding bikes in the queue and circulation.
• Treatments legitimise presence of on-road bike riders.
• The treatment is consistent with intersection conflict zone treatments.
</td></tr>
<tr><td>Disadvantages</td><td colspan="2">
• 'Interested but concerned' riders may not find the treatment appealing.
• The treatment does not assist people walking.
• Bicycle lanes on approaches are continued to the hold line, limiting control of driver entering speed.
• The time for drivers to enter the roundabout from the GIVE WAY line and cross the circulating traffic is longer. This may increase crashes where drivers misjudge the gap required (evaluation is required on gap acceptance and driver holding behaviour).
</td></tr>
</table>

Other considerations	• MUTCD Part 2, 5.4.2 b) will be amended to read: *b) At a roundabout, to indicate the safe position for a vehicle to be held before entering. The line shall be placed across the entering road. The line may be along the edge of the circulating roadway (see Figures 2.7 and 2.8) or set back up to five metres from the edge of circulating roadway to reduce to reduce the likelihood of a 'multiple threat' incident. The line may be staggered on multiple lane approaches.* • If the line is set back from the edge of the circulating roadway, a supplementary GIVE WAY line shall be used to describe the edge of the circulating roadway. • The treatment is consistent with research as lanes are not circulatory. • The treatment is consistent with intersection conflict zone marking style. • Extend splitter island and place crossing six metres from GIVE WAY line to allow path users to cross behind a holding vehicle. • Noosa trials are limited, without formal evaluation. • People do not see what they are not looking for: treatments to raise driver awareness and expectations can support safety. • Evaluation should include at least how road users are actually using the facility (concerns the treatment may be used like a bicycle storage area at signals), motor vehicle speeds and before / after crash history.
Additional references	• *Manual of Uniform Traffic Control Devices* (MUTCD).

A3 – Bicycle activated warning sign

Noosa Parade, Noosa Heads

Photo: GTA Consultants



Example layout, loops activating warning on adjacent approach

Source: GTA Consultants

Guidelines	[TRUM Volume 1] Part 10.
Use:	• on one or more approaches to a roundabout with mixed traffic • where other treatments have not been effective in modifying driver behaviour • where paths cannot be fully implemented, and • multi-lane roundabouts where the crossing task is extremely difficult and higher-order treatments are not possible (for example, grade separation, signalisation).
Avoid:	• high-volume cycling routes (if the warning light illuminates continuously it potentially loses impact value), and • as a standalone treatment.
Advantages	• The treatment warns approaching drivers of circulating bike riders. • It is only active when a potential conflict is likely. • The treatment legitimises on-road bike rider presence.
Disadvantages	• The treatment is costly to install and maintain. • It is a potential vandalism target. • It is a potential theft target (solar cells). • 'Interested but concerned' user groups may not find the treatment appealing.
Other considerations	• The treatment shall be implemented with approved sign faces (MUTCD or Traffic Control (TC) signs). • Consider activation methods that do not require people riding bikes to stop to trigger the device. • The activation method must be robust, reliable and limit false positives. • A pavement symbol may be required on road, so people riding bikes know where to ride to activate the device. • Consider power system backup to limit system failure. • People do not see what they are not looking for: treatments to raise driver awareness and expectations can support safety.

Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S6 – Central island apron. • S8 – Speed cushion with splitter kerb.

7.2 *Speed Management Toolbox*

S1 – Approach speed limit

	
Guidelines	MUTCD Part 4.
Use:	• at the deceleration zone on approach to the roundabout, and • immediately prior to the termination of the bicycle lane / shoulder on the approach to the roundabout, about 15–60 m from the GIVE WAY line.
Avoid:	• implementing as a standalone treatment.
Advantages	• The treatment supports equitable speeds prior to the merge point of the bicycle and traffic lanes. • It supports appropriate entry speeds. • Slower entry speeds and circulation may improve gap acceptance. • The treatment supports appropriate speeds at crossings (priority, non-priority). • 30 km/h zones in residential areas have been proven to save lives and save money. • The treatment assists crossing for young, elderly and people with disability.
Disadvantages	• 24/7 traffic speed reductions. • Compliance may be reduced if drivers perceive the reduced speed zone is too long or too slow.
Other considerations	• Use pavement stencils to support signage. • Re-establish the speed zone after the departure crossing point. • Is there ability to enforce?
Additional references	• Dool, van den D, Job, S. *Pedestrian Safety – can we handle the next phase?* Walk Global Conference. Sydney. GTA Consultants. 2014.

S2 – Perceptual treatments

'Dragons teeth'.

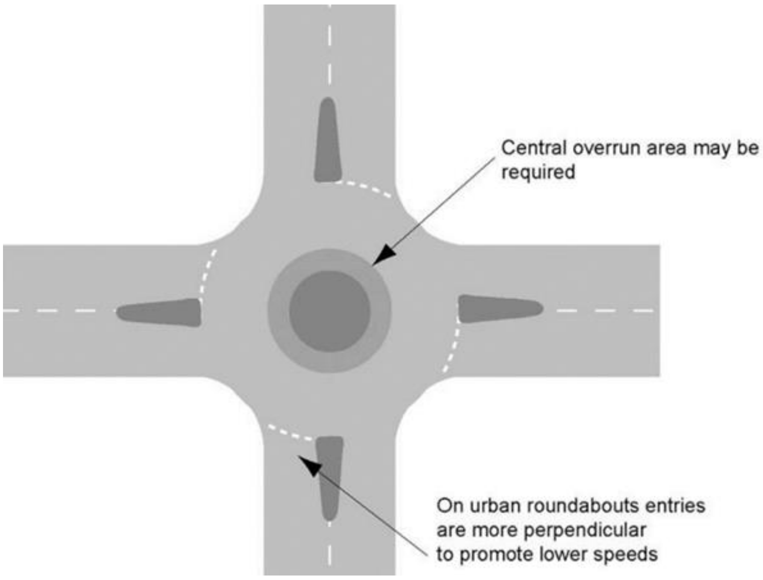
Source: RMS Technical Directions

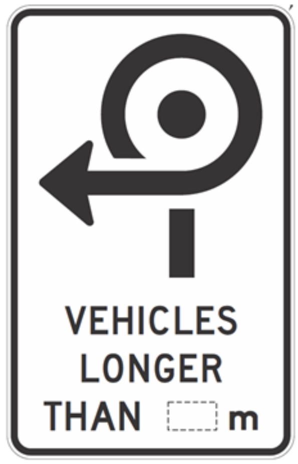
Extended chevron island on Approach, Ferguson Rd

Photo: Departmental aerial imagery

Non-standard treatments SHALL be evaluated if trialled in Queensland.	
Guidelines	MUTCD Part 2.
Use:	• immediately prior to the end of the bicycle lane / shoulder on the approach to the roundabout, and • on approach to a change in speed limit or speed environment.
Avoid:	• as a standalone treatment.
Advantages	• The treatment induces appropriate speeds prior to the merge point of the bicycle and traffic lanes. • It induces appropriate speeds prior to the crossing (priority, non-priority). • Slower entry speeds in circulation may improve gap acceptance. • The treatment assists crossing for young, elderly and people with disability.
Disadvantages	• 24/7 traffic speed reductions. • Maintenance is required.
Other considerations	• Many forms of perceptual treatments have been trialled nationally and overseas. • Evaluations indicate minor reductions in motor vehicle speed (2–13 km/h). • 'Dragons teeth', used in NSW school zones, are a non-standard treatment in Queensland. There is potential for driver confusion unless complementary community awareness communications are undertaken. • Concerns have been raised that perceptual treatments on approach to crossings may distract driver attention from path users crossing the road. • Ensure adequate slip resistance is available over treatment life. Some treatments may not be appropriate on curved approaches. • Standard treatments provided in the MUTCD are preferred (for example, visually narrow traffic lane width with extended painted chevron island on approach to splitter island).
Additional references	• UK Village Gateways research and guidelines. • NSW school zones safety research. • RMS Technical Directions. • Charlton and, Baas, 2006. Research Report 300 *Speed change management for New Zealand roads*. Land Transport New Zealand.

S3 – Compact (radial) geometry



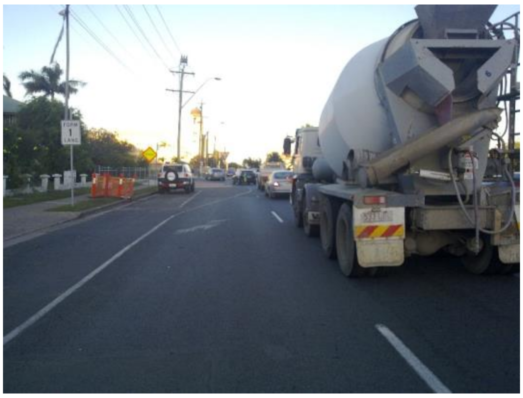


Source: Highways England, *Design Manual for Roads and Bridges*, TD-16/078	TC2343

Innovative treatment: SHALL be evaluated if trialled in Queensland.	
Guidelines	*Road Planning and Design Manual.*
Use:	• on local and collector roads in urban areas • when two-way AADT on any approach is less than 8000, and • where the speed limit is 60 km/h or less on all approaches.
Avoid:	• rural areas, and • elliptical central islands.
Advantages	• A slower approach speed and circulation speed may change the focus of driver attention, possibly improving detection of bicycles. • Perpendicular entry and exits slow vehicles throughout the circulation, which supports crossing safety. • There is less flare on entries / exits, giving more flexibility in siting crossings. • The speed differential between people riding and motor vehicles in circulation is low. • ARNDT crash modelling predicts lower crash costs compared to tangential geometry in appropriate speed environment. Refer Appendix B.
Disadvantages	• There is less capacity than tangential geometry • The treatment may increase single vehicle crash likelihood if high motor vehicle approach speeds persist.

Other considerations	• Entry kerb radius = 10 m minimum, 20 m desirable for heavy vehicle access (radii < 15 m reduce traffic capacity, radii > 20 m result in only small traffic capacity improvements). • Exit kerb radius = 15–20 m. • Lane widths at the GIVE WAY line (measured normal to the kerb) should be not less than three metres or more than 4.5 m. • Where inscribed, the circle diameter is between 28–36 m. • Raised platforms may influence motor vehicle approach speeds and reduce single vehicle loss of control issues in the circulation. • Check for semi-trailer swept path, harden encroachment areas. • Central island apron may be required to permit heavy vehicle access and control light motor vehicle speed. • TC2343 informs drivers of longer vehicles to loop around a roundabout where a direct turn would otherwise result in the vehicle encroaching over kerbs at tight radius points. This can be used to keep the kerb radius and entry speed low while also maintaining access for longer vehicles.
Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S6 – Central island apron. • S7 – Outside aprons. • S8 – Speed cushion with splitter kerb. • S9 – Splitter kerbs. • S10 – Raised crossing.
Additional references	• Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 6. • Highways England, *Design Manual for Roads and Bridges, Td 16/07*.

S4 – Convert multi-lane to single lane



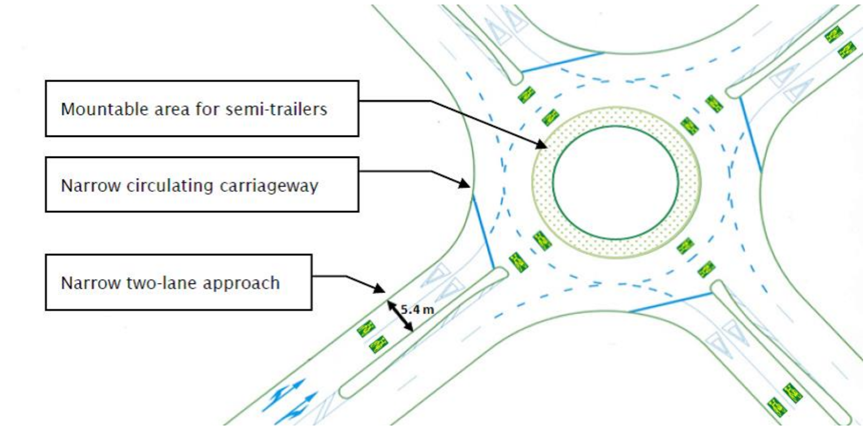
River Street, Mackay, QLD

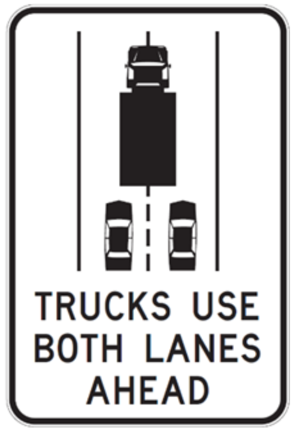
Photo: Mark McDonald

Requires support by traffic modelling.	
Guidelines	*Road Planning and Design Manual*.
Use:	• where 10-year design horizon traffic flows permit single lane on all legs.
Avoid:	• high cost conversion methods.
Advantages	• The treatment limits complexity and conflicts within the roundabout, improving perceived safety for vulnerable users. • It limits motor vehicle speed entering the roundabout, improving safety for all users. • Compared to multi-lane, a single lane crossing improves accessibility, reduces complexity and reduces exposure time for people crossing a leg of a roundabout.
Disadvantages	• The treatment may be seen as a reduction in motor vehicle level of service. • It reduces the capacity of possible motorised throughput.
Other considerations	• Consider bolt down kerb (or similar) to reduce drainage retrofit costs. • In some situations, other intersection types besides multi-lane roundabouts may be safer and more appropriate for people riding bikes: other intersection types should be considered if it is not possible to convert to a single lane roundabout.
Alternative retrofit treatments	• S5 – Convert multi-lane to C-Roundabout. • C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).

Complementary retrofit treatments	• Selected facilities from the Awareness Toolbox. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S3 – Compact geometry. • S6 – Central island apron. • S7 – Outside aprons. • S8 – Speed cushion with splitter kerb. • S9 – Splitter kerbs. • S10 – Raised crossing.
Additional references	• Austroads Guide to Road Design Part 4B. • Austroads *Guide to Traffic Management* Part 6.

S5 – Convert multi lane to C-roundabout (cyclist roundabout)

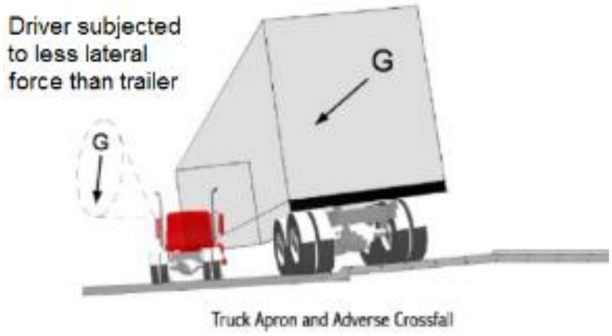




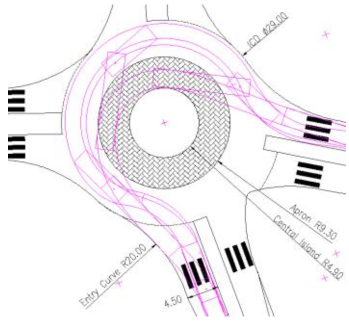
Source: Research Report 510 NZ Transport Agency	TC2039
Innovative treatment: SHALL be evaluated if trialled in Queensland.	
Guidelines	*Road Planning and Design Manual*.
Use:	• where two-way AADT on any approach is greater than 12,000, and • where the speed limit is 60 km/h or less on all approaches.
Avoid:	• as a standalone treatment, and • at elliptical central islands.
Advantages	• Heavy vehicle access is maintained while limiting light vehicle entry speeds to improve safety for people walking and bike riding. • The crossing width for people walking is minimised. • The retrofit is potentially low-cost.
Disadvantages	• Off-peak vehicular speeds may still exceed the threshold for human crash tolerance. • Constrained entry lane width may result in people riding bikes queuing with traffic during peak hours. • The treatment does not improve crossing facilities; road crossings remain difficult, particularly for children, elderly and people with a vision impairment. • Narrow lane widths may increase potential for motor vehicle sideswipe crashes.

Other considerations	• Queensland Road Rule 111 permits vehicles longer than 7.5 m turning less than halfway or more than halfway to straddle entry lanes for up to 50 m on approach the roundabout. The Road Rules do not explicitly permit lane straddling for halfway movements. • The treatment shall be supported with TC2039 signage. • The width of the two approach lanes needs to be 5–5.4 m total. • The higher the proportion of heavy vehicles, the more likely they negatively affect the capacity of the approach. • TC2343 informs drivers of longer vehicles to loop around a roundabout where a direct turn would otherwise result in the vehicle encroaching over kerbs at tight radius points. This can be used to keep the kerb radius and entry speed low while also maintaining access for longer vehicles.
Alternative retrofit treatments	• S4 – Convert multi-lane to single lane. • C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).
Complementary retrofit treatments	• Selected facilities from the Awareness Toolbox. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S6 – Central island apron. • S7 – Outside aprons. • S8 – Speed cushion with splitter kerb. • S9 – Splitter kerbs.
Additional references	• Austroads *Guide to Road Design* Part 4B. • Research Report 510 NZ Transport Agency.

S6 – Central island apron



Source: Ourston Roundabout Inc.



VPATH Semi trailer swept path analysis on compact geometry

Guidelines	*Road Planning and Design Manual*.
Use:	• so light vehicles encounter sufficient entry deflection, and • primarily in single lane roundabouts.
Avoid:	• where adverse crossfall and truck turning speeds are incompatible, or • where heavy vehicles with low underbody clearance could be expected.
Advantages	• The treatment promotes Safe System speeds for light vehicles.
Disadvantages	• The treatment is not directly supportive of the presence of bike riders on road. • Fine construction tolerances are required to be safe and effective. • Future resurfacing needs to 'mill and fill' to ensure apron remains effective.
Other considerations	• The treatment must be capable of being traversed by trailers of large goods vehicles, but unattractive to cars due to slope and/or textured surface. • The treatment nose must be visible to drivers and motorcyclists on approach (ASD). Colour should contrast with surroundings. • Roundabouts with aprons should be lit, vegetation should not shadow apron. • Nose should be reflectorized in case lighting is not operative. • Motorcycles: – vertical edges ≥50 mm are not motorcycle friendly; vertical edges should be <30 mm ('AA' on the department's Standard Drawing SD1033) – the treatment should have a semi-mountable profile at edge of apron, and – adhere to standards after maintenance (for example, resurfacing). • Articulated vehicles: – swept path analysis may assist in estimation of adverse crossfall and potential underbody clearance problems, and – check adverse crossfall and truck turning speeds are compatible (refer Austroads' *Guide to Road Design* Part 4A Appendix C, Table C3). – TC2343 informs drivers of longer vehicles to loop around a roundabout where a direct turn would otherwise result in the vehicle encroaching over kerbs at tight radius points. This can be used to keep the kerb radius and entry speed low while also maintaining access for longer vehicles.
Alternative retrofit treatments	• S5 – Convert multi-lane to C-Roundabout. • C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).

Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S3 – Compact geometry. • S4 – Convert multi-lane to single lane. • S7 – Outside aprons. • S8 – Speed cushion with splitter kerb. • S9 – Splitter kerbs. • S10 – Raised crossing.
Additional references	• Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 6. • *West Australian Coroners investigation 30/03*. • Ourston Roundabout Engineering Inc. *Accommodating Trucks on Single and Multilane Roundabouts*. TRB National Roundabout Conference 20085.

S7 – Outside aprons

Outside aprons. Note cobbles not preferred due to maintenance, durability and constructability.

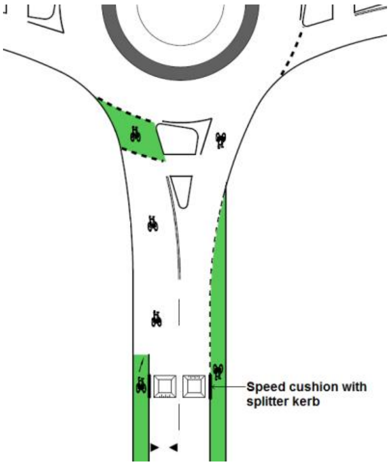
Source: CROW Guide to Turbo Roundabouts.

Innovative treatment: SHALL be evaluated if trialled in Queensland.	
Guidelines	Austroads *Guide to Traffic Management* Part 8
Use:	• so light vehicles encounter sufficient entry deflection.
Avoid:	• where adverse crossfall and truck turning speeds are incompatible (refer Austroads' *Guide to Road Design* Part 4A Appendix B, Table B2) • at the crossing point for people walking and bike riding, and • adjacent to the bicycle lane on the exit of the roundabout.
Advantages	• The treatment promotes Safe System speeds for light vehicles.
Disadvantages	• Not directly supportive of the presence of bike riders on road. • Fine construction tolerances are required to be safe and effective. • Future resurfacing needs to 'mill and fill' so the apron remains effective. • People riding bikes pressured out of the traffic stream may be destabilised.
Other considerations	• The treatment must be visible to drivers and motorcyclists on approach. • It must be capable of being mounted by the trailers of large goods vehicle, but unattractive to cars due to slope and/or a textured surface. • It must not have a vertical edge. • It should have a semi-mountable edge profile. • Lane width should not be constrained to less than 4.5 m wide. • Treatment must be adequately durable and slip resistant. • Discontinue at crossing points. • Alternatively, consider designing entry curve for light vehicles and catering for larger vehicles with TC2343, refer guidance in treatment S3.
Additional references	• Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 6. • CROW *Guide to Turbo Roundabouts*.

S8 – Speed cushion with splitter kerb

Speed cushion and splitter kerb used in combination. Yarra VIC

Photo: Jon Giles



Example layout

Source: GTA Consultants (modified)

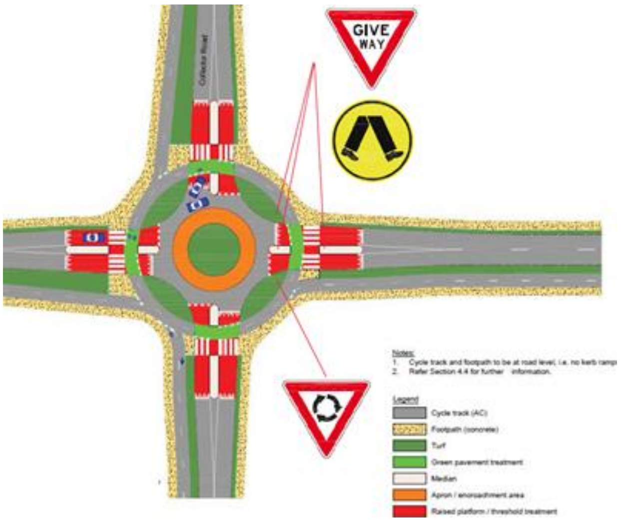
Guidelines	Austroads *Guide to Traffic Management* Part 8.
Use:	• immediately prior to the end of the bicycle lane / shoulder on the approach to the roundabout, about 15–60 m from the GIVE WAY line • prior to path crossing points, and • in all traffic lanes not separated by medians (for example, dual approach lanes, opposing lanes on single carriageway roads).
Avoid:	• at or near the crossing point (they may be a trip hazard for people using the crossing) • on routes that may attract pelotons (check with local road riding clubs), and • speed cushion without splitter kerbs (drivers seek to minimise discomfort by partially avoiding vertical displacement through driving in the bicycle lane).
Advantages	• The treatment is relatively quick and cheap to retrofit. • It is low maintenance. • It induces appropriate speeds suitable for mixed traffic. • It induces Safe System speeds prior to crossing points. • It reduces crossing difficulty for young, elderly and people with disability. • Slower entry speeds in circulation may improve gap acceptance on adjacent legs. • The treatment is traversable by emergency vehicles and buses with minimal vertical displacement.
Disadvantages	• 24/7 traffic speed reductions.
Other considerations	• The treatment may generate some noise but less than a full width platform or a mid-block situation. • Collocate with lighting, reflectorize or contrast colour with pavement so splitter kerbs are visible in low light conditions. • For improved detection on approach, consider flexible guide posts, flexible bollards or chevron markings on approach.
Additional references	• *Road Planning and Design Manual*. • Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 6. • MUTCD Part 13.

S9 – Splitter kerbs

<table>
<tr><td colspan="2">
Approach
Photo: Iain Cummings</td><td>
Depart
Photo: Iain Cummings</td></tr>
<tr><td>Guidelines</td><td colspan="2"><u>Road Planning and Design Manual</u>.</td></tr>
<tr><td>Use:</td><td colspan="2">• to provide a separated bypass treatment between non-conflicting legs
• to induce horizontal deflection to motor vehicle path of travel to achieve appropriate speeds prior to mixed traffic slow encroachment into the bicycle lane on the exit of the roundabout
• where vertical deflection devices may not be appropriate, and
• on all entries and exits of the roundabout: drivers entering on a leg without a splitter kerb may be surprised if one is located on the exit.</td></tr>
<tr><td>Avoid:</td><td colspan="2">• extending up to the GIVE WAY line, and
• permitting on-street parking nearby as it may block access to or from the facility.</td></tr>
<tr><td>Advantages</td><td colspan="2">• The treatment increases separation between people riding bikes and vehicles until safe mixing speed is achieved.
• It reduces the crossing distance for people walking.
• It protects people riding bikes from motor vehicle encroachment on approaches and departures.</td></tr>
<tr><td>Disadvantages</td><td colspan="2">• If the splitter kerb extends all the way to the GIVE WAY line, people riding bikes may adopt a road position that has a minimal buffer distance to traffic entering on the adjacent leg.
• Not all people riding bikes will use the lane behind the kerb: larger groups of people riding bikes (particularly sports riders) will use a traffic lane.</td></tr>
</table>

Other considerations	• The treatment must be visible to drivers and motorcyclists on approach (ASD). • Collocate with lighting, reflectorize or contrast colour with pavement so splitter kerbs are visible in low light conditions. • Ensure straight path of travel for bicycles to access the space behind the splitter kerb. • For improved detection of narrow splitter kerb, consider flexible guide posts, flexible bollards or chevron markings on approach. • Wider splitter kerb may permit placement of a D4-1 hazard marker sign: check this does not interfere with visibility of children or people using wheelchairs at the crossing point • Bicycle lane width should be at least 1.8 m between kerb faces. More width may be required if path of travel is curved while people riding bikes are also looking for gaps to enter the roundabout. • Terminate the splitter kerb once motor vehicle deflection is achieved. • Bolt-down splitter kerb is cheap, fast and light to install as a retrofit treatment or trial. The leading edge may become loose if frequently impacted by motor vehicles. Verify proof of concept or highlight any issues that need to be resolved before progressing to a more permanent solution.
Additional references	• Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 6. • TRUM Volume 1 Part 10.

S10 – Raised crossing



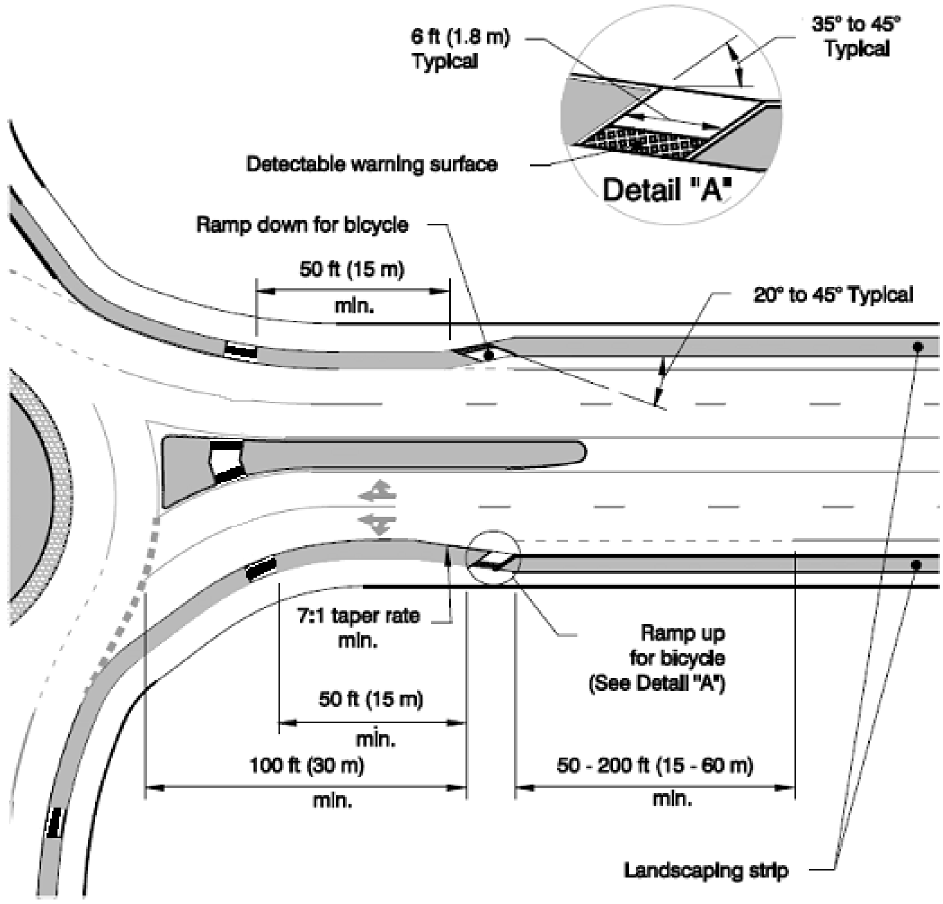
Source: *Selection and Design Of Cycle Tracks Guideline*, October 2019. Modified to include signs

Guidelines	MUTCD Part 9 and Part 10 and *Selection and Design Of Cycle Tracks Guideline*.
Use:	• within 20 m of the roundabout circulation • where 85th percentile traffic speeds do not exceed 60 km/h at the crossing point • where control of motor vehicle approach speeds cannot be controlled through horizontal deflection • on principal bicycle network or high pedestrian activity areas, and • on local and collector roads in urban areas.
Avoid:	• where low clearance heavy vehicles cannot be accommodated, and • where the leading edge is not perpendicular to traffic approaching the roundabout.
Advantages	• The treatment provides path users with the safest facility with no reduction in convenience or priority. • It induces Safe System speeds at the crossing points (80% CRF). • Slower entry speeds may improve gap acceptance for traffic on adjacent legs. • The treatment assists crossing for children, elderly and people with disability.
Disadvantages	• 24/7 traffic speed reductions.
Other considerations	• Leading edge and trailing edge of the platform should not have a vertical lip. • The slope of the leading edge should be between 1:10 and 1:15 to achieve a v85 of 25–30 km/h (1:15 desirable on bus routes). • A trailing edge slope of 1:50 will increase passenger comfort and reduce dynamic loading on pavement due to suspension bounce. • A platform height of 75 mm may be required on routes where low floor buses operate. • Locating the leading edge 5–10 m in advance of the crossing reduces motor vehicle speed at the crossing to reduce crash likelihood and crash severity. • The treatment may affect drainage flow path; this may require new drainage pits or a treatment to bridge the existing drainage channel. • The treatment may cause noise of wheel impact to hump.

Alternative retrofit treatments	• C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).
Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S4 – Convert multi-lane to single lane. • S6 – Central island apron. • S7 – Outside aprons. • S10 – Raised crossing. • T2 – Path on own alignment. • T3 – On-road-off-road transition.
Additional references	• *Road Planning and Design Manual*. • Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 8. • NCHRP report 562 report 674.

7.3 *Transition Toolbox*

T1 – Path following kerb line

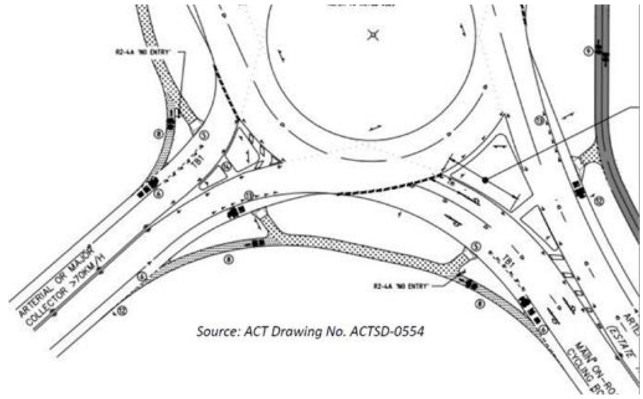
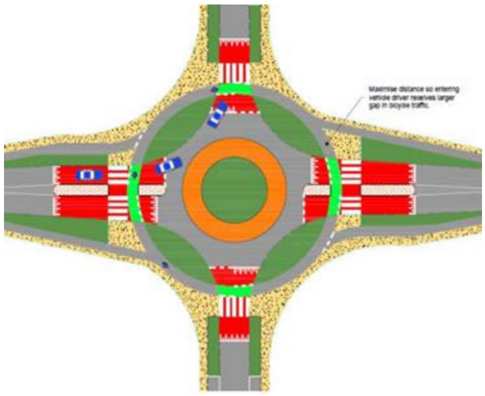


Source: NCHRP 672 (modified)

Guidelines	*Road Planning and Design Manual*.
Use:	• in constrained corridor width, and • where the volumes of people walking and bike riding are relatively low.
Avoid:	• conflicts with poles, signs and other roadside furniture that may be obstructing the path.
Advantages	• The treatment keeps people riding bikes visible to traffic. • Limited changes are required for most retrofitting.
Disadvantages	• There is potential for path user conflict if the path width is too narrow. • People walking or riding bikes waiting to cross the road may block other path users travelling longitudinally.
Other considerations	• Treatments may be required to reduce potential path user conflict. • Path width may need to be increased (2.5–3.0 m) to cater adequately for increased demand and potential path user conflict. • Potential hazards or obstructions on the path may need treatment or removal. • The path should be suitably smooth and free of trip hazards for people walking or bike riding.
Alternative retrofit treatments	• T2 – Path on own alignment.

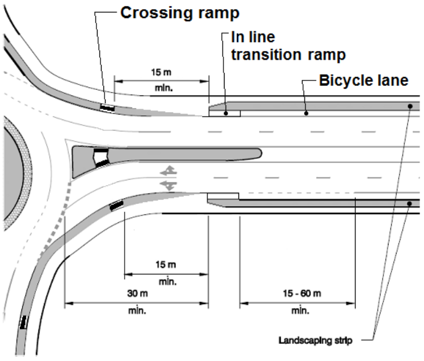
Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S4 – Convert multi-lane to single lane. • S6 – Central island apron. • S7 – Outside aprons. • S10 – Raised crossing. • T3 – On-road-off-road transition. • C3 – Non-priority crossing. • C4 – Unsignalised at-grade priority crossing. • C5 – Mid-block signals.
Additional references	• Austroads *Guide to Road Design* Part 4B, Part 6 and 6A. • Austroads *Guide to Traffic Management* Part 6.

T2 – Path on own alignment

 Source: ACT Drawing No. ACTSD-0554	 Source: The department's *Selection and Design of Cycle Tracks Guideline*
Guidelines	[Road Planning and Design Manual]().
Use:	• where corridor width permits improved geometry.
Avoid:	• landscaping that obscures visibility between the road and path.
Advantages	• People walking or riding bikes waiting to cross the road will not block other path users. • The treatment may permit separated bicycle and pedestrian paths, increasing path capacity. • It provides an option for riders to exit the road if undesirable traffic conditions exist. • It may avoid some potential conflicts with utilities and road furniture. • The transition slope to / from the road can be very flat, providing maximum comfort.
Disadvantages	• The treatment requires land area. • It is likely to be new construction.
Other considerations	• The treatment may require path width (2.5–3.0 m) to cater adequately for increased demand and potential path user conflict. • Path alignment should be relatively direct; no unnecessary curves should be included in the alignment. • Some additional signage or surface contrast may be required to warn people walking of wrong way movements, such as walking out onto the bicycle lane. • If motor vehicles are given priority at the crossing, path geometry should include tight turns to access the crossing and highlight the lack of priority to path users. • If path users are given priority at the crossing, path geometry is ideally circular and raised at the road crossings to support path priority.
Alternative retrofit treatments	• T1 – Path following kerb line.

Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S4 – Convert multi-lane to single lane. • S6 – Central island apron. • S7 – Outside aprons. • S10 – Raised crossing. • T3 – On-road-off-road transition. • C3 – Non-priority crossing. • C4 – Unsignalised at-grade priority crossing. • C5 – Mid-block signals.
Additional references	• Austroads *Guide to Road Design* Part 4B, Part 6 and 6A. • Austroads *Guide to Traffic Management* Part 6. • ACT *Design Standard DS13*. • The department's *Selection and Design of Cycle Tracks Guideline*.

T3 – On-road-off-road transition



Source: NCHRP 672 (modified)

In line transition ramp (inverted grade to be self-cleaning), Bowen Tce Brisbane

(Photo: Mark McDonald)

Guidelines	Road Planning and Design Manual.
Use:	• to provide access to an adjacent path where undesirable traffic conditions might exist on road • at the bicycle lane termination or where the bicycle lane is added • on approaches between 15–60 m from GIVE WAY line, and • on exits as soon as practicable (ideally, added lane).
Avoid:	• sharp transitions in ramp construction (rounding is permissible) • ALL BICYCLES G9-60 signs as they may create false expectations for drivers regarding the path of travel of bike riders • vertical lips in ramp construction, and • locating the ramp so people riding bikes re-enter into a mixed traffic lane.
Advantages	• There is the option for riders to exit the road if undesirable traffic conditions exist. • The treatment leads riders towards safe crossing opportunities: more riders will be attracted to this option if priority crossings are provided.
Disadvantages	• Not all people riding bikes will use the path: larger groups of people riding bikes (particularly sports riders) will use a traffic lane.
Other considerations	• 'High speed ramp' as shown in Austroads Guide to Road Design *Part 3* Figure 4.36 is preferred; however, this may collect drainage debris where the longitudinal road gradient is flat. • An inline ramp at 1:10 slope is a potential alternative design. • Supplementary treatments to the path may be required to manage path user conflict. • The treatment is ideally separated from crossing ramps; however, it may be collocated with crossing ramps in locations with low volumes of people walking.
Alternative retrofit treatments	• S8 – Speed cushion with splitter kerb. • S9 – Splitter kerbs. • C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).

Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S2 – Perceptual treatments. • S3 – Compact geometry. • S4 – Convert multi-lane to single lane. • S6 – Central island apron. • S7 – Outside aprons. • S10 – Raised crossing. • T1 – Path following kerb line. • T2 – Path on own alignment. • C3 – Non-priority crossing. • C4 – Unsignalised at-grade priority crossing.
Additional references	• Austroads *Guide to Road Design* Part 3. • Austroads *Guide to Traffic Management* Part 6.

7.4 Conflict Management Toolbox

C1 – Alternative route

Primary route

Alternative route (less desirable than primary)

Assess and compare the risk on both the primary and the alternative route	
Use:	• where local streets or parks offer a direct, competitive and lower risk alternative to a high-capacity, high-speed roundabout • where the alternative route is a coherent system and maintains good access to origins, destinations and services, and • on the Principle Bicycle Network, where cycle volumes are expected to be high.
Avoid:	• as a localised bypass to an individual roundabout • routes that have poor Crime Prevention Through Environmental Design (CPTED) properties • routes that incur significant delay in either time or distance, and • routes that are heavily used or could create conflict with other path users.
Advantages	• Bicycles are separated from heavy traffic. • Local backstreets offer good personal security and passive surveillance. • The treatment is desirable to all types of rider.
Disadvantages	• A suitably safe and convenient option may not always be available. • Some parks and underpasses may be perceived to have poor personal security and passive surveillance which may deter use. • The treatment may incur additional costs to make the alternative route safe or fully accessible. • Other corridors may require the approval of other agencies which could delay or block implementation of a suitable solution.
Other considerations	• Local backstreets may require traffic calming or intersection modifications. • The treatment may require wayfinding signage to ensure the route is legible. • It may require modifications to signals if the alternative route crosses a major road. • Ensure gradients on alternative route are desirable. • Some treatment of the roundabout may still be necessary to mitigate risk for people riding bikes who do not use the alternative route.
Additional references	• Queensland Police *CPTED guidelines*.

C2 – Eliminate left turn slip lane

Ferguson Rd and Oateson Skyline Dr

(Photo: Departmental aerial imagery)

Requires support by traffic modelling	
Guidelines	*Road Planning and Design Manual*
Use:	• where traffic queue regularly blocks access to the slip lane, and • at urban locations where many people walking or bike riding could be expected. • Remove slip lanes at roundabouts where they are not absolutely necessary.
Avoid:	• removing a slip lane if traffic safety is potentially compromised (for example, if traffic backs up onto an adjacent motorway without a slip lane).
Advantages	• The treatment reduces conflict points and intersection complexity. Drivers may be less likely to overlook people riding bikes. • It makes crossing the road easier, particularly for children, elderly and people with a vision impairment. • It may reduce motor vehicle delays on other legs as more gaps will occur between conflicting vehicle movements.
Disadvantages	• There may be additional delay for motor vehicles on the relevant entry.
Other considerations	• Provision of new or upgraded roads nearby may have reduced the traffic carrying importance of the site. • Removal of slip lanes may be supported by traffic modelling: some slip lanes provide little benefit in peak hours as access is blocked by motor vehicle queues.
Alternative retrofit treatments	• C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).
Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S10 – Raised crossing. • C4 – Unsignalised at-grade priority crossing.
Additional references	• Austroads *Guide to Road Design* Part 4B. • Austroads *Guide to Traffic Management* Part 6. • NCHRP report 674.

C3 – Non-priority crossing

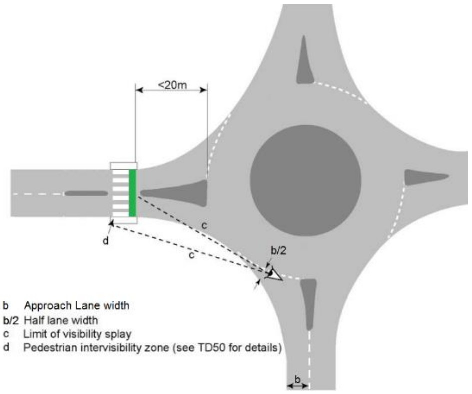
Yellow line indicates path user sight line, third approaching car potential not visible to path user.
Robina Parkway at Gooding Dr, QLD

Photo: Departmental aerial imagery

Guidelines	As per MUTCD Part 10 and TRUM Vol 1 Part 6.
Use:	• where gaps in traffic are available to cross the road, and • where priority crossings are unsuitable.
Avoid:	• where children, elderly or people with disability are known to cross the road regularly • where higher-order crossing facilities are feasible, and • vegetation or landscape terrain obscures visibility between the road and path.
Advantages	• There is minimal motor vehicle delay.
Disadvantages	• The traffic queue on approach may not permit path users to cross. • The treatment locates the crossing in the motor vehicle acceleration zone; the driver expected acceleration may reduce driver ability to stop if necessary. • Higher traffic speed increases the probability of a crash being fatal for the vulnerable road user. • Experienced bike riders will remain on-road to retain priority and reduce delay. • Non-priority crossings place responsibility on people potentially least able to judge the situation. Children cannot judge traffic speed well, people with a vision impairment struggle to judge traffic movements in free flow conditions. • The lead vehicle may obscure visibility to a following vehicle in an adjacent lane, increasing the difficulty of judging a safe gap (multi-lane multiple threat).
Other considerations	• Analyse crossing appropriateness using TRUM Vol 1 Part 6; include volumes of both people walking and bike riding (existing and projected volumes). • Refuge is desirably three metres wide, a bicycle with a baby trailer is three metres long. Refer TRUM Vol 1 Part 6 Figure 8.2.2-1.4.1(2) • Tight turn geometry on the path to access the crossing reduces approach speed and highlights lack of crossing priority. • A GIVE WAY line should be included where a bicycle path enters at grade. A GIVE WAY line not required where Tactile Ground Surface Indicator (TGSI) is used (shared path). • Consider a GIVE WAY pavement symbol instead of a small sign on pole: refer MUTCD Part 9. • A hold rail located on a flat gradient may assist comfort and prompt crossing for people riding bikes, refer details TRUM Vol 1 Part 6 Figure 8.2.1-1

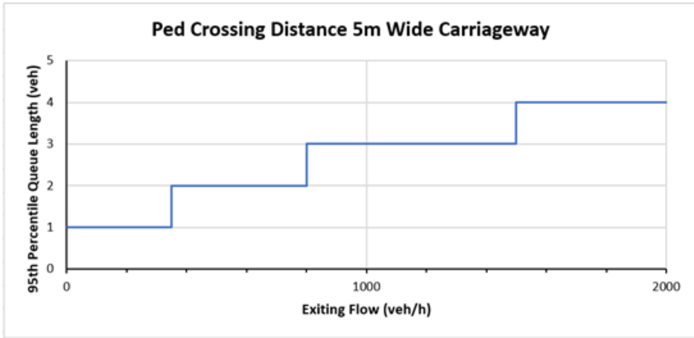
Alternative retrofit treatments	• S4 – Convert multi-lane to single lane. • C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).
Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S9 – Splitter kerbs.
Additional references	• *Road Planning and Design Manual*. • Austroads *Guide to Road Design* Part 4. • Austroads *Guide to Traffic Management* Part 6.

C4 – Unsignalised at-grade priority crossing



Intervisibility splay (modified from original)

(*UK Design Manual for Roads and Bridges*, Td 16/07[8])

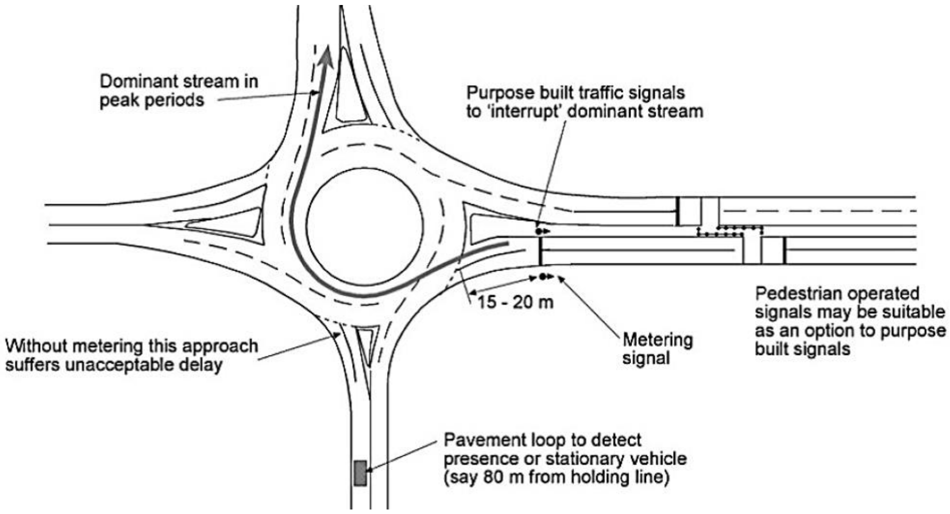


Number of motor vehicles queued at pedestrian crossing

Guidelines	MUTCD Part 10 and TRUM Vol 1 Part 6.
Use:	• as noted in MUTCD Part 10 Section 6.3a(iii) which states: *'The speed limit on approach to the crossing shall be 50 km/h or lower and the 85th percentile speed shall not exceed 60 km/h.'* • where TRUM Vol 1 Part 6 indicates a pedestrian crossing as a possible treatment • located 6–20 m from the GIVE WAY line, and • on single entry and exit lanes.
Avoid:	• on higher-speed roundabouts where traffic queued in the circulation may increase motor vehicle crash risk or severely reduce network performance, and • when vegetation or landscape terrain obscures visibility between the road and path.
Advantages	• Delay is reduced for path users. • Path users have increased connectivity. • The treatment assists people with a vision impairment to cross the road. • Crossings may randomise dominant traffic legs (similar to metering).
Disadvantages	• At-grade priority crossings may lead to a false sense of security for path users; if drivers are not attentive, they may not stop.
Other considerations	• Analyse crossing appropriateness using TRUM Vol 1 Part 6. Include volumes for both people walking and bike riding (existing or projected volumes). • Traffic approaching the roundabout is already slowing to stop, increasing the likelihood of drivers actually giving way. • Provide green surface treatment for bicycle crossing adjacent to the pedestrian crossing. • Locate a bicycle crossing downstream of a pedestrian crossing. • A mounted bike rider travelling at 10 km/h is about three times faster than an average person walking: this reduces crossing time, motor vehicle delay and queue length. *The number of motor vehicles queued at pedestrian crossings* figure shown previously may indicate overly conservative numbers of queue vehicles at priority crossings predominantly used by bicycle riders.

Alternative retrofit treatments	• C1 – Alternative route. • C5 – Mid-block signals. • C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).
Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S4 – Convert multi-lane to single lane. • S8 – Speed cushion with splitter kerb. • S9 – Splitter kerbs. • S10 – Raised crossing.
Additional references	• *Road Planning and Design Manual*. • Austroads *Guide to Road Design* Part 4. • Austroads *Guide to Traffic Management* Part 6. • NCHRP report 674.

C5 – Mid-block signals

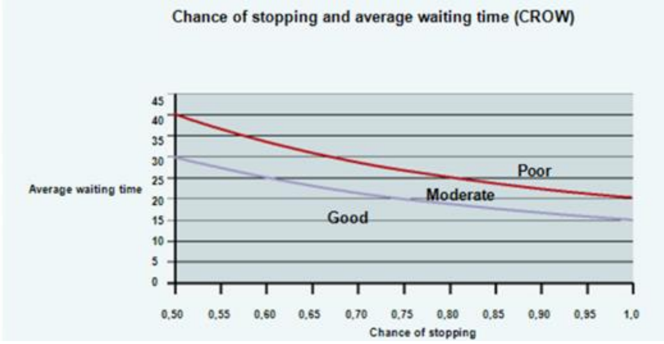


Source: Austroads *Guide to Traffic Management* Part 6

Guidelines	TRUM Vol 1 Part 6
Use:	• in urban areas near schools • at locations frequented by the elderly or people with disability • as part of a total traffic network operational improvement program • where bicycle and pedestrian routes and desire lines align well with the crossing point • where two or more lanes of traffic need to be crossed, and • where gaps in traffic are insufficient to cross safely.
Avoid:	• significant detour distances (> 500 m) or significant time delay before the call progresses to hold traffic, and • low volume crossing demand.
Advantages	• The treatment may meter traffic entering the roundabout, supporting flow on other legs that may be critical to network performance.
Disadvantages	• Excessive delay may result in people riding bikes remaining on-road, providing limited safety benefit.
Other considerations	• Intelligent crossing (detection of people walking and bike riding) may reduce motor vehicle delay when the crossing is cleared earlier than normally expected. • Approach detection on bicycle paths may reduce bike rider waiting delay.
Alternative retrofit treatments	• S4 – Convert multi-lane to single lane. • C1 – Alternative route. • C6 – Replace the roundabout with a signalised intersection. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).
Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit. • S10 – Raised crossing.

Additional references	• *Road Planning and Design Manual*. • Austroads *Guide to Traffic Management* Part 6.

C6 – Replace the roundabout with a signalised intersection

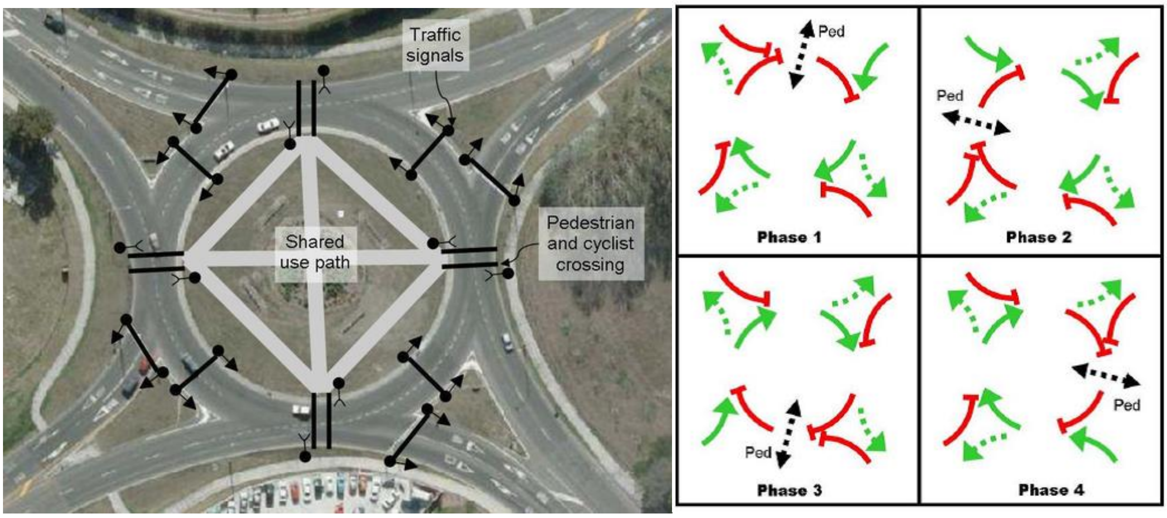


Source: The department's *Selection and Design of Cycle Tracks Guideline*

Guidelines	[Road Planning and Design Manual]().
Use:	• in urban areas near schools • at locations frequented by the elderly or people with disability, and • as part of a total traffic network operational improvement program.
Advantages	• The land requirement at the intersection point is reduced. • Control of motor vehicle flows is increased, favouring priority routes.
Avoid:	• where alternative lower cost treatments are feasible and are expected to operate safely.
Disadvantages	• The treatment increases motor vehicle storage upstream. • Delay may be increased for all road users, especially off-peak. • Crash severity for motorists may increase due to the impact angle of incidence if a motorist runs a red light. • Signalised slip lanes increase delays for people walking and bike riding. • Unsignalised slip lanes are challenging for children, elderly and people with disability as motor vehicle speed is likely to exceed human tolerance to impact force.
Other considerations	• There are installation costs. • There are operating costs in terms of system. • There are operating costs in terms of vehicles and users. • Crossings should be provided on all legs of the intersection. • Intelligent crossings (detection of people walking and bike riding) may reduce motor vehicle delay when the crossing is cleared earlier than normally expected. • Approach detection on bicycle paths may reduce bike rider waiting delay. • Short signal cycle times or double cycling of pedestrian and bicycle phases reduce delay. • Filtered right-turn movements across multiple lanes increase crashes due to the dynamic obstructions to visibility inherent in seeing through the traffic stream. Smaller road users such as motorcyclists and people riding bikes are easily obscured by other vehicles.
Alternative retrofit treatments	• C1 – Alternative route. • C7 – Signalise the roundabout. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).

Complementary retrofit treatments	• Selected facilities from the *Awareness Toolbox*. • S1 – Approach speed limit.
Additional references	• The department's *Selection and Design of Cycle Tracks Guideline*. • Austroads *Guide to Road Design*. • Austroads *Guide to Traffic Management*.

C7 – Signalise the roundabout

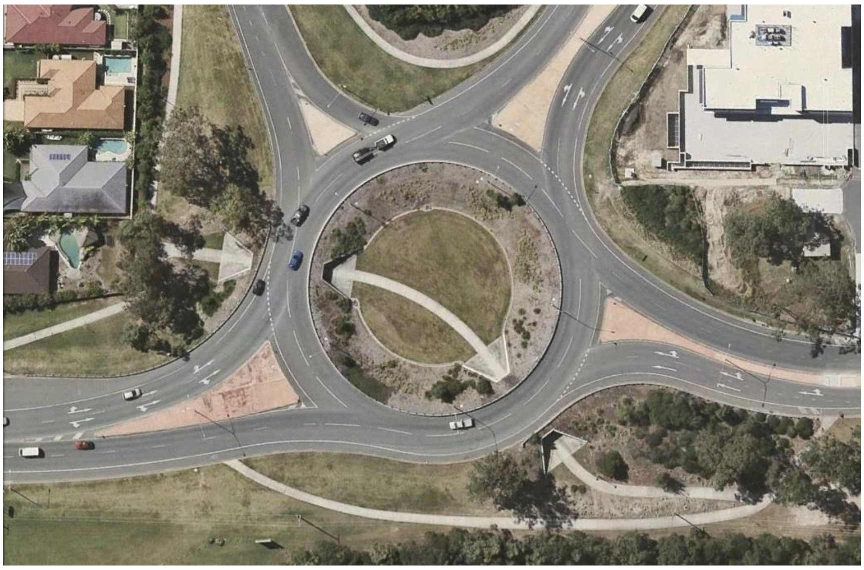


Source: Via Strada

Guidelines	The department's *Selection and Design of Cycle Tracks Guideline*. *Road Planning and Design Manual*. Austroads guides.
Use:	• at urban areas near schools • locations frequented by the elderly or people with disability, and • as part of a total traffic network operational improvement program.
Avoid:	• where alternative lower cost treatments are feasible and are expected to operate safely.
Advantages	• The treatment permits control and favouring of priority routes. • It retains a low-impact angle of incidence for motor vehicles, limiting crash severity. • The treatment requires virtually no change in land. • Traffic impact during retrofit construction is minimised. • The treatment makes a challenging road environment accessible for children, elderly and people with disability.
Disadvantages	• Motor vehicle storage upstream is increased. • Delay may be increased for all road users, especially off-peak.
Other considerations	• There are associated installation costs. • There are associated system operating costs. • There are associated vehicle and user operating costs. • Intelligent crossings (detection of people walking and bike riding) may reduce motor vehicle delay when the crossing is cleared earlier than normally expected. • Approach detection on bicycle paths may reduce bike rider waiting delay. • Short signal cycle times or double cycling of pedestrian and bicycle phases reduces delay. • Crossings need to be activated regularly so drivers do not overlook the presence of the crossings.

Alternative retrofit treatments	• S4 – Convert multi-lane to single lane. • C1 – Alternative route. • C6 – Replace the roundabout with a signalised intersection. • C8 – Grade separation (underpass). • C9 – Grade separation (overpass).
Complementary retrofit treatments	• Selected facilities from the Awareness Toolbox. • S1 – Approach speed limit. • S2 – Perceptual treatments.
Additional references	• Austroads *Guide to Traffic Management* Part 6.

C8 – Grade separation (underpass)



Tamborine-Oxenford Rd at Regatta Ave, Oxenford

Source: Departmental aerial imagery

Consider grade separation in early design stages of capital works and greenfield developments.	
Guidelines	*Bike rider and pedestrian underpasses guideline*.
Use:	• where topography supports an underpass • where good approach geometry is available, and sightlines extend the entire length of the underpass before the user enters the underpass • Where TRUM Vol 1 Part 6 (including bicycle volumes) indicates that mid-block signals are warranted, but an at-grade crossing cannot be installed due to roads with high traffic volume (for example, arterial roads, freeways and motorways) • across major roads where alternative crossing facilities are not feasible • on Principal Cycle Network Plans (PCNPs) or where extremely high volumes of people walking occur, and/or • where it can be provided as part of an adjacent development that would generate a high demand to cross at that location.
Avoid:	• where alternative lower-cost treatments are feasible and are expected to operate safely.
Advantages	• The treatment eliminates conflicts with motor vehicles. • It does not delay motor vehicle traffic. • It has less height change compared to an overpass and less physical effort for users. • There is the ability to use the central island to provide direct connection for multiple directions.

Disadvantages	• There is a high capital cost as a retrofit treatment. • Jacking construction method may only permit small underpass dimensions. • Cut and cover construction method is likely to affect traffic during construction. • The treatment can be subject to poor patronage (except at schools or where fencing is used), due to the level difference and longer travel distance. • The treatment may require changes in access points to encourage use (for example, bus stop locations, school gates). • It may reduce perception of personal security. • It may be prone to vandalism (maintenance cost). • It may be occasionally flooded (maintenance cost).
Other considerations	• Lighting should be provided as per AS 1158.3.1. • The treatment may require fencing and signage to encourage use.
Additional references	• Austroads *Guide to Road Design* Part 6. • Queensland Police *CPTED guidelines*. • The department's *Bridge design and assessment criteria*.

C9 – Grade separation (overpass)

Toowong Pedestrian and Bicycle overpass

Source: Departmental aerial imagery

Guidelines	*Road Planning and Design Manual.*
Use:	• where topography supports an overpass • where TRUM Vol 1 Part 6 (including bicycle volumes) indicates that mid-block signals are warranted, but an at-grade crossing cannot be installed due to high traffic volume roads (for example, arterial roads, freeways and motorways) • across major roads where alternative crossing facilities are not feasible • on PCNP or where extremely high volumes of people walking occur, and/or • where it can be provided as part of an adjacent development that would generate a high demand to cross at that location.
Avoid:	• where alternative lower cost treatments are feasible and are expected to operate safely.
Advantages	• The treatment eliminates conflicts with motor vehicles. • It causes no delays to motor vehicle traffic.
Disadvantages	• There is a high capital cost. • The treatment can be subject to poor patronage (except at schools or where fencing is used) due to the level difference and longer travel distance. • It may require fencing and signage to encourage use. • It may require changes in access points to encourage use (for example, bus stop locations, school gates). • Service on more than one side of the roundabout may require more than one bridge or a significant elevated ring-style structure, similar to the Hovenring. • Crash barriers are likely to be required to protect both traffic and the structure from impacts.
Additional references	• Austroads *Guide to Road Design* Part 6. • Department of Transport and Main Roads *Bridge design and assessment criteria*. • Department of Transport and Main Roads *Policy – Reduction of Risk from Objects Thrown from Overpass Structures onto Roads*.

Appendix A – Crash prediction model

A1 Background

Turner showed how covariate cycle crash models could be developed for Queensland using a wider sample set across New Zealand and for traffic signals in Adelaide; however, some care does need to be taken in using these models, based on the small number of sites that were available in Queensland at the time of the study. Ideally, data need to be collected for a larger sample set of sites so that the Queensland crash models are more reflective of local conditions. Some further refinement of the research would help to identify how the Queensland cycle crash rates differ from other jurisdictions; however, these models are accepted for use as proactive risk assessment tools until more refined models become available.

At roundabouts, the entry speed was found to be a key factor in entering versus circulating cycle crashes (where people riding bikes are circulating). This may be due to the reduced time that drivers have to scan the roundabout before entering, when there are higher speeds, and the higher likelihood drivers will not perceive the people riding bikes, especially when there are a lot of motor vehicles using the roundabout. A combination of reduced approach visibility and suitable geometry has been shown to reduce approach speeds at roundabouts.

The following sections present the cycle versus motor vehicle crash models developed for entering versus circulating (people riding bikes circulating) and 'other' cyclists crash types at urban roundabouts. The crash prediction models for roundabouts were originally developed in New Zealand by Turner et al. There were 34 models developed in total; only the preferred models are presented here.

The models indicate the number of crashes increases with increasing circulating and entering vehicle speeds, and with the presence of a downhill gradient. There was no increase observed for multiple circulating lanes, although this factor may be considered in the entering and circulating speed variable, as larger roundabouts often have higher travel speeds. In other research (Turner and Roozenberg) on higher (rural) speed limit roundabouts, it was found that motor vehicle crash rates were 35% higher than for lower-speed roundabouts. It is reasonable to assume at least a 35% increase would be expected in cycle-related crashes.

A1.1 Entering versus circulating cyclist crash model

The A_{UCAR1} model includes entering motor vehicle volumes, circulating volumes of bike riders and the mean speed of the entering motor vehicles

Equation A1.1 – A_{UCAR1} model

$$A_{UCAR1} = 3.88 \times 10^{-5} \times Q_e^{0.43} \times C_c^{0.38} \times S_E^{0.49}$$

where:

A_{UCAR1}	=	annual number of entering v circulating bike rider crashes
Q_e	=	entering flow on the approach
C_c	=	circulating bike rider flow perpendicular to the entering motor vehicle flow
S_E	=	free mean speed of vehicles as they enter the roundabout.

A1.2 'Other' cyclist crash model

The A_{UCAR2} model excludes crashes where the bike rider is circulating and the motor vehicle is entering, as this is covered by the previous model. Further disaggregation of cycle crashes was not possible given the low numbers of some cycle crash types.

Equation A1.2 – A_{UCAR2} model

$$A_{UCAR2} = 2.07 \times 10^{-7} \times Q_a^{1.04} \times C_a^{0.23}$$

where:

A_{UCAR2} = annual number of 'other' crashes involving people riding bikes

Q_a = approach flow (sum of entering and exiting motor vehicle flows)

C_a = bike rider approach flow (sum of entering and exiting cyclist flows).

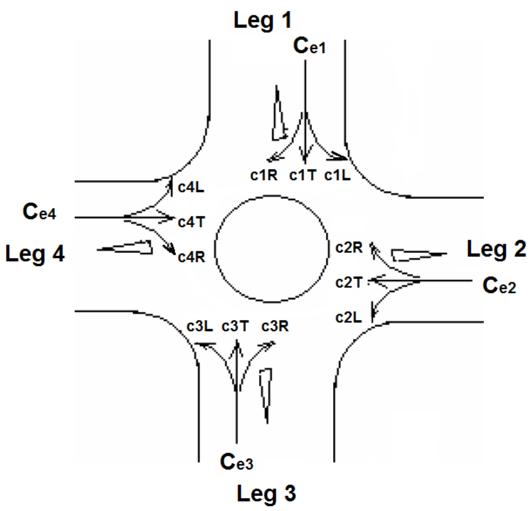
The model indicates that, as traffic volumes or bike rider volumes increase, the number of crashes also increases in almost a linear manner. The number of crashes is influenced more by an increase in the motor vehicle volume than an increase in the bike rider volume. Increasing the volume of people riding bikes has a 'safety in numbers' effect, where the per-person crash risk for bike riders drops as the number of people riding bikes increases. More evidence of this effect can be found in Turner et al.

A2 Implementation of the models

Both the A_{UCAR1} and A_{UCAR2} models need to be applied to estimate the expected average number of bicycle crashes at a roundabout.

Ideally, these models should supplement analysis using the ARNDT software developed by the department. The ARNDT software calculates 85th percentile motor vehicle entry speed, which is also the required input parameter S_E in A_{UCAR1}.

Figure A2(a) – Bicycle volume notation



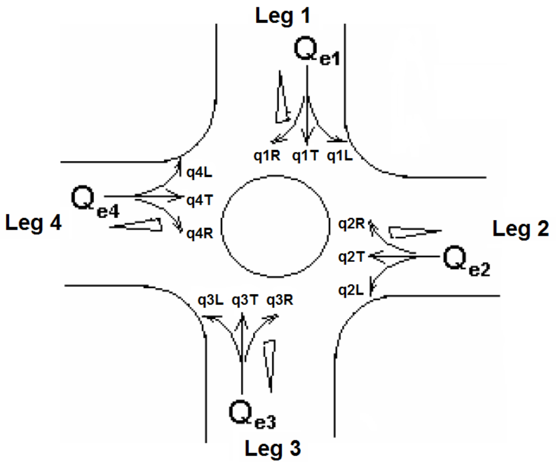
Source: Adapted from Turner and Roozenberg

The value C_e on each leg is derived from the bicycle flows occurring in front of that leg; for example:

Equation A2(a) – Bicycle volume notation

C_{e1} = c4T + c4R + c3R

Figure A2(b) – Motor vehicle volume notation



Source: Adapted from Turner and Roozenberg

The values Q_a and C_a are the two-way volumes on each leg. This could be found either through mid-block traffic counts on each leg (if available) or derived from turning movement volumes; for example:

Equation A2(b) – Motor vehicle volume notation

$$Q_{a1} = Q_{e1} + q2r + q3T + q4L$$

$$C_{a1} = C_{e1} + c2r + c3T + c4L$$

A spreadsheet tool complements this document to assist analysis.

Appendix B – Comparison of compact (radial) and tangential geometry using ARNDT crash prediction models

B1 Purpose

The ARNDT program was used to compare potential differences between radial and tangential design approaches in predicted crash types against typical tangential design.

The original ARNDT research did not include roundabouts with compact (radial) geometry in the data set, so conclusions drawn in this comparison should be considered indicative at best.

B2 Method

A series of similar roundabouts were generated using the ARNDT program. The principal variations were entry / exit geometry and approach speeds. The cases used for comparison are shown in Table B2. Figure B2(a) and Figure B2(b) show a graphical comparison of the roundabout geometry. All roundabouts had four legs, single-lane approaches and departures, a central island radius of 15 metres and circulating road width of five metres.

Table B2 – Roundabout comparison cases

Geometry	Approach Speed (km/h)	Entering Traffic on Each Leg (AADT)
Compact (radial)	40	2000
Compact (radial)	50	2000
Compact (radial)	60	2000
Compact (radial)	70	2000
Tangential	40	2000
Tangential	50	2000
Tangential	60	2000
Tangential	70	2000

Figure B2(a) – Compact (radial) geometry

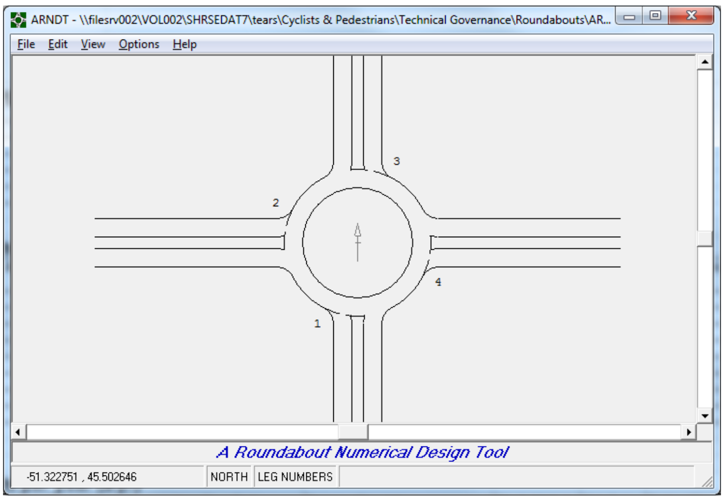
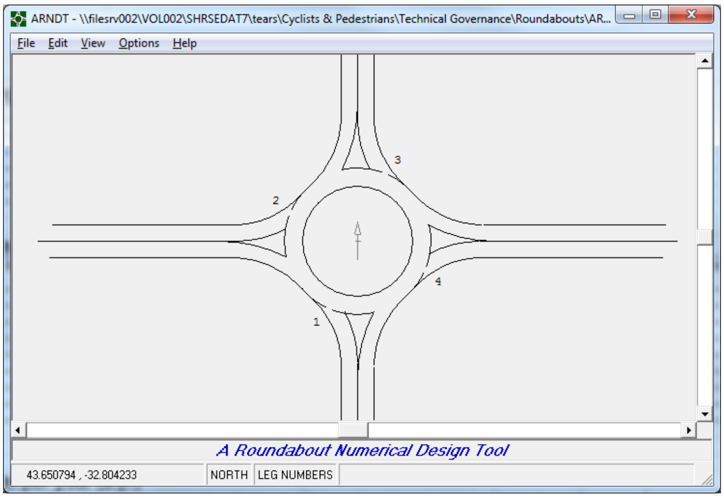


Figure B2(b) – Tangential geometry



B3 Summary of ARNDT output

Figure B3(a) shows tangential geometry and compact geometry have similar predicted overall crash costs up to an approach speed of about 60 km/h.

Figure B3(a) – Roundabout approach speed vs total annual predicted crash costs ARNDT output

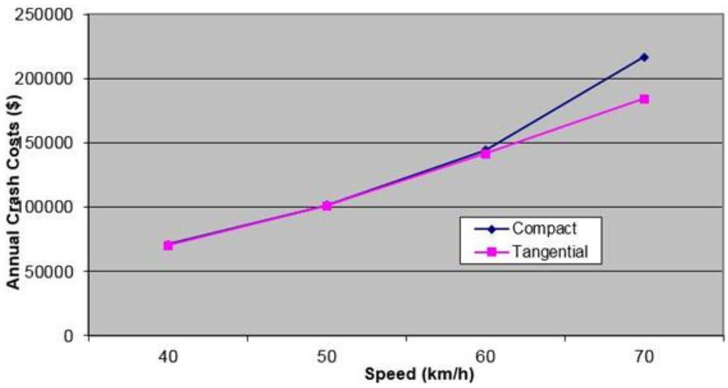


Figure B3(b) shows compact geometry results in higher predicted single vehicle crash costs compared to tangential geometry. This indicates speed control treatments on approach to a compact roundabout may be appropriate.

Figure B3(b) – Roundabout approach speed vs single vehicle predicted crash costs

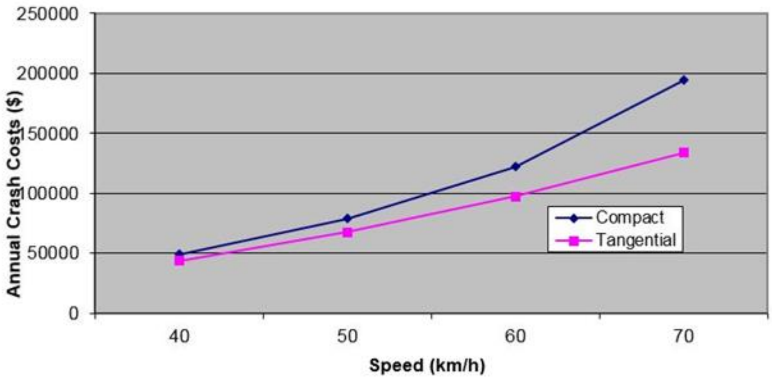
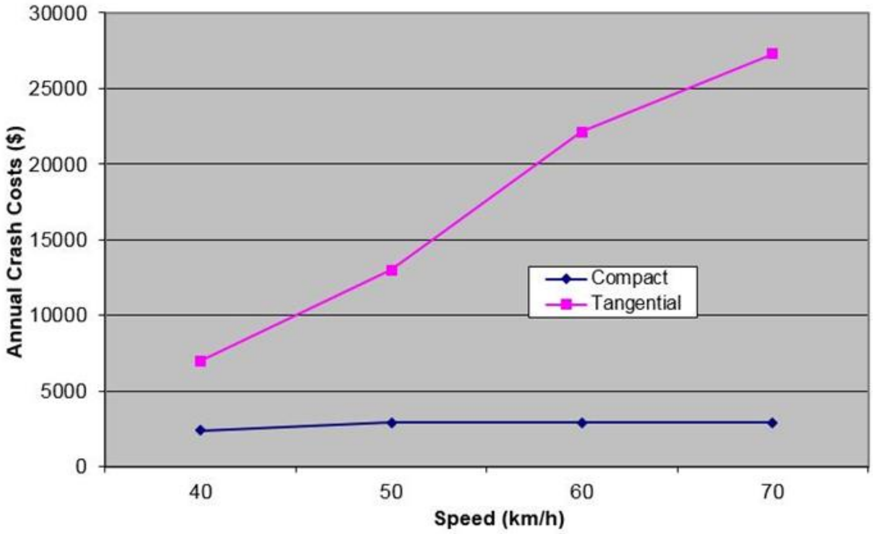


Figure B3(c) shows, compared to tangential geometry, compact geometry would be expected to significantly reduce entering / circulating crashes (DCA101 – see Section 1 Table 1 for details) for all road users. As this is the critical crash type for motorcyclists and bike riders, this indicates compact geometry may be a promising treatment for vulnerable road user safety.

Figure B3(c) – Roundabout approach speed vs entering / circulating predicted crash costs



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