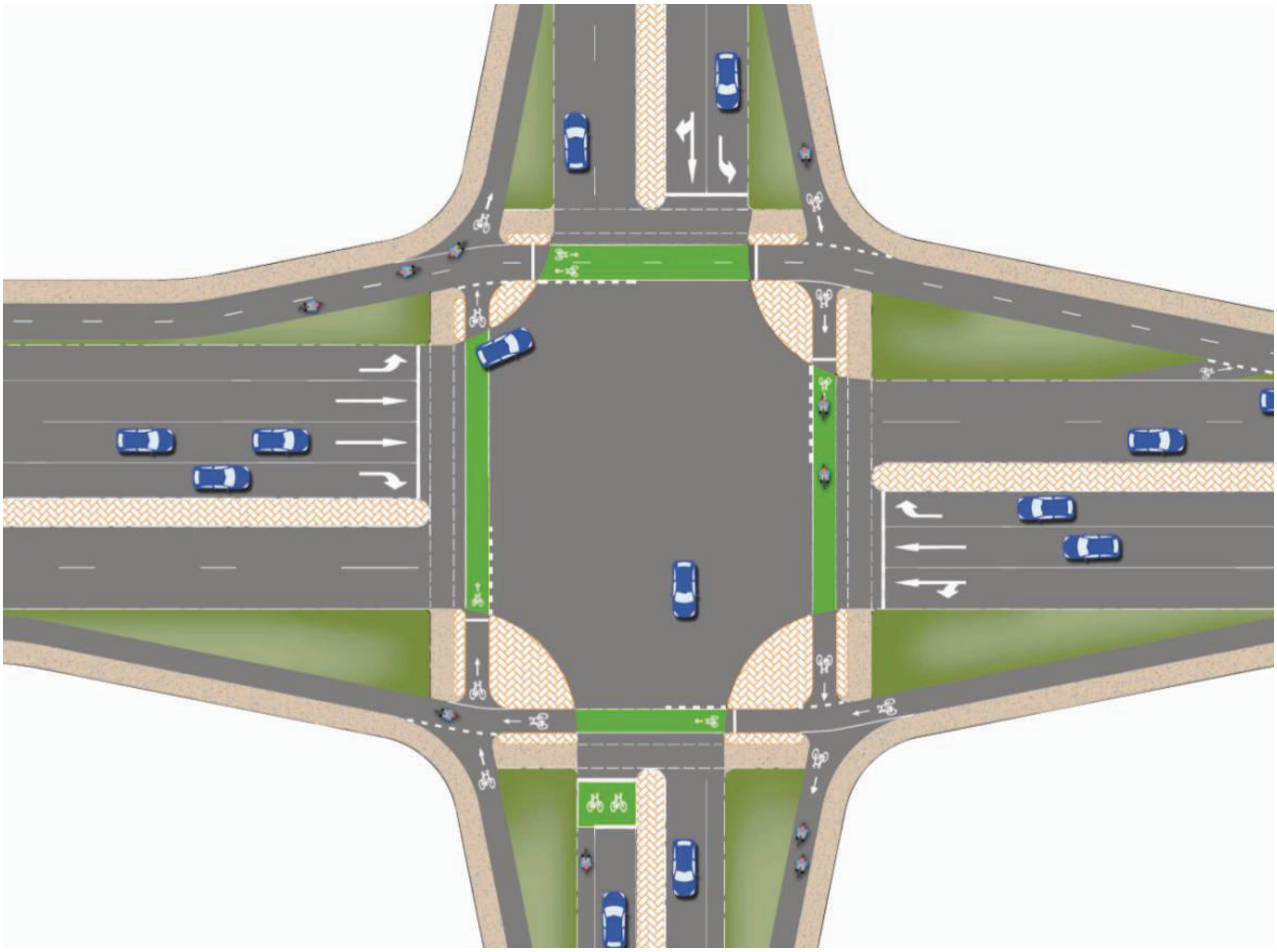


Guideline

Separated Cycleways

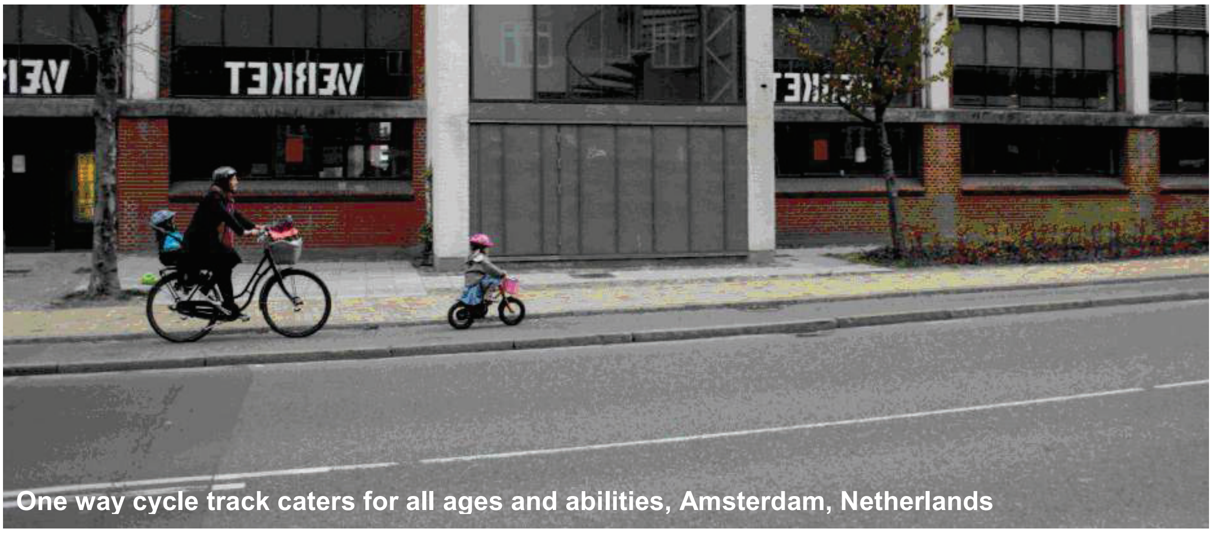
January 2014

Feedback: Please send your feedback regarding this document to: mr.techdocs@tmr.qld.gov.au

Amendment Register

Issue / Rev no.	Reference section	Description of revision	Authorised by	Date
1	Whole	Initial release	Director (Traffic Engineering and Data)	March 2014

Contents


One way cycle track caters for all ages and abilities, Amsterdam, Netherlands

1 Introduction

The *Queensland Cycle Strategy* (QCS) targets a doubling of cycling for transport by 2021. To achieve the target shown in Figure 1, road design must focus on the comfortable daily transport of new bicycle riders, especially women, as well as current bicycle riders.

Figure 2 outlines four types of bicycle riders, 59% of people who do not currently cycle for transport are categorised as 'interested but concerned' about cycling[1]. In Australia, 69% of males and 74% of females state they would cycle more regularly if dedicated lanes and off-road routes were provided[2]. To achieve QCS targets, cycling infrastructure must cater for these 'interested but concerned' people who are less confident and less tolerant to traffic than many existing riders. This guide presents design guidance relating to separated bicycle infrastructure and intersection design which separate bicycle riders from motorised traffic. Facilities such as these have been shown to improve safety, the perception of safety and increase the ridership of a wide cross section of the community[3 4 5]. These facilities align well with both crash reduction targets and cycling mode growth targets.

Figure 1: Queensland Cycle Strategy target for 2021

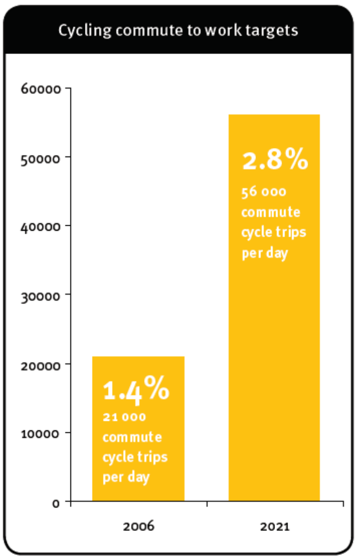
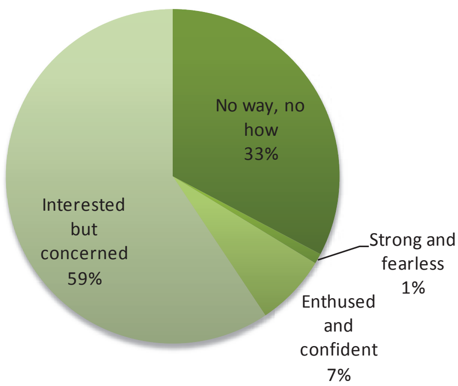


Figure 2: Four types of cyclists



1.1 Purpose

The aim of the document is to achieve a direct, safe and comfortable cycle network for people of all ages and abilities to achieve a doubling of cycle trips for transport.

This document supports the Austroads guides with supplementary guidance related to the design of separated bicycle infrastructure for daily transport of new and current bicycle riders. It has been prepared to support Transport and Main Roads *Cycling Infrastructure Policy* and to provide additional guidance to local government.

“Separation” can either be visual (bicycle lanes) or physical (paths/tracks). Existing guidelines adequately cover the design of bicycle lanes and paths not in the road corridor. While this guide focuses on physical separation within the road corridor there are situations where visual separation is the preferred treatment.

The guidance is intended to assist engineers, designers and planners with options to decide on appropriate bicycle facility type for principal cycle network or local routes. Construction and whole of life maintenance considerations are also included. It is acknowledged that in many situations optimal solutions may not be practicable.

1.2 Background

For cycling to be a legitimate and respected transport mode, specific infrastructure and the needs of bicycle riders must be integral to all road design.

The *National Road Safety Strategy 2011-2020* promotes the safe system framework, as a systematic, proactive way to reduce road safety risk. It proposes two methods to improve bicycle rider safety and reduce exposure to risk:

- Separate: prevent encounters between road users (conflict avoidance)
- Highlight: if encounters occur, design for safe speeds of motorised traffic, reducing incidence and severity of crashes (conflict presentation)[6, 7, 8, 9].

The *National Road Safety Strategy* recognises that separated bicycle facilities increase bicycle rider safety and encourages more people to cycle.

In Queensland the general urban default speed limit is 50 km/h[10]. 30 km/h zones in residential areas have been proven to save lives and save money[11]. The *Queensland MUTCD Part 4* (Amendment 8) now permits 40 km/h and 30 km/h speed zones. Reduced speed limits, creating reduced speed differentials, are an important safety measure where bicycle riders are required to mix with motorised vehicles. Traffic calming measures may be required to support safer speed limits. Well-designed traffic calming is an implicit measure to support cycling safety[6].

Where larger differences in speeds exist, such as motorised vehicle speeds above 50 km/h, physical separation from motorised vehicles reduces risks for bicycle riders, creating a safer and more comfortable environment for all road users[6]. Some experienced bicycle riders are comfortable mixing with motorised vehicles at higher speeds while others, like less experienced and traffic-intolerant bicycle riders are most comfortable when physically separated from high volume, high speed motorised vehicles.

The photos in this document show Australian facilities wherever possible. International photos are included where an Australian version is not available. Most international photos and diagrams in this document have been manipulated to depict the Australian context with traffic on the left.

1.3 Terminology and Queensland Road Rules (QRR)

Cycleway: A physically separated bicycle facility within a road corridor that provides clear bicycle priority at intersections, for example a one-way cycle track or two-way cycle track.

One-way cycle track: A one-way physically separated bicycle only facility with clear bicycle priority at intersections, defined ‘bicycle lane’ under QRR.

Two-way cycle track: A two-way physically separated bicycle only facility with clear bicycle priority at intersections, defined ‘bicycle path’ under QRR.

These terms and others are listed in Appendix A for other relevant terms.

2 Functional road hierarchy and bicycle facility type

Austroads Guide to Road Design Part 2, Section 2.4.1 and Queensland *Road Planning and Design Manual* Section 1.3 set out distinct road categories according to speed environment and volumes of road users in the urban functional road hierarchy. Where and what type of bicycle facility is appropriate for a road depends primarily on the differing speeds and volumes of road users.

The bicycle facility type must be suitable for the type of road. As differences in speeds and volumes increase, the separation of vulnerable road users must also increase[12]. Consistency in design for each road category within the road hierarchy enhances clear priority, predictability, coherence, safety and comfort for all road users[13].

The decision of what bicycle facility type is appropriate for a certain location, depends on the volume and speed of motorised vehicles, where the route sits in the road network hierarchy, and space available[12]

2.1 Bicycle facility selection

For an effective cycle network, a range of direct, safe, comfortable and attractive bicycle facility types must be selected as appropriate for the road type and be seamlessly linked.

The cycle network for transport must be designed to meet the needs of bicycle riders for directness and safety rather than for recreation.

The cycle network does not only consist of bicycle lanes, separated cycleways or off-road paths; the origins of most journeys are low speed local access streets. Current Austroads guidance for bicycle facility selection highlights the need to separate bicycle riders from vehicles and provide priority for bicycle riders at conflict points[14].

Table 1 guides the selection of bicycle facility type depending on road function, speed and volume. The table gives clear guidance but also has two overlapping areas for local access roads and collector/distributor roads. These overlaps allow for the best fit in each situation to best achieve the needs of bicycle riders for directness, safety, coherence, comfort and attractiveness. This information and table have been adapted from *Cycling Aspects of Austroads Guides, Design Manual for Bicycle Traffic*[12] and the *Presto Cycling Policy Guide*[6]. Table 1 differs slightly from current Austroads guidance, recommending physical separation at lower motorist speeds (50 km/h) to accommodate new and traffic-intolerant bicycle riders. In retrofit situations, this table should be adapted to accommodate site constraints.

Table 1: Bicycle facility selection depending on road function, speed and volume

<table>
<tr><th>Road Function</th><th colspan="2">Posted Speed (km/h)</th><th>Vehicles per day</th><th>Bicycle facility type</th></tr>
<tr><td rowspan="2">Local access road</td><td colspan="2" rowspan="2">Up to 30 km/h</td><td>1-5000</td><td>Mixed traffic (with or without advisory bicycle treatment)</td></tr>
<tr><td>>5000</td><td rowspan="2">Bicycle lanes or cycle track*</td></tr>
<tr><td rowspan="3">Collector/ distributor road</td><td rowspan="2">50 km/h</td><td>2x1 lanes</td><td rowspan="5">Not applicable</td></tr>
<tr><td>2x2 lanes</td><td>Bicycle lanes, Cycle track* or 30km/h service road</td></tr>
<tr><td colspan="2" rowspan="2">60 km/h</td><td rowspan="3">Cycle track*, 30 km/h service road or direct off-road bicycle path</td></tr>
<tr><td>Arterial road</td></tr>
<tr><td>Controlled access road</td><td colspan="2">>60 km/h</td></tr>
</table>

*Refer to Section 4.4.1 cycle track decision table for specific dimensions.

The needs of bicycle riders for safety, directness, coherence, comfort and attractiveness (explained in Section 3) must be addressed as part of the design for all bicycle facility types. Where bicycle volumes are high or expected to be high, or where the goal is to encourage cycling on a preferred route, a higher quality bicycle facility should be provided in accordance with the needs of bicycle riders (refer Section 3).

3 Mid-block bicycle facilities

This guidance should be read in conjunction with *Austroads Guide to Road Design* Part 3, Section 4.8.

The operating characteristics, capabilities and behaviour of all road users including pedestrians, bicycle riders, motorcyclists, and other motor vehicles are the basis for design of all roads[15]. In local streets where mixing bicycle riders with motor vehicle traffic is appropriate, the road design should achieve a vehicle operating speed that is comfortable for bicycle riders to share the road with motorised vehicles (≤30 km/h). As vehicle speeds and volumes increase, increasing separation between different road users is necessary for safety[16]. Figure 3 shows a one-way cycle track with a kerb on both sides, separating bicycle riders from both vehicles and from pedestrians.

To successfully provide for all ages and abilities of bicycle riders, all bicycle routes ranging from local streets to along arterial roads must meet the needs of bicycle riders to be safe, direct, cohesive, comfortable and attractive, refer Section 3.1 for the design requirements of bicycle riders.

Figure 3: One-way cycle track on arterial road, Odense, Denmark

3.1 Mid-block design requirements

This section supplements existing guidance in *Austroads Guide to Road Design* Part 6A Section 4.2.1.

To design cycling routes for transport, the infrastructure must meet the needs of all types of bicycle riders. There are five internationally recognised requirements that must be balanced in the design of cycling infrastructure[6, 17, 12, 18, 19, 20].

3.1.1 Directness

This can be measured by directness in time of travel (average speed) and directness in distance (trip length). Stops or loss of priority at crossings, delays at traffic signals, hills, detours, sharp corners, poor sight lines, shared paths (delayed by giving way to pedestrians) and rough surfaces, all impact on directness. Because bicycles are human powered, a direct route from A to B with optimal speed maintenance is essential in high quality design.

Directness in time

Compared to motorised vehicles, once slowed or stopped it takes a bicycle rider considerable time and effort to regain the required speed. Where bicycle riders are stopped or detoured they will take high safety risks in order to save travel time. Any factor that slows down bicycle riders also influences directness in time and may reduce safety. The number of intersections where bicycle riders lose priority can be calculated as stopping frequency per kilometre, another indication of directness. This number should be as close to zero as possible.

Directness in distance

Directness can be calculated as the difference between the distance as the crow flies and the shortest distance using the cycle network. A maximum ‘detour factor’ of 1.4 should be used as a guide[6]. Cycling is attractive when the ‘detour factor’ of the cycle network is less than for motorised vehicles.

3.1.2 Safety

Safety of bicycle riders primarily depends on the amount of exposure to different masses and speeds of motorised vehicles. Less confident, traffic-intolerant bicycle riders especially feel threatened when mixing in the same space as fast moving motorised vehicles. Where bicycle riders are provided exclusive space, cycling is perceived safer and more people choose to ride[21]. To safely provide for all types of bicycle riders, conflicts with motorised vehicles should be avoided with separation or clear priority highlighted with give way lines and green surface treatment to remove confusion.

Conflict avoidance

Generally, bicycle riders can safely mix with motorised vehicles up to 30 km/h; above this speed bicycle riders should be separated in time and space to remove exposure and avoid conflicts. This requires bicycle lanes where vehicle speeds are above 30 km/h and physically separated cycle tracks where vehicle speeds are above 50 km/h. If it is not possible to separate motor vehicle and bicycle traffic, speed difference will have to be minimised.

Conflict presentation

Where conflict points cannot be removed, reduce speeds and highlight clear priority to reduce severity of conflicts when they occur. For example, at intersections this should be achieved by reducing turning speeds where motorised vehicles cross the path of bicycle riders and applying give-way lines and signs. By clearly presenting these conflicts, road users are made aware of risks and adapt behaviour.

Recognisable road hierarchy

Consistent design solutions make conflict situations more predictable, intuitive and comprehendible for all road users.

Other safety factors

Obstructions, poor surface quality, visibility of the road surface (especially at dusk and in the dark) and conflicts with other road or path users also affect safety.

3.1.3 Comfort

Reduce motorised vehicle nuisance

To design a bicycle facility that is comfortable for all ages and abilities to ride on, every effort must be made to reduce the nuisance caused to bicycle riders by motorised vehicles. Where the road is shared with motorised vehicles, posted speed should be low (preferably ≤30 kph).

Maintain reasonable speed

A good design ensures bicycle riders can comfortably maintain the required design speed. Design speed depends on road function. The design speed sets the requirements for curve radii and width.

Smooth road surface

Of all road users, bicycle riders are the most sensitive to the smoothness of pavement. Surfaces for bicycle riders must be as smooth as or smoother than those acceptable for motorised vehicles. Any surface that is poorly maintained, collects debris, has joints causing vibrations or has obstacles, makes cycling a more complex task that requires more concentration and effort and reduces comfort. If there is a rough shoulder or lower quality pavement in the bicycle lane, bicycle riders will choose to ride in the smoother traffic lane, often angering motorised vehicle drivers. A defect such as a pot-hole in the bicycle lane will cause a bicycle rider to suddenly swerve into the traffic lane.

Avoid bends

The Principal Cycle Network should be direct from A to B and bends should be avoided as much as possible.

Minimise steep grades

This can be measured as gradient per kilometre. Multiple steep sections too close together reduce cycling comfort and should be avoided (even if they meet gradient requirements).

Protection for the elements

Like pedestrians, bicycle riders are exposed to sun, rain and wind and will seek shelter while riding. Bicycle riders can be protected from the elements with appropriate shade structures, vegetation or by buildings. Particular care must be taken to choose appropriate vegetation that will not cause a safety hazard or ongoing maintenance problem.

3.1.4 Attractiveness

Attractiveness of a bicycle facility relates to both perceived safety and quality of infrastructure. The surroundings encountered when cycling range from attractive to intimidating and can encourage or discourage cycling along a route. Landscaping and surroundings can make a cycling route very attractive through an area that might have otherwise been avoided, while high fences, lack of casual surveillance and no lighting at night can result in actual and perceived loss of personal security.

Where there is no bicycle infrastructure, it is a major barrier for attracting bicycle riders[22]. Bicycle infrastructure that is physically separated from motorised vehicles, direct and attractive is perceived to be safer and will generally attract all types of bicycle riders[21].

3.1.5 Coherence

Cohesion is most relevant at the broader cycle network level. The cycle network should include an appropriate density of well-connected cycle routes linking all origins to all destinations, including public transport stations, without interruption. Cycle routes that suddenly stop are a major disincentive for cycling and may force bicycle riders into a dangerous situation. Bicycle riders should always be confident that there will be a quality cycling route to all destinations. Low density development and poorly connected streets reduce the coherence on the cycle network[22].

3.2 Mixed traffic on local streets and service roads

The origin of most trips is on local access roads or service roads where cycling is mixed with low speed and low volume vehicle traffic. If both bicycle riders and motorised vehicles are expected to mix, street design should reflect the access function of the road with posted speed limit (≤30 km/h) and low vehicle volumes (≤5000 vpd). Road design should incorporate traffic calming treatments to achieve this design speed and explicit bicycle facilities are not required.

A recent North American study found that where motor vehicle speeds are less than 30 km/h, the injury risk for bicycle riders is significantly lower and ridership is higher[23].

Current Austroads guidance for bicycle facilities allows mixing bicycle riders on most roads[15]. Differences in speed should be minimised because bicycle riders are physically vulnerable[24]. To retrofit local access streets and achieve homogeneous speeds ≤30 km/h, traffic calming or 'invisible infrastructure' is needed. Road narrowing, chicanes, threshold treatments and road humps are typical treatments. Simply posting a lower speed limit will have minimal or no effect on vehicle speeds in local streets.

3.2.1 Service road with posted speed 30 km/h

Where property access is required onto an arterial road, a narrow one-way or two-way service road can perform the access function and carry a mix of bicycle riders and other road users. Figure 4 is a service road beside an arterial road with a low posted speed limit of 30km/h. One-way service roads (bicycles two-way) are preferred to two-way service roads due to reduced conflicts at intersections[15]. Low speed traffic calming treatments should be used to ensure speeds are homogenous and safe for all road users (≤30 km/h).

Figure 4: Service road designed for low speed (30 km/h), Voorburg, Netherlands

Source: Google street view

3.3 Bicycle lanes

This section supplements *Austroads Guide to Road Design* Part 3, Section 4.8.

3.3.1 Bicycle lane and at-grade footpath at side road (Appendix B2.01)

This section supplements *Austroads Guide to Road Design* Part 4, Section 8.3.1. When turning speed is lowered, drivers are more likely to give way, improving safety for bicycle riders, pedestrians and vehicle drivers. See Appendix B2.01 for details.

3.3.2 Car parking and bicycle lanes

This section supplements *Austroads Guide to Road Design* Part 3, Section 4.8.10

Where parking is provided along a road section, the risk of ‘dooring’ crash is introduced[25]. Less experienced bicycle riders and car drivers may not be aware of this significant ‘dooring’ risk. The safest option to eliminate ‘dooring’ conflicts is to remove parking on roads where bicycle lanes are required as demonstrated in Figure 5.

Where there is space for a bicycle lane and parking, bicycle traffic can be moved to the kerb side of parking to eliminate or greatly reduce the risk of dooring[25]. A buffered bicycle lane or one-way cycle track to the kerb side of parking is much safer and more comfortable for bicycle riders and can fit into the same available space as a bicycle lane with parking[12].

Figure 5: Bicycle lane, Brisbane

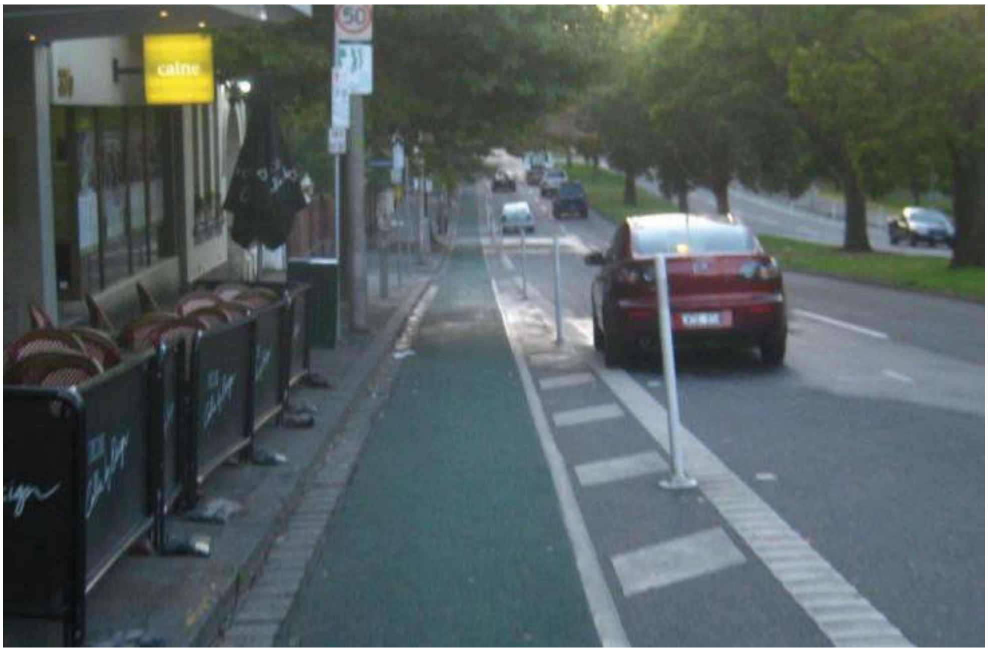
3.3.3 Buffered bicycle lane

Figure 6 shows a buffered bicycle lane in Melbourne during peak hour and Figure 7 is during off-peak times. A buffered bicycle lane cross section may be an effective preliminary retrofit to an existing bicycle lane, before physically separated cycle track is installed:

- Frangible bollards restrict car access but impact on usable bicycle lane operating space.
- Existing kerb gives clear delineation from the footpath.
- To separate the bicycle lane from traffic, painted median and frangible bollards are installed.
- The existing drainage system is utilised.

Figure 6: Buffered bicycle lane with clearway during peak hour, Albert St, Melbourne

Figure 7: Buffered bicycle lane with off-peak parking, Albert St, Melbourne



3.3.4 Contra-flow bicycle lanes (Appendix B1.03)

Austroads Guide to Road Design Part 3 section 4.8.6 recommends painted contra-flow bicycle lanes (visual separation) where posted speed is ≤50 km/h and using physical separation where posted speed is >50 km/h. A contra-flow bicycle lane is of most benefit where a logical shortcut is created (see Figures 8 and 9). Intersections and their approaches need particular consideration to ensure continuity and clear priority for the bicycle facility. See Section 4 Intersections for more details.

Figure 8: Visually separated Contra-flow bicycle lane, Sydney

Source: Google street view

Figure 9: Contra-flow bicycle lane with semi-mountable kerb separation, George St, Sydney

3.4 Separated Cycleways (One-way or two-way cycle track)

Physical separation is recommended where the posted speed is 60 km/h or higher[16, 12, 21]. Figure 10 shows an example of physically separated one-way cycle track along an arterial road. A cycle track separates bicycle riders from motor vehicles and pedestrians resulting in significantly lower injury risk for bicycle riders and increased ridership[23].

One-way cycle track (on each side of the road) is preferred over two-way cycle track because the risk of crashes is higher at intersections where bicycle riders are travelling in both directions on one side of the road[16]. One-way cycle track also offers greater flexibility in terms of legibility and local access and should be installed where there is adequate space.

A cycle track may place bicycle riders out of view of motorised vehicle drivers. For this reason, it is important to highlight the presence of bicycle riders at conflict points such as at intersections and give clear priority to bicycle riders. Safe vehicle turning speeds are needed to maximise visibility of bicycle riders and reduce severity if conflicts do occur. Give way lines and signs, raised priority crossings and green surface treatment are recommended to highlight conflict points (refer Section 4 Intersections). For details of different cross section options see Section 4.3.5.

Figure 10: One-way cycle track on arterial road, Odense, Denmark

3.4.1 One-way cycle track (both sides of the road)

A one-way cycle track functions with the same priority at intersections as a bicycle lane. It is installed on both sides of the road and functions in the same direction as the adjacent traffic but is physically separated from vehicular traffic. The amount of physical separation depends on vehicle speed and volumes and can take the form of a median, kerb, verge or buffer planting.

A minimum cycle track width of 2.0 m is recommended. On arterial roads and at steeper grades, a one-way cycle track should be wider. 2.0 m wide one-way cycle track allows comfortable overtaking and allows bicycle riders to ride side by side. Figures 11, 12 and 13 show good examples of one-way cycle track in Melbourne.

Table 2: One-way cycle track dimensions (on each side of the road)

Peak hour Volume - (bicycle riders/hour)	Width (m)	Separator (without parking)	Separator (with parking)
0 – 150	2.0 m – 2.5 m	0 m – 1.0 m+	0.75 m – 1.5 m+
150 – 500	2.5 m – 3.5 m	0 m – 1.0 m+	0.75 m – 1.5 m+
>500	3.5 m – 4.5 m	0 m – 1.0 m+	0.75 m – 1.5 m+

Where there is on-street parking or vehicle operating speeds are >60 km/h adjacent to the cycle track, a minimum 0.75 m separator is recommended. Where no parking is provided adjacent to the cycle track, the buffer can be reduced to 0m where dual kerb cycle track (see Section 3.4.5.1) is used and where vehicle operating speed is ≤60 km/h. As vehicle speeds and volumes increase, physical separation of bicycle riders should also increase.

One-way cycle track on each side of the road is preferred over a two-way cycle track for improved safety at intersections. Where a cycle track is built, it must be exclusively for use by bicycle riders. Vehicle parking must be prohibited on the cycle track. Cycle track must have continued priority over side-streets and driveways, for information refer Section 5 intersections. Where bicycle riders are observed travelling the wrong direction on one-way cycle track, directional arrows should be added.

Figure 11: One-way cycle track, Latrobe St, Melbourne

Figure 12: One-way cycle track with parking, with at-grade footpath at side road, Latrobe St, Melbourne

Figure 13: One-way cycle track under construction, Latrobe St, Melbourne

3.4.2 Two-way cycle track (one side of the road)

One-way cycle track on each side of the road is preferred over two-way cycle track because of reduced delay and improved safety at intersections. The risk of crashes is higher at intersections where bicycle riders are travelling in both directions on one side of the road[16, 12].

However, two-way cycle track requires slightly less overall space than one-way cycle track on each side of the road. Figure 14 is a good example of two-way cycle track in a constrained retrofit location in Sydney. Two-way cycle track on one side of the road is suitable:

- at school frontages
- where there are long distances between intersections on limited access roads
- where attractions such as shops are located along only one side
- where very few or no accesses are located along one side of the road
- where the continuation of a two-way cycle track is the most coherent solution
- where road corridor width is very constrained in a retrofit situation.

Figure 14: Two-way cycle track, Bourke St, Sydney

For a two-way cycle track, a width of 3.0m is recommended, with a minimum width of 2.4 m at constrained locations. The recommended width, based on the projected usage is shown in Table 3. Where there is on street parking or vehicle speeds are above 60 km/h adjacent to the cycle track, a 1.0 m separator is recommended. As an absolute minimum the separator between the two-way cycle track and parked vehicles or traffic can be reduced to 0.4 m (see Figure 16). Where traffic speeds are higher (>60 km/h a 1.0 m separator should be provided (regardless of the absence of on-street parking).

Arterial roads are often already on the future Principal Cycle Network, are usually the flattest and most direct routes, and are the best location for a cycle track. A two-way cycle track is especially effective where it follows the desire line and there are very few accesses on one side. For large urban arterial roads with few crossing opportunities, a two-way cycle track on each side of the road may be the best solution.

On an urban collector road with parking, a minimum kerb to kerb road width of 13.4 m is recommended to accommodate the two-way cycle track, parking, two traffic lanes and a separator. This can be reduced further. For example in Figure 14, Bourke St in Sydney has traffic lanes reduced to 2.9 m, centreline is removed and parking to 2.1 m to fit the two-way cycle track on one side and car parking on both sides within 12.8 m kerb to kerb. Figure 15 shows a good example of an urban collector road with no parking and a two-way cycle track.

Table 3: Two-way cycle track dimensions

Peak hour Volume - (bicycle riders/hour)	Width (m)	Separator (without parking)	Separator (with parking)
0 – 150	3.0 m (min 2.4 m)	0.4 m – 1.0 m+	0.4 m – 1.5 m+
150 – 500	3.0 m	0.4 m – 1.0 m+	0.4 m – 1.5 m+
>500	4.0 m	0.4 m – 1.0 m+	0.4 m – 1.5 m+

For further guidance refer to TRUM Technical Note: Calculating the Widths of Shared Paths and Separated Bicycle Paths.

Figure 15: Two-way cycle track, Groningen, Netherlands

Source: Google street view

Figure 16: 2.4 m wide two-way cycle track with 0.4 m separator and no parking, College Rd, Sydney

3.4.3 Contra-flow separated cycle track

Austroads Guide to Road Design Part 3 Section 4.8.6 recommends contra-flow bicycle lanes where posted speed is ≤50 km/h. Where posted speed is >50 km/h, physical separation is recommended. A separated contra-flow bicycle lane is of most benefit where a direct route or logical shortcut is created (see Figure 17).

Figure 17: Contra-flow one-way cycle track, Perth

Source Warren Solomon

Intersections and their approaches need particular consideration to ensure continuity and clear priority for the bicycle facility. See Section 4 for more details.

Table 4: Contra-flow cycle track dimensions

Peak hour Volume - (bicycle riders/hour)	Width (m)	Separator (without parking)	Separator (with parking)
0 – 150	1.5 m – 2.5 m	0 m – 1.0 m+	0.4 m – 1.5 m+
150 – 500	2.5 m – 3.5 m	0.4 m – 1.0 m+	0.4 m – 1.5 m+
>500	3.5 m – 4.0 m	0.4 m – 1.0 m+	0.4 m – 1.5 m+

3.4.4 Cycle track cross section types (Appendix B1.04)

Three basic cross section types are available for cycle track infrastructure. Each cross section option has varying impacts on access, constructability, drainage, maintenance, separation and utilities. Cross section consistency along a route is ideal. However the cross section may vary especially in retrofit situations where high cost or non-negotiable constraints are more likely to govern project development.

Preference should be given to a separator kerb profile that is semi-mountable on the bicycle side with a barrier kerb on the motor vehicle side. A semi-mountable kerb profile is acceptable on the motor vehicle side in constrained low speed situations (motor vehicle v85 30-40 km/h).

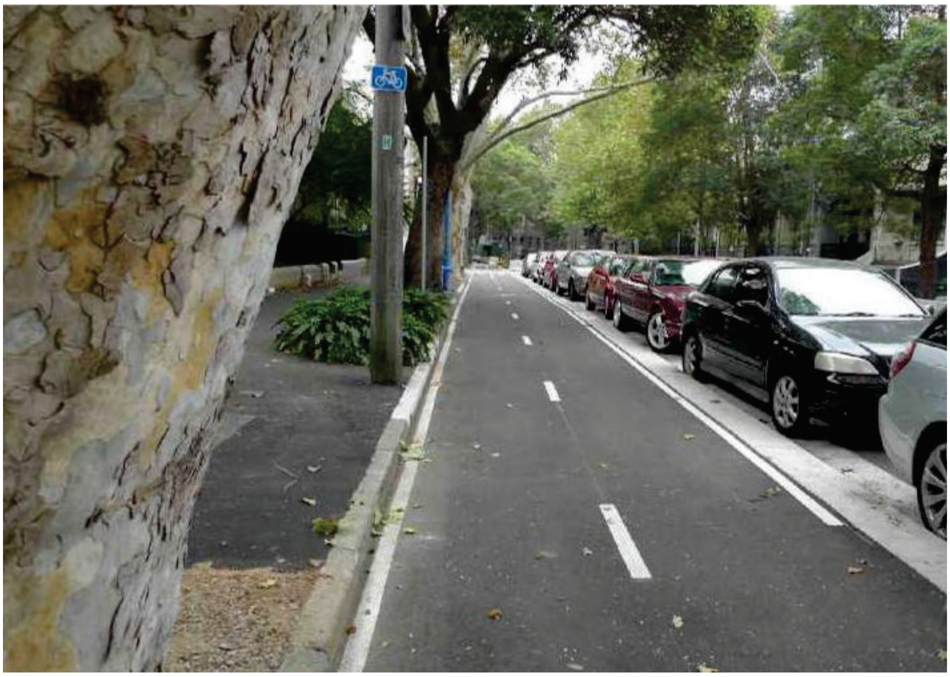
Where separation is provided adjacent to moving traffic, the width should increase with higher traffic speeds. Careful consideration should be given to the surface finish of the separator. Any vegetation that is planted within the median should be low growing (<300 mm) and require minimal maintenance.

3.4.4.1 Dual kerb cycle track

For examples see Figures 18 and 19. The key elements of a dual kerb cross section include:

- Fits within a constrained cross section and gives clear delineation from the footpath.
- To form the cycle track the existing kerb may be retained and a new kerb is provided, the existing roadway is covered with new asphalt.
- Kerb heights of 100 mm are desirable and an absolute minimum of 50 mm is recommended.
- Existing drainage is retained, with road run-off inlet pits placed in the new kerb and along the parking edge, existing drainage pits are adjusted to suit new levels/ cross-falls to channel run-off to the existing road drainage pipes (see Figure 19).
- Minimise height of the existing kerb to reduce chance of bicycle pedal strike on the left (see Figure 18).
- A 2-4% cross-fall is provided across the cycle track towards the kerb and channel. A dual-kerb cycle track cross section is appropriate where there is inadequate space to accommodate a footpath level cycle track cross section with landscaping to separate bicycle riders from pedestrians on the footpath. For a one-way separated cycle track, particular attention should be given to kerb height and associated cross-fall to ensure it does not exceed 4%.

Figure 18: Two-way cycle track, dual kerb profile. Sydney



Source: City of Sydney

Figure 19: Dual kerb two-way cycle track with drainage pits at both kerbs, Bourke St, Sydney

3.4.4.2 Median separated cycle track

For examples see Figures 20, 21, 22, 23, and 24. The key elements of a median separated cross section include:

- Existing kerb gives clear delineation from the footpath.
- To create the cycle track, a small median is constructed to separate the cycle track from traffic.
- Minimise kerb height to reduce chance of bicycle pedal strike.
- The existing drainage system is utilised. Gaps are carefully aligned to allow water to drain to existing pits along the retained kerb and channel.
- This median separated cross section may be the most cost effective physical separation option if the existing drainage can be retained.

Figure 20: One-way cycle track, median separated profile. La Trobe St, Melbourne

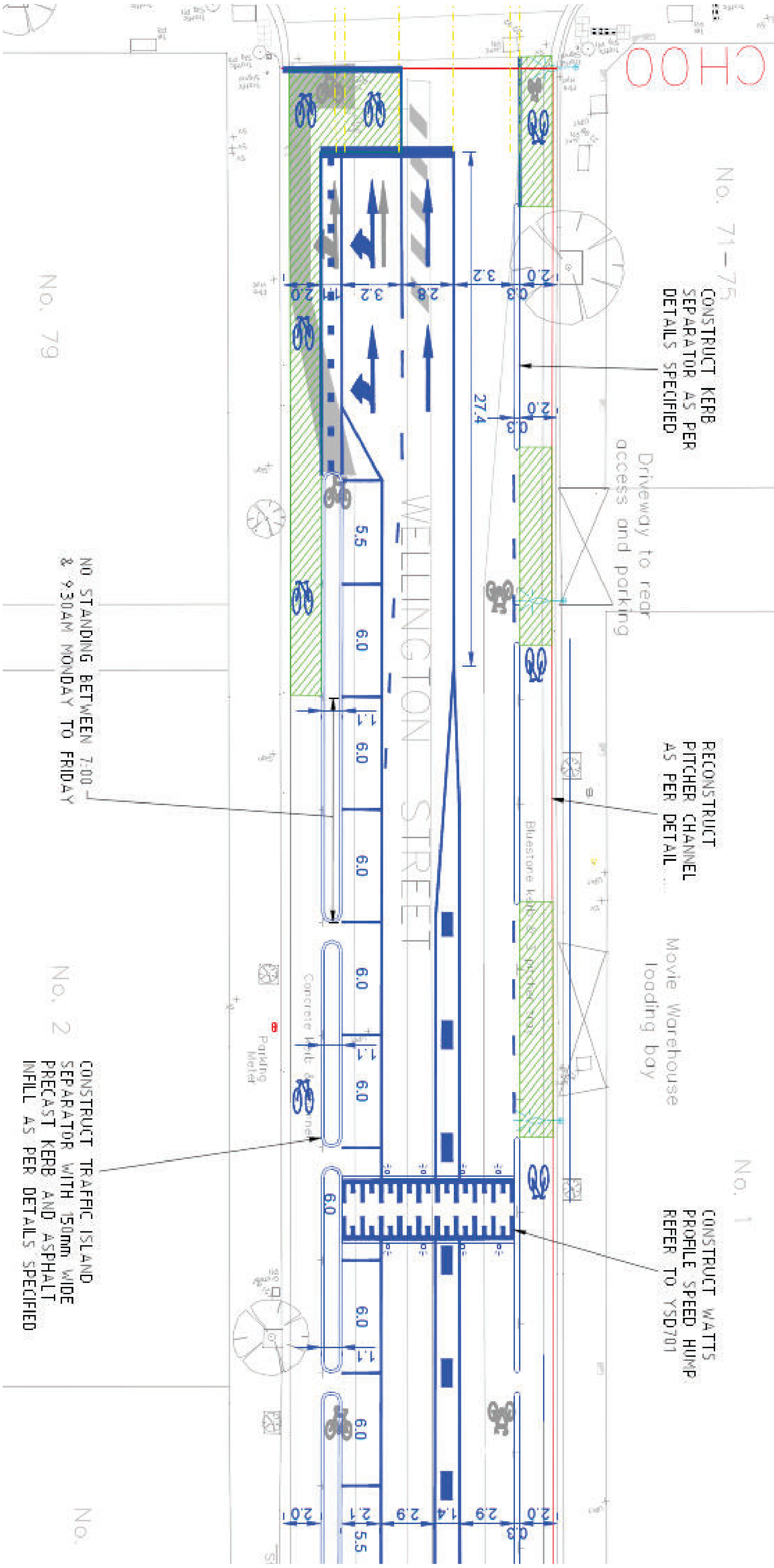
Figure 21: Two-way cycle track, median separated profile. Sydney

Source: City of Sydney

Figure 22: Two-way cycle track on 1-way multilane road, median separated profile, Brisbane

Figure 23: One-way cycle track on 2-way multilane road, median separated profile, Latrobe St, Melbourne. This example shows 1.1 m median with parking and further down a 0.3 m median where there is no parking

Figure 24: Draft design drawing showing one-way cycle track on two-way two lane road, median separated profile, straight transitions to bicycle lane at the intersections, Wellington St, Melbourne. Showing 1.1 m medians with parking and 0.3 m medians with no parking



3.4.4.3 Cycle track at footpath level

For examples see Figures 25 and 26. The key elements of a footpath level cross section include:

- A planting strip (minimum 0.5 m) is used to separate the cycle track from the footpath. If no planting strip is provided, pedestrian intrusion onto the cycle track may occur as there is no grade separation.
- To create the cycle track, new kerb and channel installed in the existing roadway. New asphalt is installed between new kerb and the existing kerb.
- Existing drainage line is retained, with road run-off inlet pits placed in the new kerb along the parking edge and along the edge of the cycle track to channel run-off to the existing road drainage pits.
- Paving between the cycle track and footpath is provided to allow egress between parked cars and footpath. Paving is to be differentiated from the main footpath to reinforce separation.
- No kerb to footpath side results in no chance of bicycle pedal strike.
- A 2% crossfall is provided across the cycle track towards the planting strip.
- A footpath level cross section is only appropriate where there is adequate width within the footpath to accommodate the planting strip and also maintain sufficient footpath width to cater for pedestrian demand.
- A drain to the existing storm water drainage system, alongside the planting strip, is required to channel run-off from both the cycle track and footpath to the existing road drainage pits.

Figure 25: Two-way cycle track, one-step profile. Bourke St, Sydney

Source: City of Sydney

Figure 26: Two-way cycle track at footpath level with drain alongside planting strip, Bourke St, Sydney

4 Intersections

Treatments that reduce exposure, reduce the number of conflict points, create safe turning speeds and highlight conflict points improve intersection safety for all road users.

Where motorised vehicles cross the path of pedestrians or bicycle riders, higher severity conflicts result, even if the relative speed is low[26]. At conflict locations such as intersections where motor vehicles cross a cycle route, priority for bicycle riders should be highlighted in the design with safe turning speed, give-way lines and signs and green pavement treatment.

4.1 Clear right-of-way to reflect functional road hierarchy

A clear functional road hierarchy results in clear expectations for all road users. Clear priority for the dominant road is required where it meets a lower order road such as a local access road.

Intersection treatments on the Principal Cycle Network for urban road functions:

- Controlled access roads and motorways
  - grade separation
    - signalised intersection (channelised turns)
    - give-way unsignalised T intersections, left in, left out
- Arterial roads
  - signalised intersections (channelised turns not recommended, refer section 4.4.5)
    - roundabouts
    - give-way unsignalised intersections (local access side road)
- Collector/distributor roads (40-60 km/h)
  - roundabouts
    - give-way unsignalised intersections
    - signalised intersections
- Local access roads
  - design to ensure safe mixing speeds at the intersection of two local roads.

4.2 Intersection requirements for bicycle riders

To provide for all road users at intersections, the main requirements are directness, safety and comfort[12]. Table 5, adapted from *Design Manual for Bicycle Traffic*, gives explanations of the main requirements at intersections.

Table 5: Summary of the main requirements for intersections from the Dutch Design Manual for Bicycle

Main requirement	Important aspects	Explanation
Directness	Directness in time	Directness in time depends on delays, detours and maintaining design speed. Delays can be limited by minimising the chance of stopping and minimising waiting times. This includes using bicycle friendly adjustment of signal phasings, such two phases per cycle for bicycles during peak hour. Where a cycle route crosses a major road mid-block, a refuge can significantly reduce delay.
	Directness in distance	Bicycle riders having to make illogical movements at intersections or being diverted around intersections should be avoided.
Safety	Risk of (serious) conflicts	The number of conflicts with motorised traffic is minimised. Where large speed and/or mass differences are involved (vehicle speed >60km/h) crossing traffic movements are grade separated. For at-grade crossings, speed differences are minimised based on bicycle speed (20 to 30km/h). In built up areas where speed is ≤60km/h, cycle track should be located within the motorists' field of vision (not bent-out) to locate the crossing where vehicle speed is low due to turning. The requirements for visibility (of bicycle riders) and evenness (smooth pavement) are met. Design principles and basic principles are applied in a uniform manner appropriate to the function of the intersecting roads. Intersections are sufficiently visible, also when dark.
Comfort	Smooth road surface	The paving is sufficiently smooth and ramp transitions are bicycle-friendly.
	Minimise delay	The risk of waiting (delays) is minimised.
	Clear passage	Curve radii take account of the design speed appropriate to the function concerned. Ongoing bicycle riders at intersections are not hindered by stationary bicycle riders or vehicles.
	Traffic nuisance	Bicycle riders are not subjected to nuisance from motorised traffic. In complex situations, the cycle route is separated.
	Weather nuisance	Nuisance due to wind, rain and sun is minimised, for example shade at waiting areas.
Attractiveness	Casual surveillance	Intersections meet the CPTED requirements for casual surveillance: they are lit, there is supervision from the surrounding area, the surroundings are visible and the public space is well maintained.

Adapted from Design Manual for Bicycle Traffic, 2007

4.2.1 Unsignalised intersections with bicycle priority over the side road (Appendices B2.01 and B2.02)

For separated facilities, this section is to be read in place of *Austroads Guide to Road Design* Part 4 Section 9.6. In urban areas, the design of unsignalised intersections must highlight the priority of bicycle riders on the bicycle facility over traffic on the side streets. Appropriate design of give-way crossings improves conspicuity and visibility of bicycle riders, and removes confusion by clearly showing the priority that applies.

Three options for layout of bicycle priority intersections include ‘straight’, ‘bent-in’ or ‘bent-out’ crossings[27]. Welleman and Dijkstra (1988) and recently Schepers and Voorham (2010) have shown that ‘straight’ (with cycle track 2 to 5 m away from the main carriageway) treatments have a better safety record than ‘bent-in’ (0 to 2 m from the carriageway) and ‘bent-out’ (>5 m from the carriageway) in built-up areas[28]. Also, T-intersections and offset T-intersections are preferred over four-way intersections to reduce conflicts[12, 29].

One-way bicycle facility crossings are preferred to two-way bicycle facility crossings because drivers turning in or out of the side road tend to only scan to the right. For a driver turning left from the side road, bicycle riders are expected from the right, but not expected from the left. This results in a decrease in bicycle rider safety at two-way bicycle priority crossings[27, 30]. This is also the case for shared path crossings.

For this reason, additional safety measures must be included to raise driver awareness at bicycle priority crossings. Figure 27 shows an unsignalised priority crossing in Melbourne that is not raised. Raised crossings have been shown improve safety for all road users due to decreased motor vehicle turning speed[31, 32]. Additional signage and line marking can be used to support give way line marking[12].

Figure 27: Two-way cycle track with priority crossings, not raised, Melbourne. Note the turning restriction during certain times for motor vehicles

4.2.1.1 Bent-in intersection treatment (Appendix B2.01)

On-road bicycle lanes continue with priority past unsignalised side roads when two continuity lines are marked across the intersection (see Figure 28). Transitions allow a one-way cycle track to become a bicycle lane through an intersection[27]. (see *Austroads Guide to Road Design* Part 4 Figure 9.11). Green surface treatment and continuity lines through the intersection highlight the conflict area and require turning drivers to give way to continuing bicycle riders. Austroads report AP-R380-11 indicates intersections with defined bicycle operational space combined with green coloured surface treatments improve bicycle rider safety over unmarked conditions.

This arrangement requires drivers to choose a safe moment to turn across the bicycle operating space, if an error occurs the consequences can be severe. Consequently, this treatment is suited to lower speed road environments (<60 km/h[12]) with low turning volumes and low turning speeds.

The bent-in treatment may be an acceptable option where there is insufficient space for a straight or bent-out crossing (see following sections). Straight (see Appendix B2.01) treatments are generally safer and preferred over bent-in or bent-out treatments[28].

Bent-in treatments are appropriate for one-way cycle track, but for safety reasons, are not advised on two-way cycle tracks.

Figure 28: Bicycle lane with priority at side road, Brisbane

4.2.1.2 Straight crossing at side road (Appendix B2.01)

This guidance supports *Austroads Guide to Road Design*, Part 4, Figure 9.10. This design is appropriate where the main carriageway has a posted speed up to 60 km/h, either with or without parking.

Straight crossings enhance safety by providing a raised platform where pedestrians and bicycle riders cross (see Appendix B2.01 and Figures 29 to 33). This treatment effectively spans the road related area across the side road and provides visual and physical cues to support QRR74.

Straight crossings place parallel bicycle traffic 2 to 5 m from the main carriageway and safely cater for both one-way and two-way cycle tracks.

A straight crossing is the preferred intersection design where a side road crosses the bicycle facility. It provides more protection and comfort than bent-in or bicycle lane and is more direct and visible than bent-out. Particular attention must be given to controlling the entering vehicle speeds using visual and physical cues: tight turn radius, give-way lines and signs, a 1 in 6 gradient ramped crossover to a raised platform and contrasting pavement[25].

Where parking is provided, it is possible to provide a 5m storage area (also known as stacking space) for vehicles turning into or out of the side road. This configuration is similar to a 'bent-out' crossing and is most applicable where side road traffic is >5000 vehicles per day. One advantage is that exiting vehicles do not block the cycle track. However, bicycle riders are less conspicuous because they are further from the main carriageway.

Dutch *Design Manual for Bicycle Traffic* guidance describes the vehicular ramp as 'exit construction' and requires a steep, driveway-style leading edge ramp to ensure safe turning speeds for motor vehicles entering the side road[12]. (refer Figures 31 & 32). While improving safety for all road users due to reduced vehicle turning speeds, this also improves conspicuity and priority for continuing pedestrians and bicycle riders.

Figure 29: Two-way cycle track raised priority crossing in Delft, Holland

Source: wiki.coe.neu.edu

Figure 30: Two-way cycle track raised priority crossing (same location as Figure 29)

Source Google street view

Figure 31: Example of Dutch 'exit construction' (1 in 4 gradient mountable kerb) at a two-way cycle track raised priority crossing at side road

Source: http://wiki.coe.neu.edu/groups/nl2011transpo/wiki/ad80f/SAFETY_AT_INTERSECTIONS.html

Figure 32: Examples of two-way cycle track raised priority crossing at side road

Source: http://wiki.coe.neu.edu/groups/nl2011transpo/wiki/ad80f/SAFETY_AT_INTERSECTIONS.html

Figure 33: Two-way cycle tracks with raised priority crossings at side roads, Melbourne

4.2.1.3 Bent-out raised priority crossing at side road

A 'bent-out' crossing is similar to a 'straight' crossing but locates bicycle riders >5m from the parallel carriageway (see Figure 34). This treatment is most applicable on roads where operating speeds are >60 km/h or with no parking on carriageway. The 'bent-out' treatment provides storage area between kerbside lane and bicycle facility for turning vehicles, reducing the risk of rear end (DCA 301) conflict from fast moving through vehicles[12, 27]. At operating speeds >60km/h, the greater separation can improve comfort and safety for bicycle riders[33].

Bent-out treatments can cater for both one-way and two-way cycle tracks. A consistent cycle track width is required on the approach to and through the intersection. Smooth curves are required on the bicycle facility as the intention is not to slow down bicycle riders. Pavement markings, including give way line marking are required through the intersection to show clear priority for bicycles. The crossing should be raised to highlight the conflict point.

Figure 34: Two way cycle track, bent-out raised priority crossing at side road, Sydney

4.2.2 Mid-block bicycle priority crossings (Appendix B2.03)

This section should be read in conjunction with *Austroads Guide to Road Design* Part 4 Section 9.2.5.

An unsignalised mid-block priority crossing is recommended where a Principal Cycle Network route crosses a two lane road mid-block within an urban area (see examples in Figures 35 to 38). The priority crossing should be used in place of a pedestrian crossing (zebra). This is important, because legally, bicycles are prohibited from riding across a pedestrian crossing.

There are three options presented in Appendix B2.03: for a shared path, a bicycle only path and for a bicycle only path with separated footpath.

The priority crossing should be on a raised and extended platform and the road narrowed to highlight the priority for bicycles and to ensure appropriate vehicle speed at the crossing point. As with all road intersections, sight distance requirements must be met.

Figure 35: Shared path, bicycle only path and bicycle only path with separated footpath priority crossings mid-block at a two lane road. Refer Appendix B2.0

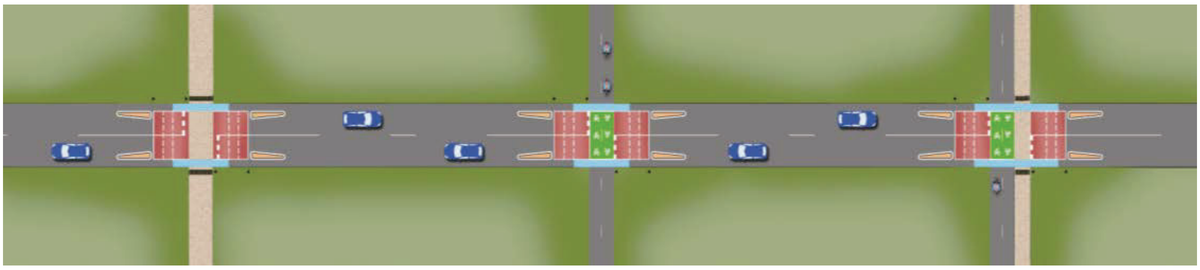


Figure 36: Bicycle only path with separated footpath priority crossing details. Refer Appendix B2.03

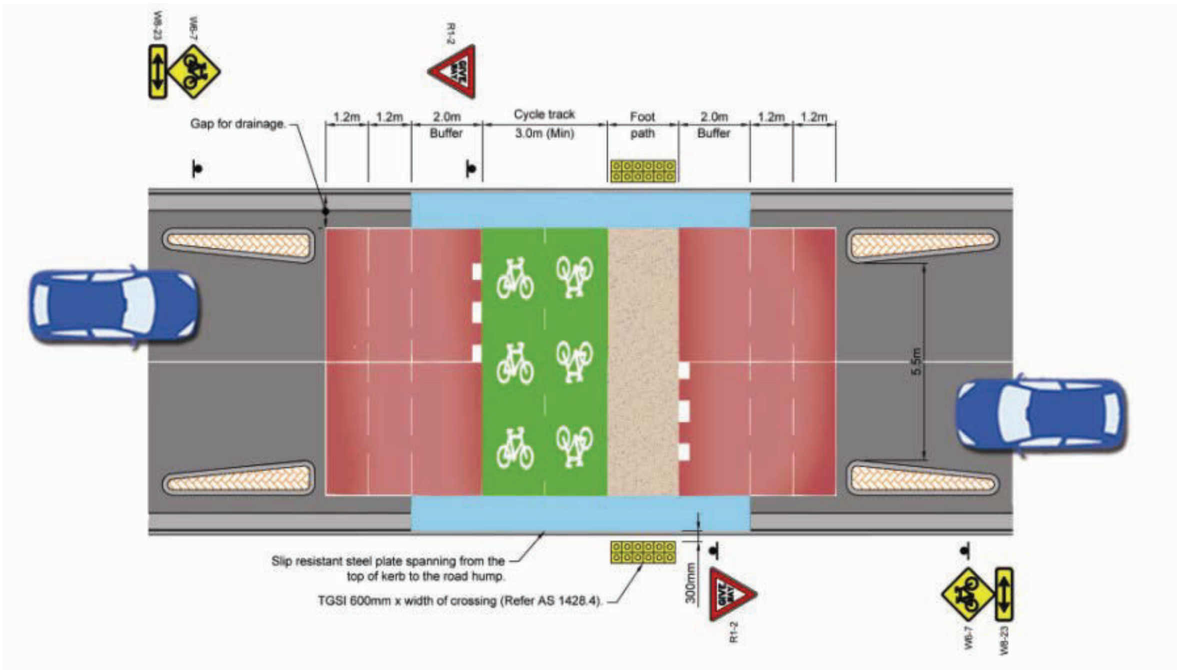
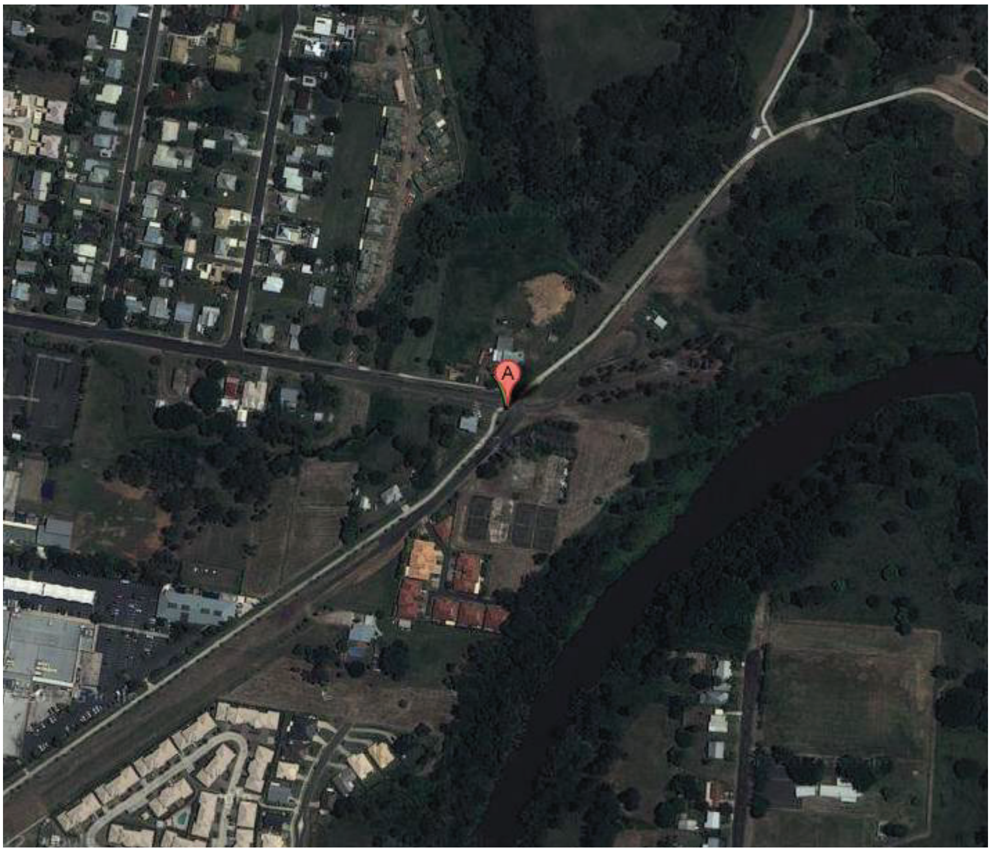


Figure 37: Mid-block shared path raised priority crossing, Ipswich, Queensland

Source: Google Maps

Figure 38: Aerial view of mid-block shared path raised priority crossing (as seen in Figure 37), Ipswich, Queensland



4.2.3 Roundabouts (Appendices B3.01 and B3.02)

For the safety of pedestrians and bicycle riders at roundabouts, motor vehicle speed must be reduced[34]. International and local research recommends radial or compact geometry roundabout design with lower, safer speeds instead of traditional tangential roundabout geometry which allows faster, more dangerous motor vehicle speeds, especially at exits. Small radius entry and exit curves, horizontal deflection and vertical deflection should be used to achieve safe, equitable speeds[35, 36].

To safely provide for bicycle riders at roundabouts, bicycle lanes marked within the circulating space should be avoided on new roundabouts[37]. International research has shown that this is more dangerous than providing no explicit bicycle provision due to increased number of conflict points[6].

Single lane mixed-traffic roundabouts with low traffic speeds (<30 km/h), and volumes (<6000 vpd) have been shown to be the safest of all intersection types for bicycle riders. Separated cycle tracks are recommended on single lane roundabouts with more than 6000 vehicles per day (see Figures 39 to 44). Due to increased number of conflicts and increased speed difference on multiple-lane roundabouts, grade separation is recommended. Where grade separation is not achievable, radial geometry with raised lane dividers and separated cycle tracks are recommended.

4.2.3.1 Effective horizontal deflection

For appropriate speed control at a roundabout, compact design for lower speeds should be used instead of traditional tangential geometry. Horizontal deflection devices such as kerb build-outs, centre island apron with safety edge, rumble areas and splitter islands safely influence the design speed of vehicles entering, circulating and exiting a roundabout.

4.2.3.2 Effective vertical deflection

Vertical deflection is useful for reducing speed and for highlighting a priority crossing. A platform device may be retrofitted to an existing roundabout that has inadequate horizontal deflection. An extended raised platform across each leg of the roundabout influences both entry and exit speeds, creating safe turning speeds that increase the chances of the motor vehicle giving way at a priority crossing. The raised platform at a priority crossing also highlights right of way for pedestrians or bicycle riders.

4.2.3.3 Urban single-lane roundabouts (Appendices B3.01 and B3.02)

Where separated cycle tracks are used at a roundabout on an urban cycle route, the design should include bicycle priority crossings at all legs. Bicycle priority crossings are designed in conjunction with pedestrian crossings. In Queensland, bicycle priority crossings should be located on a raised platform road hump to further highlight the possible conflict area and achieve safe vehicle speed. For more information on road hump design refer Appendix B3.02 and also TRUM 1.29.

Figure 39: Single lane roundabout, separated cycle track with priority crossings, not raised

Figure 40: Dutch single lane roundabout, separated cycle track, priority crossings, not raised. See appendix for detailed design. Includes 'sharks teeth' give-way line marking which is currently not approved for use in Queensland

Figure 41: Pedestrian and bicycle priority crossings at a single lane roundabout, Groningen, Netherlands

Source: Google Street View

Figure 42: Same single lane roundabout as seen in Figure 41, posted speed 60 on approach, Groningen, Netherlands

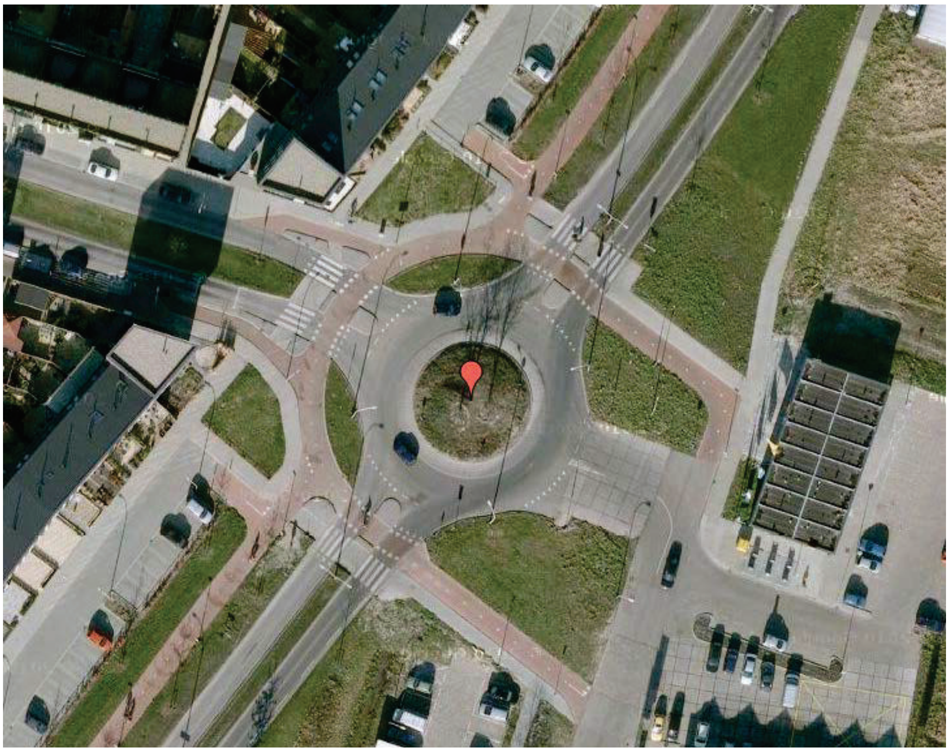
Source: Google Maps

Two-way cycle tracks on roundabouts are also possible, such as where cycle traffic continues on a two-way path on one side of a major road (see Figures 43 and 44). However, two-way cycle tracks on roundabouts present a safety risk because drivers of motor vehicles do not expect bicycle riders from the unexpected (anti-clockwise from the left) direction[12]. Where two-way cycle tracks are constructed, all crossings should be located on a raised platform road hump and have two-way line-marking to highlight that bicycle riders will travel in both directions[12]. The ultimate safe solution is to grade separate bicycles from vehicles (see Figures 45 and 46).

Figure 43: Pedestrian and bicycle priority crossings at a single lane roundabout, Pijnacker, Netherlands

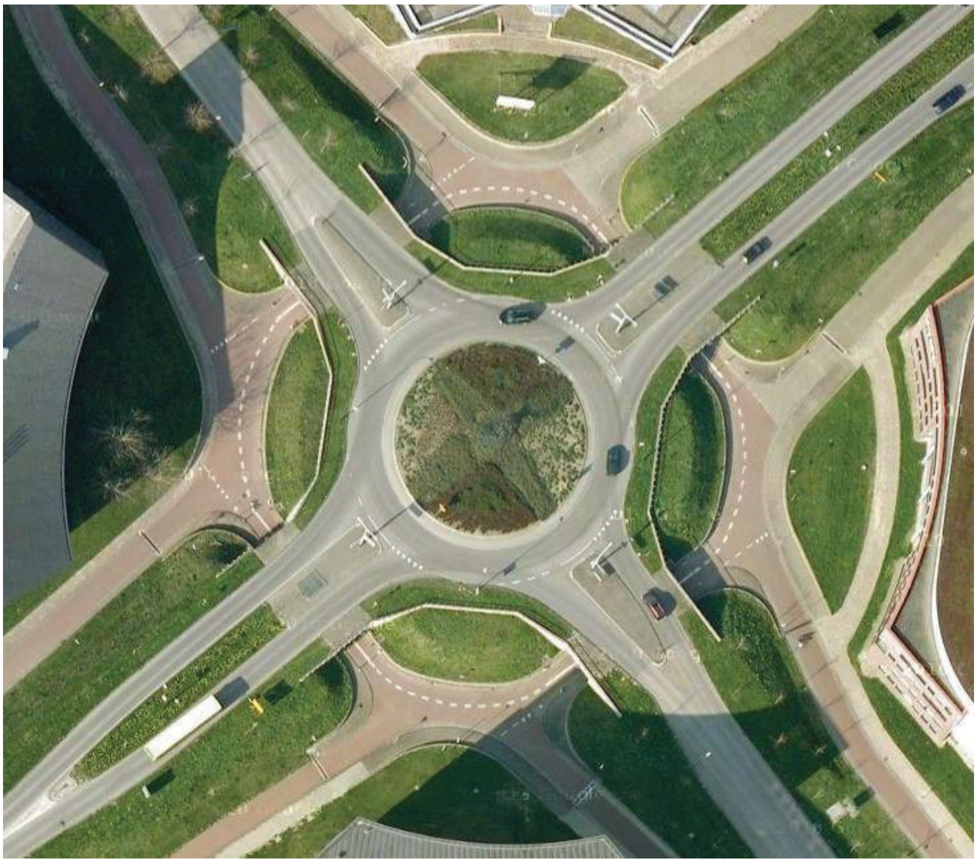
Source: Google Street View

Figure 44: Single lane roundabout (as seen in Figure 43), Pijnacker, Netherlands



Source: Google Maps

Figure 45: The ultimate safe solution: pedestrian and bicycle underpasses for grade separation at a single lane roundabout, Houten, Netherlands



Source: Google Maps

Figure 46: Grade-separated roundabout (as seen in Figure 45), Houten, Netherlands

Source: Peter Berkeley

4.2.3.4 Urban multiple-lane roundabouts

Multiple-lane roundabouts without a grade separated alternative are a major barrier to both experienced and new bicycle riders and have a higher bicycle crash risk than single lane roundabouts[26]. A major risk is vehicle acceleration speed at two-lane exits. In urban areas, it is recommended that two-lane exits are not used if a priority crossing is built for bicycle riders and pedestrians[12].

New multiple-lane roundabouts with two-lane exits are not recommended for roads on the Principal Cycle Network, unless a direct and attractive grade-separated bicycle path is built or the roundabout is built with only single-lane exits (see Figures 47 and 48). To improve bicycle safety at multiple-lane roundabouts, conversion to a single lane roundabout with separated cycle track and priority crossings should also be considered.

Figure 47: Urban multiple lane roundabout with priority crossings on one leg, Rotterdam, Netherlands

Source: Google Street View

Figure 48: Urban multiple lane roundabout (as seen in Figure 47), Rotterdam, Netherlands

Source: Google Maps

4.2.3.5 Multiple-lane roundabouts outside the urban area

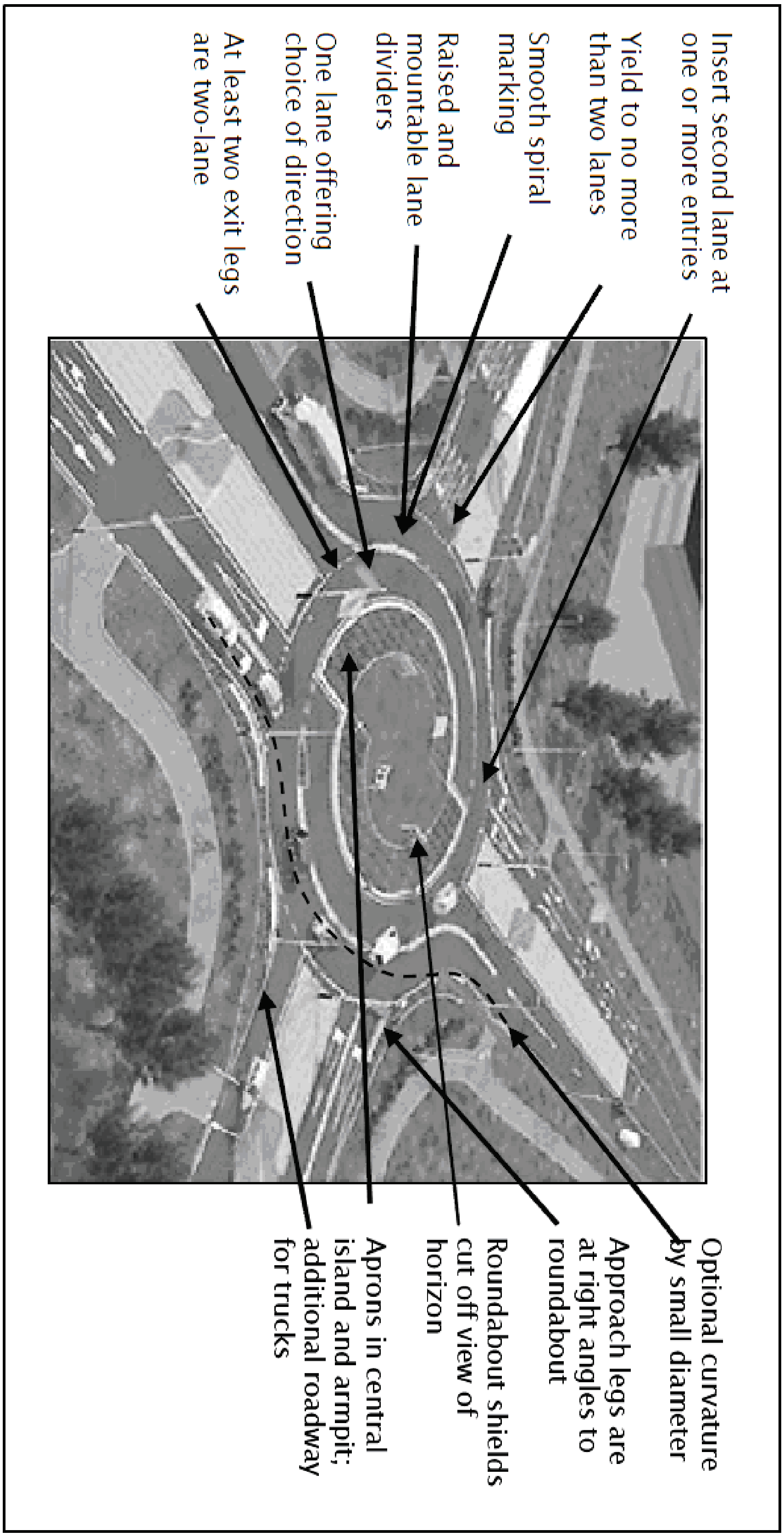
At multiple-lane roundabouts outside urban areas, a grade separated path such as an underpass is recommended. Where the path is at-grade priority should be assigned to road traffic. Comfort can be increased by providing foot rails and hand rails that are located on a flat area with good sight distance.

Turbo roundabouts

Recent research in New Zealand has recommended the trial of the Dutch 'turbo-roundabout' for urban and non-urban multiple-lane roundabouts[38]. This design which includes mountable lane dividers and compact geometry has better safety and capacity performance compared to conventional multiple-lane roundabouts (see Figure 49).

For effective horizontal deflection, raised lane dividers and raised centre island aprons are installed. These measures ensure the motorist chooses the correct lane before entering the roundabout, eliminating side-swipe crashes in the circulating space and providing effective deflection. These measures reduce circulating speed, generating more acceptable gaps and creating safer give-way situations where bicycles and pedestrians have more crossing opportunities where motor vehicles have priority outside urban areas.

Figure 49: Design features of a turbo roundabout outside urban areas without bicycle and pedestrian priority crossings



Source: Campbell, Jurisich and Dunn 2012

4.2.4 Signalised intersections (Appendices B4.01 to B4.04)

This section is to be read in conjunction with *Austroads Guide to Road Design 4*, Section 9.4.

To achieve safe signalised intersection design for bicycle riders the focus must be on reducing severity of conflicts between vulnerable road users and motorised vehicles. This is achieved by designing for safe turning speeds and highlighting conflicts with green surface treatment and continuity lines (see Figure 50) to show clear priority[39].

Design of traffic signals is generally focussed on quick and safe flow of the more dominant motorised vehicles. When compared to roundabouts, signalised intersections have many more conflict points and produce higher severity crashes such as head-on. For these reasons, signalised at-grade intersections are not as safe as grade separation and not as safe as effectively designed compact roundabouts[12, 26]. Signalised intersections are appropriate where the construction of grade separation or a roundabout is not feasible.

Figure 50: Two way cycle track signalised intersection. Fitzroy Street, St Kilda, Victoria

4.2.4.1 Signalised intersection with on-road bicycle lanes

On collector roads where vehicle operating speeds are >30 km/h but <60 km/h, on-road bicycle lanes are an appropriate treatment. Current Australian guidance for signalised intersections with bicycle lanes gives clear guidance for providing bicycle operating space at mid-block, transition, approach, waiting and departure elements, but does not provide guidance at the most critical through element. See *Austroads Guide to Road Design* 4A Intersections, Figure 10.8.

Most conflicts with motorised vehicles occur on the through element. Road user awareness of these conflict points can be improved by presenting the conflict area with the use of continuity lines and green painted bicycle lane treatment. For further guidance refer TRUM 1.34 Coloured surface treatments for bicycle lanes. Figure 51 clearly highlights the continuing bicycle operating space through the signalised intersection in red.

Figure 51: Dutch on-road bicycle lane painted red through signalised intersection, Delft, Netherlands

Source Google street view

Bicycle lane at left turn (Appendix C, TC1769)

Where a deceleration lane is provided for left turning vehicles, a bicycle lane can be retrofitted within this lane. This is explained further in drawing TC1769. This retrofit treatment reduces speed difference in the shared bicycle and left turn lane and takes less space than the traditional auxiliary left turn lane to the kerb-side of a bicycle lane. However, when left turning cars are queued, bicycle riders cannot pass them and must queue behind.

4.2.4.2 Signalised intersection with separated bicycle facilities

On roads where vehicle operating speeds are 60 km/h or more, physically separated bicycle facilities are recommended. Intersections present the greatest risk of conflict on most routes and should be the first improvement in a retrofit situation.

At an intersection where a road with bicycle lane and a road with cycle track meet, the bicycle lane should transition into a cycle track on the approach. Figure 52 shows a good example of a bicycle lane transitioning to one-way cycle track. This type of transition can be as simple as a splitter island beginning on the approach or could be a larger island with signal hardware and appropriate landscaping.

Figure 52: Dutch on-road bicycle lane transitioning to cycle track at signalised intersection, Delft, Netherlands

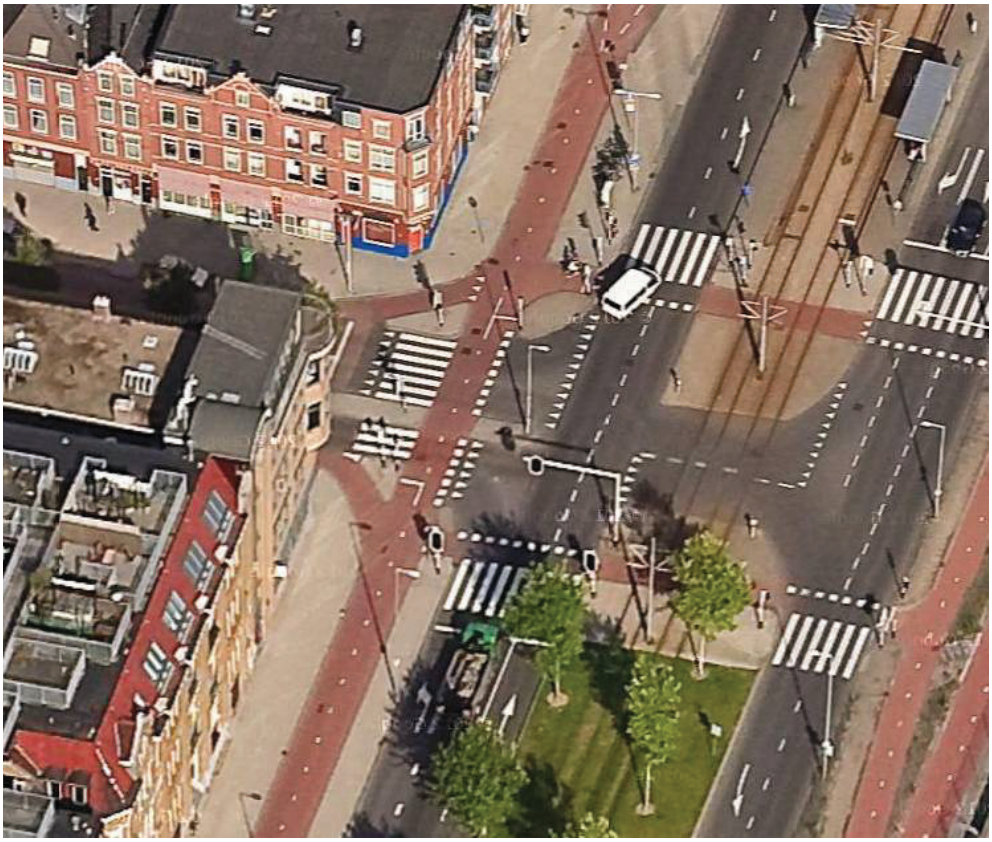
Source: Google street view

4.2.4.2.1 Bicycle safety at left turns

Compared with a basic left turn with cycle track, channelised left turns with a bicycle lane at the approach result in extended exposure for bicycle riders, increased vehicle speed at conflict point, rewarding poor driving practice and expanded area of pavement where conflict can occur[39, 40]. Taking into account extended exposure due to larger conflict area and higher speeds at conflict points, the current practice of bicycle lanes at channelised left turns that weave across a continuing bicycle lane present a safety risk that can be avoided (as seen in Figures 53 and 54). The exposure also causes unnecessary stress for bicycle riders and does not provide for all ages and abilities of bicycle riders[41].

Figure 55 compares both the conflict area and vehicle turn path for a channelised left turn (red) and for a basic left turn with cycle track (blue). The drawings also clearly demonstrate that the land area used for this safety improvement treatment is similar or even less than for a standard high entry angle slip lane and bicycle lane with off-road shared path.

Figure 53: Dutch two-way cycle track at signalised intersection, Rotterdam, Netherland

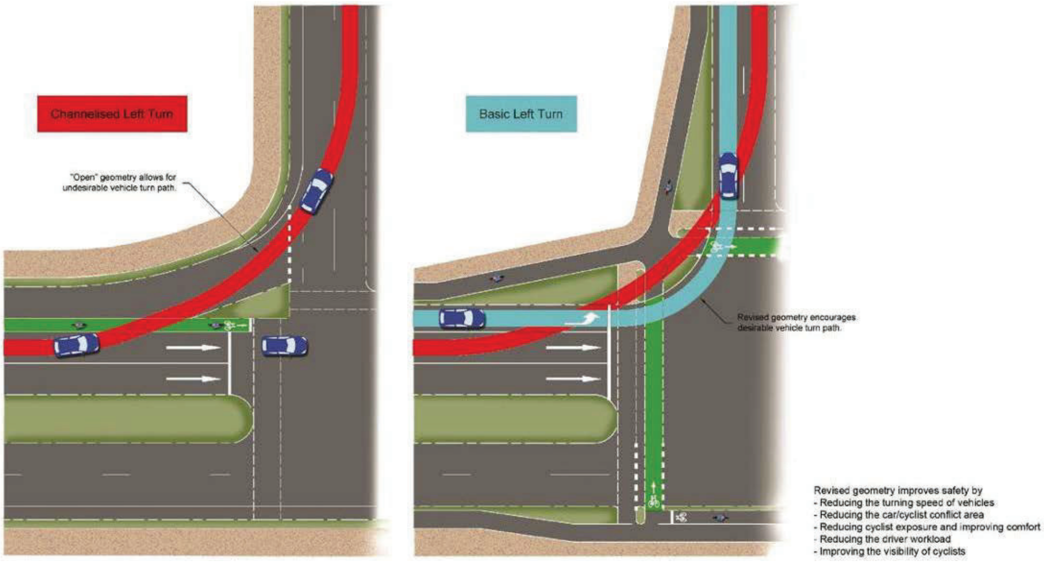


Source: Google maps

Figure 54: Dutch two-way cycle track at signalised intersection, Rotterdam, Netherlands in street view (refer to Figure 53)

Source: Google street view

Figure 55: Channelised versus basic left turn: comparison of vehicle turn paths



Remove left turn conflict with grade separation

At controlled access roads such as urban arterial roads or motorways where bicycles are completely separated from motor vehicle traffic, off-ramp style exits are appropriate. At these locations bicycles are ideally grade separated.

Highlight conflict at left turn slip lane

Where grade separation is not possible and a conflict with bicycles is created, vehicle turning speed must be reduced to <30 km/h and cross the cycle path at right angles to visually alert road users of possible conflicts[42]. Vehicles and bicycles should be time separated by signals or clearly marked priority such as raised pedestrian and bicycle crossings with give-way line-marking and signs.

Time separate

Adopt dwell-on-red for left turns, may be appropriate for low volume left turns. Also ensures low motor vehicle speeds through the turn.

Permit sub-conflicts (filter left turn through bicycle riders going straight)

Sub-conflicts between motorised vehicles and bicycles are permitted to achieve reduced waiting times. The applicable sub-conflict is where motor vehicles turning left conflict with bicycles continuing straight. Where this sub-conflict is permitted every effort must be made to clearly present priority for bicycles. This can be achieved through safe turning speeds, give way lines and with supplementing green surface pavement treatment.

Sub-conflict between bicycle riders continuing straight and motorists turning left should not be permitted where:

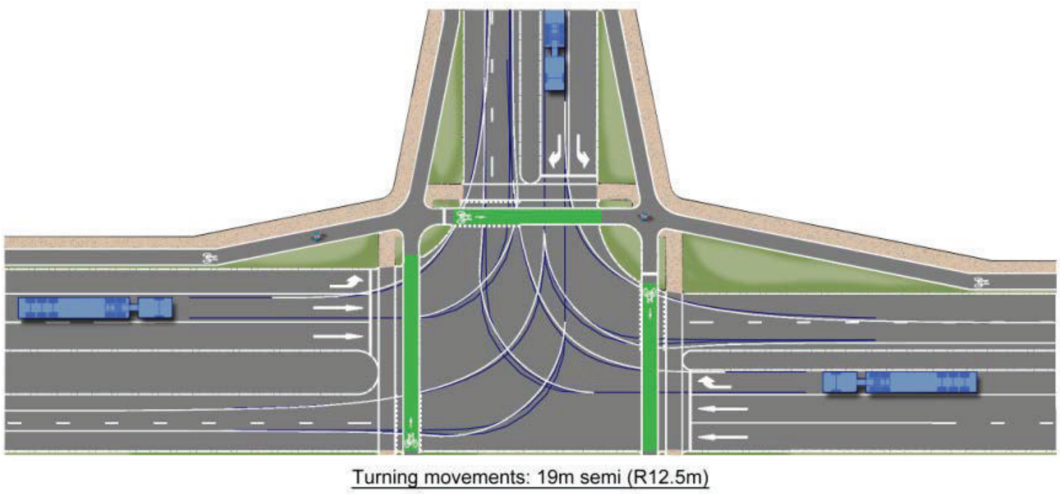
- motorised vehicle turning volume is ≥150 vehicles per hour
- the bicycle facility is a two-way cycle track
- a high volume of turning heavy vehicles (>5%)
- at rural intersections81.

Sub-conflicts between riders continuing straight and motorists turning right should not be permitted.

Maintaining safe turning speed while accommodating the design vehicle

Design for basic left turn should take into account *Queensland Road Rules* Section 28 allows the driver of a vehicle 7.5 m long or longer to approach and enter the intersection from the marked lane next to the left lane as well as, or instead of, the left lane. The turning path of a 19 m semi-trailer is illustrated in the Figure 56 below and in Appendix B4.04.

Figure 56: Design vehicle turning path. For more detail see Appendix B4.04



Corner protective islands for safe turning speeds

At the intersection of high volume roads such as urban arterial roads, signalised intersections are appropriate. To ensure safe turning speeds, corner protective islands should be used to increase safety for bicycle riders without losing space for other road users (see red highlighted areas in Figures 57 and 58). A corner island can vary in size depending on road geometry. Corner islands are primarily to ensure appropriate safe turning speed and secondly to protect storing bicycle riders and pedestrians.

Figure 57: Two corner protective islands highlighted in red. For more detail see Appendix B4.01

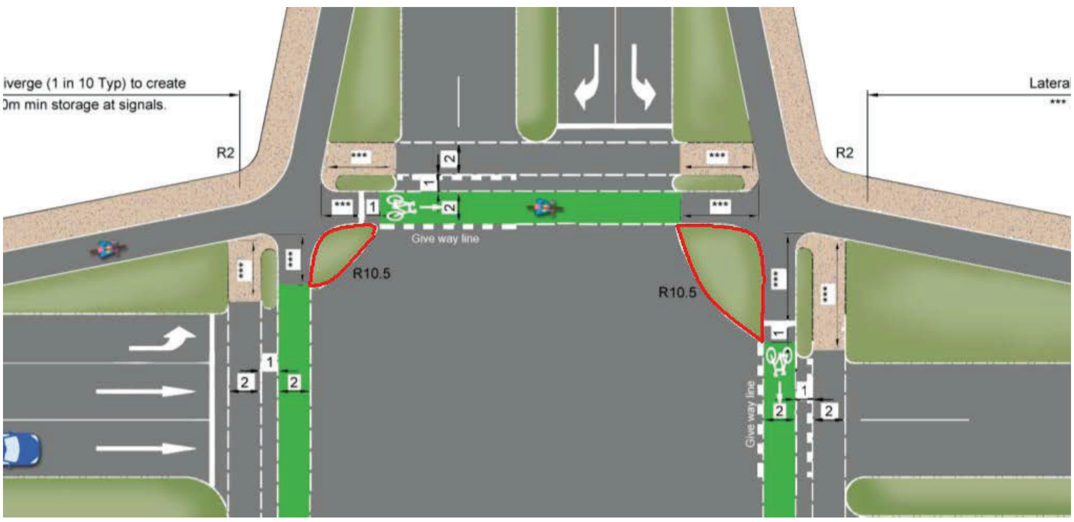
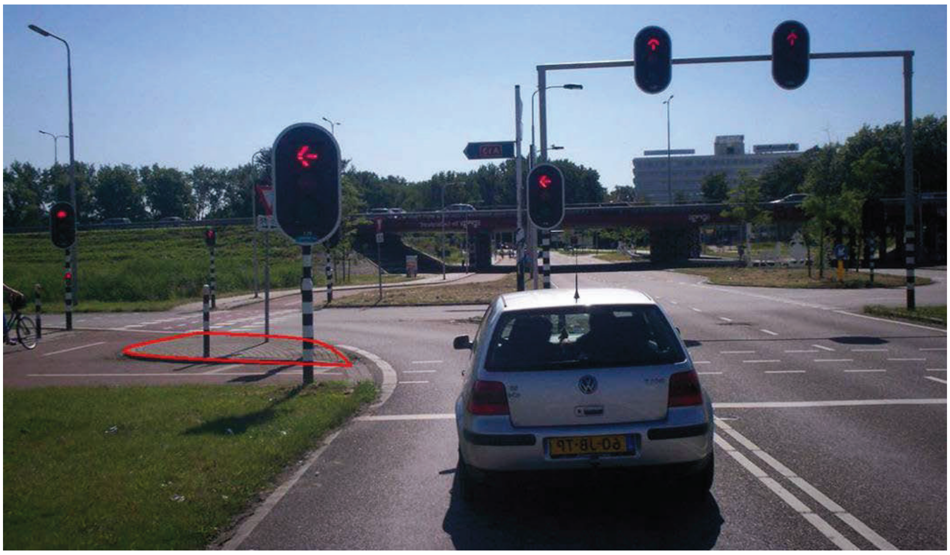


Figure 58: Arterial road (limited access) crossing a two-way cycle track, with corner island circled in red. This intersection is time separated by signals triggered in advance by bicycle riders to reduce the chance of stop



Source wiki.coe.neu.edu

4.2.4.2.2 Optimised signal phasing

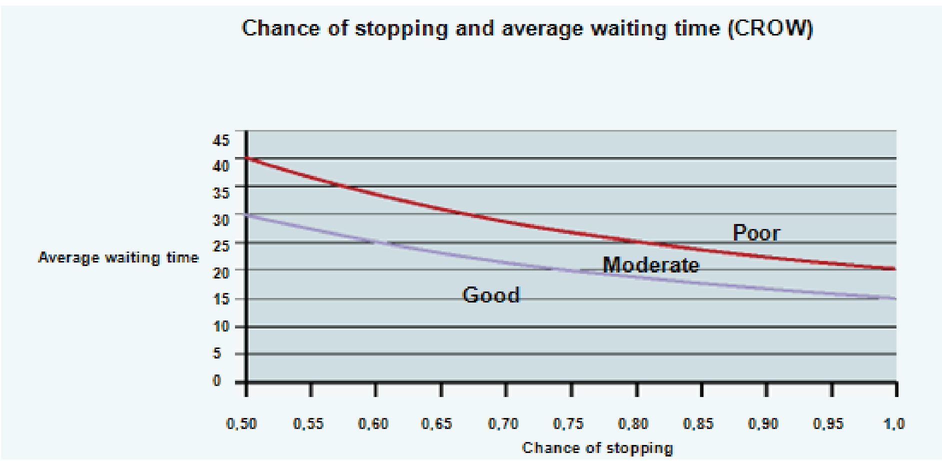
Chance of stopping and average waiting time

The most significant criteria for achieving bicycle-friendly signalised intersection design are the chance of being stopped and the average waiting time[12]. Bicycle riders are greatly impacted by loss of speed maintenance through stopping, delays when stopped and then the physical effort of getting back up to speed (loss of directness in time and discomfort). Where bicycle riders are stopped or detoured they will take high safety risks in order to save travel time.

"Energy use of stopping and starting just once is equal to cycling 100 to 200 metres"[43].

In most cases signals will delay bicycle riders more than crossing without signals. For this reason signals should be avoided unless absolutely necessary. However, one advantage is the limit on maximum waiting time. Figure 59 from the Dutch *Design Manual for Bicycle Traffic* guidelines shows the acceptable average waiting (not maximum waiting time) depending on chance of stopping[12].

Figure 59: This chart from the Design Manual for Bicycle Traffic shows the relationship between chance of stopping and acceptable average waiting time at traffic light



Safe signal cycle time for bicycles

Appropriate cycle times are very important to achieve a bicycle-friendly intersection. Dutch research at intersections has shown that green light times for motorised traffic are set too long 'as a precaution[12]. Immediate improvements in flow of all road users can be achieved with shorter cycle times.

Dutch *Design Manual for Bicycle Traffic* guidance considers cycle times up to 120 seconds acceptable for motorists. Cycle times longer than 90 seconds cause unsafe levels of non-compliance and are not recommended on bicycle routes[40]. Shortening cycle times for all road users depends on clearance times. Intersections should be designed to be as compact as possible with short crossing distances for pedestrians and bicycle riders, so the cycle time will be quicker for all road users.

Advanced bicycle detection

Placing a bicycle detection loop in the bicycle lane or cycle track on the approach to signals can dramatically reduce the chance of stop for bicycle riders and reduce delay for other road users. This approach is quite effective at an isolated mid-block signalised crossing and can be combined with puffin detection to reduce delays for vehicles when bicycles clear the intersection quickly.

Bicycle head start

Bicycle head start of a few seconds so that bicycle riders arrive at conflict point before motorists. Also referred to a 'leading bicycle interval'.

Two bicycle phases during a cycle

This technique may be applicable during peak times.

Combining right turning motorists and bicycle riders

Combine right turning motorists with two-stage right turning bicycle riders.

Green Wave for bicycle riders

Coordinate signals to create a 'green wave' for bicycle riders.

All directions green for bicycle riders

Bicycle riders are highly manoeuvrable vehicles and can navigate by each other at close passing distances. The all directions green is the same function as a scramble crossing for pedestrians. This function can also be combined with a scramble crossing for pedestrians. Bicycle riders should be reminded to give way to pedestrians.

Hold green for bicycles

On Principal Cycle Network routes, green on the dominant leg for bicycles can be held. Vehicles turning across the bicycle facility are controlled. Bicycle traffic is controlled when turning vehicle is detected.

Countdown timers to improve compliance

Countdown timers to indicate remaining waiting time are useful for improving compliance. They can also be used to indicate remaining green and clearance times.

4.2.4.2.3 Physical improvements for signalised intersections

The following physical measures can be taken to make the intersection more bicycle friendly.

Bicycle left turn bypass

See Austroads *Guide to Road Design* Part 4A section 10.6.4, Figure 10.12.

Advanced stop line for bicycles

See Austroads *Guide to Road Design* Part 4A section 10.6.4, Figure 10.8.

Push button located conveniently

Push buttons should be located within the zone of reach of most bicycle riders in accordance with Transport and Main Roads Standard Drawing 1428. Desirable set-back should be 300 to 400 mm and maximum 500 mm.

Holding rails and foot rails

Holding rails and foot rails at signalised intersections are an easy way to improve bicycle rider comfort, especially where the chance of stopping is high. Figure 60 shows a mid-block signalised crossing in Melbourne with hand and foot rails for waiting bicycle riders.

Figure 60: Holding rails and foot rails for comfortable waiting at signalised crossing, Melbourne

4.2.5 Grade separated intersections

Installing a tunnel or bridge completely removes the conflict between bicycle and motorised traffic. This measure is most appropriate on Principal Cycle Network routes both in urban areas and outside the built-up area. Figure 61 is a good example of grade separated two-way cycle track with separated footpath.

Figure 61: Pedestrian and bicycle underpass, Pijnacker, Netherlands

Source: wiki.coe.neu.edu

5 Bicycle facilities outside the road corridor

On bicycle transport routes located outside of the road corridor but within the urban area, separation from pedestrians is recommended for increased comfort, safety, directness and capacity for both bicycle riders and pedestrians[44].

A shared path is a compromise of pedestrian comfort due to the speed difference of passing bicycle riders and compromises directness for bicycle riders that must give way to all pedestrians when conflicts occur. On recreational routes with low volumes of pedestrians a shared path facility is appropriate. Figure 62 shows the construction of a two-way bicycle only path and separated footpath at University of Queensland, St Lucia, Brisbane.

Figure 62

6 Design Considerations

6.1 Detailed design

The five principles listed in Section 3 apply to all aspects of design for bicycle riders. For further detailed design requirements refer Austroads *Guide to Road Design* Part 3 Section 7. The following additional design considerations are to be read in conjunction with existing Austroads guidance.

6.1.1 Clearances

The horizontal width of a bicycle facility does not include clearances to obstacles such as parked cars or other hazards. The recommended clearance widths to various hazards are shown in Table 6. All hazards should be considered, including beyond the kerb. Existing street trees that bend towards the path should have a minimum 0.5m clearance (Figure 63).

Table 6: Clearances

Feature	Minimum clearance	Desirable clearance
One-way cycle track with no car parking adjacent	0 m	1.0 m desirable for arterial roads
Parked cars adjacent to one-way cycle track	0 m	0.75 m desirable
Parked cars adjacent to two-way cycle track	0 m	0.40 m desirable
Bus stop, railing, crash barrier, poles, bollards, street tree, wall or fence	0.50 m	0.50 m

Where a cycle track or path is constrained by physical barriers, railings, crash barrier, fence etc. on both sides, the clearance shown in Table 6 is recommended on each side of the cycle track or path. In order to ensure there is sufficient vertical clearance, a clear height of 2.5 m (2.2 m bicycle rider height and 0.3 m clearance) is required. Refer to Austroads *Guide to Road Design* Part 6A Section 4.2 for further information on bicycle rider requirements.

Figure 63: Two-way cycle track diverted around existing street tree, Bourke St, Sydney

6.1.2 Bus Stop Treatments (Appendices B5.01 and B5.02)

Several conflicts may arise at bus stops, including those between bicycle riders, passengers waiting for the bus and passengers entering or alighting from bus services.

In order to provide access for pedestrians between the footpath and bus stop, clear crossing points can be provided at appropriate locations with adequate sight distance. Barrier or lean rail can be used within the bus stop area to guide pedestrians to designated crossing points. For specific guidance see Appendices B5.01 and B5.02. Figures 64 and 65 are examples of constrained bus stops in Sydney and in Copenhagen.

Figure 64: Two-way cycle track at bus stop, Bourke St, Sydney

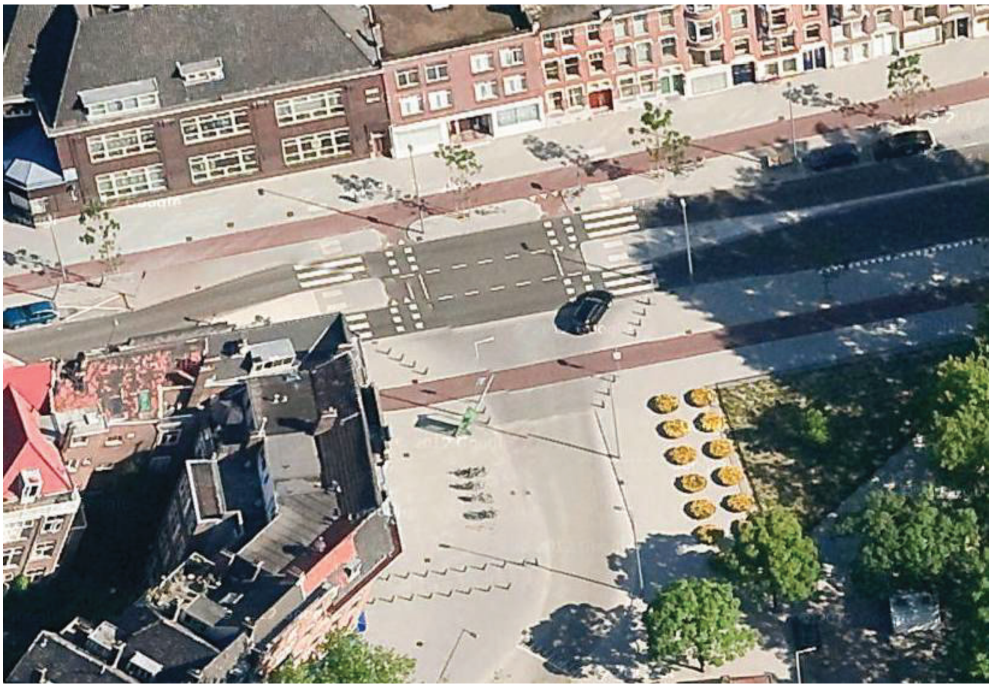
Figure 65: One-way cycle track at bus stop, Copenhagen

Source: Jonathan Maus, Bike Portland

6.1.3 Pedestrian access

Access for pedestrians, particularly people with a mobility or vision impairment, is an important consideration in the separated cycle track design. If poorly designed, separation can act as a barrier to pedestrians. Intersection treatments for bicycle facilities must take into consideration pedestrian desire lines. Figures 66 and 67 are an example of pedestrian and bicycle access across a collector road in Rotterdam, Holland.

Figure 66: One-way cycle track on collector road with pedestrian crossings and refuges, Rotterdam Holland



Source: Google maps

Figure 67: One-way cycle track on collector road with pedestrian crossings and refuges, Rotterdam Holland in street view (refer to Figure 66)

Source: Google street view

6.1.4 Commercial driveways (See Appendix B2.01)

In some cases such as this service station in Figure 68, the cycle track can avoid conflict with a large commercial entrance by going around. Figures 69 and 70 show the appropriate treatment where a large commercial or industrial driveway crosses the cycle track.

6.1.5 Green surface treatment

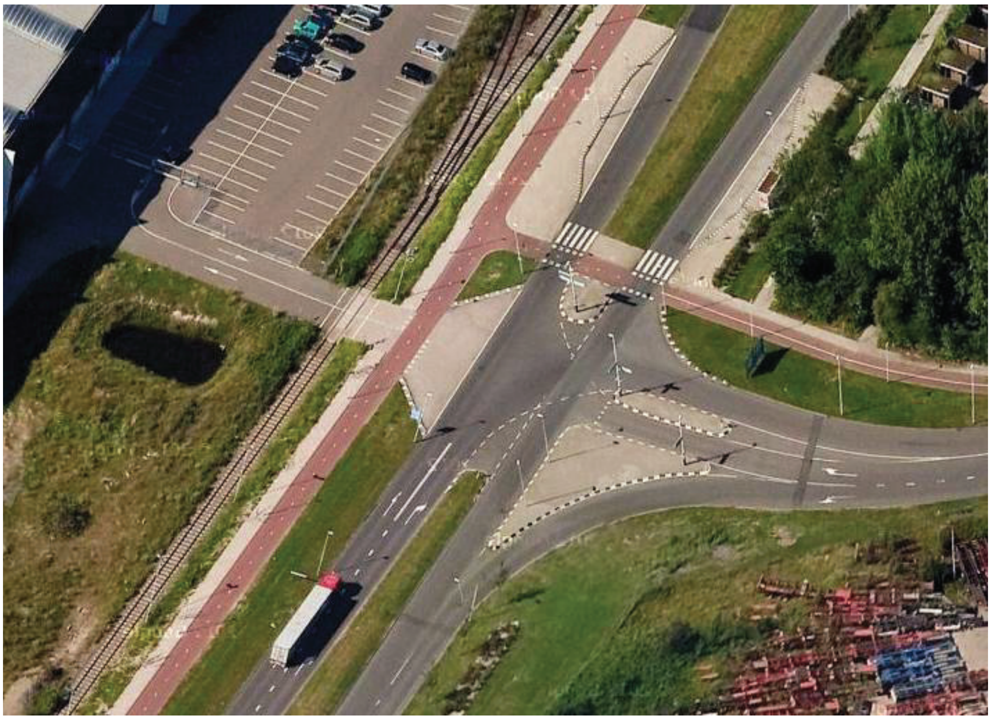
The use of green surface treatment at commercial and large residential driveways where there are a high number of vehicle movements and a heightened risk of conflict between bicycle riders and vehicles is appropriate.

However, due to the need to highlight the conflict area only and the high cost associated with its installation, the use of green surfacing should be limited to the immediate lengths of driveway and not on approach to them. For further information on coloured surface treatments refer TRUM 1.34 Coloured surface treatments for bicycle lanes. Avoiding the conflict at major commercial driveways such as service stations is recommended.

Figure 68: Two-way cycle track and footpath on arterial road built behind the service station to avoid crossing conflicts, Rotterdam

Source Google maps

Figure 69: Industrial area driveway crossing two-way cycle track, Rotterdam



Source Google maps

Figure 70: Industrial area driveway crossing two-way cycle track, Rotterdam in street view (refer to Figure 69)

Source Google street view

6.1.6 Lighting

Along transport routes, street lighting is essential to create a high quality environment that is safe, comfortable and secure for bicycle riders at all hours of the day and night. Recreational routes generally cater for daylight hours and do not need to be lit, unless the route also performs a transport function.

Typically lighting on bicycles is to be seen, rather than to illuminate the road or path ahead. Adequate lighting is required to allow visibility between riders, pedestrians and vehicles as well as visibility to any hazards. The existing street lighting along a cycle route should be reviewed to ensure the lighting levels are in accordance with AS/NZS 1158.3.1.

6.1.7 Street trees

Retained street trees should be checked to ensure both appropriate horizontal and vertical clearance and sight lines are acceptable. In some cases the alignment of the bicycle facility may need to be adjusted to avoid the street tree. A 1 m/s lateral shift would be appropriate (see Figures 71 and 72). Lighting should highlight the change in alignment.

Figure 71: Treatment of a street tree

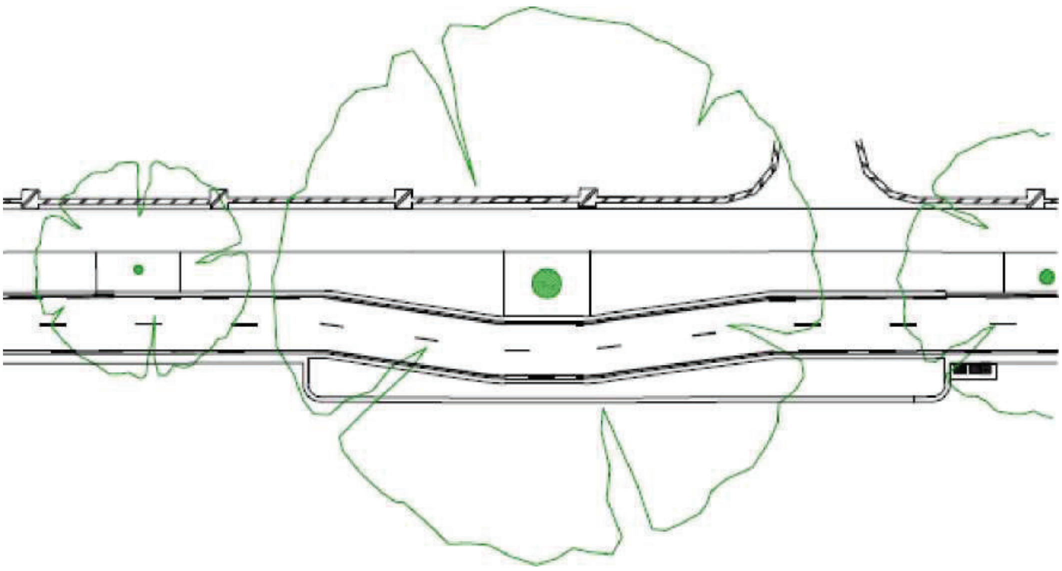


Figure 72: Two way cycle track diverted to retain street tree, Bourke St, Sydney

Appendix A – Definitions

Bend-in Transition: A one-way cycle track transition to a bicycle lane at a road intersection, from a road related area to a road.

Bend-out Transition: A cycle track or bicycle path that bends away from a road intersection.

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.

Bikeway: A bicycle path or shared path most commonly located off-road for recreational use.

Cycle track: A bicycle-only facility, physically separated from pedestrians and motor vehicles that provides priority to the road related area at intersections with roads.

Cycle track (One-way): A cycle track that only permits one-way movements. Defined as road related area under QRR.

Cycle track (Two-way): A cycle track that permits two-way movements. Defined as road related area under QRR.

Cycleway: A named bicycle route mainly comprised of paths separated from traffic, separation from pedestrian and priority at unsignalised intersections.

Intersection: Without altering the QRR definition this guide also defines an intersection as the meeting one path with at least one other road, path or driveway.

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.

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.

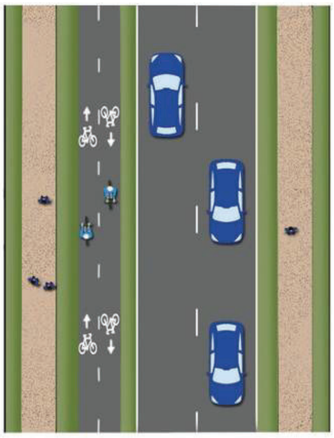
Shared path: A pedestrian and bicycle facility that gives pedestrians priority under QRR.

Transition: A bicycle path connection, possibly a ramp, between road and road related area (or vice versa), such as a Bend-in Transition.

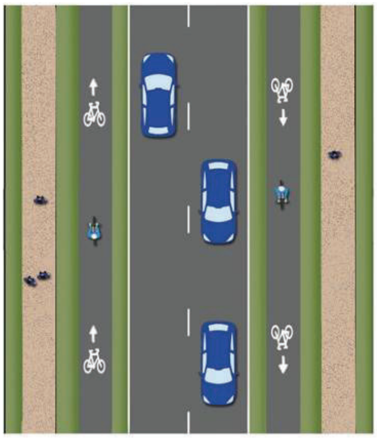
Veloway – an arterial standard bicycle path designed cater for high bicycle volumes. Conflicts and delays eliminated through features such as grade separation at intersections with roads.

Appendix B – Drawings

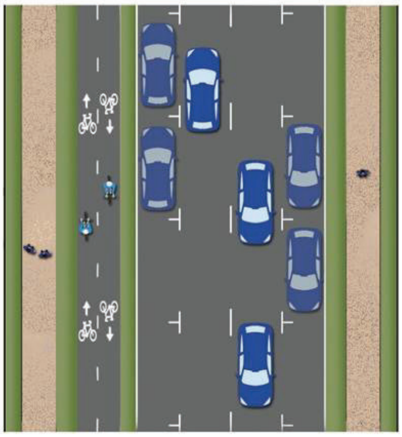
Appendix B1.01: Cycle tracks on two lane undivided roads



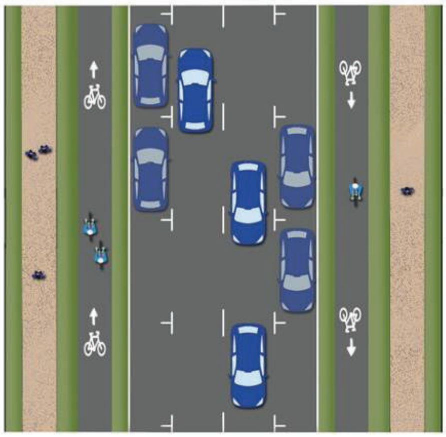
Two-way cycle track on
two lane undivided road with no parking



One-way cycle tracks on
two lane undivided road with no parking



Two-way cycle track on
two lane undivided road with parking



One-way cycle tracks on
two lane undivided road with parking

CYCLE TRACKS ON TWO LANE UNDIVIDED ROADS

FIGURE B1.01 A

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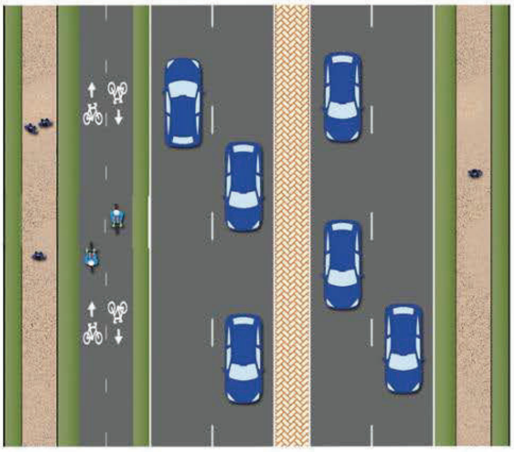
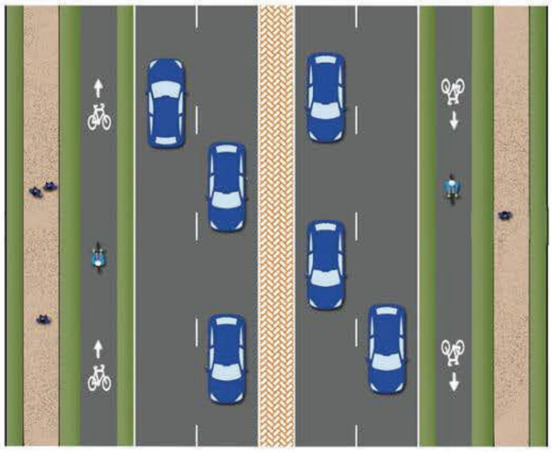
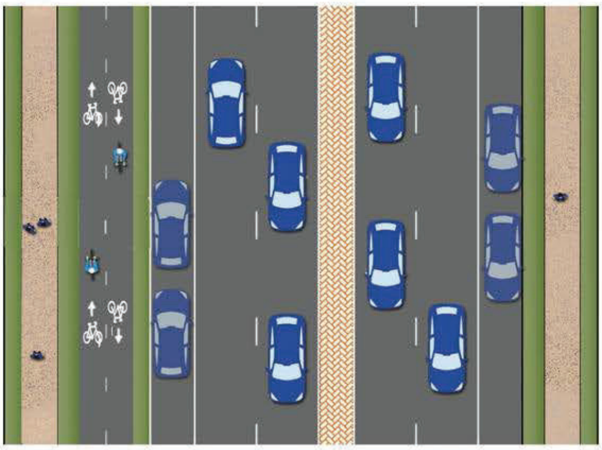
Appendix B1.02: Cycle tracks on four lane divided roads



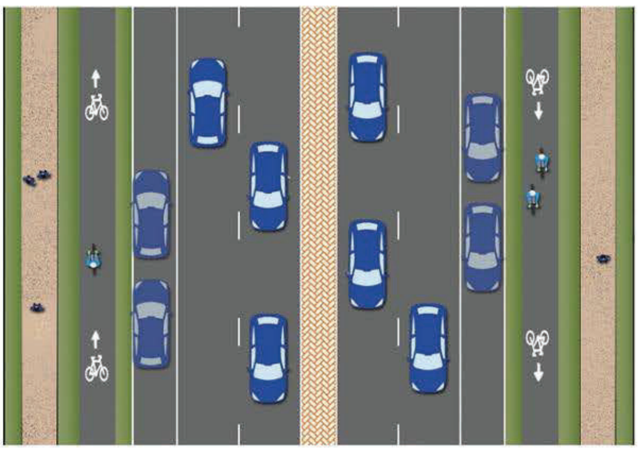
Two-way cycle track on four lane divided road with no parking



One-way cycle tracks on four lane divided road with no parking



Two-way cycle track on four lane divided road with parking



One-way cycle tracks on four lane divided road with parking

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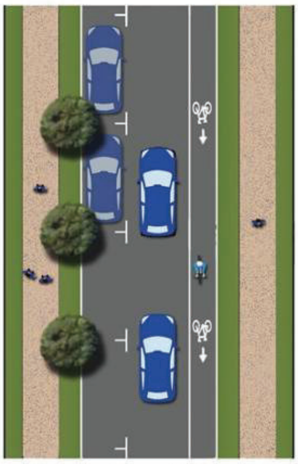
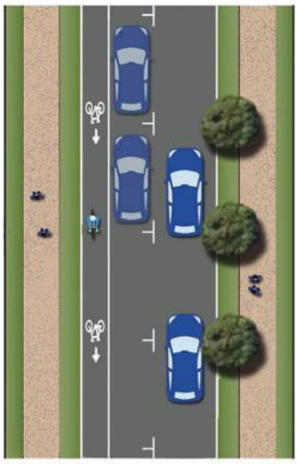
CYCLE TRACKS ON FOUR LANE DIVIDED ROADS

FIGURE B1.02 A

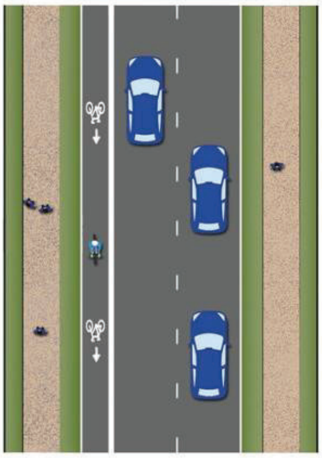
Appendix B1.03: Contra-flow bicycle lanes



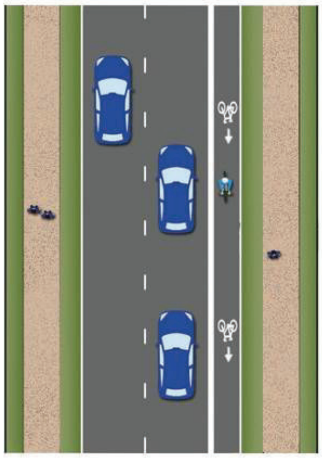
Contra-flow bicycle lane with linemarking only on right hand side of the road (preferred)



Contra-flow bicycle lane with linemarking only on left hand side of the road



Contra-flow bicycle lane with minor separation on left hand side of the road



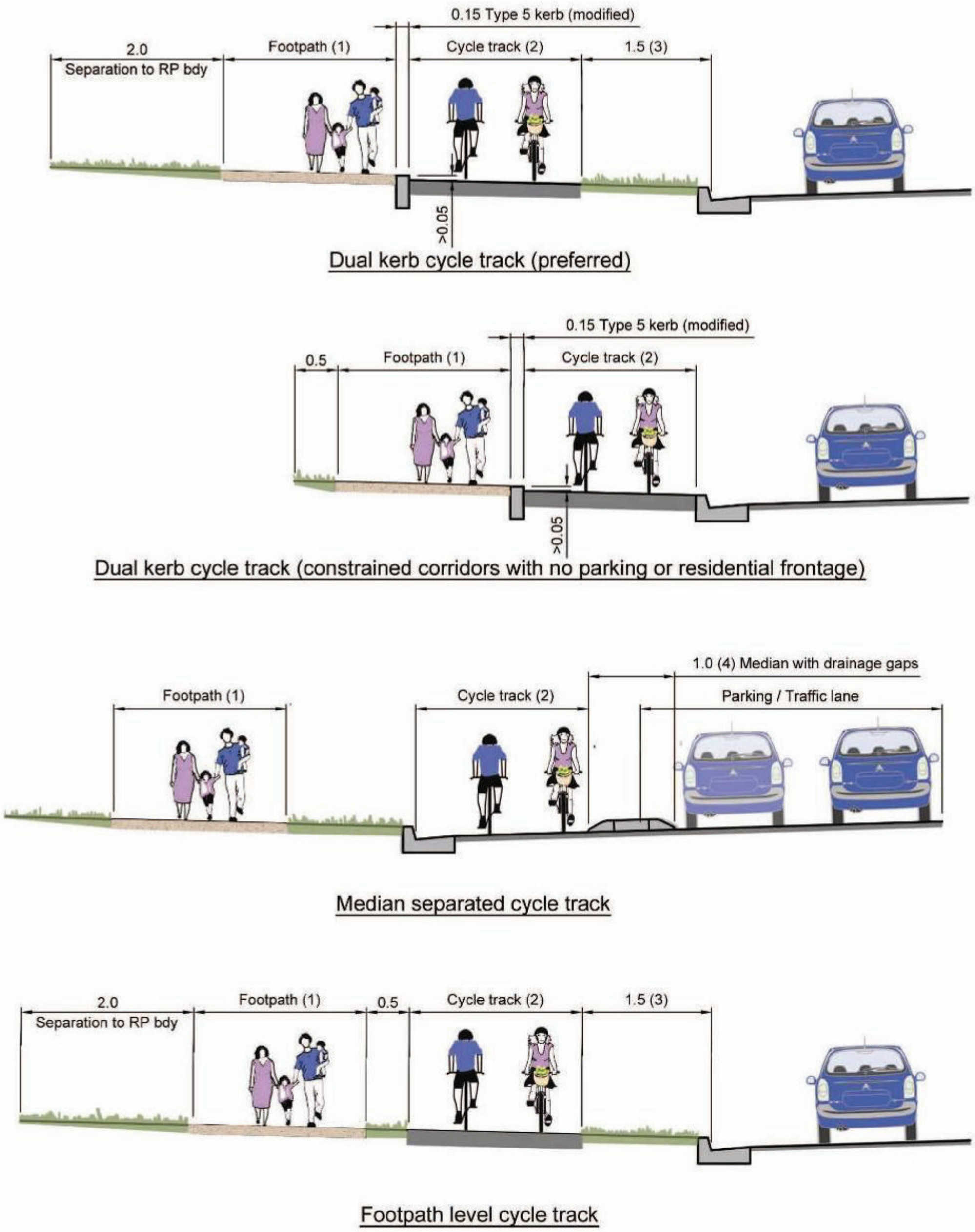
Contra-flow bicycle lane with minor separation on right hand side of the road

G:\Projects\Cycleways\Separated Cycleways Drawings\June 2013\Contra Flow Bicycle Lanes.dwg

CONTRA-FLOW BICYCLE LANES

FIGURE B1.03 A

Appendix B1.04: Cycle track cross sections



Notes:

1. Refer Austroads Guide to Road Design Part 6A Table 6.1.
2. One-way cycle track refer Table 2. Two-way cycle track refer Table 3.
3. 1.5m allows for:
- 0.6m clearance from the bus / traffic lane to power poles, street lights, road furniture;
- 0.5m clearance from the cycle track to power poles, street lights, road furniture; and
- Storage for wheelie bins.
4. 1.0m allows for:
- Clearance for parked cars to open doors;
- Space for passengers to exit parked cars; and
- Storage for wheelie bins.

CYCLE TRACK CROSS SECTIONS

FIGURE B1.04 B

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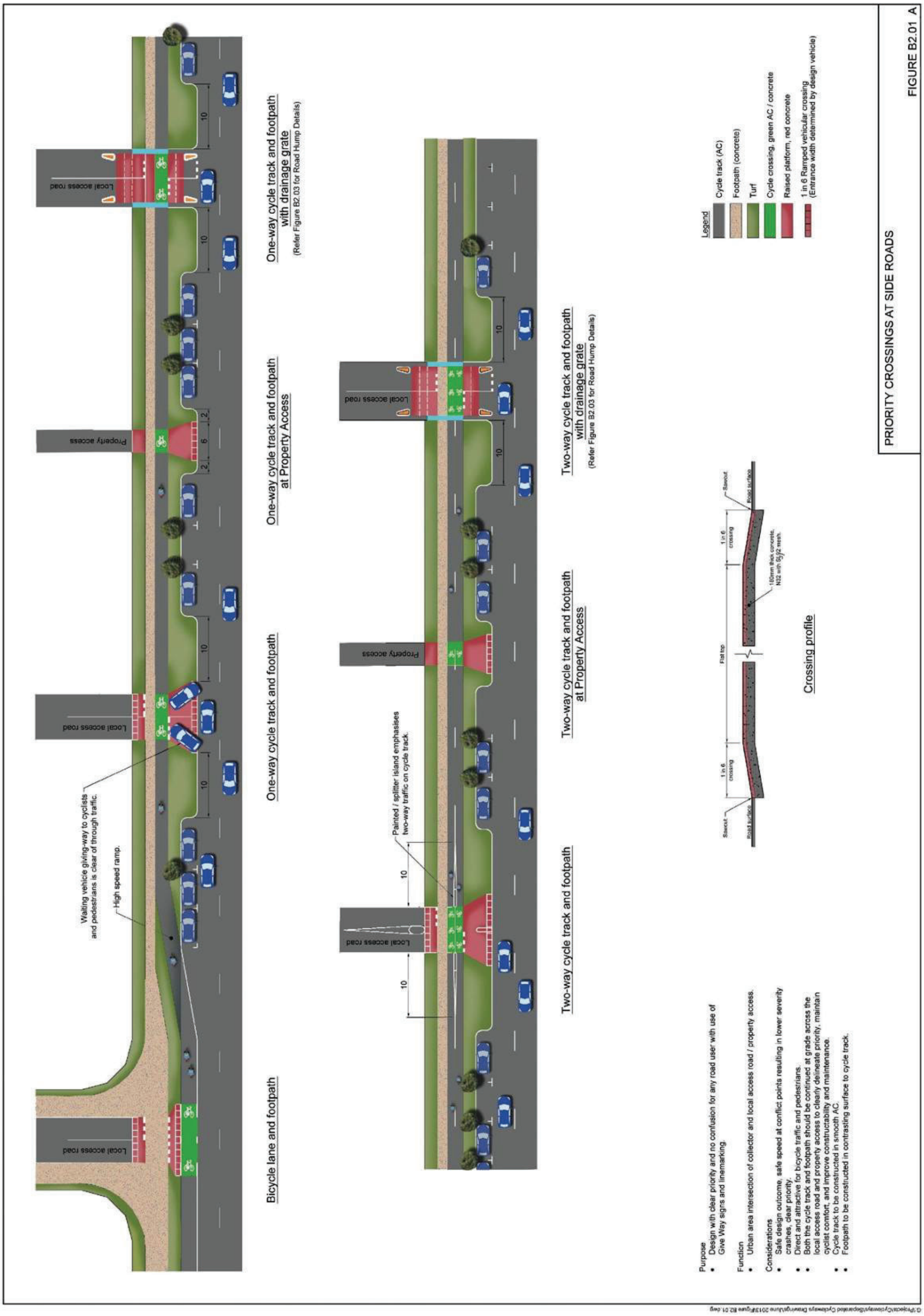
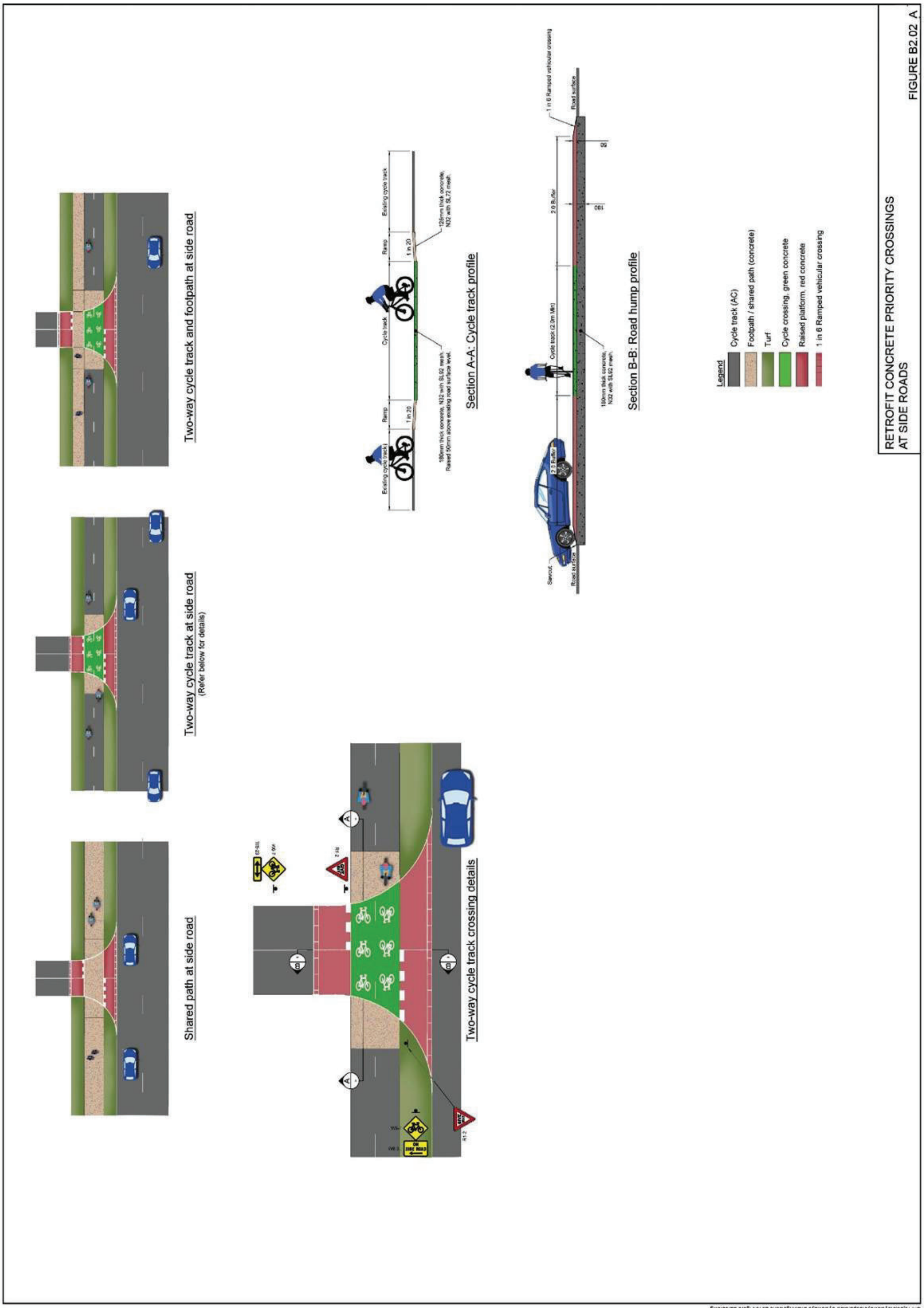
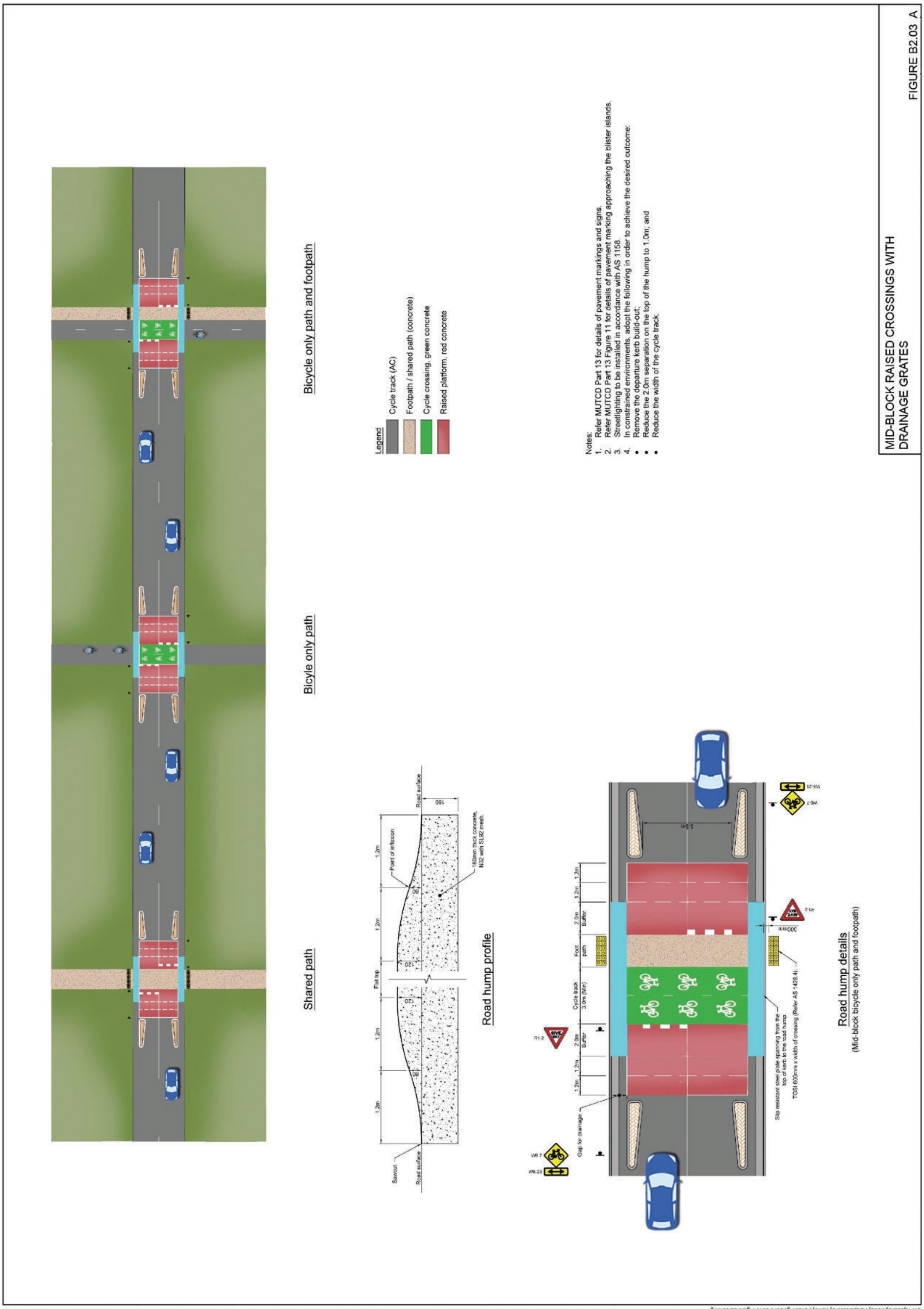
Appendix B2.01: Priority crossings at side roads



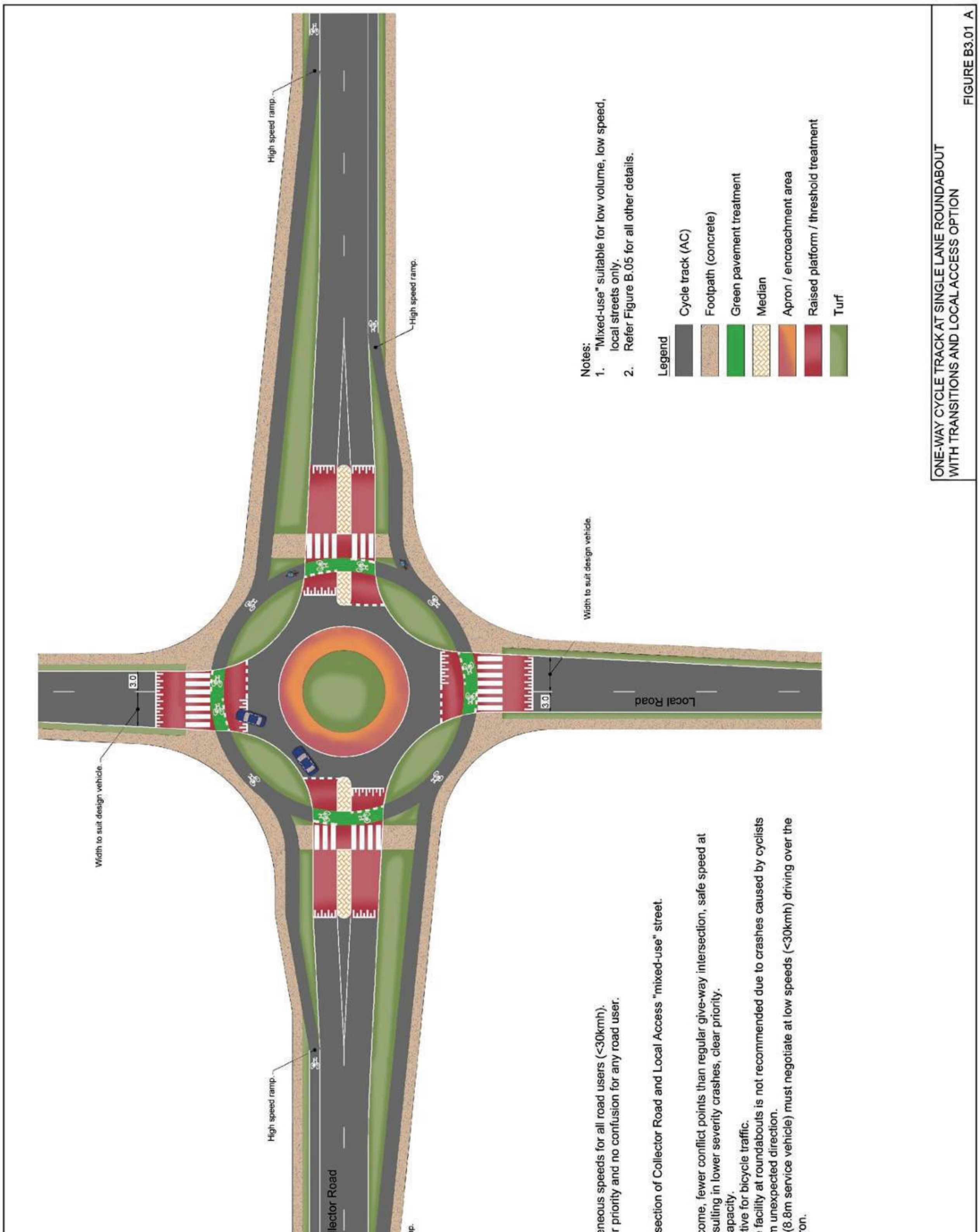
Appendix B2.02: Retrofit concrete priority crossings at side roads



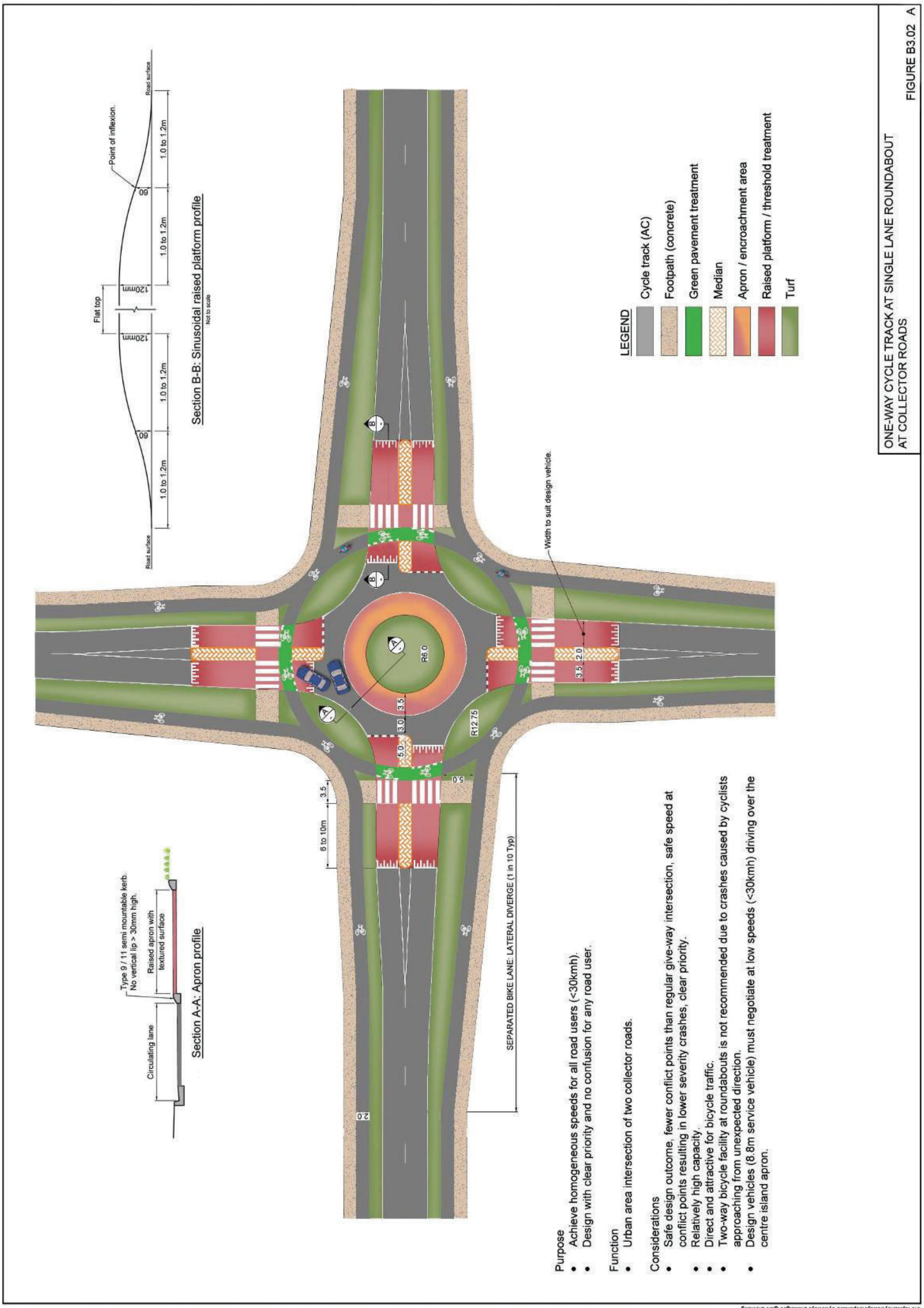
Appendix B2.03: Mid-block raised crossings with drainage gates



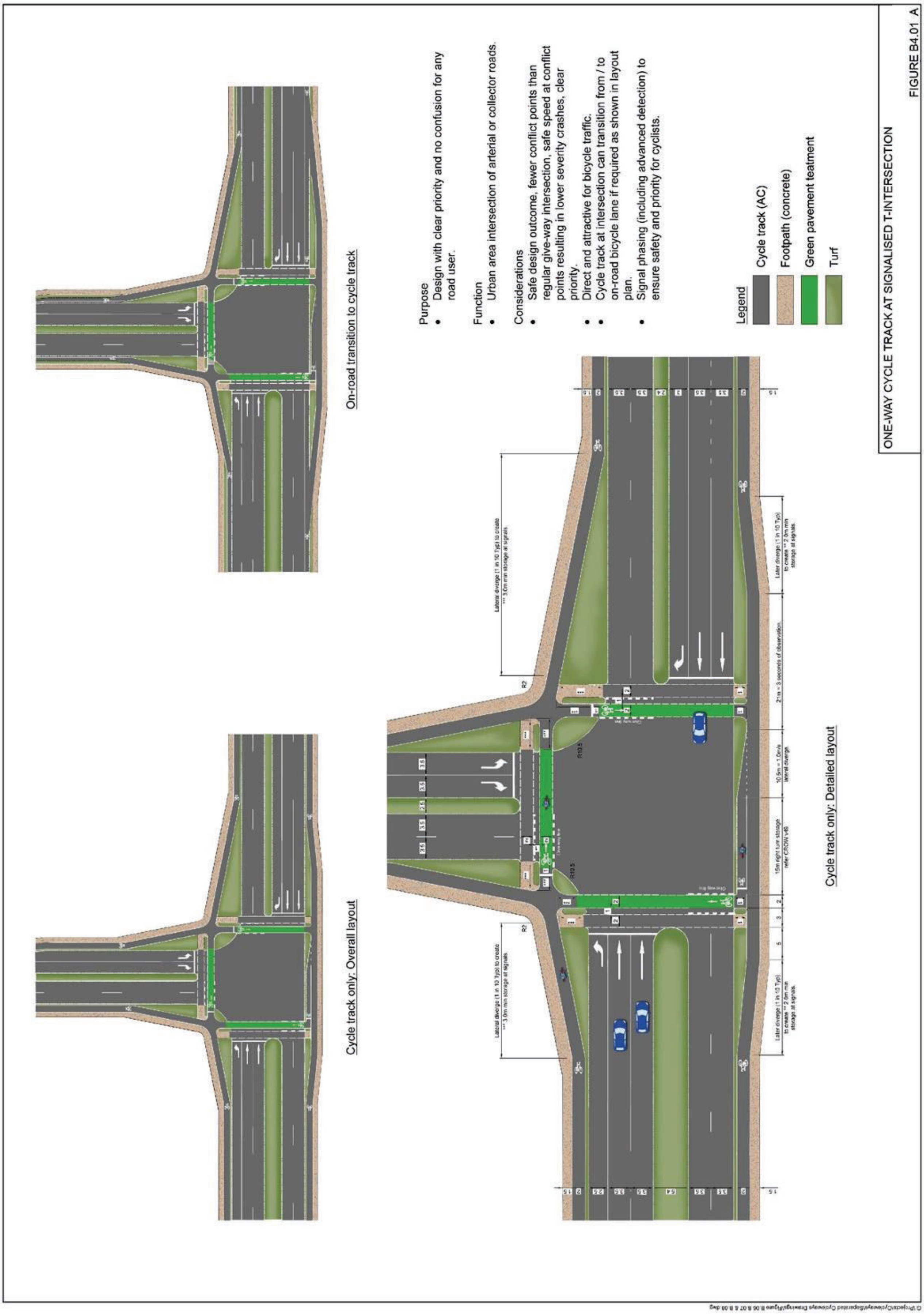
Appendix B3.01: One-way cycle track mixed-use options



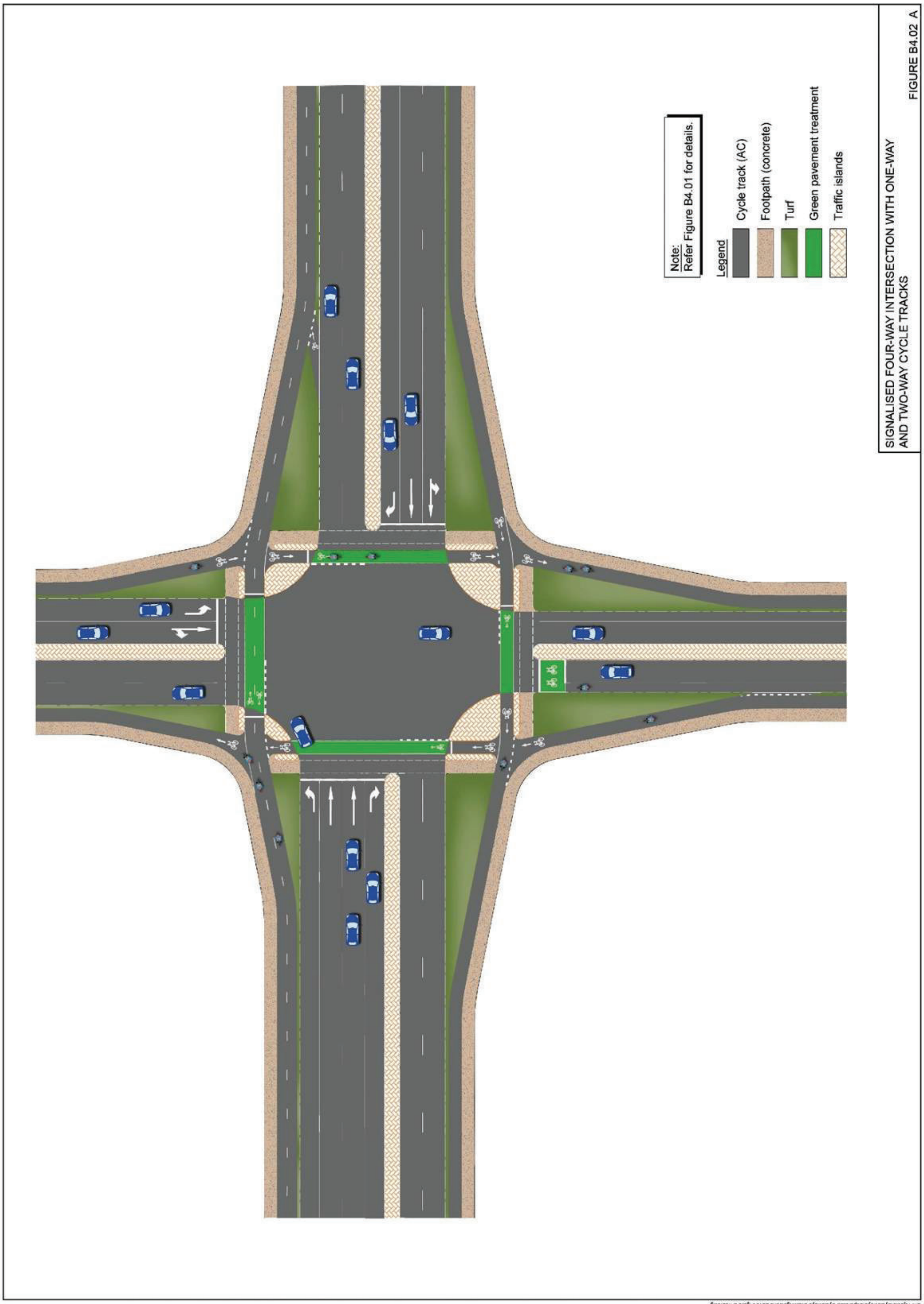
Appendix B3.02: One-way cycle track at single lane roundabout at collector roads



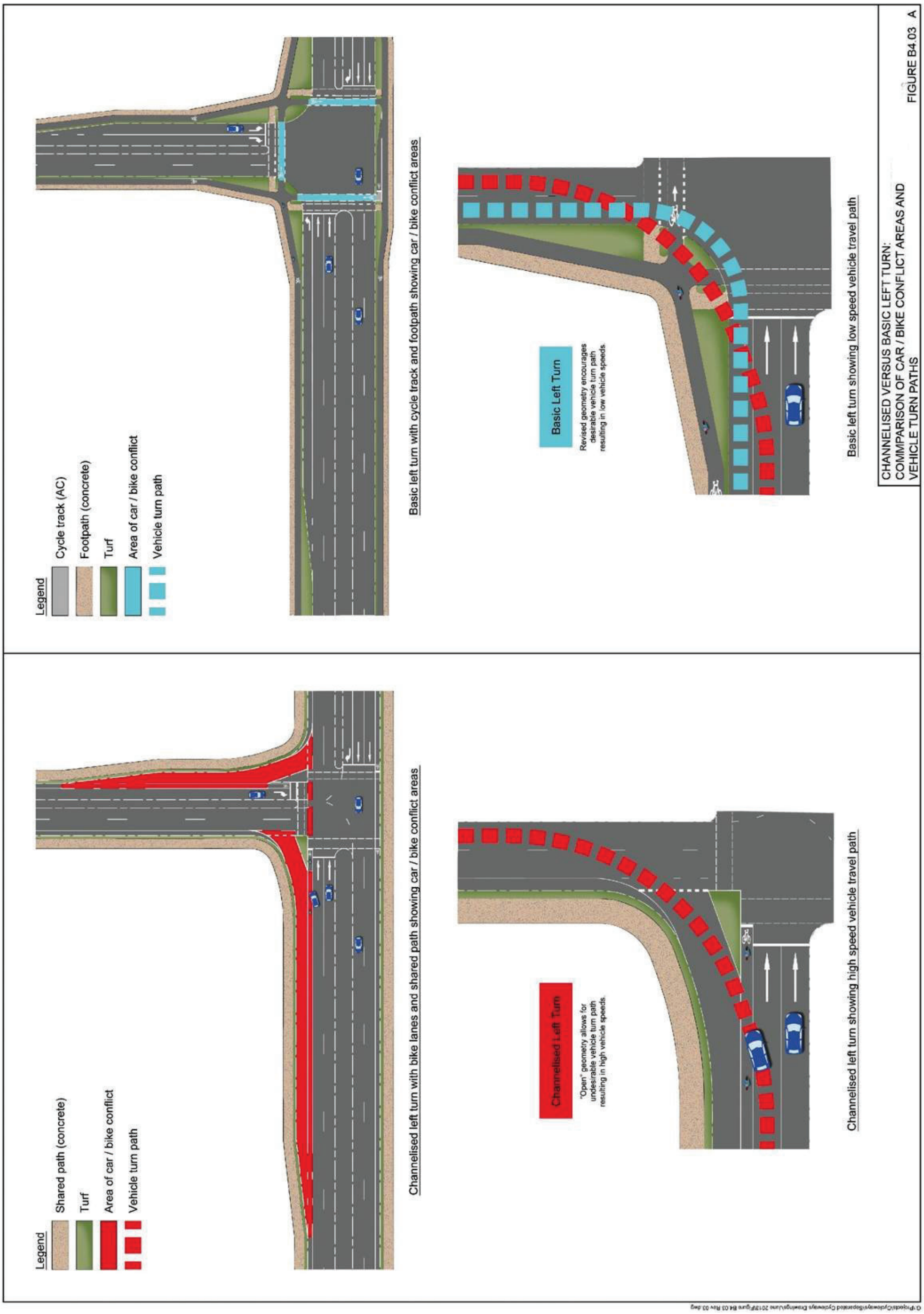
Appendix B4.01: One-way cycle track at signalised t intersection (B4.01 a)



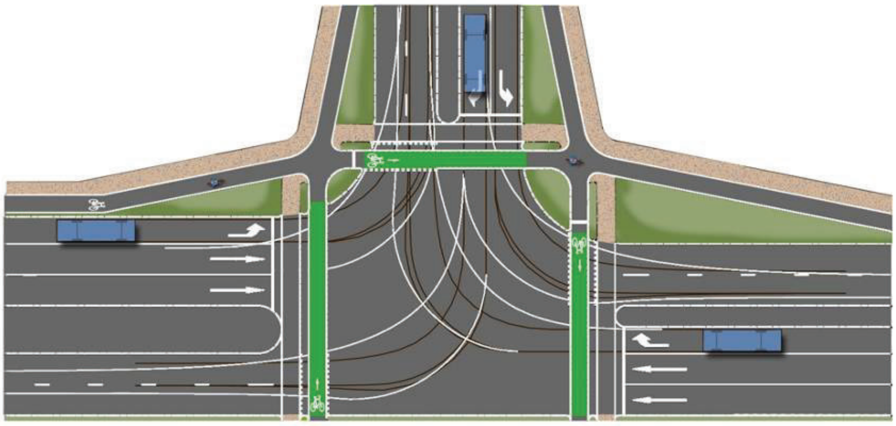
Appendix B4.02: Signalised four way intersection with one-way and two-way cycle track



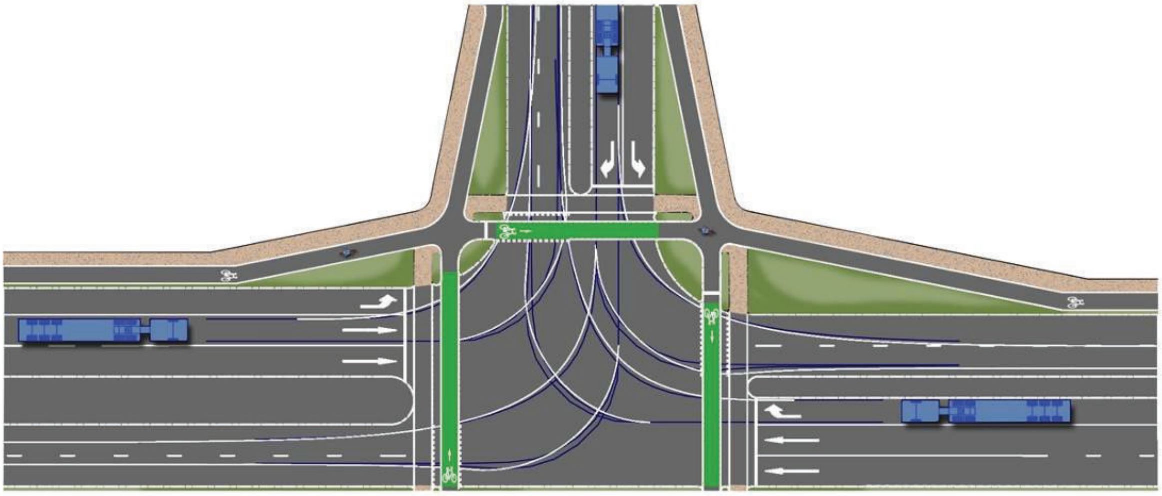
Appendix B4.03: Channelised versus basic left turn comparison of car/bike conflict areas and vehicle turn paths



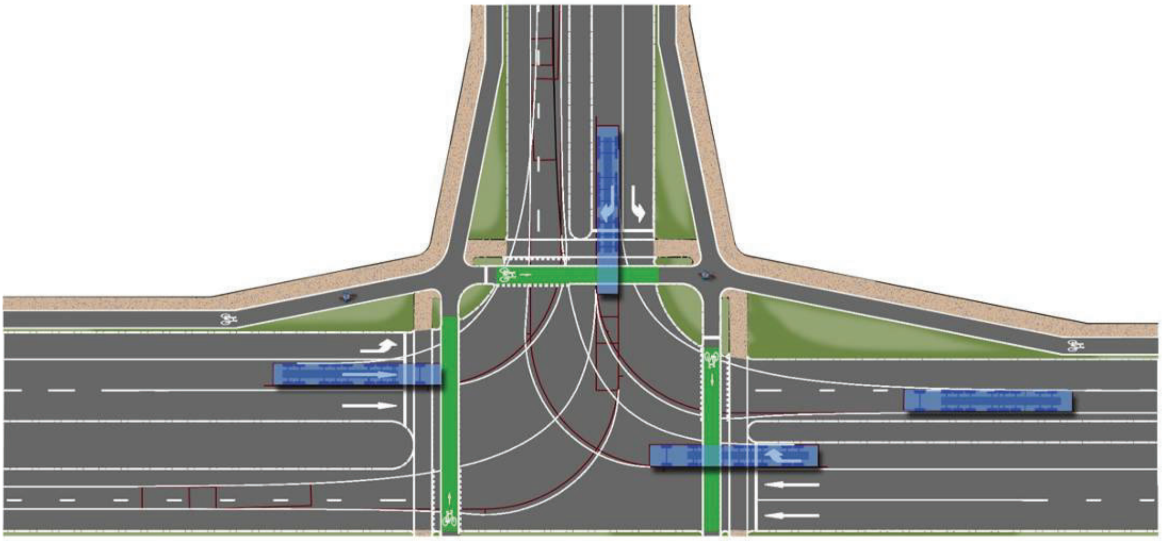
Appendix B4.04: Turn movements for service vehicles



Turning movements: Service vehicle (R12.5m)



Turning movements: 19m semi (R12.5m)



Turning movements: 19m semi (R15m)

TURN MOVEMENTS FOR SERVICE VEHICLE AND 19m SEMI AT
SIGNALISED T-INTERSECTION WITH ONE-WAY CYCLE TRACK

FIGURE B4.04 A

Appendix B5.01: Dual kerb cycle track at indented bus stop

Appendix B5.02: Dual kerb cycle track at constrained bus stop

For details contact: jonathan.p.giles@tmr.qld.gov.au

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