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AUSTROADS RESEARCH REPORT

# Cycling on Higher Speed Roads


Austroads

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# Cycling on Higher Speed Roads

Austroads

Sydney 2012

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- provide expert technical input to national policy development on road and road transport issues
- promote improved practice and capability by road agencies.
- promote consistency in road and road agency operations.

Austroads membership comprises the six state and two territory road transport and traffic authorities, the Commonwealth Department of Infrastructure and Transport, the Australian Local Government Association, and NZ Transport Agency. Austroads is governed by a Board consisting of the chief executive officer (or an alternative senior executive officer) of each of its eleven member organisations:

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- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department of Planning, Transport and Infrastructure South Australia
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- Department of Lands and Planning Northern Territory
- Department of Territory and Municipal Services Australian Capital Territory
- Commonwealth Department of Infrastructure and Transport
- Australian Local Government Association
- New Zealand Transport Agency.

The success of Austroads is derived from the collaboration of member organisations and others in the road industry. It aims to be the Australasian leader in providing high quality information, advice and fostering research in the road transport sector.

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# SUMMARY

This report investigates the provision of facilities for bicycles on sealed roads with speed limits of 70 km/h or more. It outlines how to improve these roads for cyclists where off-road alternatives or on-road, lower speed, direct options are not available.

It is a challenging area because the differences in speed and mass of bicycles and high speed motor vehicles are very different. The greatest road safety benefit will be achieved by separating cyclists from high speed vehicles. However cyclists are lawful road users and they shouldn’t be restricted from roads unless alternatives are good quality, lower speed, just as direct and do not present a higher overall risk to cyclists. Australian jurisdictions have adopted the safe systems approach which seeks to provide a road system which ensures no road user is killed or seriously injured.

International guidelines and practice in ‘cycling’ countries such as the Netherlands and the UK provide cyclists with paths separated from high speed traffic. In Australia and NZ, jurisdictions are providing more off-road paths along urban freeways and generally sealed shoulders along high speed rural roads.

Techniques for improving the cycling space may fall under planning (e.g. developing networks), engineering (e.g. space on roads), education (e.g. advertising campaigns), encouragement (e.g. behaviour change) and enforcement (e.g. policing). This report focuses in particular on engineering techniques (and substitutes) to help reduce the inherent conflict to more acceptable levels. These include:

- providing an alternative route, such as an off-road path or an alternative lower speed route
- providing space on-road
- reducing the speed limit
- using non-infrastructure solutions such as technology and advertising campaigns (for example, real time information may be provided for drivers to alert them that a cyclist is present).

Ways in which space can be provided on high speed roads include:

- Using exclusive bicycle lanes. These should be at least 2 m wide, increasing in width with increasing vehicle speeds. Bicycle lanes wider than 2.5 m should be separated from the general traffic lane in some way (e.g. painted buffer zone, raised separator, off-road) to discourage drivers from using the bicycle lane as a general traffic lane.
- Using sealed shoulders. As for bicycle lanes, sealed shoulders should be at least 2.0 m on high speed roads. Shoulders should ideally be sealed with asphalt (urban areas) or a spray seal with stone size of 10 mm or less. Additional width should be provided where there are a large number of heavy vehicles.
- At intersections. Designers should continue bicycle lanes and shoulders through the intersection, ensuring the side road stop line and median are set back by at least 2 m from the edge of the traffic lane. It may also be desirable to reduce the number of conflict points by grade separating cyclists from other traffic.
  - At signalised intersections, provide cyclists with advanced stop lines, assistance in turning right and ensure detection equipment can detect cyclists where needed.
  - At roundabouts, consider signalising the intersection, providing cyclists with a separate path, slowing vehicles or providing cyclists with an alternative route. This is the subject of a separate report by the ABC currently being undertaken.

— There are two types of diverge points: slip lanes and off ramps. Where slip lanes cannot be removed, the conflict point with through bicycles should be set back from the diverge point. Across freeway off ramps, cyclists can be diverted to a crossing point along the off ramp so that they are not trapped between two lanes of high speed traffic. Equivalent treatments can be employed at merge points.

— Consider the most appropriate delineation type in each situation: standard line marking (including painted islands), raised lines (audio tactile edge line), raised rubber separators or raised traffic islands.

Where space cannot be provided for bicycles, consideration may be given to allowing them to share a bus lane, which would desirably be between 4.5 and 5.0m wide.

There are two main maintenance practices that can be used to improve high speed roads for cyclists. The first is sweeping areas along identified bicycle routes that collect debris. This may include shoulders and bicycle facilities that are not swept in routine maintenance (e.g. a separated bicycle lane). Secondly, bicycles should be considered when resurfacing a road. This may result in using a smaller aggregate size to improve the surface, smoothing the cycling surface and providing additional space for cyclists.

Every situation is different and limitations may mean the level of provision presented here cannot be achieved in some situations. Risk of crashes, physical limitations, funding availability, the need to provide for other road users and the level of political will and community support will all influence the final facilities provided. This report discusses the importance of considering the benefits that can be gained by making incremental improvements for cyclists on high speed roads.

To better assist designers in providing for cyclists on high speed roads, the Austroads Guidelines can be modified by:

- discussing the benefits and disbenefits of reducing the posted speed limit, particularly for road users other than car occupants
- providing more information about bicycle lanes, including marking buffer zones
- providing more detailed information on how best to provide a sealed shoulder for cyclists
- providing more guidance on the preference of treatments for bicycles at intersections
- providing a more in depth discussion on available delineation treatments and in what circumstances they are best used
- discussing alternative solutions available.

# 1 INTRODUCTION

## 1.1 Purpose

This report investigates how best to provide facilities for cyclists on roads where the speed limit is 70 km/h or greater (referred to as high speed roads in this report). Current practice varies across Australia and New Zealand in how, and whether, provision is made for bicycle riders on high speed roads.

This report considers current practices and guidelines for bicycles on high speed roads, and how these may be improved based on existing practice and experience. This is a practical document, and recognises:

- There is an inherent risk where bicycles and high speed vehicles share road space, as for all road users. However as cycling is a legitimate transport mode and bicycles are legally allowed to use roads, people have a right to expect to be able to cycle safely.
- There are variations between riders and this influences what they need or expect from a bicycle facility.
- The practicalities and limitations in following best practice.

The report is designed to assist engineers and designers in planning on-road bicycle facilities where good quality, lower speed, direct alternatives are not available. It is for this reason that only limited reference is made to the provision of off-road alternatives.

## 1.2 Scope

This study focuses on how best to provide for bicycle riders on roads with traffic speeds of 70 km/h and above. These roads may be located in urban, peri-urban or rural areas. It is limited to on-road solutions, which according to the Austroads Guide to Road Design Part 3 (Austroads AGRD03 2010a) includes:

- lanes dedicated for use by bicycles, including those separated from motor vehicles
- sealed shoulders
- widened lanes for use by bicycles and motor vehicles (moving or parked)

This study applies only to roads where the carriageway (at least) is sealed. Unsealed roads do not have any line marking or delineation, so it is not possible to provide a dedicated on-road bicycle facility. It is also rare that bicycles use unsealed, high speed roads.

## 1.3 Methodology

This study involved the following stages, discussed in more detail in the following sections:

- research
- consultation
- review
- reporting.

#### 1.3.1 Research

A review of literature relating to bicycles on high speed roads was conducted, including published articles and design guidelines that were:

- publically available on the internet
- available through technical journals and conference proceedings
- Austroads guidelines and Australian Standards.

Most guidelines do not refer explicitly to bicycle facilities *on high speed roads*, except to emphasise the importance of separating bicycles from high speed traffic. This report considers guidelines as they were at the time of preparing this report (January 2011).

#### 1.3.2 Consultation

Phone conferences with state and territory transport agencies in Australia and NZ were conducted. These discussions with road and bicycle planners and engineers included:

- current practices in their jurisdiction and guidelines that are used in addition to the Austroads guidelines
- how the decision to exclude or provide for cyclists on freeways[1] is made
- thoughts for better providing for cyclists on high speed roads
- practicalities and limitations of doing so, and where the preference should be to provide alternative routes (either along other roads or paths).

#### 1.3.3 Review

Based on the findings of the research and consultation, best practice for providing bicycle facilities on high speed roads was identified. This report considers the factors that influence the best solution.

A review of the Austroads guidelines (and relevant Australian Standards) highlighted areas where Australian guidance:

- is silent
- conflicts with best practice
- is similar to best practice.

It makes judgements as to the relationship between the Austroads guidelines and best practice. From this, practical recommendations are made for bringing the guidelines in line with best practice.

#### 1.3.4 Reporting

The findings of the study were disseminated through this report and a web based toolkit developed for practitioners to readily identify practical treatments for their particular circumstance.

[1] This term is used throughout the report and includes motorways and access controlled highways

# 2 BICYCLES AND HIGH SPEED VEHICLES

High speed roads will always present a safety risk to all road users, including cyclists. This section discusses:

- crash severity
- acceptable risk
- policies
- design guidelines
- variation in cyclist requirements
- best practice.

## 2.1 Crash severity

There is overwhelming evidence that as vehicle speed increases so the injuries sustained in a crash tend to become more severe. This is particularly evident for vulnerable road users, including those riding bicycles and motorcycles, and pedestrians. Figure 2.1 summarises the evidence from Adelaide (McLean et al. 1994), the UK (Ashton and Mackay 1979) and Finland (Pasanen and Samivaara 1993) of the likelihood of a pedestrian fatality in a collision with a motor vehicle at varying speeds. A recent study of German crash data by Rosén and Sander (2009) found lower absolute fatality rates compared to these studies, but confirmed that the relative risk increases with increasing impact speed. Through all of these studies the main message remains the same. When a pedestrian is hit by a vehicle at 70 km/h or above they have only a small chance of survival.

A similar speed/fatality relationship also applies for cyclists because of the large difference in speed and mass between bicycles and motor vehicles, and the absence of significant protective equipment on a cyclist. Boufous et al. (2010) reviewed Victorian cycling injury data and determined that a collision on a high speed road increased the likelihood of a serious or fatal injury, and that 22% of police reported crashes involving cyclists were on high speed roads. Kim et al. (2006) also explored factors that contribute to the severity of cyclist injuries in crashes involving motor vehicles. It found:

> as estimated vehicle speed prior to impact increases beyond 32.2 km/h (20 mph) there is a threshold effect, which greatly increases the probability of injury or fatality in an accident... As speeds pass 64.4 km/h (40 mph) the change in probability of fatal injury in an accident exceeds 1000%, indicating a more than 11-fold increase in the probability of fatal injury in high-speed accidents (Kim et al. 2006 p. 247).

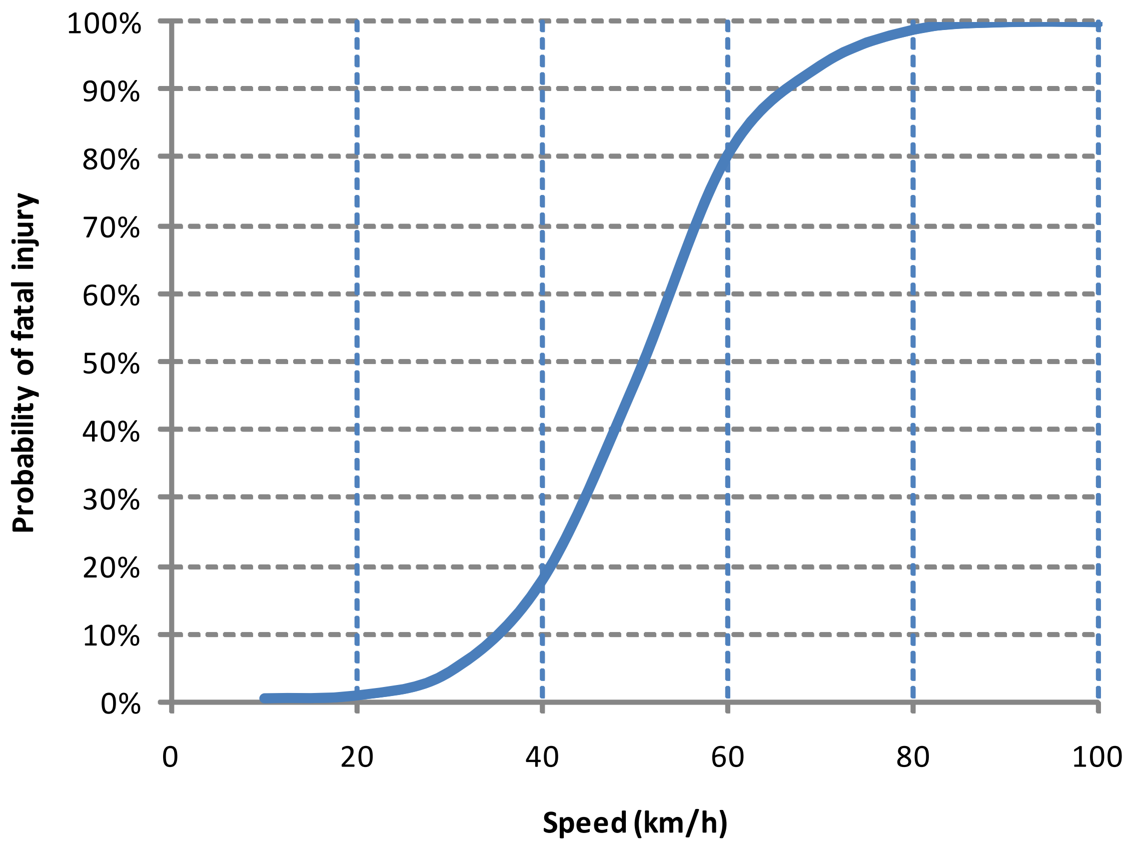


Figure 2.1: Probability of pedestrian fatality by motor vehicle speed

Klop and Khattak (1999 p. 84) investigated factors influencing the crash severity of cyclists on undivided roads in North Carolina. It found:

> roadway characteristics that increased severity were speed limit, straight grades, and curved grades, again likely related to driver- and cyclist-impaired braking, acceleration, and manoeuvrability. Environmental factors including fog and unlighted darkness increased injury severity, most likely related to their effect on driver reaction time and speed differentials at the point of impact. Average annual daily traffic, an interaction of the shoulder-width and speed-limit variables, and street lighting were associated with decreased injury severity.

Although the severity of crashes involving bicycles and motor vehicles has been studied in detail, there is much less evidence available on injury risk. This is because of the limited exposure data available to estimate injury likelihood (e.g. cyclist counts). The risk of a crash may be increased when the rider or driver is inexperienced, or when heavier vehicles such as buses and trucks are involved because of reduced vision and higher mass.

## 2.2 Acceptable risk

High speed motorised traffic brings with it inherent safety risks for all road users. The elimination of bicycle-vehicle crash risk altogether would require either the removal of cyclists or the removal of motor vehicles from a road. Some jurisdictions ban cycling altogether on some types of high speed roads (e.g. freeways); others allow cycling under certain conditions. In some locations, the reaction to (driver and cyclist) safety on high speed roads has been to ban cyclists from the roads altogether without providing alternative routes. Such a reaction may solve the local issue (provided people obey it) but the wider issue of how to provide a realistic cycling network with acceptable levels of safety remains. Furthermore, it is possible that redirecting cyclists to use an alternative route may expose them to greater overall risk. For example, removal of cyclists from grade-separated freeways onto busy urban arterial roads may present greater risks due to closer proximity of motor vehicles and cyclists, kerbside parking and at-grade intersections.

The community makes implicit judgements as to acceptable levels of road safety and crash risk. In practice some level of risk is deemed acceptable in order to obtain the obvious benefits that come from travel. Techniques to reduce the level of risk to acceptable levels include the separation of bicycles in space (e.g. a separate path, road widening, shoulder sealing, delineation and barriers) or separation in time (e.g. traffic signals). This report considers both techniques.

Many jurisdictions in Australia and overseas are moving towards a safe systems approach to road safety, which raises the bar for what is considered acceptable crash risk. According to Austroads AGRD03 (2010a p. 4):

> adopting a safe system approach to road safety recognises that humans, as road users are fallible and will continue to make mistakes, and that the community should not penalise people with death or serious injury when they do make mistakes. In a safe system, therefore, roads (and vehicles) should be designed to reduce the incidence and severity of crashes when they inevitably occur.

The National Road Safety Strategy for Australia (Australian Transport Council, 2011) reinforces Australia's formal adoption of the Safe Systems Approach in which no person should be killed or seriously injured on the road. It also outlines the commitment to improve the safety of roads for cyclists along with other road users, with one of the key challenges being to reduce the number of serious casualty crashes involving cyclists.

Given the difference in speed and mass between high speed motor vehicles and cyclists, the safe system approach would dictate that sharing such road space would not be acceptable. However, as discussed later in this report in practice there are valid reasons to retain cyclist access to high speed roads in many circumstances.

## 2.3 Variation in the cycling community

When providing for bicycle riders, designers should consider the types of people who are likely to want to ride, and for what purpose they would choose to cycle. Austroads AGRD06A (2009d) outlines six basic requirements for everyone who cycles, both on roads and on paths:

- **Space to ride.** This includes a 1 m wide design envelope free of obstacles and wide enough to cater for the expected number of people.
- **A smooth surface, free of debris.** Cyclists require a smoother surface than is acceptable for motor vehicles.
- **Speed maintenance.** Bicycles can be effective as a means of transport if cyclists do not have to slow or stop often, as it takes significant effort and time to regain speed.
- **Appropriate sight lines to path surface.** Bicycle routes should be designed in the same way as roads, with sight distances and curves that are appropriate for the users.
- **Connectivity.** This refers to facilities that are continuous and provide connections to places people want to ride.
- **Information.** Cyclists should be provided with information about upcoming destinations and distances to them.

However the guidelines also acknowledge that there are different types of cyclists and ‘human and other factors’ will influence their needs and behaviour.

> Cycling on freeway or motorway shoulders and other high speed roads is only appropriate for experienced riders and such facilities cannot form part of the general bicycle network ... where comfortable and safe sharing of roads is not achievable due to high speeds some form of separation is needed such as sealed shoulders or off-road paths (RTA 2005 pp. 14 - 15).

There are three main reasons that cyclists ride on high speed roads. The reasons encompass purpose, experience and risk aversion. The main reasons, in no particular order, include:

- **Sporting**. Cycling trips where the trip itself is the primary objective, such as for fitness, often for long distances at high speeds and sometimes in large groups. People cycling for this reason generally prefer on-road, direct routes.
- **Touring**. People riding around to explore an area, sometimes for many days at a time.
- **Commuter and utility**. People riding for a specific purpose e.g. to work, the shops.

Ideally, all high speed roads would cater for this range of abilities with a good quality sealed shoulder or bicycle lane (for roads that are not access controlled) and an off-road path. The on-road route is generally more suitable for people wanting to move fast (e.g. training) and the off-road path would be more suitable for cyclists who want to feel safe and be away from high speed traffic, sometimes at the expense of speed. An alternative route with lower traffic speeds may also be beneficial. However the best solution will depend on the road environment. DfT (2008) recognises that along a road with lots of intersecting roads and driveways, an on-road route may be more attractive than an off-road route as priority may be better retained. It also notes that on-road cyclists need more separation from vehicles as the difference in speed increases.

## 2.4 Best practice

The importance of separating bicycles from high speed vehicles is well established. Boufous et al. (2010 p. 12) found that:

> the association between higher speed limits and increased crash risk and injury severity for cyclists ... suggests the need for the separation of bicyclists from high-speed traffic. For example, separate bicycle paths on roadways that have a speed limit of over 60 km/h and over should be considered ... Consideration should also be given to lower speed limits on popular cycling training routes.

The findings of Kim et al. (2006 p. 249) ‘suggest the importance of separating bicycling from high-speed traffic, for example separate bicycle paths on roadways that have a speed limit of 50 km/h or over’.

Table 2.1 outlines the practice in other countries in providing for bicycles along high speed roads. In all cases the international guidelines recommend that cyclists are separated from high speed traffic, generally by providing an off-road path although in some circumstances bicycle lanes are acceptable.

Table 2.1: International practice in providing for cyclists on high speed roads

| Country | Practice | Reference |
|---|---|---|
| UK | Where the 85th percentile speed is greater than 40 mph (64.4 km/h), segregated bicycle facilities (tracks/paths) should generally be provided. For high speed roads with low traffic volumes (less than 3,000 vehicles per day/less than 300 vehicles in the typical AM peak hour), on-road bicycle lanes may also be considered. | TfL (2005) |
| Germany and Denmark | Provision of fully integrated off-road paths and bicycle lanes along roads and at intersections in cities and surrounding areas. | Pucher and Buehler (2008) |
| The Netherlands | Cyclists should always be separated from high speed traffic by providing a separate path or alternative (cycling) route. Consideration should also be given to lowering traffic speeds. | CROW (2007) |
| New Zealand | On urban roads with a speed limit of 80 km/h or more, cycle paths should be provided. Where speed limits are 70 km/h, sealed shoulders may be acceptable where there are fewer than 2,000 vehicles per day. | LTSA (2004) |

Therefore international best practice for providing a cycling network on high speed roads is to provide cyclists with space separated from motor vehicles that forms a complete network. All new major roads should include an off-road shared path as part of the project. However there are practicalities and limitations to providing this on every high speed road in Australia and New Zealand. This is discussed in Section 4.1.

### *2.4.1 Design guidelines*

Many jurisdictions, including NSW (RTA 2005); Queensland (Queensland Transport 2007); NZ (LTSA 2004, shown in Figure 2.2); the UK (TfL 2005; DfT 2008; DTO 2002) and the Netherlands (CROW 2007) provide guidance about the most suitable type of bicycle facility on urban roads based on the traffic speed and volume. At traffic speeds of 80 km/h and above, a bicycle path separated from the road is almost universally the recommended treatment (for example, see Figure 2.2). On 70 km/h urban roads with low traffic volumes, and all high speed rural roads, some guidelines suggest sealed shoulders (or bicycle lanes) are also acceptable.

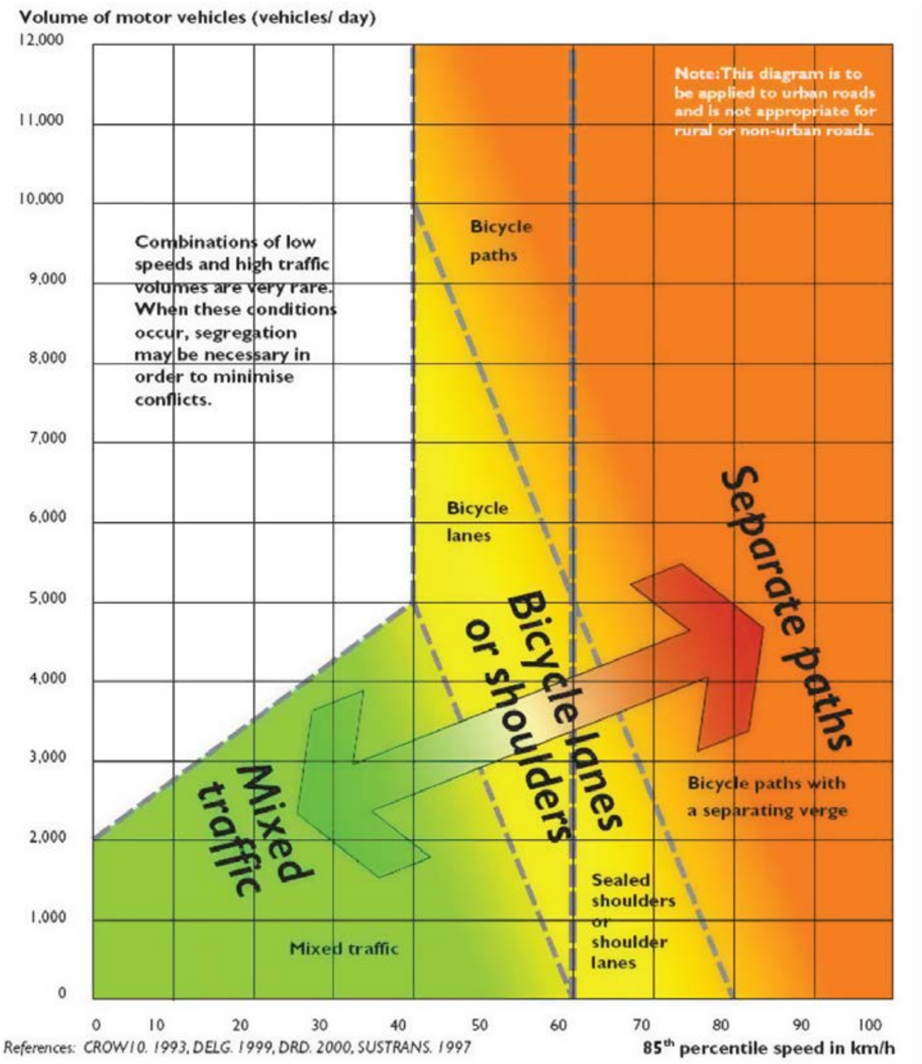


Figure 2.2 Preferred separation of bicycles and motor vehicles according to traffic speed and volume (Austroads AGTM04 (2009f))

Figure notes:

- In general, roads with higher traffic speed and traffic volumes are more difficult for cyclists to negotiate than roads with lower speeds and volumes. The threshold for comfort and safety for cyclists is a function of both traffic speed and volume, and varies by cyclist experience and trip purpose. Facilities based on this chart will have the broadest appeal.
- When school cyclists are numerous or the route is primarily used for recreation then path treatments may be preferable to road treatments.
- Provision of a cycle path does not necessarily imply that an on road solution would not also be useful, and vice-versa. Different kinds of cyclists have different needs. Family groups may prefer off-road cycle paths while racing or training cyclists, or commuters, tend to prefer cycle lanes or wide sealed shoulders.

In the UK, DfT (1987) recommends that cyclists are not encouraged to use high speed rural roads because of the high risk of injury and vulnerability of cyclists in a crash. It recommends a bicycle track in the verge, segregated from any footpath, along routes with 200 or more cyclists per day. In the Australian context, there are few high speed roads outside urban areas that would have anywhere near 200 cyclists per day. Other UK guidelines (DfT 2008; DTO 2002) reinforce the preference for segregated paths on high speed roads.

### *2.4.2 Policies*

Many current federal and state/territory design guidelines and policies require designers and engineers to consider the safety of all road users in new roads and upgrades. How the policies translate into practice varies. However most Australian states and territories now include off-road paths for people who want to walk or cycle when new major urban roads are constructed. Along with simply providing for cyclists, many jurisdictions also have policies which actively encourage a mode shift from private cars to bicycles (and other sustainable modes). Australian state and territory bicycle strategies (e.g. City of Sydney 2007, DTEI 2006, Queensland Transport 2003, and VicRoads 2010) suggest separating cyclists from high speed traffic to encourage less confident people to ride and also increase the number of trips made by bicycle.

### *2.4.3 State and territory practice*

Most jurisdictions in Australia and New Zealand follow the Austroads Guidelines in providing for cyclists on high speed roads, with some having additional, supplementary guides. Generally cyclists are permitted to use high speed roads, with restrictions often due to road geometry (e.g. squeeze points) rather than risks relating to high traffic speeds. The Australian Road Rules do not require specific users to be prohibited. However, they do make allowances for prohibition. Austroads AGRD04C (2009b) suggests that safety should be the main consideration in this decision.

There are two main approaches taken by Australian and New Zealand road authorities:

- Provide for existing cyclists but don't actively promote high speed routes to new cyclists (risk management). These jurisdictions tend to improve the existing conditions for cyclists (e.g. install, widen or smooth shoulders) but do not identify them as cycling facilities.
- Provide marked cycling facilities wherever possible. This can include both 'official' bicycle facilities (e.g. bicycle lanes) and 'unofficial' bicycle facilities (e.g. a shoulder with painted bicycle symbols, which has no legal status as a bicycle facility).

The following sections outline the practices in each Australian state and territory and New Zealand in providing for cyclists on high speed roads. They are based on information provided by each of the jurisdictions in teleconferences and subsequent emails.

*Australian Capital Territory*

All roads in the ACT are available for use by cyclists. Most high speed urban arterial roads include on-road bicycle facilities. These take the form of either a marked bicycle lane or a shoulder with a painted bicycle symbol. When new urban roads are constructed, bicycle lanes are included. Off-road paths are also provided along many high speed roads, but these tend to be less direct and are provided for cyclists who prefer not to ride along the road.

Along identified cycle routes where there is insufficient road width to install bicycle lanes, TAMS have used the following techniques:

- narrow the traffic lanes (down to 3.3 or 3.0 m) to provide sufficient space to install bicycle lanes
- provide an alternative option (e.g. off-road path or bicycle friendly local street)
- provided an unmarked shoulder

*New South Wales*

Cyclists are permitted to use most roads in NSW, including urban freeways. They are banned on some sections of high speed road where there are lengthy tunnels or no shoulders. In these cases, RTA tends to provide an alternative route (e.g. shared path). Some arterial roads don't have space for bicycle lanes or shoulders, so the high speed routes are actually more attractive and possibly safer.

Shoulders are provided on many urban high speed roads, generally as a part of the vehicle requirements (e.g. space to pull over, correct). RTA tends to provide for existing cyclists on high speed roads (e.g. training cyclists) rather than encouraging new cyclists. Therefore most shoulders are not marked as bicycle facilities. Along some high speed roads, alternative off-road paths are provided as well as shoulders. For example, along the M7 Westlink, some cyclists choose to use the shoulder and others prefer to use the parallel off-road path.

*New Zealand*

Cyclists are permitted on all roads except motorways (generally controlled access roads with a 100 km/h speed limit). NZTA don't proactively encourage cyclists on high speed roads, but do try to provide for existing demand. The exception is cycle tourism for which national off-road bicycle trails are built. When new motorways are built, parallel off-road paths or low speed alternative routes are generally provided. If cyclists are permitted to use a new high speed road, then designers must consider providing shoulders for the entire length, including across bridges and at ramps.

In rural areas along routes with higher cyclist volumes, NZTA generally provide unmarked shoulders. In aiming to provide a minimum standard of safety for cyclists on rural roads, shoulders are sometimes added when they are upgraded. There are also a few examples of dedicated bicycle facilities on high speed roads (either a bicycle lane or off-road path).

*Northern Territory*

Cyclists are permitted on all roads in the Northern Territory with the exception of some parts of the interchange of Tiger Brennan Drive and the Stuart Highway where the risk to cyclists interacting with other traffic is unacceptable.

Extensive networks of off-road facilities are provided in major urban areas of the Territory and some arterial roads have wider kerbside lanes to enable shared on-road cycling.

*Queensland*

Cyclists are permitted on most roads, except for some motorways. The Queensland Planning and Design Manual contains an appendix which outlines warrants for prohibiting cyclists on motorways. This requires a full assessment of risks and options and consultation with stakeholders before cyclists are prohibited from a particular road.

Due to the high cost of providing shoulders on rural roads, they are generally provided primarily for road safety and maintenance benefits, with use by cyclists a secondary benefit. Often they are sealed with 14 mm aggregate to reduce costs.

There is currently a proposal to amend the Road Planning and Design Manual. This would require all new roads and major road upgrades in rural areas to include a sealed shoulder unless there are fewer than 300 vehicles per day and it is not a priority cycling route. The required width depends on whether it is a priority cycle route and the average annual daily traffic.

*South Australia*

Cyclists are permitted on all roads except three motorways, which have controlled access and speed limits of 100 kph or more. Two of these are in peri-urban settings and have parallel shared paths along the full length of the road. The third is predominantly a rural motorway and has an off-road path part of the way with an alternative on-road route for the remainder.

Along routes in non urban areas that have been identified where a large number of training cyclists are expected:

- Shoulders are sealed using a mix of 10 and 5 mm aggregate to ensure a smooth surface. These are not marked with bicycle symbols.
- If it is not possible to provide shoulders, bicycle warning signs and supplementary distance plates are erected at locations where it may be difficult to see cyclists in advance (e.g. on high speed, narrow roads with sharp bends or crests).

*Tasmania*

Cyclists are permitted to use all roads in Tasmania. Off-road paths are provided along some high speed roads, particularly on recently constructed highways. In some other areas efforts have been made to provide adjacent off-road or alternative on-road routes with lower traffic speeds and volumes.

The Department of Infrastructure, Energy and Resources provides unmarked sealed shoulders of various widths on some high speed roads. In the past, these shoulders have been provided mainly with motor vehicle safety and maintenance benefits in mind. Increasingly consideration is being given to provision of sealed shoulders that also meet the needs of cyclists, with regard to width, seal treatment, maintenance regime and other factors.

In a few peri urban environments, shoulders of various widths have been marked with bicycle symbols.

*Victoria*

Cyclists are permitted on most roads except for access controlled urban freeways. Exclusion from urban freeways is because of the risk posed by double lane on and off ramps and sections of narrow road shoulders (e.g. at bridge abutments). Other high speed urban roads sometimes contain wide kerbside markings, formal bicycle lanes or off-road paths to provide for cyclists. All new urban freeways from which cyclists are prohibited must consider the provision of an off-road parallel shared path.

In rural areas, sealed shoulders are provided on some high speed roads. Generally these are not marked as bicycle facilities.

*Western Australia*

Cyclists are permitted on most urban state roads with the exception of Control of Access Highways. Where cyclists are excluded on-road then off-road facilities, typically in the form of Principal Shared Paths (PSP's), are provided within the adjacent road reserve. PSPs have either been provided or are planned to be provided alongside all freeways and Control of Access Highways that are planned as future freeways.

Sealed shoulders are the preferred facility for on-road cycling in locations where, for a particular reason, on-road cycling facilities are preferred to paths. In such cases sealed shoulders are provided on new high speed roads and are considered in the scope of improvement works to existing roads.

Sealed shoulders, to the same standard as on urban roads, are the preferred facility on rural high speed roads where the expected number of cyclists are used to warrant their provision.

# 3 HOW TO PROVIDE FOR BICYCLES

Based on the considerations of the previous sections, this section discusses how best to provide for cycling on high speed roads (Figure 3.1). However, as discussed in Section 2.3, the most suitable provision will depend on a person's reason for cycling and trade off between feelings of safety (e.g. separation from traffic) and speed or directness (e.g. on-road lanes).

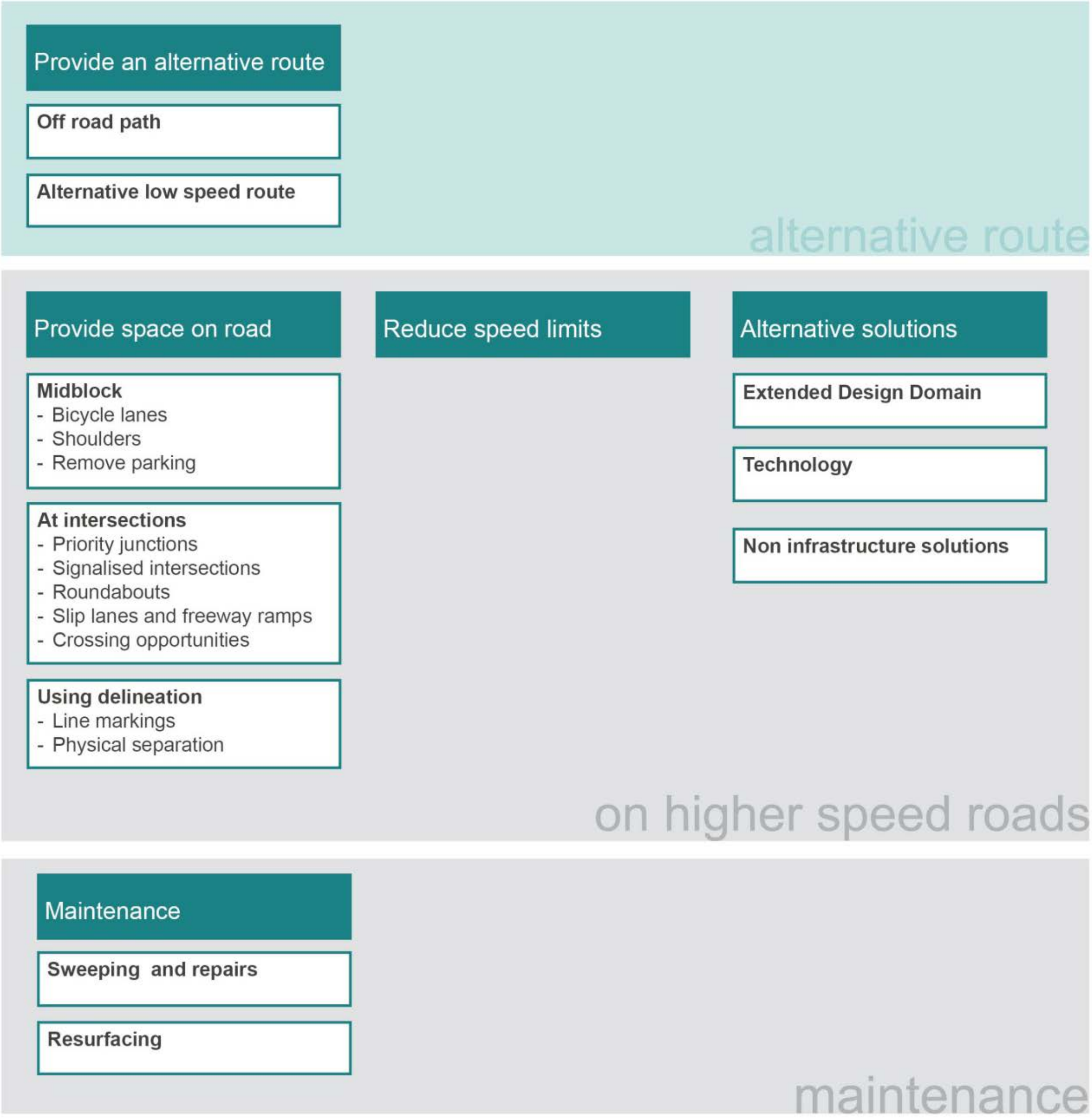


Figure 3.1: Considerations for providing for bicycles on high speed roads

## 3.1 Summary of treatments

Table 3.1 summarises best practice for each of the road elements discussed in this report. It considers the best solution for the main types of cyclists found on high speed roads (training, touring, utility and commuter). The remainder of this chapter describes these practices in more detail. Other cyclist types may use high speed roads (for example children in the vicinity of a school) and designers need to also consider and cater for these situations.

Table 3.1: Matrix of best practice in providing for bicycles on high speed roads

| Road design element | Summary | Section ref |
|---|---|---|
| Provide an alternative route | Provide an off-road path to separate cyclists from high speed motor vehicles.<br>Provide an alternative on-road cycling route that is good quality and lower speed. | 3.2 |
| Provide space on-road | | 3.3 |
| Midblock | Provide exclusive bicycle lanes at least 2 m wide, wider as vehicle speeds get higher. Bicycle lanes wider than 2.5 m should be separated from the traffic lane in some way (e.g. painted buffer zone, raised separator, off-road).<br>Provide sealed shoulders for cyclists at least 2 m wide, wider as vehicle speeds get higher. Shoulders should be sealed with asphalt (urban areas) or a spray seal with stone size of 10 mm or less.<br>Prohibit on street parking and provide off street parking where possible so that parked cars do not force cyclists into the traffic lane. This is particularly relevant in rural tourist areas.<br>Ensure items such as drainage grates and line markings are flush with the road surface and well designed so they do not create a hazard for cyclists.<br>Where the proportion of heavy vehicles is greater than 10% provide a shoulder or bicycle lane at least 2.5 m wide.<br>Where a separate space cannot be provided for cyclists and they are to share a bus lane, the desirable width of the shared lane should be between 4.5 and 5.0 m. | 3.3.1 |
| At intersections | At priority junctions, set back the minor street stop line and median by at least 2 m from edge of the main road traffic lane. Provide cyclists with an exclusive bicycle lane even where there is not one midblock.<br>At signalised intersections, provide advanced bicycle stopping facilities on all approaches and assist right turning cyclists (e.g. jug handle see Figure 3.6). Enhance the signalling for cyclists. Further information on providing for bicycles at signalised intersection is available in Austroads (2011).<br>Research has found bicycle lanes within roundabouts may be less safe than shared lanes (e.g. Boufous *et al*. 2010). Alternatives include signalising, providing an off-road path, slowing vehicles or providing an alternative route. This subject is currently under review as part of an Australian Bicycle Council research project.<br>There are two types of diverge points: slip lanes and off ramps. At slip lanes, the conflict point with through bicycles should be set back from the diverge point and consideration should be given to tightening geometry to slow vehicles. Across freeway off ramps, cyclists can be diverted to a crossing point along the off ramp. Equivalent treatments can be employed at merge points.<br>Where there are likely to be insufficient crossing opportunities for cyclists (at merge and diverge points or midblock) installing treatments such as grade separation or signalisation may assist them. | 3.3.2 |
| Using delineation | Audio tactile edge markings should be used in rural areas where the shoulder is sealed and sufficiently wide for bicycles.<br>In urban areas, the delineation can be stronger, such as a raised rubber separator or a raised kerb. | 3.3.3 |
| Reduce speed limits | Lower speeds improve safety for all road users. | 3.4 |
| Alternative solutions | Consider incremental improvements where the guidelines cannot be met.<br>Use technology and non infrastructure solutions to further improve cyclist safety on high speed roads. | 4 |
| Maintenance | Along high speed roads in urban areas and popular rural cycling routes consider the timing and frequency of sweeps.<br>Repairs to surfaces to ensure a smooth, even surface is retained.<br>Consider realigning traffic lanes to provide space for cyclists when road is resurfaced. | 5 |

## 3.2 Provide an alternative route

In some circumstances it will be possible to provide an off-road path or alternative, lower speed road route. This report does not cover the design of off-road paths, however Austroads AGRD06A (2009d) provides some guidance. Off-road paths should be sufficiently protected (e.g. fenced) or separated (e.g. distance) from a road to ensure path user safety. In areas where cyclists are permitted to ride on the footpath, this may form part of an off-road route.

> Bicycles are vehicles and have the same rights to use the highway network as other vehicles - except where prohibited. Their removal from otherwise safe carriageways should be the last resort “unless they (the treatments employed) offer greatest overall advantage” (TfL 2005 p. 78).

Consider the relative risk of restricting bicycles from a road:

- Is the problem ‘real’ or perceived?
- What are the alternative routes and do they provide a good quality alternative? This may include physical considerations (e.g. traffic volumes, lane widths, on street parking, risk of ‘dooring’ and surface quality) and personal safety considerations.
- Is a ban likely to be obeyed?
- Is the alternative suitable for all weather and light conditions?
- What is the reaction from drivers likely to be (on both the existing and alternative routes)?

It is possible, for example, that the risk profile on a lower speed arterial road may be higher than on a grade-separated freeway. Furthermore, it is important to consider the cyclist needs – utilitarian cyclists generally prefer a direct route, while training cyclists are unlikely to tolerate paths or road routes that have regular stops.

## 3.3 Provide space on-road

### *3.3.1 Midblock*

If bicycles are permitted to use the road, then there are two types of on-road facilities that can be provided: bicycle specific facilities (e.g. a bicycle lane) or general facilities (e.g. a smooth shoulder free of debris). In some cases, the two are physically identical except for regulatory bicycle lane signs and pavement markings.

> A sealed shoulder separated from motor vehicle traffic lanes by an edge line is appropriate for bicycle use where the shoulder is wide enough to accommodate bicycles but bicycle numbers or other traffic conditions do not require it to be signed as a bicycle lane. A sealed shoulder will not normally require signs or markings related to bicycle use, but if some bicycle traffic is expected, the Bicycle warning sign ... or bicycle pavement symbols, or both, should be considered. Pavement symbols at up to 1 km spacing will generally be adequate (Standards Australia 2000 p. 16).

In some places, the road shoulder is marked with bicycle symbols, but signs are not erected and so it is not legally a bicycle lane. This may be done with the intention of providing cyclists with guidance about where to ride and alerting drivers to the possible use of the shoulder by bicycles.

#### *3.3.1.1 Provision and width of bicycle lanes*

In urban areas where roads often have kerbs, bicycle lanes are more commonly provided than shoulders. An exclusive bicycle lane is one used only by cyclists and not shared with other vehicles such as buses or parked cars. Transit New Zealand (2008) recommends 2.0 m as the minimum width of a bicycle lane in which one cyclist can overtake another without exiting the lane. Austroads AGRD03 (2010a) suggest increasing widths for exclusive bicycle lanes as traffic speeds increase. Table 3.2 compares these recommendations with other jurisdictions.

Table 3.2: Comparison of recommended exclusive bicycle lane widths on high speed roads in urban areas

| Jurisdiction | Recommended minimum bicycle lane width by speed limit (m) | | |
|---|---|---|---|
| | 60 km/h | 80 km/h | 100 km/h |
| Australia (Austroads AGRD03, 2009a) | 1.5<br>(1.2 – 2.5 acceptable) | 2.0<br>(1.8 – 2.7 acceptable) | 2.5<br>(2.0 – 3.0 acceptable) |
| NZ (Transit New Zealand 2008) | 2.0 where traffic speeds are high (e.g. 100 km/h) and there are few large vehicles, or where traffic speeds are moderate (e.g. 70 km/h) and there is a substantial number of large vehicles<br>Max of 2.5 – beyond this paint the area between the traffic and bicycle lanes with chevrons | | |
| Canada (City of Ottawa 2000) | 2.0<br>1.5 is acceptable where there is limited space<br>2.5 when traffic volumes and speeds are high and there is a substantial number of large vehicles | | |
| US (AASHTO 1999) | 1.5 | Additional width above 80 km/h or where there is a substantial number of trucks | |
| UK (DfT 2008) | 2.0 for speeds above 64 km/h (40 mph) | | |

Austroads AGRD03 (2009a p. 68) adds that:

> the width of the lane is normally measured from the face of the adjacent left hand kerb...surface conditions are to be of the highest standard [and] where there are poor surface conditions ... then the width of the exclusive bicycle lane should be measured from the outside edge of that section.

Where bicycles share a lane with parked cars, the lane must be wider, as outlined in Table 3.3. Transit New Zealand (2008) specifies similar lane widths, with an absolute minimum of 4.2 m along roads with mean vehicle speeds of 70 km/h.

Table 3.3: Bicycle/car parking lane dimensions (parallel parking) (Austroads AGRD03, 2010a)

| Speed limit (km/h) | Overall facility width (m) | |
|---|---|---|
| | 60 | 80 |
| Desirable | 4.0 | 4.5 |
| Acceptable range | 3.7 – 4.5 | 4.0 – 4.7 |

Notes: The posted or general speed limit is used, unless 85th percentile speed is known and is significantly higher.
Interpolation for different speed limits is acceptable.

If parking is permitted on the carriageway, consideration can be given to swapping the traditional positions of bicycle lane and parking lane so that cyclists are separated from moving vehicles by parked vehicles.

### Coloured surface treatments

Coloured surface treatments are used in bicycle lanes to better differentiate them from traffic lanes. They may increase driver awareness and expectation of cyclists, reducing the risk of crashes involving cyclists (Boufous et al. 2010). In Australia, their use on high speed roads has been limited. They are generally used only in bicycle lanes at conflict points e.g. a bicycle lane on approach to an intersection. Meldrum (2010) conducted a review of the use of coloured surfaces in bicycle lanes within Australia and found coloured surface treatments should be slip resistant and highly visible.

#### *3.3.1.2 Provision and width of a sealed shoulder for bicycles*

For the purposes of this report, a shoulder refers to the area on the left side of the carriageway and not to a median shoulder. According to Austroads AGRD03 (2010a), shoulders provide two functions; structural (lateral support to the road pavement) and traffic (e.g. space for vehicles to pull off to the side of the road, recovery for errant vehicles and space for cyclists).

In urban areas, shoulders are generally only provided on freeways. Austroads AGRD03 (2010a) recognises that they may also be used on major urban roads to provide space for cyclists.

**Traffic lane widths**

Edge lines marked at the edge of the traffic lane distinguish the traffic lane from the shoulder on a road with sealed shoulders, reducing the likelihood of moving traffic using the shoulder. Standards Australia (2009) outlines which roads require edge lines (Table 3.4).

Table 3.4: Requirements for marking edgelines, based on information in Standards Australia (2009)

| Road type | Divided? | Further description | Requirements regarding edge lines |
|---|---|---|---|
| Rural | No | Sealed pavements less than 5.5m wide | Edge lines shall not be used |
| | | Sealed pavements between 5.5m and 6.8m wide | Edge lines are generally not used unless the conditions are poor (e.g. poor alignment, frequent fog, etc). Edge lines shall not be used unless:<br>a dividing line is also marked and<br>the lane widths within the edge lines are at least 3.0m or if there is a high proportion of heavy vehicle traffic, 3.2m<br>There are some exceptions, for example at localised pavement narrowing. |
| | | Sealed pavements 6.8m wide or greater | Edge lines are normally required |
| | Yes | Including rural expressways | Edge lines shall be marked |
| Urban | No | Two lane unkerbed | Edge lines shall not be used unless the lane widths within the edge lines are at least 3.0m or if there is a high proportion of heavy vehicle traffic, 3.2m |
| | | Multi-lane kerbed | Edgelines may be used to separate a parking lane from a running lane |
| | Yes | Including one-way roads | Edge lines are normally required but may be subject to road authority practice.<br>Edge lines, if provided, shall be placed on both edges of an unkerbed one-way roadway.<br>Edge lines are not required on a kerbed roadway if the kerbs provide adequate edge delineation. |

Austroads AGRD03 (2010a) suggests that 3.5 m is generally sufficiently wide for a traffic lane that is used only by motorised vehicles and not shared with cyclists. There is little evidence to support the commonly held belief that wider traffic lanes lead to safer roads, particularly for lanes wider than 3.5 m (Austroads AGRD03 2010a, Dumbaugh 2005, Noland 2002, Parsons Transportation Group 2003). Where traffic lanes are wider than 3.5 m, reducing them and using the space at the edge of the road for cyclists instead may be a better overall use of the existing road width.

> On rural roads, wide lanes and narrow shoulders are less beneficial to cyclists than conventional width traffic lanes with wide shoulders. Therefore, on rural roads, wide shoulders are the preferred treatment (as opposed to wide lanes) if cycle lanes can not be provided (Transit New Zealand 2008 p. 11).

### Wide kerbside lanes

Lanes that allow bicycles and vehicles to share the lane side by side are referred to as wide kerbside lanes. These are generally between 4.2 and 5.0 m in width. Lanes wider than 4.6 m may result in cars travelling side by side in urban areas. On high speed roads, a better use of the width is to mark separate traffic and bicycle lanes/shoulders (Austroads AGRD03 2010a, Queensland Transport 2004).

### Sealed shoulder widths

The benefits of sealing a high speed road shoulder are broader than just improving the route for cyclists. This includes:

- improving road safety for vehicle occupants by increasing the space available for errant vehicles to correct, and reducing the risk of rolling or collision with fixed objects (Austroads AGRS05 2006c; Austroads AGRD03 2010a; City of Ottawa 2008)
- reducing maintenance costs (Austroads AGRD03 2009a; Litman et al. 2006; Transport Canada 2009)
- extending the life of the road (Litman et al. 2006)
- controlling the amount of moisture under the pavement (Austroads AGRD03 2010a)
- removing the drop off at the edge of the traffic lane (Austroads AGRD03 2010a)
- providing seal to a concrete gutter where roads are kerbed (Austroads AGRD03 2010a)
- providing space for slower road users such as tractors (City of Ottawa 2008)

Partially sealing the shoulder can minimise the effects of wind erosion on the unsealed section of shoulder (Austroads AGRD03 2010a).

Austroads recommends the minimum sealed shoulder widths shown in Table 3.5. It notes that the cost of maintaining a shoulder is not proportional to the width, although the initial construction or reconstruction cost may be significant. Standards Australia (2009) note that pavement widening may also be considered where the sight distance is reduced by a vertical curve. The same would apply for a horizontal curve that limits sight distance.

Table 3.5: Minimum sealed shoulder widths by road type (based on information in Austroads AGRD03 2010a)

| Road type | Minimum sealed shoulder width |
|---|---|
| Urban freeway | Between 2.0 and 3.0 m (3.0 m allows enough room for a truck to pull off clear of the traffic lane)<br>3.0 m adjacent to a safety barrier or on a freeway with 3 or more lanes |
| Rural road - single carriageway | Between 0 and 1.5 m, increasing with increasing traffic volumes |
| Rural road - divided carriageway | 1.5 m where design AADT < 20,000, or 2.5 m if it is beside safety barriers and on the high side of superelevation<br>3.0 m where design AADT > 20,000, or 3.0 m if it is beside safety barriers and on the high side of superelevation |
| General | A minimum of 0.5 m where AADT <1,000<br>Consideration should be given to sealing the full width of the shoulder under certain conditions (see p. 38 of Austroads AGRD03 2009a for a more extensive list)<br>A minimum of 2.0 to 3.0 m to cater for bicycles |

This suggests shoulders on roads with cyclists should be sealed to a width of at least 2.0 m. However it does not define when a road should cater for bicycles. MRWA (2000) suggests a sealed shoulder along main roads regularly used by more than 25 cyclists per day. Alternatively the decision to seal a shoulder may be more strategic, based on an understanding of local cyclist needs in the context of the overall network, combined with crash histories.

Other guidance suggests providing additional shoulder width on roads used by cyclists where traffic speeds are in excess of 80 km/h, there are a high percentage of heavy vehicles or where there are roadside objects, including a kerb (AASHTO 1999; City of Ottawa 2008; Litman et al. 2006).

Generally guidance suggests that shoulder widths should increase with increasing traffic volume. This recognises that the same two lane road with 200 vehicles per day feels very different to ride along than if there are 5,000 vehicles per day. Austroads AGRD03 (2010a) suggests that roads with less than 3,000 vehicles per day are generally suitable for cyclists and drivers to share the same space. However on high speed roads with volumes in excess of this, cyclists will be constantly passed by motor vehicles and sufficient width should be provided for them to travel side by side. It also notes that this applies both along the road and at intersections.

To further improve cyclist safety on roads with sealed shoulders:

- Shoulders should be continuous, particularly at pinch points such as bridges and intersections (Transit New Zealand 2008). Intersection treatments are described in Section 3.3.2 of this report.
- Gravel roads and driveways that connect to the main road should be sealed for at least 4.5 m from the road to reduce the amount of gravel shifting into the shoulder (Litman et al. 2006). This benefits motor cycle safety as well.

#### *3.3.1.3 Remove parking*

Parking on high speed roads is generally not permitted or practiced, except where roads have service lanes or in tourist areas. If parking presents a problem in providing for cyclists on a high speed road, consideration may be given to removing parking. Transit New Zealand (2008) suggests that on rural roads parking should be discouraged and off-road parking provided in places where parking is expected e.g. tourist areas.

#### *3.3.1.4 Pavement surface*

Along with providing cyclists with space to ride, it is important to ensure that the surface is smooth and free from obstructions. Raised obstructions are potential hazards to both cyclists and other road users as they may cause cyclists to act unpredictably in avoiding them.

The surface of the seal used in shoulders is an important consideration if it is expected that cyclists will use the shoulder. In urban areas, asphalt is commonly used and provides an acceptable surface if it is well maintained. However in rural areas, roads (and shoulders) are often sealed using a sprayed seal. A large aggregate generally feels rougher to cyclists and they may choose to ride in the traffic lane where the surface has been smoothed by vehicles. A stone size less than 14 mm provides a more comfortable ride for cyclists (Austroads AGRD06A 2009d).

The usual stone size used in spray sealing rural roads is 14 mm and so many authorities interested in providing for cyclists have begun thinking about how to address this. Perhaps the most obvious way is to use a smaller aggregate size. Austroads AGRD03 (2010a) suggests the use of a 10mm seal within 20 km of towns where cyclists are expected. However smaller aggregates are more expensive to use, and for road authorities managing hundreds of kilometres of road, this adds up to a significant cost. A smaller stone size may also be unsuitable along high volume truck routes.

Some innovative solutions are being used by Australian and New Zealand road authorities to avoid sealing the entire carriageway with 10 mm aggregate but still improving the shoulder for cyclists. These include:

- using a smaller aggregate size on the shoulders than in the traffic lanes
- using sand seals in the shoulder when only the traffic lanes are resurfaced to fill voids and improve the surface quality
- using a mix of smaller sized aggregates to make a smoother surface
- using a double spray seal with a larger stone for the base (e.g. 14 mm) and a smaller stone size for the top layer (e.g. 7 mm)
- alternating between aggregate sizes in subsequent seals (e.g. use 14 mm one year and then 10 mm for the next resurfacing).

Other practices suggested that have not yet been trialled include:

- using slurry sealing for existing shoulders that are unsealed
- redirect vehicles to use the shoulder immediately after it is (re)sealed for a short period to smooth the surface. Before doing this, the strength of the shoulder needs to be considered as often it is not designed to support high volume, high speed traffic.
- Other good practices that improve the surface for cyclists but do not relate to the aggregate size include:
- rolling the edge of the traffic lane to reduce the lip between the traffic lane and shoulder when only the traffic lanes have been resurfaced
- ensuring resurfacing contracts include a limit on how many stones per square metre can remain after the contractor has swept the shoulder.

More information on the practice in each jurisdiction is provided in Section 5.2.

#### *3.3.1.5 Drainage grates*

Drains within the carriageway (in the shoulder, bicycle lane or traffic lane) should be covered and level with the road surface.

Drainage pit lids should be designed with (concrete in-filled) cast iron covers (Austroads AGRD03 2010a). Grated pit covers should be designed so they don’t cause cyclists to alter their path with bars spaced at 20 mm and aligned perpendicular to the direction of travel of traffic (Austroads AGRD05 2010a).

#### *3.3.1.6 Heavy vehicles*

Heavy vehicles, including buses and trucks, at high speeds can cause problems for bicycles because of their large mass. A sideswipe crash can be caused by the wind effect (proportional to a vehicle’s size, speed and distance from the cyclist) of a heavy vehicle passing a cyclist, without any initial contact (Queensland Transport 2006b). Cyclists may become stressed when there are a large number of heavy vehicles, particularly on bridges and in tunnels as cyclists do not have an escape option (Transit New Zealand 2008).

### Crash severity

Further to the discussion on crash severity in Section 2.1 on, trucks increase the probability of fatal and serious injuries when involved in a crash with a bicycle (Kim et al. 2006). Boufous et al. (2010) noted from cyclist fatalities in Victoria that:

- Over 27% of fatal cyclist crashes involved heavy vehicles
- A casualty crash which involved a heavy vehicle resulted in a cyclist fatality 12% of the time compared to only 2% for all casualty crashes.

### Clearances

Providing space between vehicles and cyclists can reduce the chance of crashes with heavy vehicles. ‘Wide sealed shoulders (> 0.9m), which allow for better sharing of the road with heavy vehicles, have been found to be associated with reduced crash incidences and injury severity’ (Boufous et al. 2010 p. 65). Austroads AGRD03 (2010a) recommends designing roads with sufficient clearance for cyclists from heavy vehicles (Table 3.6).

Table 3.6: Desirable clearance to cyclist envelope from adjacent truck (Austroads AGRD03 2009a)

| Speed limit (km/h) | 60 | 80 | 100 | 100+ |
|---|---|---|---|---|
| Desirable clearance (m) | 1.0 | 1.5 | 2.0 | 2.0+ |

Queensland Transport (2006b) support this principle, recommending increased separation with increased speed of trucks (as per Figure 3.2), providing an off-road path or reducing the speed limit.

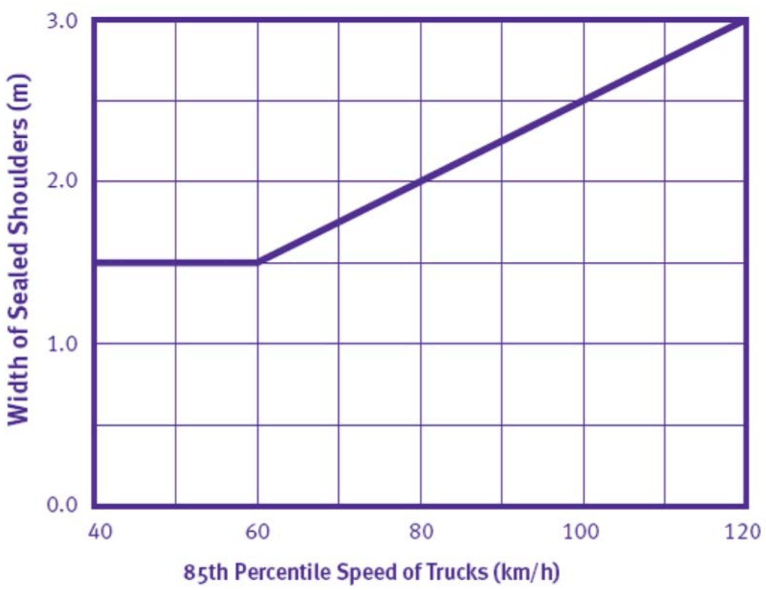


Figure 3.2: Minimum recommended sealed shoulder widths for bicycle riders (Queensland Transport 2006b)

On curves, trucks may require additional space because of the variation in tracking of the rear wheels. Queensland Transport (2006b) recommends widening the traffic lane on curves to allow enough space for large vehicles to remain in the traffic lane and not have to use the shoulder, where cyclists may be riding. This conflicts with Austroads guidance which suggests marking the traffic lane at 3.5 m on curves and providing full pavement depth for the area of shoulder which heavy vehicles will overrun.

Austroads AGRD03 (2009a) also suggests:

- designing horizontal curves with radii greater than 300 m to avoid lane widening
- considering wider traffic lanes where very large vehicles (Type 2 (triple) road trains or larger) are expected.

**Shared bus/bicycle lanes**

Austroads (2005) investigated Australian and international practice in providing for cyclists in shared bus/bicycle lanes[2]. It found little international guidance relating to bus-bike interactions, generally because other countries tend to recommend separation (from all motor vehicles). The report discusses the extent of separation of cyclists from buses in high speed environments (e.g. off-road path, a bicycle lane). If a separate bicycle lane is to be provided in high speed environments, the report recommends placing it between the bus lane and the kerb (where it is a kerb running bus lane).

Austroads (2005) also discusses the issues that are often encountered. For example, in shared bus/bike lanes a ‘leap frog’ effect where the cyclist overtakes the bus at a stop and then the bus overtakes the cyclist between stops. Where cyclists are provided with a separate bicycle lane, treatment at bus stops should consider bikes passing stationary buses and the potential conflict with bus passengers.

Austroads GRD03 (2010a) recommends that where cyclists are to share the bus lane on an 80 km/h road, the lane should desirably be between 4.5 and 5.0 m wide (4.3 m minimum). However on a 4.5m shared lane a cyclist will potentially experience a 1.8kg side force from a bus operating at 80km/h (assuming bus V85 is equivalent to posted speed). This is above the 1.6kg threshold recommended by the Federal Highway Administration (FHWA 1976).

On 5m shared lanes consideration could be given to using road markings to visually separate the bike lane and bus lane to provide more certainty to bus drivers and manoeuvring space to cyclists.

### *3.3.2 Shared bus/bicycle lanes are not appropriate on roads with a speed limit above 80km/h. At intersections*

There are many examples in Australia of roads where bicycle facilities are provided midblock, but disappear at the intersections. Often this is because of the need to provide for additional movements at an intersection e.g. right turn lanes. Austroads AGRD03 (2010a) recognises the need to provide a left lane of sufficient width for cars and bicycles to travel side by side, including at intersections. Cyclist movements should be considered in all directions, not just those along the designated bicycle route (TfL 2005).

This section considers how to best provide for cyclists at different types of high speed intersections.

[2] Throughout this report, we refer to ‘shared bus/bicycle lanes’. While in most states and territories of Australia this is the same as a bus lane, in Victoria and Western Australia, bicycles are not permitted in bus lanes unless otherwise signed.

### *3.3.2.1 Priority junctions*

The most common unsignalised intersections along high speed roads are T intersections where a minor street ends at a major road. This is because intersections of more than one major road in high speed environments are usually either signalised or controlled by a roundabout. Austroads AGRD04 (2009c) notes that unsignalised Y-intersections are unsafe because of the poor sight distance. It also observes that unsignalised cross roads are generally not safe at speeds above 80 km/h.

Where the major road has sealed shoulders, one of two situations commonly occurs at a priority junction:

- a left turn lane is developed in the shoulder area
- left turning vehicles have to cross into the shoulder

A third layout can be provided where a left turn lane is built in addition to the shoulder, which is marked as a bicycle lane. These three layouts are shown in Figure 3.3. The advantages and disadvantages of each of these options are discussed in Table 3.7.

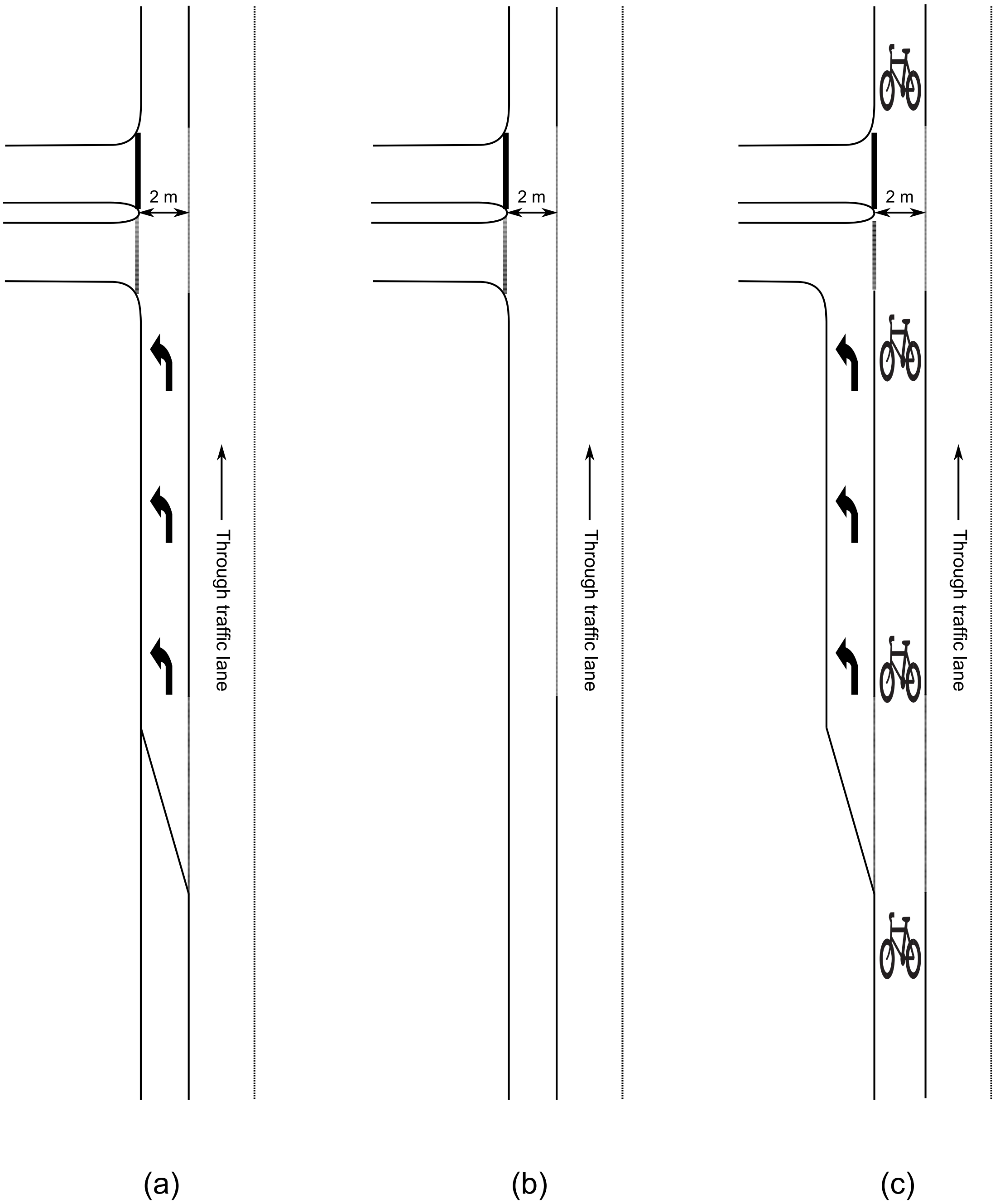


Figure 3.3: Three possible road layouts at priority junctions

Figure note: Arrows represent allowable movements and not lane markings.

Table 3.7: Advantages and disadvantages of the three priority junction layouts

| Layout | Advantages | Disadvantages |
|---|---|---|
| (a) Left turn lane developed in shoulder | Deceleration space provided for vehicles. Clear definition of where turning vehicles should move left. | Cyclists continuing straight would legally have to use the traffic lane unless signed otherwise (in practice, they tend to ride in the turning lane, particularly when there are no left turning vehicles). Cyclists have to give way to motor vehicles – both left turning and through. |
| (b) No designated left turn lane, vehicles use the shoulder | Minimal space and linemarking required. Cyclists in the shoulder have priority over left turning traffic. | Drivers may be unsure of where to enter the shoulder. Designated space is not provided for deceleration, which may lead to an increase in rear end crashes. |
| (c) Left turn lane in addition to a bicycle lane (marked shoulder) | Cyclists do not have to mix with left turning traffic. Cyclists have priority over left turning traffic. Defined road space for cyclists. | Cyclists have to ride between two lanes of high speed traffic when there is a high left turn demand. High speed motor vehicles are required to give way to slower through cyclists. |

In all situations, space should be provided across the minor street so that cyclists do not have to ride in the high speed traffic lane. The shoulder should be continued through the junction with the minor street stop line (and any median islands) set back to the edge of the shoulder (Austroads AGRD04A 2010b; DfT 1987).

Under certain circumstances, alternatives may be used. These may include:

- an off-road path set back from the intersection
- full grade separation
- signalising the whole intersection.
- These alternative treatments will particularly benefit less confident cyclists. However an off-road path or grade separation that is less direct or requires cyclists to stop and give way to motor vehicles may be ignored by more confident cyclists.

**Seagull treatments**

A seagull treatment is shown in Figure 3.4. In this situation, right turning cyclists from the side street end up in the right lane of a multi lane road with high speeds. Alternatives to this layout are a two-staged crossing treatment where right turning bicycles are stored in the median until there is a sufficient gap in traffic on the farside carriageway. Alternatively, complete signalisation of the intersection could also be considered.

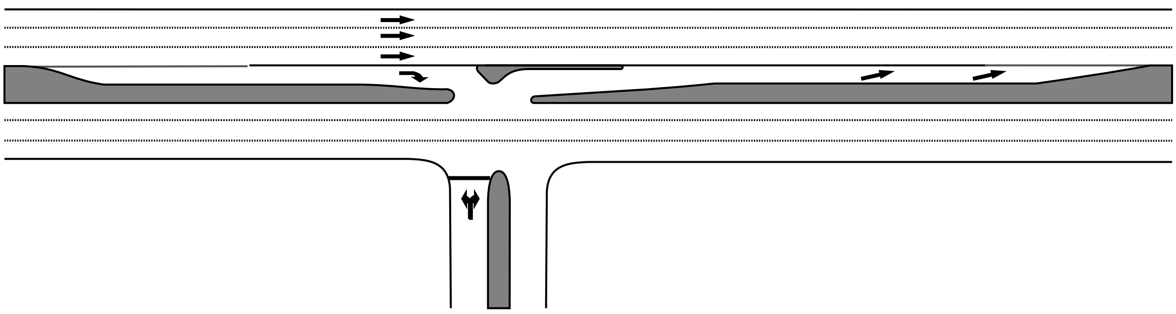

Figure 3.4: A seagull treatment does not provide for cyclists and pedestrians crossing the major road

Figure notes: Cyclist facilities along the major road are not shown. Arrows represent allowable movements and not lane markings. A median break can be provided to provide cyclists with a two stage crossing.

### *3.3.2.2 Signalised intersections*

An intersection that is controlled by traffic signals is one of the safest types of intersections for cyclists (DfT 2008). At a signalised intersection, designers need to consider two issues:

- providing space at the intersection, including advanced stopping facilities and catering for right turns
- intersection operation, including traffic light sequencing depending on the bicycle facilities provided.

Austroads (2011) reviewed cycling facilities at signalised intersections and developed crash prediction models to relate cyclist crashes to variables such as road features and cyclist and motor vehicle volumes. This report provides additional information on providing for cyclists at signalised intersections.

**Advanced stopping facilities**

Space can be created for cyclists at a signalised intersection by providing an advanced stop line (Figure 3.5). An advanced stop line is used in a bicycle lane where the bicycle stop line is closer to the intersection than the vehicle stop line. An advanced bicycle stop line can store one cyclist.

Advanced cyclist stopping facilities improve access and safety for cyclists at an intersection. Cyclists tend to like them because they are given more space and drivers are able to see them more easily (Austroads AGRD04A 2010b; Boufous et al. 2010).

Standards Australia (2000) and Austroads AGRD04A (2010b) recommend an advanced stop line 2 m ahead of the vehicle stop line.

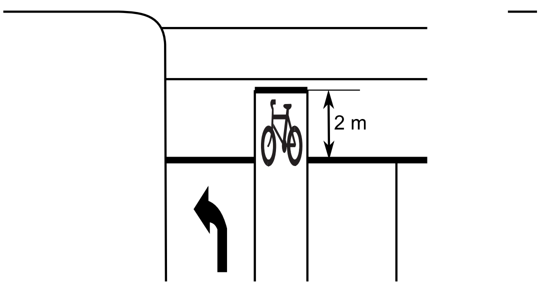


Figure 3.5: Advanced stop line for bicycles.

Figure note: Arrows represent allowable movements and not lane markings.

**Continuity of lanes through intersections**

In some situations, it may be preferable to continue bicycle lane markings through intersections. Austroads AGRD04A (2010b) recommends considering this treatment at intersections where the layout required for motor vehicles may put cyclists at risk. Bicycle lanes through intersections are common practice in some European countries (FHWA 2010a; Pucher and Buehler 2008).

Austroads AGRD04A (2010b) also emphasises the importance of termination points for bicycle lanes; they should lead cyclists to a place where there is sufficient space, such as near a sealed shoulder.

### Right turns

> Right-turn lanes for cyclists are rarely used and should generally not be provided for cyclists ... on arterial roads or busy traffic routes because of the difficulty and crash risk for cyclists moving from the left of an intersection [on the approach road] to the centre of the road in order to utilise such treatments (Austroads AGRD04A 2010b p. 99).

In Australia and New Zealand, an alternative way for cyclists to turn right is to make a hook turn, reducing their exposure to cross traffic.

At signalised T intersections, it is possible to construct a jug handle for right turning cyclists. This treatment directs them onto a path off to the left of the road and provides a storage area where they can wait until they are given a green signal to cross the main road (Figure 3.6). The bicycle signal for this treatment can run at the same time as any or all of the following, non conflicting movements:

- pedestrians crossing the right arm of the top of the T
- motor vehicles turning right from the main road into the minor street
- motor vehicles turning left from the minor street into the main road.

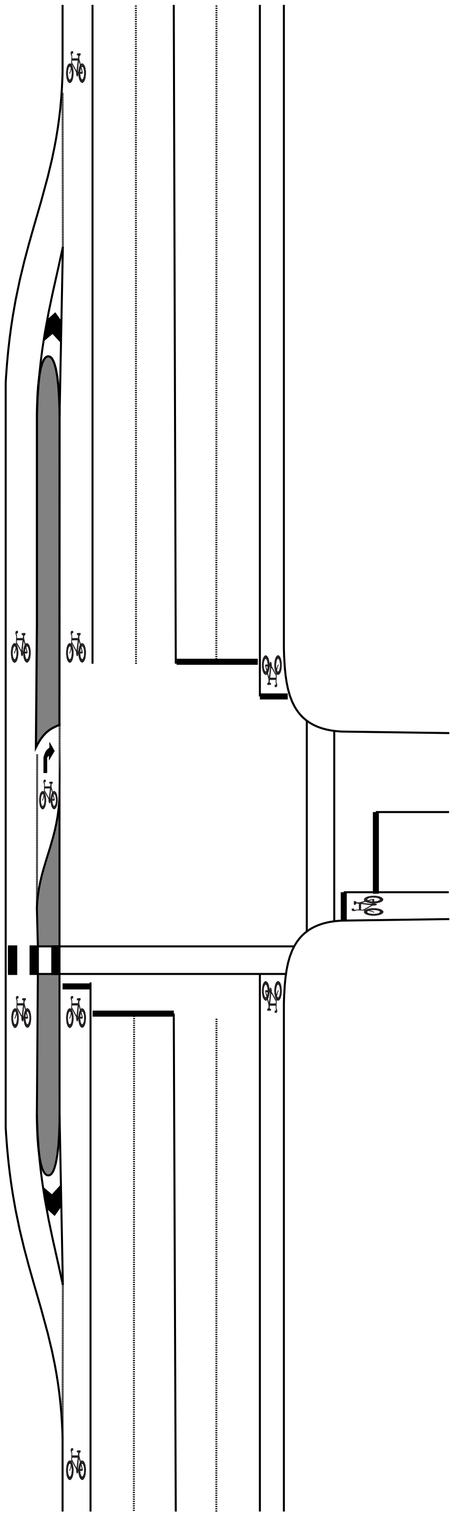

Figure 3.6: A jug handle (and off-road bypass) treatment for cyclists at a signalised T intersection

**Detection**

There are two standard ways in which cyclists can be detected at intersections:

- inductive loops
- push button.

Generally, it is not necessary to detect cyclists separately from motor vehicles. At intersections, the signals often default to the main road phase, even if no vehicles (bicycles or motor vehicles) are detected. However on roads with low traffic volumes, inductive loops should be well positioned with suitable sensitivity levels to detect cyclists so that cyclists do not have to wait for a motor vehicle to trigger the lights before they get a green light.

Where there are special signal phases for cyclists, inductive loops can be used in a bicycle lane to detect cyclists. In this case, they have to be placed in a cyclist only area, as they are not able to differentiate between bicycles and motor vehicles. Alternatively, a push button can be used, either exclusively for cyclists or shared with pedestrians.

**Signalling**

In certain situations, it may be desirable to provide cyclists with a separate, bicycle only phase or to adjust the existing phases to better cater for cyclists. Such a phase can run as part of every light cycle or only when cyclists are detected.

Some examples of how signals can improve riding conditions include the following from SKM (2008):

- Early starts for cyclists.
- All red to vehicles, allowing cyclists to cross the intersection in any direction. Providing a cyclist only phase (where other vehicles have a red signal) reduces conflict with vehicles (as other vehicles remain stationary) and may improve safety (Boufous et al. 2010).
- Dwell on green for cyclists (particularly where a path crosses a minor road).
- Additional clearance at the end of green or all red time extension to provide cyclists with sufficient time to cross an intersection.
- Riding across the top of a T intersection when the vehicle light is red (see below).

**Other**

Other practices that may improve the riding conditions at intersections include restricting motor vehicles (but not bicycles) from making certain turns and altering the turning radius of corners using traffic islands and bollards to slow cars (Pucher and Buehler 2008). In certain situations, it may be desirable to reduce the number of conflict points by grade separating cyclists from other traffic.

### *3.3.2.3 Roundabouts*

> A well-designed roundabout is the safest form of intersection control. Numerous 'before and after' type studies have shown that in general, fewer motor vehicle casualty crashes occur at roundabouts than at intersections containing traffic signals, stop, or give-way signs. Unfortunately, this same safety record does not apply to cyclists or pedestrians (Austroads AGRD04B 2009e p. 3).

TfL (2005) reports that at large roundabout with four or more arms, cyclists are 14 times more likely to be involved in a crash than other vehicles. It also notes that increasing numbers of circulating lanes and traffic volumes increase the difficulty for cyclists trying to negotiate them. According to VicRoads (2005), the main conflict points for cyclists within a single lane roundabout are where the circulatory lane meets the entry lanes. At multi lane roundabout, the points where the circulatory lanes meet the exit lanes can also create conflict. Examples are shown in Figure 3.7.

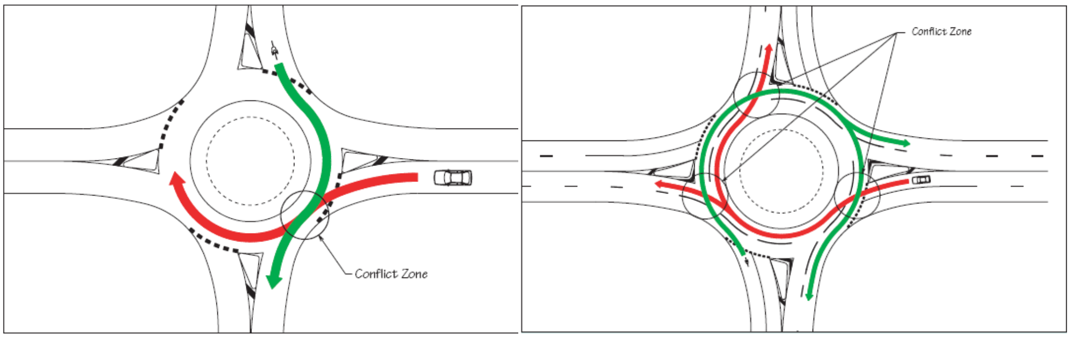


Figure 3.7: Main conflict points for cyclists on single lane and multi lane roundabouts (VicRoads 2005)

Ways to improve roundabouts for cyclists include:

- signalise the intersection
- provide a separate path
- slow vehicles
- provide an alternative route.

Which treatment (of combination thereof) is most suitable will depend on the specific situation. The use of bicycle lanes through roundabouts is currently the subject of an Australian Bicycle Council research report.

**Signalise the intersection**

Replacing a roundabout with traffic signals reduces the risk of a crash for cyclists (refer Section 0). Austroads AGRD04B (2009e) suggests considering this treatment when there is a roundabout on a designated commuter cyclist route.

Alternatively, it may be preferable to signalise the approaches. DfT (2008) reports that crashes involving cyclists may be reduced by about 70 % when full time signals are installed on some or all or the legs.

Consideration should be given to the overall safety of the intersection for all modes of transport when any infrastructure changes are being considered.

**Provide a separate path**

To reduce the risk of a collision involving a cyclist in a roundabout, a separate off-road cycle path may be provided. This is the safest roundabout design for cyclists when there are high traffic volumes (Austroads AGRD04B 2009e). TfL (2005) suggests signalising the path crossing of the roundabout legs if there are more than 25,000 vehicles per day using the roundabout. DfT (2008) notes that although separated tracks may make cycling safer, they can add considerable time and effort for the cyclist. Therefore it is important to design separate paths at roundabouts well so that cyclists do not continue to use the road instead.

At three leg roundabouts, a cyclist bypass across the top of the T may be suitable.

### Slow vehicles

One of the key factors in roundabout safety is the speed of motor vehicles, and designing the roundabout to reduce speeds is important where there are cyclists (Transit New Zealand 2008; Boufous et al. 2010). Lower speeds encourage cyclists to ‘claim the lane’, positioning them where they are more likely to be seen by drivers (DfT 2008).

On high speed roads, it may not be appropriate to significantly reduce traffic speeds through a roundabout and other treatments may be more appropriate. However, if it is a suitable treatment, ways in which roundabouts may be altered to reduce speed include:

- tightening the geometry (entry and exit legs, circulating space)
- reducing the number of lanes (entry, exit, circulating)
- installing rumble strips or raised tables on approach to the roundabout to slow vehicles
- lower the speed limit

DfT (2008) reports that continental style roundabouts (tight geometry with a centre island 20 – 40 m in diameter) may be 10 to 20 % safer for cyclists than signalised intersections. It also suggests the use of an over run apron to allow large vehicles to use the intersection. The continental style roundabout reduces vehicle speeds as well as the number and severity of crashes for all users (Campbell et al. 2006).

While reducing the motor vehicles speeds through a roundabout will benefit cyclists, roundabouts can still be difficult for a right turning cyclist to negotiate. Through multi lane roundabouts, cyclists either have the choice of moving across to the right lane and negotiating the roundabout from there, or using the left lane to perform a hook turn. At a roundabout, cyclists performing a hook turn have to stop and give way to vehicles exiting the roundabout before they can continue the second part of the turn. They also require space to wait (e.g. a bicycle lane or a hook turn box).

Austroads AGRD04B (2009e) suggests that while there is currently no treatment that safely provides for right turning cyclists at roundabouts, providing bicycle lanes through multi lane roundabouts on arterial roads offer some advantages (increased driver awareness of cyclists, designated space and assistance in performing a hook turn).

However, this view that providing designated space in a roundabout for cyclists is beneficial is disputed by much of the literature. Standards Australia (2000) and TfL (2005) advise not to mark bicycle lanes in roundabouts. A review of recent literature on multi lane roundabouts by Campbell et al. (2006) found:

- bicycle lanes through the circulating part of multi lane roundabouts is generally not recommended due to concerns about cyclist safety
- a reduced speed through multi lane roundabouts is preferable for cyclist safety and amenity (achieved through designs such as the continental style).

Cumming (2010) suggests that providing a bicycle lane through the circulating part of a roundabout is equivalent to adding a lane. This increases the number of conflict points from 4 in a one lane roundabout to 16 in a two lane roundabout.

### Provide an alternative route

It may also be preferable to change the designated cycling route all together, removing the need for cyclists to pass through the roundabout. However it is important that the alternative route is just as fast as the original route, otherwise cyclists may not choose to use it. It is also important for designers to note that even if the roundabout is not on a bicycle route, it may still be used by cyclists who would benefit from the improvements discussed previously. This case where fewer cyclists remain on the route may contribute to a reduction in driver expectation of cyclists.

#### *3.3.2.4 Slip lanes and freeway ramps*

Slip lanes and freeway on and off ramps are treated similarly in a high speed road context. Bicycle facilities can be provided at these points even when there at no midblock bicycle lanes, so long as markings guide cyclists through conflict points and are clear to drivers (Australian Standards 2000). Austroads AGRD04A (2010b) recommend bicycle lanes are marked in the merge areas of high speed acceleration tapers to provide space for cyclists and warn motorists that bicycles may be present. Treatments that reduce vehicle speeds or reduce the distance where cyclists are vulnerable should be considered (DfT 1987).

In most cases, diverge and merge points include only one lane of traffic for cyclists to cross. However in higher volume locations two (or more) lanes may merge with or diverge from the main traffic stream. As soon as there is more than one lane of traffic for cyclists to cross, the task becomes much more complex due to the additional time and distance to cross and added difficulty in selecting an appropriate gap. Therefore it is better to design the facility in such a way that cyclists only have to cross one traffic lane. This may be done by developing the second lane before or after the crossing point or removing it all together. The following techniques are most appropriate for single lane crossings, due to the added complexity as discussed above.

**Diverges**

On approach to a signalised intersection (e.g. arterial road)

Left turn slip lanes at at-grade intersections generally increase the traffic capacity of an intersection, however they require drivers to cross the path of approaching bicycles (and typically to do so at higher speed), creating a conflict point. Removing slip lanes completely will benefit cyclists (DfT 1987) and pedestrians by reducing the number of conflict points.

If this cannot be done, then designers should consider moving the conflict point between left turning vehicles and through cyclists ‘back’ from the intersection, as in Figure 3.8. This way space is retained for left turning vehicles to decelerate (likely improving vehicle occupant safety) and simplifies the driver’s decision making processes (Wilke and Koorey 2005). Left turning drivers are required to give way to through cyclists. One disadvantage of this layout is that cyclists travel between two lanes of high speed traffic. Reducing the radius of the slip lane may help reduce the speed of left turning vehicles.

The Austroads Guides are silent on what distance is reasonable for a cyclist to travel between two lanes of moving traffic. The required length for a slip lane is discussed in Austroads AGRD04A (2010b) and depends on the distance required by vehicles to move completely into the slip lane (the diverge distance), the deceleration length and any required storage space. Where cyclists are exposed for long distances next to slip lanes, the following could be considered to provide them with better protection:

- use of coloured pavement to reinforce the bicycle lane
- reduce the length of the slip lane (depending on traffic volumes, speed and intersection layout)
- reduce the length of the dashed line section (depending on required diverge distance) to encourage vehicles to move across earlier rather than later

- reinforce the bicycle lane line on the slip lane side using trafficable, raised lane line markers (e.g. audio tactile linemarking, lane dividers). This should only be done where the bicycle lane is sufficiently wide that cyclists are unlikely to need to cross the line. Alternatively, if there is a traffic island, the island could be extended back towards the diverge point if there is sufficient road width.

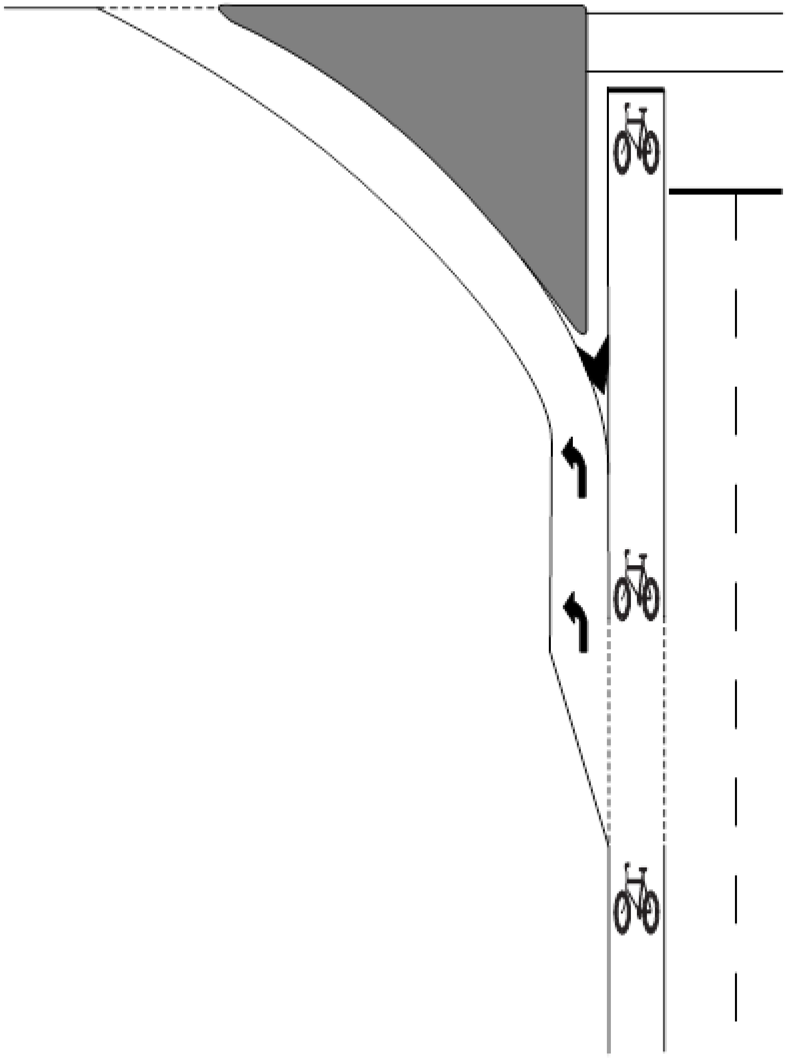

Figure 3.8: Diverge point where cyclists have priority over left turning vehicles

On a continuous section of road (e.g. freeway)

Along continuous sections of road where there are no at grade intersections and speeds are generally higher, the bicycle route may follow the kerb and then be diverted to cross the exiting lane after motor vehicles have diverged from the main traffic stream (Figure 3.9). This reduces the possibility of a cyclist being trapped between two lanes of high speed traffic and does not have to be marked as a bicycle lane (a shoulder with signs directing cyclists is often sufficient). However it also generally requires the cyclist to give way to traffic, which can cause delays for cyclists if there is a large volume of exiting traffic. The form shown in Figure 3.9 requires space to store cyclists to the left of the diverging lane and in the median island. Alternatively, cyclists can be directed to cross the diverging lane prior to the median island and straight into the shoulder or bicycle lane adjacent to the traffic island.

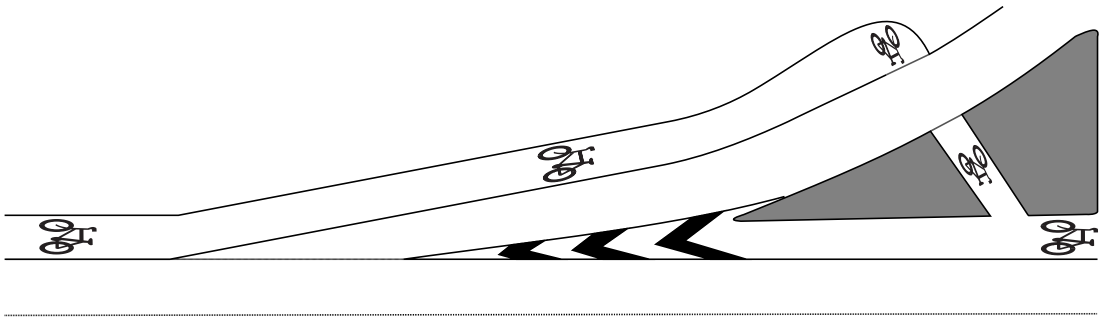

Figure 3.9: Diverge point where cyclists give way to exiting vehicles

Figure note: Cyclists can also be directed into the gore area at the end of the traffic island.

**Merges**

The equivalent of these treatments can also be used for merging lanes and is common at on ramps on freeways. One example is shown in Figure 3.10.

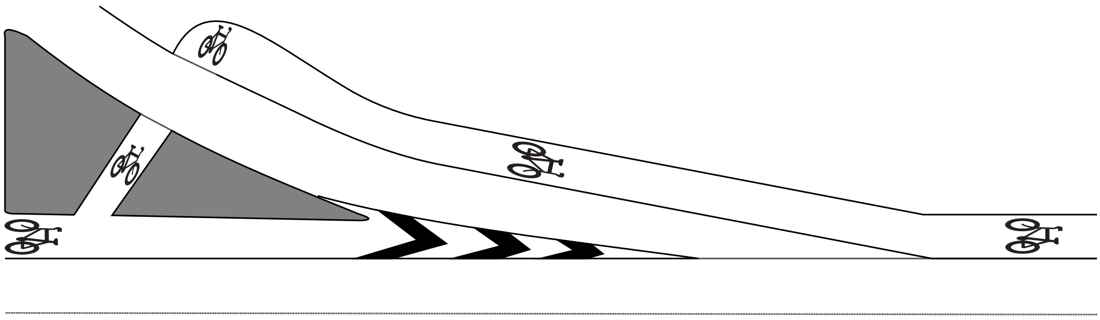

Figure 3.10: Merge point where cyclists give way to entering vehicles

Figure note: Cyclists can also be directed to cross from the gore area at the end of the traffic island.

### *3.3.2.5 Crossing opportunities*

In the examples where cyclists have to give way to vehicles, the crossing opportunities can be calculated based on the number and speed of vehicles using the ramp. Austroads AGRD04C (2009b, Commentary 6) suggests a minimum gap of seven seconds is required for cyclists to safely cross in front of a car (two seconds for the previous car to pass, three seconds to cross and a further two seconds before the next car). This value is based on theoretical calculations and ideally further research would be undertaken to better understand cyclist gap acceptance in these circumstances.

It continues on to suggest that if average delays to cyclists are longer than 15 seconds in the peak hour, cyclists may accept unsafe gaps and the following may be employed:

- direct cyclists to use the exit ramp, cross the intersecting road and then use the on ramp to get back onto the freeway
- investigate the feasibility of grade separation
- investigate an alternative route.

The first option is unlikely to be followed by cyclists as it requires them to ride a further distance (due to the vertical separation) and may increase delays, particularly if the intersection with the cross road is signalised.

It may instead be possible to use signals to assist cyclists in crossing. Providing signals may be inappropriate on freeway exits as vehicles could queue back into the freeway traffic lane. On ramps on freeways may be more suitable for signalisation and could link with ramp metering controls where installed. Existing signals that control the on ramp flows (including intersection signals) may already provide sufficient gaps in traffic for cyclists to cross or may be adjusted to do so. In addition to vehicle volumes, consideration should be given to cyclist volumes and site geometry in making decisions on appropriate treatments.

Cyclists may also need assistance in crossing at midblock locations, such as to access a shared path. Similar treatments to those described above (grade separation, alternative routes and signalisation) may be employed where crossing opportunities are limited. In addition, providing a median island gives cyclists somewhere to wait and can simplify the crossing by breaking it into two parts, each with a single direction of traffic. The most appropriate solution will depend on the specific site and conditions.

#### *3.3.2.6 Approach visibility*

CROW (2007) discusses the need for good visibility of approaching traffic when cyclists are crossing roads. The required approach visibility depends on how fast the traffic is approaching the crossing point (referred to as closing speed), the crossing distance and delay time (including safety margins and reaction time).

Table 3.8: Approach visibility (CROW, 2007)

| Crossing distance (m) | Approach visibility (m) for various closing speeds | | | |
|---|---|---|---|---|
| | 30 km/h | 50 km/h | 70 km/h | 80 km/h |
| 4 | 45 | 100 | 180 | 205 |
| 5 | 45 | 105 | 185 | 210 |
| 6 | 50 | 110 | 190 | 220 |
| 7 | 50 | 115 | 200 | 225 |
| 8 | 55 | 120 | 205 | 235 |

### *3.3.3 Using delineation*

As well as separating cyclists from high speed traffic in space (e.g. off-road path, shoulder), delineation such as line markings and physical separators can also be used.

Table 3.9 outlines various types of delineation that can be used along bicycle lanes or sealed shoulders.

Table 3.9: Delineation treatments for bicycle lanes and shoulders on high speed roads

| Treatment | Examples | Restrictiveness |
|---|---|---|
| Standard line marking | Lane and edge lines<br>Hatched road markings (e.g. painted medians, chevrons beside bicycle lanes and traffic islands) | Minimal. Users can cross it relatively easily |
| Raised line markings | RPMs<br>Audio tactile edge lines | Minimal, although can cause cyclists to lose control. |
| Raised rubber separator | Tram lane delineator (as used in Melbourne) | Can be mounted, but can be slippery for cyclists or cause them to lose control. |
| Raised traffic islands | Copenhagen style bicycle lane | Similar to a kerb, users would only mount it with intention. |

### Standard line marking

As well as being flush with the road surface, linemarking should provide cyclists with sufficient traction in the wet (Litman et al. 2006). Hatched areas can be good for reinforcing the bicycle lane separation where sufficient space is available (e.g. a bicycle lane with a 0.5 m hatched lane adjacent means a large truck can overhang the traffic lane but will not encroach into the bicycle lane).

### Raised line markings

Raised lane and edge lines and raised pavement markers (RPMs) within the path of travel may present a hazard to cyclists. Standards Australia (2009) suggests that RPMs are considered level with the road surface and intended to be trafficable. However for cyclists, a difference in level of even 10 mm can be hazardous (Austroads AGRD06A 2009d), causing cyclists to come off their bicycles or lose control and swerve into the path of a vehicle. RPMs are used to supplement linemarking, particularly at hazardous locations (e.g. a substandard horizontal curve, a narrowed bridge). Standards Australia (2009) only permits the use of RPMs to supplement edgelines where they are also used to supplement lane or dividing lines. It also recommended they are placed outside the edgeline (i.e. in the shoulder), with the exception of unsealed shoulders, to prolong their lifespan. However, this more than likely also places them in close proximity to cyclists. The bicycle safety audit checklist in Austroads AGRD03 (2010a) considers whether RPMs are located outside of the path of travel of cyclists. From a cyclist point of view, it is preferable that they are.

Along bicycle paths, Austroads AGRD06A (2009d) recommends that separation lines should not be raised or supplemented with RPMs. UK guidance recommends that road markings should not be more than 6 mm above the road surface and raised markers (less than 100 mm) should not be used to delineate lanes (DfT 1987). As the same issues are faced by on-road cyclists, these treatments should also not be employed along bicycle lanes or shoulders used by cyclists.

Therefore, where roads are used by bicycles, designers should consider alternative treatments that can be used in place of RPMs. If it is necessary to use RPMs, it is preferable that they are not located in the shoulder or bicycle lane to reduce the potential hazard for cyclists. This is particularly relevant when the quality of the shoulder is poor (e.g. covered with debris) or narrow.

Using audio tactile edge lines have been effective in improving safety on rural roads (Austroads AGRS05 2006c). Recently, they have also been used in urban areas to delineate bicycle lanes, however the authors are not aware of any studies that have been conducted determining their effectiveness. Anecdotally, they reduce the number of vehicles encroaching into the bicycle lane, cyclists like them and their installation can result in increased rider numbers along a route (Bicycle Network 2010). Walton et al. (2005) investigated the hazard to cyclists of various road features, including audio tactile line marking. The study found that the level of instability for cyclists was similar for audio tactile lines and commonly used line markings. It also recommended comprehensive testing should be undertaken to better determine the effect of various linemarkings on cyclist stability.

Audio tactile lines are most effective in providing feedback to a driver at higher speeds, therefore are appropriate along bicycle routes on high speed roads. They also are placed over the existing line, so do not reduce the width of the bicycle lane or shoulder, or create a hazard within the cycling area. AASHTO (1999) recommends that audio tactile lines and RPMs are only used on roads used by cyclists when the shoulder is at least 1.2 m wide, or 1.5 m where there is a barrier next to the road (e.g. guardrail).

Austroads AGTM10 (2009g) recommends a sealed roadway width of 9.0 m (two 3.5 m lanes and two 1.0 m shoulders) before audio tactile edge lines are used. The absolute minimum is 7.0 m, provided the edge lines are at least 150 mm from the edge of the seal.

**Raised rubber separators**

Raised rubber separators are often used in locations where vehicles (and bicycles) should not have to cross it, such as along tram lanes on some Melbourne streets. As it is raised, it can cause riders and drivers to lose control if they do not expect it. Various forms of raised rubber separators have been trialled along bicycle lanes in Melbourne and Sydney. SKM (2008) found these separators significantly reduced the frequency of motor vehicles driving (partially) in the bicycle lane.

**Raised traffic islands**

Raised traffic islands are used to create a bicycle route separated from moving (and sometimes parked) motor vehicles. This creates a route similar to an off-road path, however cyclists still have priority at junctions. The islands can be either continuous or discontinuous, depending on location, pedestrian activity and drainage.

## 3.4 Reduce speed limits

Traditionally speed limits (in linear speed zones) have been set according to a broad range of factors including the speed below which 85% of drivers travel in light traffic, when they are free to choose their speed. This approach is not consistent with the safe systems approach (Austroads AGRS03, 2008). There is a compelling case to address speed limits in a more rigorous manner now that the relationship between small speed increases and large increases in crash risk are better understood (ECMT 2006).

It is well established that speed is related to safety, not just for cyclists but for all road users, including motor vehicle occupants. Figure 2.1 shows that reducing the speed at which a crash occurs from 70 km/h to:

- 60 km/h reduces the risk of a pedestrian (or cyclist) fatality by about 15%
- 50 km/h reduces the risk of a pedestrian (or cyclist) fatality by about 45%.

Research used in Sweden's road safety policy Vision Zero found that an occupant of a modern car will not survive a side impact of more than 50 km/h or a frontal impact with a similar car at more than 70 km/h. Therefore, it recommends that where there is a risk of these crashes, speed limits should be set accordingly (ECMT 2006).

ECMT (2006) reports that most OECD countries adopt a speed limit of between 90 and 100 km/h on main highways (not including freeways) and between 80 and 90 km/h on rural roads. This compares to a common 100 km/h speed limit on main highways and rural roads in Australia. This is at the higher end of the range.

In some countries, safety has become one of the highest priorities in road design. This includes safety of both vehicle drivers and other road users. FHWA (2001) reported that road authorities in some European countries were willing to sacrifice higher speeds in order to improve safety on high speed rural roads. For example, in Sweden a 90 km/h limit is adopted on main highways and 70 km/h on undivided rural roads (ECMT 2006).

A lower speed limit provides drivers with more time between realising they are in a potentially dangerous situation and the time of impact. Lowering the speed limit is likely to reduce the probability of a collision (as drivers can react and stop in a shorter distance) and the speed of impact if a collision occurs (reducing severity of injuries).

When weighing up the benefits and disbenefits of reducing the speed limit, the following should be considered:

- What type of road is it? What is its purpose?
- What speed is the road designed for?
- Is reducing the speed limit in line with policies?
- Would it be politically acceptable?
- Is a reduced speed limit likely to be obeyed?
- Will it be enforced?
- What is the safety record of the road (number and severity of crashes including crashes involving only motor vehicles)?
- Are there any safety issues associated with design (e.g. access points, sight distances)?
- How many vulnerable road users are there and would more be expected as a result of a lower speed limit?
- What benefits and disbenefits would be expected as a result? Reducing the speed limit can also create safety benefits for motor vehicle drivers.

In Australia, there are many rural, high speed roads used by a low number of vehicles for travelling between cities and towns. Reducing the speed limit would generally not be practical on such roads, and so other approaches to improve cyclist safety should be considered.

Reducing the speed limit on a road does not exclude the possibility of also making other improvements for cyclists as discussed in the previous sections. In fact, by reducing the speed limit, it may be possible to provide a bicycle lane in line with the guidelines where one wasn't possible before (see Section 0, narrower bicycle lanes are permitted on lower speed roads).

# 4 WHAT IF THE GUIDELINES CANNOT BE MET?

Austroads AGRD01 (2010b p. 6) recognises that:

> in situations where road designs are not constrained by topography, natural or man-made features, environmental considerations, or budgetary requirements, the most suitable detailing of a design should not be difficult. However, many situations arise in which constraints apply and, in such cases, the experience and judgement of the designer, together with relevant research and literature, play a significant role in developing the most appropriate outcomes.

Guidelines represent a consolidation of practice and experience. However, they should not be applied without considering the factors particular to any one situation and in practice other factors may restrict their applicability.

> The Austroads Guide to Road Design is intended to provide designers with a framework that promotes efficiency in design and construction, economy, and both consistency and safety for road users. However, the Guide moves away from rigid design limits as the basis for achieving these goals, and promotes the concept of 'context-sensitive design'. The intention is to allow designers the flexibility to exercise their critical, engineering judgement, for example, by choosing design values outside of normally accepted limits when prevailing constraints require, provided that they recognise their responsibility to be able to produce strong, defensible evidence in support of that judgement (Austroads AGRD012010b p. 7).

As such, it is important to bear in mind that a design that does not 'comply' with the relevant guideline is not necessarily 'deficient'. Rather, what is important is that the design has been subject to careful design and review, and where it is in some way novel or unusual, subject to monitoring and evaluation.

## 4.1 Practicalities and limitations

The previous chapter discussed how best to provide for bicycles on high speed roads. However there are many factors that influence why this is currently only done infrequently in Australia.

Road authorities have to make decisions about where they will provide bicycle facilities and what form they will take. They have to try to strike a balance in providing for all road users within the constraints of many factors, discussed further in this chapter.

### *4.1.1 Risk*

Some high speed roads in rural areas have a low number of vehicles, and even fewer (if any) cyclists. Often in these areas, the perceived risk of a vehicle-bicycle crash is very low and there may be no history of crashes involving bicycles, although any crashes are likely to result in serious injuries or fatalities – refer Section 2.1. This may give authorities little incentive to install bicycle facilities.

Conversely, on some sections of road the risk of a crash is perceived to be higher than reflected by the actual crash rate (e.g. narrow roads with sharp bends). It is important that decisions are made after considering the actual risk, as well as the perceived risk.

### *4.1.2 Physical limitations*

In some situations, the road reserve and adjacent land uses preclude the addition of bicycle facilities. On many roads, there is not enough existing sealed width to provide a bicycle facility without reallocating the road space (e.g. removing a traffic or parking lane). In some cases the sealed width can be extended (often at great cost), however in some areas, particularly urban areas, there is simply not enough space.

#### *4.1.3 Funding*

Money is one factor that invariably influences decisions about bicycle investment. Road authorities have limited budgets that must be distributed between providing, improving and maintaining facilities for all road users. The benefits of larger bicycle projects often need to be proven before authorities will invest in them. Financial limitations, both in initial construction costs and then recurring maintenance costs, can be difficult to justify where existing cyclist demand is low (as it will often be on high speed roads). Even relatively cheap activities such as shoulder sweeping can become significant when long lengths of roadway require sweeping. The justification for such activities will often require the case to be made not only on cycling needs but also on other benefits (such as motorist safety). Funding may also be linked to cyclist volumes – current, future estimated or as a proportion of all modes.

When preparing business cases (and benefit cost ratios), the wider benefits of treatments should be considered. For example, there are various benefits of shoulder sealing, as discussed in Section 0.

#### *4.1.4 Other road users*

It is a role of the road authority to achieve a balance between providing for bicycles and other road users. This includes the allocation of funds and space within a roadway. For example, the installation of wire rope safety barrier in the median of an access controlled high speed road may reduce the amount of sealed road available for bicycles. Significant road widening may be required in this situation to provide a sealed shoulder or bicycle lane.

#### *4.1.5 Political will and community support*

Many jurisdictions have policies supporting improvement of bicycle facilities to encourage more cycling. However this sometimes comes at the expense of other road users, for example removing a parking lane and replacing it with a bicycle lane will benefit cyclists but reduces the space available for people to park their cars. Almost invariably, those who would lose out from a particular scheme will tend to be able to identify most strongly with their loss and so would be most vocal. Strong political will is necessary to provide such facilities and community support also helps projects succeed. The community may be vocal in their opposition to new bicycle facilities if they consider other projects to have higher priority or if they feel that the project will negatively impact them. These issues can be managed by clear explanation of the problem and solutions to the community. Mitigating treatments may also be included as part of the project scope to address community concerns.

## 4.2 Consider alternative solutions

In some circumstances where the guidelines cannot be met, incremental improvements may be better than the current situation. Designers should consider whether providing a facility that doesn’t meet the guidelines is an improvement on what is already currently available. For example, along a road without any bicycle facilities, a 1 m bicycle lane across a bridge on a road where the shoulder otherwise meets the guidelines may be acceptable. There may be plans to widen the bridge as part of the next bridge restoration, providing enough space for a bicycle lane that meets the guidelines.

The benefits and costs of various treatments need to be considered in order to find a balance between providing something or nothing at all. How expensive or difficult would it be to meet the guidelines? What is the cycling demand? It is also important that designers consider the current situation and compare the options in a relative (not absolute) manner. For example, would providing a bicycle lane narrower than the guidelines create a safer situation than the current situation of no provision at all? It is not possible to declare any road element safe, as other factors like the weather and road user behaviour will always be outside designers' control. It is likely in many high speed situations that a sub-optimal situation, such as providing a narrow shoulder, would be safer than to not provide any shoulder.

The Austroads Guides to Road Design discuss the concept of Extended Design Domain (EDD); an acknowledgement that conditions are often constrained along existing roads. Table 4.1 outlines when EDD and NDD (Normal Design Domain) values may be considered. AGRD03 (Austroads 2010a) and AGRD04A (Austroads 2010b) provide EDD values that may be used in place of those presented in the body of the guide under appropriate circumstances.

Table 4.1: Typical use of normal and extended design domains (Austroads AGRD02 2006a)

| Normal Design Domain | Extended Design Domain |
|---|---|
| New construction ('green field' sites).<br>Significant lengths of reconstruction of existing roads.<br>New carriageway of a duplication. | Assessment of existing roads.<br>Improving the standard of existing roads in constrained situations.<br>New carriageway of a duplication in constrained situations.<br>Temporary situations (e.g. projects where it is known that imminent development will cause a permanent reduction in the operating speed). |

Many international guidelines also include advice about alternative options when recommended widths cannot be met. Examples of solutions where insufficient road width exists to construct a bicycle facility in line with the guidelines include:

- Provide a bicycle lane only in the uphill direction due to the greater difference in speed between cyclists and motor vehicles and to account for the 'wobble' effect of uphill cyclists (Austroads AGRD03 2010a).
- With reference to clearance to be provided from heavy vehicles, Austroads AGRD03 (2010a p. 61) suggests that the 'inability to achieve these clearances should not preclude the provision of a facility having a lesser clearance unless a suitable alternative route or means of accommodating cyclists exists'.
- Provide an off-road path (MRWA 2000).
- Allow cyclists to use footpaths where there are few pedestrians (DfT 1987).
- Consider clip on bridges or alternative routes (Transit New Zealand 2008).
- Reduce lane widths (traffic and shoulder) proportionately to improve overall safety (Transit New Zealand 2008).
- Allow narrower bicycle lanes for up to 50 m at pinch points where the cost of widening is prohibitive (Territory and Municipal Services 2007).
- Any shoulder width is better than none at all (*AASHTO 1999).*

Where constraints restrict the provision of sealed shoulders along the entire length of a high speed road, critical points may be prioritised (e.g. horizontal or vertical curves that restrict the sight distance). There may also be the opportunity to provide lengths of sealed shoulder or 'slow vehicle turnouts' which provide space for vehicles to overtake cyclists (and other slow vehicles).

As a last resort, warning signs may be used to alert drivers to popular cycling routes where cyclists may not be seen in advance. DTEI (2010) provides advice on the use of bicycle warning signs and distance plates when a sealed shoulder cannot be provided. The following section discusses the use of real time signs to alert drivers to a cyclist present on the road.

*Technology*

Many technologies already exist and are being used to detect cyclists, for example inductive loops and push buttons (see Section 0). These can be used to warn drivers in real time that a cyclist is present. This is particularly useful in dangerous locations (e.g. narrow bridges, in tunnels, curves with poor sight lines) or locations when drivers are unlikely to expect cyclists.

For example, a driver along the same remote, rural road every day will very rarely pass a cyclist and therefore is unlikely to anticipate one. A real time sign which is activated when a cyclist is detected will likely be more valuable in alerting the driver than a standard warning sign. Examples of this technology include:

- Auckland, NZ. An electronic warning sign was installed at an intersection with high crash rates involving vehicles turning right into through cyclists. When the inductive loops in the bicycle lane detect a cyclist they activate a sign warning drivers that cyclists are approaching (Dearnaley 2009).
- Chattanooga, TN, USA. Prior to entering a road tunnel, cyclists press a button at the side of the road which activates a light above a sign reading ‘Bikes in tunnel when flashing’ (McKnight 2007).

*Non infrastructure solutions*

Some examples of non infrastructure solutions to improve cyclist safety on high speed roads include:

- encouraging truck and bus drivers to use their radios to communicate with other drivers about cyclists they see on the road, giving them details about the location
- running an advertising campaign targeted at specific road users, for examples cyclists and trucks. Advise people about the rights and responsibilities of both cyclists and drivers and the legitimacy of all modes.

# 5 MAINTENANCE

## 5.1 Sweeping and repairs

Continued maintenance of bicycle facilities is important to ensure they provide a safe path for riders (DfT 1987). Even a well designed bicycle facility can quickly become an undesirable place to ride if debris collects in the path of travel or the surface becomes uneven. ‘Cyclists are more adversely affected than motor vehicles by glass or other debris which occurs particularly on sections of the carriageway not regularly traversed by motor vehicle wheels’ (DfT 1987 p. 8/2). This is important for road authorities to understand, as otherwise cyclists may chose to ride in the traffic lane instead – exposing themselves to greater risk.

The most common way to reduce a build up of debris and litter is to sweep the roads. ‘Where even moderate use of the road is made by cyclists it is important to maintain regular sweeping of such roads’ (DfT 1987 p. 8/2). Most road operators in Australia and New Zealand have a regular sweeping program for kerbed, urban roads. However because of the prohibitive length of high speed rural roads, it is not feasible to regularly sweep these roads. In addition, tow truck drivers in some jurisdictions are required to sweep the road following a crash. This could improve the surface for cyclists if the debris is swept completely off the sealed shoulder, but could also reduce the surface quality if it is only swept as far as the shoulder (where cyclists ride).

In urban areas, one of the main focuses is bicycle lanes which cannot be cleaned in routine road maintenance (Austroads AGRD03 2010a). Examples include bicycle lanes segregated from the road by a kerb. In these instances, it may be necessary to have a specific maintenance program for the bicycle lane. The timing of the sweeps may also be important. For example, along a bicycle route used by commuters, sweeping the road on a Sunday evening will ensure the glass and other debris that accumulates over a weekend is cleared in time for the Monday morning ride. In addition, sweeping where necessary after exceptional events (such as street parties or serious crashes) will assist cyclists.

In rural areas, the shoulder area closest to the traffic lane generally has less debris and a smoother surface than the remainder of the shoulder. This is partly because vehicles occasionally track into this area and partly because the proximity of vehicles tends to push material away from the roadway. Cyclists may ride in this area rather than the outer part of the shoulder on a road that is not swept. One way for authorities to improve cycling routes is to conduct sweeps in accordance with cycling requirements rather than motor vehicle requirements (which are less frequent). For example, this may mean sweeping a particular route used by cyclists four times each year compared to twice for other rural roads. Alternatively it may involve more regular inspections and sweeping as necessary. This ensures any problems are quickly responded to.

Perhaps the most critical roads are on the fringe of urban areas and rural townships where cycling is relatively common on high speed roads that generally do not have kerbs. Shoulders within 20 km of urban areas or rural townships could be swept on a more regular basis than other rural roads, complementing the Austroads AGRD03 (2010a) recommendation for smaller aggregate sizes in shoulders in these areas.

Other maintenance activities that should be carried out on a needs basis include:

- Repairs to faded linemarking.
- Repairs to damaged surfaces. Cycling routes should be inspected regularly to identify hazardous surfaces, including potholes or cracks.

- Removal of obtrusive vegetation. This includes overgrown trees and bushes which obscure sight lines and can force cyclists closer to high speed traffic. Tree roots also can cause damage to the road pavement.
- Repairs to vandalised signs, structures and paths.

The level of detail required to provide a high quality cycling route may be too extensive to be identified and addressed by standard routine maintenance. A system to report these hazards (e.g. a call centre, email address or online hazard reporting) could be provided in addition to periodic maintenance. Ideally all defects would be logged and geo-coded, assisting works crews in locating the issue and determine the priority level for repairing it.

## 5.2 Resurfacing

When a road is resurfaced or lines are remarked, this provides an opportunity to improve the conditions for cycling. Resurfacing may include sealing unsealed shoulders, rehabilitating existing sealed shoulders to improve the surface and resurfacing the entire road or general traffic lanes only.

Rather than simply repainting the lines in these situations, consideration should be given to whether lane markings can be realigned to provide (more) space for cyclists. This can be achieved in various ways, such as by realigning lane markings or sealing a wider area and creating a shoulder or bicycle lane.

Resurfacing provides the opportunity to remove any uneven surfaces within the bicycle space, including pit lids. When just the road is resurfaced, care should be taken not to create a hazard to cyclists at the transverse or longitudinal edge of the resurfacing treatment.

## 5.3 Australian and New Zealand Practice

In urban areas, asphalt is often used to seal roadways, which provides a smooth surface for cyclists. In rural areas, a spray seal is often used. As discussed in Section 0, a spray seal using an aggregate size of 10 mm or less is preferable when providing on-road cycling facilities. Table 5.1 outlines the maintenance practices used in each jurisdiction in Australia and New Zealand based on information provided during the consultation phase.

Table 5.1: Outline of maintenance practices in jurisdictions across Australia and New Zealand

| Jurisdiction | Sweeping | Resurfacing (rural roads) |
|---|---|---|
| ACT | Urban high speed roads are swept four times each year, focussing on the shoulders. | Sometimes when a road is resurfaced, the shoulder is resurfaced using a stone smaller than that used on the main carriageway.<br>Contractors must sweep the shoulder/bicycle lane after resurfacing and contracts have a maximum allowable limit on remaining stones per square metre. |
| NSW | On common cycling routes, regular sweeping is conducted to match cycling requirements rather than vehicle requirements (e.g. | Current practice is to use the same pavement seal on the shoulder as is used on the carriageway. On motorways where the seal doesn't extend into the shoulder, RTA uses a sand seal on the shoulder to fill the voids and make it smoother for cyclists. They also roll the edge of the seal to reduce the lip between the traffic lane and shoulder. |
| NZ | Rural roads are not swept. Urban roads are swept according to contracts put in place by individual Councils. Sometimes these contracts include special provision to sweep bicycle lanes (e.g. Christchurch).<br>There are also examples of changes to the day | Often the same aggregate size is used in the shoulder as on the carriageway. The idea of running traffic over the shoulder immediately following construction to smooth it out for cyclists has been raised but not yet trialled. |

| Jurisdiction | Sweeping | Resurfacing (rural roads) |
|---|---|---|
| | sweeps occur to provide the best conditions during peak cycling times. For example, sweeps were moved from a Thursday night to a Sunday night to remove debris that gathers over the weekend. | |
| NT | No information provided. | No information provided. |
| Qld | No information provided. | Usually a 14 mm aggregate is used on rural road shoulders to reduce costs. |
| SA | Urban roads are maintained (including sweeping) by local Councils. Rural roads are not regularly swept. Requests for sweeping are sometimes received prior to large cycling events. | Shoulders on rural roads along cycling routes are sealed with a mix of 10 and 5 mm aggregate. |
| Tas | Shoulders along rural roads are not swept. Efforts are made to sweep urban roads frequented by cyclists more regularly than standard, and the timing of sweeps has been altered in some cases to provide a better environment for cyclists. The protocols for sweeping these roads are to be reviewed in 2012. | Shoulders are sealed with the same size aggregate as the main carriageway. Resurfacing alternate between 10 mm and 14 mm treatments, so the road is more 'cyclist friendly' following the size 10 resurfacing.<br>Shoulder sealing protocols for roads on cycling routes are to be reviewed on 2012. |
| Vic | No specific sweeping program for cyclists. Streets are swept on a needs basis. | Consider the use of smaller size stones on shoulders where cyclists are known to use the route. |
| WA | The sweeping program varies depending on the area. For example, an urban freeway may be swept as regularly as once a fortnight and a rural highway may never be swept as part of ongoing maintenance. | A 14 mm aggregate is used across the entire carriageway, including the shoulders. It is difficult to justify the use of a finer aggregate as cyclist volumes are very low. |

# 6 IMPROVING THE AUSTROADS GUIDELINES

Table 6.1 compares the Austroads Guidelines to best practice in providing for cyclists on high speed roads. It discusses areas where the guidelines are similar, conflicting or silent with respect to best practice, and what changes can be made to improve them.

Table 6.1: Changes that could be made to improve the Austroads guidelines

| Topic | Relevant guidelines | What do the guidelines recommend? | Comparison to best practice (Table 3.1) | What changes could be made to improve them? |
|---|---|---|---|---|
| Provide an alternative route | | | | |
| off-road | AGRD Part 3 – Geometric Design<br>AGRD Part 6A – Pedestrian and Cyclist Paths | An off-road exclusive cyclist path provides the highest level of safety and priority. | Similar in recommending off-road paths. Detailed design of off-road paths has not been reviewed. | No change. |
| on-road | | | Silent. | AGRD to discuss the decision to prohibit cyclists from a road. This should consider cyclist needs and only be done when there are alternative on-road routes available which are lower speed, direct and good quality. |
| Provide space on-road | | | | |
| Midblock (bicycle lanes) | AGRD Part 3 – Geometric Design | Bicycle lanes should be between 1.5 – 2.5 m wide on high speed roads, increasing with increasing speed.<br>Lane width should only be measured from where the surface is in good condition.<br>Shared bicycle and parking lane should be 4.5 m wide on an 80 km/h road. | Similar but could be improved. | In addition, bicycle lanes wider than 2.5 m should be separated from the traffic lane in some way (e.g. painted buffer zone, raised separator, off-road) to discourage motor vehicles from using the bicycle lane. See also 'Delineation'.<br>Parking on high speed roads is uncommon, except where service lanes are provided. In areas with high parking volumes, consideration should be given to banning on-road parking and instead providing an off street car park if necessary. |
| (sealed shoulders) | AGRD Part 3 – Geometric Design | Providing a minimum sealed shoulder of 2.0/3.0 m where there is bicycle demand. | Similar but could be improved. | Recommended shoulder widths to match recommended bicycle lane width (e.g. increasing with increasing speed).<br>Discourage parking on high speed roads by providing off-road car parks.<br>Consider reducing traffic lane widths to create space. |
| (remove parking) | | | Silent. | AGRD Part 3 – Geometric Design discusses parking as a criterion in selecting appropriate bicycle facilities, but it should also suggest designers consider removing parking along bicycle routes. This is particularly relevant on rural roads in tourist areas, where parking can be provided off-road. |
| (pit lids) | AGRD Part 3 – Geometric Design | Pit lids should be flush with the road | Similar. | No change |
| (drainage grates) | AGRD Part 5 – Drainage Design | Drainage grates should not be a hazard to cyclists | Similar. | No change |

| Topic | Relevant guidelines | What do the guidelines recommend? | Comparison to best practice (Table 3.1) | What changes could be made to improve them? |
|---|---|---|---|---|
| (trucks) | AGRD Part 3 – Geometric Design | When there are a high number of heavy vehicles, provide increasing clearance from the traffic lane to the cycling envelope.<br>Around curves, mark the lane at 3.5 m but provide full pavement depth into the shoulder for the width required by heavy vehicles. | Similar. | Revise to include specific proportion of heavy vehicles, i.e. where the proportion of heavy vehicles is greater than 10%. |
| (buses) | AGRD Part 3 – Geometric Design | A shared lane between 4.5 and 5.0 m (4.3 m minimum) provides sufficient width for cyclists and buses to share the lane. | Similar but could be improved. | In addition, recommend providing a separate (or off-road) path for cyclists where buses travel at high speeds as the first preference. |
| At intersections | | | | |
| (unsignalised intersections) | AGRD Part 4A – Unsignalised and signalised intersections | Shoulders should continue through intersection and islands should be set back at least 1.5 m from the edge of the traffic lane. | Similar but could be improved. | More details regarding the advantages and disadvantages of the various priority junctions as per Section 0. |
| (signalised intersections) | AGRD Part 4A – Unsignalised and signalised intersections<br>AGTM Part 6 –<br>Intersections, Interchanges and Crossings | Various forms of advanced stopping facilities and bypass treatments are discussed. | Similar, but no guidance is provided on *when* these treatments should be provided.<br>Silent on signal phasing. | Provide guidance on when they should be installed e.g. at all signalised intersections and whenever a road is resurfaced.<br>A more in depth discussion around how to enhance signals for cyclists in AGTM Part 6. |
| (roundabouts) | AGRD Part 4B - Roundabouts | Off-road paths provide a safe route for less confident cyclists.<br>Consider signalising the roundabout when on a bicycle commuter route.<br>Consider an off-road path. | Similar but could be improved. | In addition, a discussion of treatments to improve it for cyclists (signalisation, off-road path, slowing vehicles, provide an alternative route). |
| | | Bicycle lanes may be considered for use through roundabouts. | Conflicting. | International studies have found bicycle lanes through roundabouts may be less safe than shared lanes. This is also consistent with the Australian Standards. The use of bicycle lanes through roundabouts is the subject of a current ABC research project, so no recommendations are made for changing the Austroads guidelines in this report. |
| (slip lanes and freeway ramps) | AGRD Part 4A – Unsignalised and signalised intersections | Provide cyclists with a crossing point before the merge. At a rural free flow left turn island, provide a cut through of the traffic island so that cyclists do not travel between two lanes of high speed traffic.<br>In urban areas (at intersections), continue the bicycle lane to the stop line, requiring left turning traffic to cross the bicycle lane. | Similar. | In addition, AGRD Part 4A should discuss the possibility of additional merge/diverge lanes. In particular, the added complexity these present to cyclists in crossing should be outlined. |

| Topic | Relevant guidelines | What do the guidelines recommend? | Comparison to best practice (Table 3.1) | What changes could be made to improve them? |
|---|---|---|---|---|
| Using delineation | AGRD Part 6A – Pedestrian and Cyclist Paths | RPMs should not be used to supplement separation lines (on paths). | Similar.<br>Silent on the use of RPMs on roads in relation to cyclists. | Extend the recommendation for paths to roads in AGRD Part 3. RPMs should not be used along edge lines on cycling routes where the shoulder or bicycle lane is narrow or likely to become covered with debris. If there are no alternatives to RPMs in areas of low or poor lighting, avoid placing them in the shoulder. |
| | AGTM Part 10 – Traffic Control and Communications Devices | A sealed roadway width should be 9.0 m (two 3.5 m lanes and two 1.0 m shoulders) before audio tactile edge lines are used. The absolute minimum is 7.0 m, provided the edge lines are at least 150 mm from the edge of the seal. | Silent with respect to how audio tactile linemarking or raised separators could be used to improve cycling conditions. | Standard linemarking should not create a hazard for cyclists, including painted bicycle symbols.<br>Consider the use of audio tactile linemarking or raised separators along bicycle lanes or shoulders that meet the recommended width.<br>Make reference to AGTM Part 10 in AGTD Part 3. |
| Reduce speed limits | AGRD Part 3 – Geometric Design | The section on speed considers what speed drivers are likely to want to travel at, but not who else may be using the road and the benefits to them of lower speeds. | Conflicting. | AGRD Part 3 to refer to AGRS Part 3 in setting a speed limit to ensure wider issues (such as cyclist safety) are considered. |
| | AGRS Part 3 – Speed Limits and Speed Management | Lower speeds improve road safety. | Similar. | No change. |
| Alternative solutions | | | Silent. | Discuss available technology and non infrastructure solutions and how they can be used to improve cyclist safety. |
| Maintenance | AGRD Part 3 – Geometric Design<br>AGPT Part 7 – Pavement Maintenance | Consider how to keep separated bicycle lanes clean.<br>Consider altering lanemarking to provide for cyclists (when resurfacing).<br>General information on pavement cleaning, including sweeping. | Similar but could be improved. | Consider the most appropriate time for sweeping and how frequent they should be to cater for bicycles. This is particularly applicable to high speed roads:<br>in and on the edge of urban areas<br>near rural townships<br>in rural areas that are popular cycling routes. |

Note: AGRD = Austroads Guide to Road Design; AGRS = Austroads Guide to Road Safety; AGTM = Austroads Guide to Traffic Management

# 7 CONCLUSIONS

The difference in mass and speed of bicycles and motor vehicles means a cyclist involved in a crash on a high speed road has only a small chance of surviving. However where cycling provision cannot be made off-road or good quality, lower speed, direct alternative routes are not available, then bicycles should not be restricted from the road.

Internationally, the first response is generally to provide cyclists with a path separated from the road along high speed roads. In Australia and NZ, many jurisdictions are providing off-road paths along new freeways or along roads where cyclists are not permitted to ride. In rural areas, on-road shoulders are often the preferred treatment due to the long distances, high costs of off-road paths and few cyclists.

The most suitable type of facility will depend on who it is being provided for and why they are riding (do they want a fast, direct route or would they prefer a route where they don't have to worry about interacting with traffic?). Sometimes both an on-road and off-road options would ideally be provided to cater for the range of cyclist preferences. However any provision is usually better than none as all cyclists are likely to benefit.

This report found techniques to help reduce the inherent conflict to more acceptable levels. These include:

- providing an alternative route, such as an off-road path or an alternative lower speed route
- providing space on-road
- reducing the speed limit
- using technology (e.g. real time information for drivers alerting them that a cyclist is present) and advertising campaigns.
- Space for cyclists can be provided in many ways on high speed roads.
- Exclusive bicycle lanes. Bicycle lanes should generally be provided along identified bicycle routes in urban areas. These should be at least 2 m wide, increasing in width with increasing vehicle speeds. Bicycle lanes wider than 2.5 m should be separated from the general traffic lane in some way (e.g. painted buffer zone, raised separator, off-road) to discourage drivers from using the bicycle lane as a general traffic lane.
- Sealed shoulders. Sealed shoulders are generally used in rural areas where the cost of bicycle specific facilities cannot be justified. As for bicycle lanes, sealed shoulders should be at least 2.0 m on high speed roads. Shoulders should be sealed with asphalt (urban areas) or a spray seal with stone size of 10 mm or less. Additional width should be provided where there are a large number of heavy vehicles.
- Intersections. Bicycle lanes and shoulders should continue through intersections, and the side road stop line and median should be set back by at least 2 m from the edge of the traffic lane.
  - At signalised intersections, advanced stop lines should be provided and in some cases assistance in turning right. Detection equipment needs to be sensitive enough to detect cyclists.
  - At roundabouts where cyclist safety is a concern, consider signalising the intersection, providing cyclists with a separate path, slowing the vehicles or providing cyclists with an alternative route.

— There are two types of diverge points: slip lanes and off ramps. Where slip lanes cannot be removed, the conflict point with through bicycles should be set back from the diverge point. Across freeway off ramps, cyclists can be diverted to a crossing point along the off ramp so that they are not trapped between two lanes of high speed traffic. Equivalent treatments can be employed at merge points.

— Consider the most appropriate delineation type in each situation: standard line marking (including painted islands), raised lines (audio tactile edge line), raised rubber separators or raised traffic islands.

Where space cannot be provided for bicycles, consideration may be given to allowing them to share a bus lane, which would desirably be between 4.5 and 5.0m wide.

In common with lower speed roads, items such as drainage grates and line markings should be flush with the road surface so they do not create a hazard for cyclists. Maintenance regimes can be improved to better cater for cyclists by sweeping the road at appropriate times and intervals. When roads are resurfaced, consideration should be given to realigning the traffic lanes to provide space for cyclists.

Every situation is different and limitations may mean the level of provision presented here cannot be achieved in some situations. Risk of crashes, physical limitations, funding availability, the need to provide for other road users and the level of political will and community support will all influence the final facilities provided. The Austroads Guidelines should be reviewed and modified to better reflect how to provide for cyclists on high speed roads.

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**Keywords:** active transport, advanced stop line, bicycle, bicycle crossing, bicycle lane, bicycle infrastructure, buffer zone, bus lane, coloured pavement, cycling, cyclist, delineation, diverge, drainage grate, electronic warning sign, freeway, freeway ramp, heavy vehicle, high speed road, jug handle, line marking, maintenance, merge, off-road path, parking, pavement surface, prioritised junction, roundabout, seagull treatment, sealed shoulder, signalised intersection, speed limit, road repairs, resurfacing, slip lane, sweeping, vulnerable road user

**Abstract:** This report investigates the provision of facilities for bicycles on sealed roads with speed limits of 70 km/h or more. It outlines how to improve these roads for cyclists where off-road alternatives or on-road, lower speed, direct options are not available.