GUIDE TO ROAD DESIGN

Part 4A: Unsignalised and Signalised Intersections
Guide to Road Design Part 4A: Unsignalised and Signalised Intersections

Summary
The Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections provides road designers and other practitioners with guidance on the detailed geometric design of all at-grade intersections (excluding roundabouts). However, some of the guidance in Part 4A may be appropriate for the design of approaches to roundabouts and is relevant to the design of the design of ramp terminals where freeway ramps intersect with the minor road at an interchange.

Part 4A does not provide all the information that is necessary to design a satisfactory intersection and therefore, depending on the situation, should be used in conjunction with all other parts of the Austroads Guide to Road Design, in particular:

- Part 4: Intersections and Crossings – General (Austroads 2009b)
- Part 4B: Roundabouts (Austroads 2009c)
- Part 4C: Interchanges (Austroads 2009d).

In addition, road designers should also refer to the Austroads Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007) which provides guidance on the traffic management aspects of intersection design and road users’ requirements.

Keywords
Design domain, normal design domain, extended design domain, design process, alignment, sight distance, types of intersection, selection of intersection, basic, auxiliary, channelised, auxiliary lanes, traffic islands and medians, right-turn treatments, left-turn treatments, U-turn treatments, signalised intersections, pedestrians, cyclists

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Project Manager
David Hubner, DTMR Qld

Prepared by
Gary Veith, ARRB Group

Published by Austroads Ltd
Level 9, Robell House
287 Elizabeth Street
Sydney NSW 2000 Australia
Phone: +61 2 9264 7088
Fax: +61 2 9264 1657
Email: austroads@austroads.com.au
www.austroads.com.au
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- promoting harmonisation, consistency and uniformity in road and related operations
- undertaking strategic research on behalf of road agencies and communicating outcomes
- promoting improved and consistent practice by road agencies.

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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 sector.
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Mr Pat Kenny  
Roads and Traffic Authority, New South Wales

Mr David Barton  
Roads Corporation, Victoria (VicRoads)

Mr Anthony Barton  
Roads Corporation, Victoria (VicRoads)

Dr Owen Arndt  
Queensland Department of Transport and Main Roads (Project Manager)

Mr Rob Grove  
Main Roads Western Australia

Mr Noel O’Callaghan  
Department for Transport, Energy and Infrastructure, South Australia

Mr Graeme Nichols  
Department of Infrastructure, Energy and Resources, Tasmania

Mr Peter Toll  
Department of Planning and Infrastructure, Northern Territory

Mr Ken Marshall  
ACT Department of Territory and Municipal Services

Mr Peter Aumann  
Australian Local Government Association

Mr James Hughes  
NZ Transport Agency

Mr Tom Brock  
The Association of Consulting Engineers

Mr Michael Tziotis  
ARRB Group Ltd
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1 INTRODUCTION

1.1 Purpose

Austroads Guide to Road Design seeks to capture the contemporary road design practice of member organisations (Guide to Road Design – Part 1: Introduction to Road Design (Austroads 2006b)). In doing so, it provides valuable guidance to designers in the production of safe, economical and efficient road designs.

The purpose of the Guide to Road Design – Part 4: Intersections and Crossings – General (Austroads 2009b) is to provide guidance to road designers on the geometric design of all types of road intersections and crossings. The guide comprises four parts:

- Part 4A: Unsignalised and Signalised Intersections.
- Part 4B: Roundabouts (Austroads 2009c).
- Part 4C: Interchanges (Austroads 2009d).

Part 4 covers intersection design principles that apply generally to intersections and crossings and the other three parts provide guidance specifically related to the type of intersection. Consequently, the purpose of Part 4A: Unsignalised and Signalised Intersections is to provide:

- information on the types of unsignalised and signalised intersections and their use
- an intersection layout design process and factors to be considered
- detailed geometric design requirements for various types of intersection.

Figure 1.1 shows that Part 4 is one of eight parts that comprise the Austroads Guide to Road Design. Collectively these parts provide information on a range of disciplines including geometric design, drainage, roadside design, and geotechnical design, all of which may influence the location and design of intersections.

![Flow chart of the Guide to Road Design](image)
It should be noted that the *Guide to Road Design – Part 6* comprises three guides, namely:

- Part 6B: Roadside Environment (Austroads 2009g).

### 1.2 Scope of this Part

Part 4 of the *Guide to Road Design* is limited to the design of intersections. While Figure 1.1 outlines the structure of the *Guide to Road Design*, designers should be aware that there are nine other subject areas spanning the range of Austroads publications that may also be relevant to road design and the design of intersections [www.austroads.com.au].

Austroads *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings* (Austroads 2007) should be regarded as a related document to this part of the *Guide to Road Design*, as it provides traffic management advice for the selection, location and design of intersections. Part 6 of the *Guide to Traffic Management* should be consulted when determining the appropriate type of intersection to be provided, and when considering the design of particular features from a traffic management and road user perspective.

Part 4 of the *Guide to Road Design*, when used in conjunction with other relevant parts of the *Guide to Road Design* and *Guide to Traffic Management*, provides the information and guidance necessary for a road designer to prepare detailed geometric design drawings that are adequate to facilitate the construction of intersections and crossings.


### 1.3 Road Safety

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 safe system approach requires, in part (Australian Transport Council 2006):

- Designing, constructing and maintaining a road system (roads, vehicles and operating requirements) so that forces on the human body generated in crashes are generally less than those resulting in fatal or debilitating injury.
- Improving roads and roadsides to reduce the risk of crashes and minimise harm: measures for higher speed roads including dividing traffic, designing ‘forgiving’ roadsides, and providing clear driver guidance. In areas with large numbers of vulnerable road users or substantial collision risk, speed management supplemented by road and roadside treatments is a key strategy for limiting crashes.
- Managing speeds, taking into account the risks on different parts of the road system.

In New Zealand, practical steps have been taken to give effect to similar guiding principles through a Safety Management Systems (SMS) approach.

Road designers should be aware of and, through the design process, actively support the philosophy and road safety objectives covered in the *Guide to Road Safety* (Austroads 2006 – 2009).
1.4 Design Criteria in Part 4A

The Austroads Guide to Road Design seeks to capture the contemporary road design practice of member organisations (Guide to Road Design – Part 1: Introduction to Road Design (Austroads 2006b)). In doing so, it provides valuable guidance to designers in the production of safe, economical and efficient road designs.

Part 4 of the Guide to Road Design defines greenfield and brownfield sites within the context of road design and suggests that in most cases the application of NDD values will be suitable and possible for both. However, it is also acknowledged that situations will arise where it may not always be practical or possible to achieve all the relevant NDD values (e.g. in constrained locations) in which case road authorities may consider the use of values outside of the NDD.

The body of this guide (Part 4A) contains NDD values that should be used for the design of all unsignalised and signalised intersections, including new intersections on new or existing roads, and modifications to existing intersections. Appendix A contains EDD values that relate to intersection design and, through research and/or operating experience, have been found to provide a suitable solution in constrained situations. EDD values have only been developed for particular parameters, where considerable latitude exists within the NDD values.

Guidance on use of values outside of the design domain (i.e. outside of the NDD and EDD) is not provided in this part. Designers should consult the delegated representative from the relevant road authority for advice and direction with respect to an appropriate standard when values within the design domain are not achievable.

In applying this guide:
1. Normal design domain values given in the body of this guide should be used wherever practical.
2. Design values outside of the NDD are only to be used if approved in writing by the delegated representative from the relevant road authority. The relevant road authority may be a state road authority, municipal council or private road owner.
3. If using EDD values, the reduction in standard associated with their use should be appropriate for the prevailing local conditions. Generally, EDD should be used for only one parameter in any application and not be used in combination with any other minimum or EDD value for any related or associated parameters.

1.5 Road Design Objectives

Road design objectives are discussed in the Guide to Road Design – Part 2: Design Considerations (Austroads 2006c) and these objectives also apply to the design of intersections and crossings, and should be considered in the design of unsignalised and signalised intersections.

1.6 Intersection Safety

Road designers should be aware that intersection design takes place in a broader context where designs are influenced by many factors, including cost and economic considerations. However, it is important that intersections should perform the intended function and operate as efficiently as possible, but it is paramount that intersections are designed to be as safe as possible.
Section 1.3 describes the safe system approach whereby safer roads and roadsides, safer speeds and safer vehicles combine to produce a reduction in road trauma. Therefore, a key objective of an intersection is that it should function as safely as possible and make a major contribution to the development of a safe system.

An understanding of the types of crashes that occur at different types of intersections, and of the factors that contribute to crashes is essential in the development of effective designs and related road safety countermeasures. Appendix B provides an indication of the types of crashes that might be expected at an unsignalised cross intersection in Australia based on a study of the effect of intersection geometry on crash rates (Arndt 2004). Similar New Zealand information is available for various types of intersections (Turner & Wood 2009).

1.7 Grade Separation of Traffic Movements

The design of at-grade intersections, particularly those in urban situations, often requires traffic analysis to establish the number of traffic lanes and length of traffic queues that should be accommodated to achieve a satisfactory capacity and level of service in the design year. Guidance on the required analysis is available in the Guide to Traffic Management – Part 3: Traffic Studies and Analysis (Austroads 2009h).

Generally at-grade intersections can be designed to provide adequate capacity and safety. However, situations do arise where a particular traffic movement results in serious congestion or road safety problem cannot be resolved through traffic management or at-grade treatment. In such cases the road authority may choose to grade separate one or more movements. These treatments can involve various layouts to suit local situations and traffic movements and typically have the normal features of an at-grade design (e.g. auxiliary lanes). To improve safety they may result in the major road intersections comprising only left turns and auxiliary lanes.
2 LAYOUT DESIGN PROCESS

2.1 Design Process

The process of designing an intersection layout is shown on the flow chart in Figure 2.1. It involves operational and geometric requirements that are inter-related and determine the information that is presented on conceptual and functional design plans.

![Intersection layout design process flow chart](chart)

Establish the alignment of the approaches

Draw road mid-block cross-sections

At intersection draw lanes required for traffic operation and safety

Check that design features can be accommodated

Determine the required pavement and the location and shape of median noses and kerbs

Draw turning lane lengths including tapers and match to mid-block cross sections

Draw the left and right-turn treatments

Check that sight distance requirements are met

Design special requirements

Draw all road markings

Add key dimensions to drawing including parking limits

Figure 2.1: Intersection layout design process
Table 2.1 provides a summary of some considerations in relation to the intersection layout design process.

Table 2.1: Considerations in the intersection layout design process

<table>
<thead>
<tr>
<th>Design aspect</th>
<th>Key considerations</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Establish the alignment of the approaches.</td>
<td>Straight and flat alignments are ideal. Where it is necessary for a road to change direction as it passes through an intersection the tangent points for the horizontal curve should be located (i.e. locate tangent points) on approaches some distance from the intersection (rather than have a sharp change in direction at the intersection). Align the side road to intersect the major road at 90° and a straight on the immediate approach.</td>
<td>Guide to Road Design Part 3 Section 3.4</td>
</tr>
<tr>
<td>Determine and draw the mid-block cross sections on each leg of the intersection.</td>
<td>Provide the details with which the intersection layout must match on each leg (i.e. mid-block road space allocation). May include verges, paths, parking lanes, special use lanes, medians, public transport reservations (in the median or roadside).</td>
<td>Guide to Traffic Management Part 5 Section 3, Guide to Road Design Part 3</td>
</tr>
<tr>
<td>For each leg draw the traffic lanes (approach and departure) required for satisfactory operation and safety.</td>
<td>Number of through lanes and turn lanes are determined by traffic analysis. Road function may require bus, transit or bicycle lanes, or tram lines. Specify median width, where on one is to be provided. Provide adequate footpaths.</td>
<td>Guide to Traffic Management Part 3 Section 6</td>
</tr>
<tr>
<td>Ensure that roadside area can accommodate required design features and infrastructure.</td>
<td>Consider drainage, roadside safety, safety barriers, road furniture, signage, utilities, lighting, paths and environmental requirements.</td>
<td>Guide to Road Design Part 5 Section 5</td>
</tr>
<tr>
<td>Determine the required pavement and the location and shape of median noses and kerb returns.</td>
<td>Use appropriate turning template or computer software for the design vehicle. Use appropriate turning radii for templates and clearances to kerbs and other vehicles. Plot the required pavement area and the location and shape of the median noses, turning lines and edge lines, other kerbs etc; locate stop and give way lines.</td>
<td>Guide to Road Design Part 4 Section 5</td>
</tr>
<tr>
<td>Draw the left-turn and right-turn treatments.</td>
<td>Appropriate treatment determined by traffic analysis, consideration of road user requirements and safety. Give way situations – high entry angle treatment. Free-flow and signalised left-turns – design for an appropriate turning speed. Check observation angles. Provide right-turn treatment based on traffic analysis – may require relatively wide median on intersection approach.</td>
<td>Section 8 Section 7</td>
</tr>
<tr>
<td>Draw turning lane lengths including tapers and match treatment to mid-block cross-sections.</td>
<td>Determine the lengths of auxiliary lanes and draw the lanes with appropriate physical tapers for both left-turn and right-turn lanes, based on deceleration length, storage length (from traffic analysis), and queue lengths in adjacent through lanes.</td>
<td>Section 5</td>
</tr>
<tr>
<td>Check that sight distance requirements are met.</td>
<td>Approach sight distance, safe intersection sight distance, and minimum gap sight distance.</td>
<td>Section 3</td>
</tr>
<tr>
<td>Design special requirements.</td>
<td>Design any special requirements such as bus bays and DDA compliant bus stops and/or tram stops, bicycle lanes etc. Consider bus route through intersection. Locate stops (incorporate stops into traffic islands?)</td>
<td>Guide to Road Design Part 4</td>
</tr>
<tr>
<td>Draw all road markings.</td>
<td>Plot the line marking, including stop lines, give way lines, marked pedestrian crossings, lane lines, turning lines, pavement arrows and symbols.</td>
<td>AS 1742 Guide to Traffic Management Part 102 MOTSAM Part 2: Markings (Transit NZ 2008) in NZ</td>
</tr>
</tbody>
</table>
The design of a signalised intersection must also result in the production of a signal layout plan that shows the location and types of all signals and associated hardware and infrastructure. Table 2.2 summarises key aspects of a signal layout plan, some of which need to be considered in the geometric design of the intersection.

**Table 2.2: Considerations in developing a signal layout plan that may influence geometric design**

<table>
<thead>
<tr>
<th>Design aspect</th>
<th>Key considerations</th>
<th>Reference</th>
</tr>
</thead>
</table>
| **Locate appropriate signal poles in relation to stop lines and in a position where they have adequate clearance to adjacent traffic lanes.** | Mast arms and joint use poles have large foundations. Consider:  
- overhead and underground services  
- coordination of foundation locations with drainage pits and pipes  
- accommodation of signage on traffic signal poles. | Guide to Traffic Management Part 9 |
| **Add symbols that describe the signal aspects.** | Controllers are expensive; choose location where:  
- it is not vulnerable to run-off-road crashes  
- maintenance technician has a clear view of traffic movements  
- maintenance vehicle can be parked adjacent to controller (desirable)  
- power source is readily available. | Guide to Traffic Management Part 9 |
| **Choose an appropriate site for the traffic signal controller and plot its location.** | Where possible, locate power cable pits outside of pedestrian paths and storage areas. Coordinate power conduit location with drainage and underground services. | |
| **Draw location of power conduits, power cable pits, detectors and detector pits.** | Where possible, locate power cable pits outside of pedestrian paths and storage areas. Coordinate power conduit location with drainage and underground services. | |
| **Define required parking limits in relation to statutory rules and traffic operation.** | Queue lengths of left-turn movements. | Guide to Traffic Management Part 3 Australian Road Rules.3 |
| **Add a schedule of signs relating to the signalisation of the intersection.** | Regulatory and warning signs are most important to operation. Coordinate with proposed or existing signage on approaches. | AS 1742 |

Note:

1. Australian Road Rules, National Transport Commission.
2.2 Alignment of Intersection Approaches

Once the preferred intersection location, the general alignment of the intersecting roads, type of layout and form of control have been determined, the first step in the layout design process is to determine the detailed alignment of each leg of the intersection.

Issues may arise and adjustments may have to be made to the layout during this part of the process, perhaps because original site assumptions or information were not entirely correct.

2.2.1 Horizontal Alignment

Road centrelines should be designed to intersect as close to 90° as possible so that driver observation angles to potentially conflicting vehicles are satisfactory. This is particularly important for older drivers who may have limited ability to turn their head and neck to observe potentially conflicting traffic (Veith 2004).

The best site condition for an intersection is where all approaches are able to have straight horizontal alignments and relatively flat vertical alignments. This provides approaching drivers with the best view of the intersection layout and other vehicles. Where this is not possible, it is desirable that any curved horizontal alignment for a through movement at the intersection is of a constant radius and that tangent points are located a substantial distance from the intersection. This practice is desirable at rural and urban sites.

The available road reservation or other constraints at some urban sites may result in tangent points being located close to the intersection and a misalignment of lanes through an intersection. This in turn can adversely affect lane discipline through the intersection and therefore lanes may have to be delineated within the intersection (e.g. raised pavement markers).

On curved horizontal alignments it is inevitable that reverse curvature will be involved in some turning movements and this can create difficulties, particularly with crossfall. In urban environments, a minimum 10 to 15 m length of straight should be provided between reverse curves, as shown in Figure 2.2. This distance approximates one to two seconds travel time and allows drivers to make any reverse steering manoeuvres necessary. Each movement should be checked with a turning path template and the length of straight increased as necessary. Careful attention to the kerb profiles must be done interactively.

![Figure 2.2: Typical arrangement of reverse curves with short straight used at urban sites](source: Austroads (2005).)
In rural situations a curved approach on a terminating leg requires a length of straight to allow for plan and/or crossfall transition. From a driver’s perspective it is also most desirable to have a straight rather than curved alignment on the immediate approaches to intersections. A suitable length of straight ensures that sight distance lines occur above the road formation giving drivers the best opportunity to see the intersection and brake on a straight rather than on a curved alignment. In addition, it is often difficult for drivers to judge the location of intersections that are located at the end of horizontal curves.

In rural situations the road geometry on a side road can be used to progressively slow drivers so that they can safely give way or stop at the intersection. Reference should be made to Austroads Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) for design parameters that are appropriate to a particular intersection approach.

The desirable requirements for rural sites are illustrated in Figure 2.3. If these requirements cannot be met the designer should consider a minimum treatment or realignment in order to increase the length of straight in the side road.

Where a short length of median is proposed on the side road it may be desirable to lengthen the straight to simplify construction of the median. The minimum length of median in these instances is 10 m.

Note: Straight section required to provide a transition between an approach curve and the intersection.
Source: Austroads (2005).

Figure 2.3: Desirable minor road approach alignment at rural sites
2.2.2 Vertical Alignment

A steep upgrade on the approach to an intersection generally results in both sight distance and operational problems. Upgrades greater than 3% on the minor approach to an intersection are undesirable, especially where traffic has to stop before entering. Where such approach grades are necessary, preferred practice is to grade the road at 3% or less for a minimum distance of 10 m from the lip of the channel or edge line (maximum of 4%). This limitation is required in order to facilitate acceleration and to improve sight distance. This situation is illustrated in Figure 2.4 and is more critical for upgrades than downgrades. If a significant number of heavy vehicles use the side road the distance provided should accommodate the design vehicle. A similar approach is recommended for downgrades on the minor road.

On downhill approaches of side roads to intersections, grades should desirably not exceed 3% with a maximum of 5% in order to limit the effect of steep grades on stopping distances. Alternatively, truck stopping sight distance and high friction surfaces or transverse grooving on the downhill approaches to such intersections should be provided.

At ‘T’ intersections where it is not possible to maintain sight distance to the pavement on the minor road, short vertical curves (e.g. 5 m to 10 m long) may be used. These vertical curves should not encroach into the traffic lanes on the main road. In this situation it is generally desirable to provide a median in the minor road that extends over the crest to provide a cue to drivers that they are approaching an intersection. All minor roads that have priority through an intersection (i.e. at intersections between two minor roads) should be designed with vertical alignment standards which are consistent with the operating speed on the approaches.
Notes:
1. Crossfall grade not to be exceeded for 10 m in approach to edge/lip line.
2. Maximum algebraic change of grade for alternative grade line 12%.
3. ASD 1.1 m to 0.0 m to be provided to stop/give-way line and median nose.
4. The objective is to provide a reasonably flat section prior to the stop line so that a relatively easy entry condition occurs. The sight distance problems at such sites should be noted.

Source: Austroads (2005).

Figure 2.4: Cross-section of major road showing grading options for minor road intersection approaches

Where there is a choice it is preferred that intersections are located away from horizontal curves. It is desirable that approach sight distance (ASD) is available (Section 3.2.1) to the road surface at all intersections. Unfortunately, locating a leg of an intersection on the back of a curve invariably results in drivers approaching from that direction not being able to see the intersection and its layout.

Where it is necessary to place a leg of an intersection on the outside of a superelevated curve it is therefore important to achieve the best possible sight distance outcome. The options are illustrated in Figure 2.5. The grading shown as line 1 is not generally practicable or favoured because of the extent and cost of the earthworks required to provide acceptable minimum sight distances. Where line 1 is not practicable, the preferred grading is line 2 comprising a uniform approach grade with a short vertical curve to join it to the crossfall of the major road. This also results in a relatively flat ‘standing’ area similar to the 10 m shown in Figure 2.4.
In the case of line 2, an island is provided on the minor road approach with appropriate signing to warn approaching drivers of the intersection ahead.

The requirements illustrated in Figure 2.6 apply to designs based on line 2. It should be noted that:

- at least 10 m of the island should be visible to approaching drivers for a distance equal to the ASD for the 85th percentile operating speed on the approach
- the island should, as far as possible, be directly in the line of sight of drivers for a distance equal to the ASD for cars
- the island should be kerbed to increase conspicuity
- the average grade for vehicles at the stop line should be as flat as possible in order to facilitate acceleration into the major road
- the short vertical curve should not encroach onto the shoulder of the major road
- the island should be visible for all approaching truck drivers from the appropriate truck stopping distance.
### 2.2.3 Combined Horizontal and Vertical Curves

The coordination of horizontal and vertical curves is discussed in the *Guide to Road Design – Part 3 – Geometric Design* (Austroads 2009a). Situations may occur where vertical and horizontal geometry must be coordinated at intersections but it is preferable that intersections are located on straight and relatively flat sections of road.

### 2.2.4 Superelevation at or near intersections

Superelevation at intersections is associated with horizontal curves that pass through the intersection. While intersections on the inside of small radius horizontal curves produce difficult observation angles for drivers, those on the outside of curves result in:

- greater difficulty for a driver in the side road to perceive the presence of the through road, the vehicles on the road and the speed of the vehicles
• obscured visibility to oncoming major road vehicles by the vehicles travelling in the opposite direction on the major road

• greater difficulty for a driver on the major road to perceive the location of the intersection due to the superelevation that is normally required on the major road horizontal curve.

Superelevation and changes in superelevation (i.e. crossfall) within an intersection can have a detrimental effect on driver and passenger comfort and vehicle stability, particularly for heavy vehicles. (Appendix C) In general the crossfall adopted for turning roadways where vehicles can turn at moderate speed should desirably not exceed +7% or -3%. For a turn executed at very slow speed (say < 10 km/h), the desirable maximum adverse crossfall (i.e. the vector sum) is -5%. Figure 2.7 shows how a 3% crossfall and a 3% longitudinal fall can combine to result in a 4.2% adverse crossfall throughout a right turn. Where a site is constrained and approach speeds are low a larger adverse crossfall may be considered under EDD (Appendix A).

![Figure 2.7: Illustration of adverse crossfall for a right-turn movement](image)

With respect to adverse crossfall within intersections it is desirable that there are no surprises for drivers and in particular the magnitude of the adverse crossfall should not increase markedly throughout the turning movement. Where longitudinal grades are significant (e.g. ≥ 5% in hilly areas) and trucks with high loads turn at the intersection, it may be necessary to construct a flatter area in the longitudinal grade in order to achieve satisfactory crossfalls for turning traffic. This requirement can also apply to left-turn movements.
3 SIGHT DISTANCE

3.1 General

It is fundamental to the safety of intersections that drivers approaching in all traffic streams are able to:

- recognise the presence of an intersection in time to slow down or stop in a controlled and comfortable manner
- see vehicles approaching in conflicting traffic streams and give way where required by law or avoid a crash in the event of a potential conflict.

Intersection safety performance is therefore largely dependent upon adequate sight distance in relation to both horizontal and vertical geometry for all drivers approaching and entering the intersection. Consequently, sight distance is a key consideration in the location and design of intersections.

A feature of intersections is that sight lines are often required at large angles to the user’s normal viewpoint and the driver of a vehicle may have to look through the side windows. In addition, the paths travelled are often curved, which means that drivers may find it more difficult to view other vehicles and estimate distances.

Large angles can be a significant issue for older drivers, particularly those who may have difficulty in turning their head and neck to detect the presence of conflicting vehicles (Veith 2004). For new at-grade intersections where right of way is not restricted, the roadway should meet at a 90° angle to provide the best sight lines. For re-design of existing at-grade intersections where right of way is restricted, the roadway should meet at an angle of not less than 70°.

The type and extent of sight distance available will significantly influence the design and location of an intersection. Both horizontal and vertical sight lines must be checked to ensure that they are not disrupted by natural objects such as trees, and structures such as fences, buildings and safety barriers.

Adequate sight distance at proposed intersections and remodelled intersections must be achieved when developing the horizontal and vertical alignments of new and upgraded roads, and should be checked as the design proceeds through various iterations.

It is equally important that sight distance requirements are achieved at all pedestrian, cyclist and rail crossings.

3.2 Sight Distance Requirements for Vehicles at Intersections

The types of sight distance that must be provided in the design of all intersections include:

- approach sight distance (ASD)
- safe intersection sight distance (SISD)
- minimum gap sight distance (MGSD).

Intersections should be designed to provide the more conservative value of SISD or MGSD for all vehicle movements that may be required to give way to other vehicles at the intersection.
Designers should also be mindful that the sight distance values provided in this guide are based on particular reaction times and that there will be a percentage of the driver population that requires a reaction time and decision time greater than 2.5 s, for example. However, there is evidence to suggest that these drivers (e.g. older drivers) travel more slowly than other drivers, especially when general traffic speeds are high (Veith 2004). Wherever it is physically and economically practicable designers should therefore consider the provision of a more generous sight distance than the values tabulated in this section, and should provide for at least a 2.5 s reaction time where drivers are not likely to be alert (e.g. rural and outer urban roads).

In addition to the above specific intersection sight distance requirements, stopping sight distance (SSD) in accordance with the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) must be available at all locations through the intersection. This guide provides reaction times, longitudinal deceleration rates, vertical height parameters (e.g. driver eye height) for sight distance requirements for road design in general. Specific sight distance values for intersections are provided in the following sections.

It should be noted that entering sight distance (ESD), as published in previous guides, is not included in this design guide. While ESD is theoretically desirable it has been found to be impracticable in practice and has therefore rarely been applied in intersection design by road authorities. See Commentary 1.

**3.2.1 Approach Sight Distance (ASD)**

**Provision of ASD for cars**

ASD is:

- the minimum level of sight distance which must be available on the minor road approaches to all intersections to ensure that drivers are aware of the presence of an intersection.

- also desirable on the major road approaches so that drivers can see the pavement and markings within the intersection and should be achieved where practicable. However, the provision of ASD on the major road may have implications (e.g. cost; impact on adjacent land and features) in which case SSD is the minimum sight distance that should be achieved on the major road approaches to the intersection and within the intersection.

- numerically equal to normal car SSD – which is defined as the distance travelled by a vehicle between the time when driver receives a stimulus signifying a need to stop, and the time the at which the vehicle comes to rest (Guide to Road Design – Part 3: Geometric Design, (Austroads 2009a)).

- different from SSD in the object height used in its calculation. ASD is measured from a driver’s eye height (1.1 m) to 0.0 m, which ensures that a driver is able to see any line marking and kerbing at the intersection whereas SSD is measured from 1.1 m to 0.2 m (a nominal object height).
Equation 1 provides the formula for ASD and Figure 3.1 illustrates the application of ASD.

\[
ASD = \frac{R_T \times V}{3.6} + \frac{V^2}{254 \times (d + 0.01 \times a)}
\]

where

\[
\begin{align*}
\text{ASD} &= \text{approach sight distance (m)} \\
R_T &= \text{reaction time (s) – refer to Guide to Road Design – Part 3: Geometric Design for guidance on values} \\
V &= \text{operating (85th percentile) speed (km/h)} \\
d &= \text{coefficient of deceleration – refer to Table 3.1 for values} \\
a &= \text{a longitudinal grade in % (in direction of travel: positive for uphill grade, negative for downhill grade).}
\end{align*}
\]

Figure 3.1: Application of approach sight distance (ASD)
Values for ASD are provided in Table 3.1 and correction factors for gradient are provided in Table 3.3.

**Provision of ASD for trucks**

The various sight distance requirements discussed above apply to cars. ASD for trucks should be provided at intersections to ensure that trucks approaching the intersection, at the 85th percentile operating speed of trucks, are able to stop safely. Approach sight distances for trucks are numerically the same as the SSD values for trucks provided in the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a).

**Table 3.1: Approach sight distance (ASD) and corresponding minimum crest vertical curve size for sealed roads (S<L)**

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Based on approach sight distance for a car&lt;sup&gt;1&lt;/sup&gt;</th>
<th>Truck stopping capability provided by the minimum crest curve size&lt;sup&gt;4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R&lt;sub&gt;T&lt;/sub&gt; = 1.5 s&lt;sup&gt;3&lt;/sup&gt;</td>
<td>R&lt;sub&gt;T&lt;/sub&gt; = 2.0 s</td>
</tr>
<tr>
<td></td>
<td>ASD (m)</td>
<td>K</td>
</tr>
<tr>
<td>40</td>
<td>34</td>
<td>5.3</td>
</tr>
<tr>
<td>50</td>
<td>48</td>
<td>10.5</td>
</tr>
<tr>
<td>60</td>
<td>64</td>
<td>18.8</td>
</tr>
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<td>70</td>
<td>83</td>
<td>31.1</td>
</tr>
<tr>
<td>80</td>
<td>103</td>
<td>48.5</td>
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<td>90</td>
<td>126</td>
<td>72.3</td>
</tr>
<tr>
<td>100</td>
<td>151</td>
<td>104</td>
</tr>
<tr>
<td>110</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>120</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>130</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

1. If the average grade over the braking length is not zero, calculate the approach sight distance (ASD) values using the correction factors in Table 3.3 (or use Equation 1) by applying the average grade over the braking length.

2. In constrained locations (typically lower volume roads, less important roads, mountainous roads, lower speed urban roads and tunnels), a coefficient of deceleration of 0.41 may be used. For any horizontal curve with a side friction factor greater than the desirable maximum value for cars (in constrained locations), use a coefficient of deceleration of 0.41. The resultant crest curve size can then be calculated according to using the relevant equations in the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a).

3. A 1.5 s reaction time is only to be used in constrained situations where drivers will be alert. Typical situations are given in Table 4.2 of the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a). The general minimum reaction time is 2 s.

4. This check case assumes the same combination of design speed and reaction time as those listed in the table, except that the 120 km/h and 130 km/h speeds are not used.

Notes:

- Combinations of design speed and reaction times not shown in this table are generally not used.
- Refer to the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a) to determine the ASD for trucks around horizontal curves.

### 3.2.2 **Safe Intersection Sight Distance (SISD)**

SISD is the minimum distance which should be provided on the major road at any intersection. Designers should note that the object height for the application of SIS

D has been increased to 1.25 m (previously driver eye height was used i.e. 1.1 m) based on research by the Queensland Department of Main Roads (Lennie et al. 2008). The basis of the 1.25 m object height cars is that this height is 0.2 m less than the 15th percentile height of passenger cars (1.45 m) as determined by the study.
SISD:

- provides sufficient distance for a driver of a vehicle on the major road to observe a vehicle on a minor road approach moving into a collision situation (e.g. in the worst case, stalling across the traffic lanes) and to decelerate to a stop before reaching the collision point.

- is viewed between two points to provide inter-visibility between drivers and vehicles on the major road and minor road approaches. It is measured from a driver eye height of 1.1 m above the road to points 1.25 m above the road which represents drivers seeing the upper part of cars. Figure 3.2 illustrates the longitudinal section for the two cases representing inter-visibility; one for drivers on the major road and the second for a driver waiting in the minor road for an opportunity to enter the major road.

- assumes that the driver on the minor road is situated at a distance of 5.0 m (minimum of 3.0 m) from the lip of the channel or edge line projection of the major road. SISD allows for a 3 s observation time for a driver on the priority legs of the intersection to detect the problem ahead, (e.g. car from minor road stalling in through lane) plus the SSD.

- provides sufficient distance for a vehicle to cross the non-terminating movement on two-lane two-way roads, or undertake two-stage crossings of dual carriageways, including those with design speeds of 80 km/h or more.

- should also be provided for drivers of vehicles stored in the centre of the road when undertaking a crossing or right-turning movement.

- enables approaching drivers to see an articulated vehicle, which has properly commenced a manoeuvre from a leg without priority, but its length creates an obstruction.

- is measured along the carriageway from the approaching vehicle to the conflict point, the line of sight having to be clear to a point 5.0 m (3.0 m minimum) back from the holding line or stop line on the side road.

Where practicable, designers should provide a larger sight distance than SISD. Values for SISD are given in Table 3.2 and corrections for grade are given in Table 3.3.
Figure 3.2: Safe intersection sight distance (SISD)

Equation 2 provides the formula for SISD.

\[
SISD = \frac{D_T \times V}{3.6} + \frac{V^2}{254 \times (d + 0.01 \times a)}
\]

where:

- **SISD** = safe intersection sight distance (m)
- **DT** = decision time (s) = observation time (3 s) + reaction time (s): refer to the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) for a guide to values
- **V** = operating (85th percentile) speed (km/h)
- **d** = coefficient of deceleration – refer to Table 3.2 and the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) for a guide to values
- **a** = longitudinal grade in % (in direction of travel: positive for uphill grade, negative for downhill grade).
Table 3.2: Safe intersection sight distance (SISD) and corresponding minimum crest vertical curve size for sealed roads (S<L)

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Based on safe intersection sight distance for cars 1</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$h_1 = 1.1; h_2 = 1.25; d = 0.362; \text{ Observation time} = 3 \text{s}$</td>
</tr>
<tr>
<td></td>
<td>$R_t = 1.5s^3$</td>
</tr>
<tr>
<td></td>
<td>SISD (m)</td>
</tr>
<tr>
<td>40</td>
<td>67</td>
</tr>
<tr>
<td>50</td>
<td>90</td>
</tr>
<tr>
<td>60</td>
<td>114</td>
</tr>
<tr>
<td>70</td>
<td>141</td>
</tr>
<tr>
<td>80</td>
<td>170</td>
</tr>
<tr>
<td>90</td>
<td>201</td>
</tr>
<tr>
<td>100</td>
<td>234</td>
</tr>
<tr>
<td>110</td>
<td>-</td>
</tr>
<tr>
<td>120</td>
<td>-</td>
</tr>
<tr>
<td>130</td>
<td>-</td>
</tr>
</tbody>
</table>

Minimum SISD capability provided by the crest vertical curve size

- Car at night
  - $d = 0.46$, $h_1 = 0.65$ m, $h_2 = 1.25$ m, \text{observation time} = 2.6 s.
  - $d = 0.46$, $h_1 = 1.1$ m, $h_2 = 0.75$ m, \text{observation time} = 2.5 s.

- Truck
  - $d = 0.24$, $h_1 = 2.4$ m, $h_2 = 1.25$ m, \text{observation time} = 3.0 s.

- Truck at night
  - $d = 0.29$, $h_1 = 1.05$ m, $h_2 = 1.25$ m, \text{observation time} = 1.8 s.
  - $d = 0.29$, $h_1 = 2.4$ m, $h_2 = 0.75$ m, \text{observation time} = 3.0 s.

1. If the average grade over the braking length is not zero, calculate the safe intersection sight distance (SISD) values using the correction factors in Table 3.3 (or use Equation 2) by applying the average grade over the braking length.
2. A coefficient of deceleration of greater than 0.36 is not provided in this table. The provision of SISD requires more conservative values than for other sight distance models (e.g. the stopping sight distance model allows values up to 0.46 in constrained situations). This is because there is a much higher likelihood of colliding with hazards at intersections (that is, other vehicles). Comparatively, there is a relatively low risk of hitting a small object on the road (the stopping sight distance model).
3. A 1.5 s reaction time is only to be used in constrained situations where drivers will be alert. Typical situations are given in Table 4.2 of the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a). The general minimum reaction time is 2 s.
4. These check cases assume the same combination of design speed and reaction time as those listed in the table, except that the 120 km/h and 130 km/h speeds are not used for the truck cases.
5. Many of the sight distances corresponding to the minimum crest size are greater than the range of most headlights (that is, 120–150m). In addition, tighter horizontal curvature will cause the light beam to shine off the pavement (assuming 3 degrees lateral spread each way).

Notes:
- To determine SISD for trucks around horizontal curves, use Equation 2 with an observation time of 2.5 s.
- Combinations of design speed and reaction times not shown in this table are generally not used.
Table 3.3: Grade corrections to ASD and SISD (cars)

<table>
<thead>
<tr>
<th>Design speed (major road) (km/h)</th>
<th>Correction (m)</th>
<th>Upgrade</th>
<th>Downgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2%</td>
<td>4%</td>
<td>6%</td>
</tr>
<tr>
<td>40</td>
<td>-1</td>
<td>-2</td>
<td>-2</td>
</tr>
<tr>
<td>50</td>
<td>-1</td>
<td>-3</td>
<td>-4</td>
</tr>
<tr>
<td>60</td>
<td>-2</td>
<td>-4</td>
<td>-6</td>
</tr>
<tr>
<td>70</td>
<td>-3</td>
<td>-5</td>
<td>-8</td>
</tr>
<tr>
<td>80</td>
<td>-4</td>
<td>-7</td>
<td>-10</td>
</tr>
<tr>
<td>90</td>
<td>-5</td>
<td>-9</td>
<td>-13</td>
</tr>
<tr>
<td>100</td>
<td>-6</td>
<td>-11</td>
<td>-16</td>
</tr>
<tr>
<td>110</td>
<td>-7</td>
<td>-13</td>
<td>-19</td>
</tr>
<tr>
<td>120</td>
<td>-8</td>
<td>-16</td>
<td>-22</td>
</tr>
<tr>
<td>130</td>
<td>-10</td>
<td>-18</td>
<td>-26</td>
</tr>
</tbody>
</table>

Note: Corrected sight distances should be rounded up to the nearest 5 m.

The SISD model should also be applied to the following cases to ensure that adequate visibility is provided between:

- vehicles approaching on the major road and vehicles turning right from the major road for BAR turn treatments (i.e. no right-turn lane provided, Figure 4.1). This is a similar requirement to the line of sight required between approaching major road vehicles and a stalled vehicle turning right from the minor road at all types of right-turn treatments.

- vehicles turning right from the major road and oncoming major road vehicles at all types of right-turn treatments, including those on divided roads.

The ability to achieve SISD in these cases could be influenced by the horizontal alignment, the vertical alignment, or a combined horizontal and vertical alignment. Figure 3.3 shows the application of the SISD model to an intersection on the outside of a horizontal curve.
### Minimum Gap Sight Distance (MGSD)

#### General

MGSD is based on distances corresponding to the critical acceptance gap that drivers are prepared to accept when undertaking a crossing or turning manoeuvre at intersections. Typical traffic movements are shown in Figure 3.4 and Figure 3.5. Information on gap acceptance theory in relation to intersection capacity is provided in the Guide to Traffic Management – Part 3: Traffic Studies and Analysis (Austroads 2009h).

MGSD is:

- shown as ‘D’ in Figure 3.4 and Figure 3.5
- measured from the point of conflict (between approaching and entering vehicles) back along the centre of the travel lane of the approaching vehicle
- measured from a point 1.1 m (driver’s eye height) to a point 0.65 m (object height – typically a vehicle indicator light) above the travelled way.

The MGSD required for the driver of an entering vehicle to see a vehicle in the conflicting streams in order to safely commence the desired manoeuvre is dependent upon the:

- length of the gap being sought (critical acceptance gap time $t_a$)
- observation angle to approaching traffic.

Figure 3.4 illustrates that for left turns the sighting angle is restricted to a maximum of 120° for a give way situation and 160° to 180° for a free flow left turn. The sighting angles are restricted to a maximum of 110° for right turns, and 170° to 180° for right-turn merges (Figure 3.5).
Critical acceptance gaps and follow-up headways

The critical acceptance gap time varies according to:

- the type of manoeuvre – left-turn/right-turn/crossing
- the width of carriageway – increased time required for greater widths
whether the major road has a one-way or two-way traffic flow – increased time required to look both ways.

Table 3.4 shows critical acceptance gap times for various manoeuvres into, from and across various through carriageway widths for both one-way and two-way traffic. The corresponding distances are given in Table 3.5.

**Table 3.4: Critical acceptance gaps and follow-up headways**

<table>
<thead>
<tr>
<th>Movement</th>
<th>Diagram</th>
<th>Description</th>
<th>ta</th>
<th>tf</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left-hand turn</td>
<td>[Diagram]</td>
<td>Not interfering with A</td>
<td>14-40 sec</td>
<td>2-3 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Requiring A to slow</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td>Crossing</td>
<td>[Diagram]</td>
<td>Two lane/one way</td>
<td>4 sec</td>
<td>2 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Three lane/one way</td>
<td>6 sec</td>
<td>3 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Four lane/one way</td>
<td>8 sec</td>
<td>4 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two lane/two way</td>
<td>5 sec</td>
<td>3 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Four lane/two way</td>
<td>8 sec</td>
<td>5 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Six lane/two way</td>
<td>8 sec</td>
<td>5 sec</td>
</tr>
<tr>
<td>Right-hand turn from major road</td>
<td>[Diagram]</td>
<td>Across one lane</td>
<td>4 sec</td>
<td>2 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Across two lanes</td>
<td>5 sec</td>
<td>3 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Across three lanes</td>
<td>6 sec</td>
<td>4 sec</td>
</tr>
<tr>
<td>Right-hand turn from minor road</td>
<td>[Diagram]</td>
<td>Not interfering with A</td>
<td>14-40 sec</td>
<td>3 sec</td>
</tr>
<tr>
<td></td>
<td></td>
<td>One way</td>
<td>3 sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Two lane/two way</td>
<td>5 sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Four lane/two way</td>
<td>8 sec</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Six lane/two way</td>
<td>8 sec</td>
<td></td>
</tr>
<tr>
<td>Merge</td>
<td>[Diagram]</td>
<td>Acceleration lane</td>
<td>3 sec</td>
<td>2 sec</td>
</tr>
</tbody>
</table>

Note: $t_a =$ critical acceptance gap and $t_f =$ follow up headway.
Source: Austroads (2005).

**Table 3.5: Table of minimum gap sight distances (‘D’ metres) for various speeds**

<table>
<thead>
<tr>
<th>Critical gap acceptance time (ta) (secs)</th>
<th>65th percentile speed of approaching vehicle (km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>6</td>
<td>17</td>
</tr>
<tr>
<td>7</td>
<td>19</td>
</tr>
<tr>
<td>8</td>
<td>22</td>
</tr>
<tr>
<td>9</td>
<td>25</td>
</tr>
<tr>
<td>10</td>
<td>28</td>
</tr>
</tbody>
</table>

Source: Austroads (2005).
**Detailed sight distance requirements for left-turning drivers**

Figure 3.6 illustrates the sight distance to a through vehicle from a vehicle turning left. Sight requirements for left turns depend on the direction of approaching traffic and right-of-way regulations. For drivers of vehicles entering a priority road, sight lines should be considered to:

- through vehicles approaching from the left and right
- turning vehicles on other approaches.

The acceptable maximum observation angle of 120° is based on the visibility requirements from vehicles illustrated in Commentary 2.

### 3.3 Pedestrian Sight Distance Requirements

At intersections, pedestrian crossing facilities should be located where there is a clear view between approaching drivers and pedestrians on the crossing or waiting to cross a roadway (Figure 3.7).

This requires that:

- ASD should be provided between approaching vehicles (1.1 m eye height) and the surface of the roadway (0 m) at the crossing.
- crossing sight distance (CSD) should be provided between approaching vehicles (1.1 m eye height) and a pedestrian waiting to cross the road. The pedestrian eye height should be taken as 1.07 m which represents the lower bound of the range applicable to a person in an A80 wheelchair (Appendix A of the *Guide to Road Design – Part 6A: Pedestrian and Cyclist Paths*, Austroads 2009f).
CSD is:

- necessary to ensure that the pedestrian can see approaching traffic in sufficient time to judge a safe gap and cross the roadway
- calculated from the critical safe gap (in the traffic stream) and the speed of approaching traffic
- given by Equation 3.

\[ CSD = t_c \times \frac{V}{3.6} \]

where:

\begin{align*}
\text{CSD} &= \text{sight distance required for a pedestrian to safely cross the roadway} \\
\text{t}_c &= \text{critical safe gap (s) = (crossing length x (walking speed))} \\
\text{V} &= \text{85th percentile approach speed (km/h)}. 
\end{align*}

It is important that the line of sight is not obstructed. Provision of ASD (1.1 m to 0.0 m) ensures that, even if there is no pedestrian actually on the crossing, the driver should be aware of the crossing by seeing the associated pavement markings and other cues and therefore be alerted to take the appropriate action if a pedestrian steps onto the crossing without due attention to approaching traffic.

It is important that the line of sight for CSD is not impeded by any object such as:

- street furniture (e.g. poles, mailboxes, telephone booths, trees, decorative planters)
- parked vehicles.

Parked vehicles can cause visual obstructions, especially for children, wheelchair occupants, or individuals of small stature. This may require banning parking for some distance on each side of the crossing, the distance being determined for each case to ensure that parked vehicles will not obscure the required sight lines. At locations where there is a strong requirement by adjoining land uses to retain legal on-street parking, consideration should be given to extending the width of the footpath to improve the visibility of pedestrians.

Minor obstructions, such as posts, poles and tree trunks less than 200 mm diameter within the sight line may be ignored.
3.4 Sight Distance at Property Entrances

Section 7 of the Guide to Road Design – Part 4: Intersections and Crossings – General (Austroads 2009b) provides guidelines that relate to property access in general. It also provides reference to a New Zealand planning policy manual that covers integrated planning and development of state highways including accessway standards and guidelines (Transit NZ 2007a).

Desirably, sight distances at accesses should comply with the sight distance requirements for intersections, i.e. that approach sight distance (ASD), safe intersection sight distance (SISD), and minimum gap sight distance (MGSD) are achieved.

The criteria above often cannot be obtained at accesses on roadways with tighter horizontal and vertical alignments, or sensitive vegetation. For new roads comprising such geometry, minimum sight distances at accesses should comply with the following:

- minimum gap sight distance in Section 3.2.3
- safe intersection sight distance using values given under the extended design domain (EDD) criteria for sight distance at intersections (Table A 9 to Table A 14).

Obtaining ASD at domestic accesses is often not necessary due to the familiarity of their location by the users. At other than domestic accesses, ASD will need to be provided only if adequate perception of the access is not provided through other means.
Care should be taken to ensure that the minimum sight distances are not restricted by the location and height of roadside furniture and vegetation.
4 TYPES OF INTERSECTION AND THEIR SELECTION

4.1 General

This section describes the types of intersection available to road designers, their features and the factors that may influence the selection of an appropriate type of intersection to suit a particular site or circumstances. Generally these factors include traffic operation, road safety and physical conditions at the particular site. Detailed guidance on the layout design of commonly used intersection treatments is provided in Section 7 and Section 8.

It is important that requirements for safe pedestrian movement and safe cycling should be considered in the development of all intersection layouts and facilities and should be provided where a need exists. Consequently some of the illustrated treatments include specific provision for cycling.

Where no specific bicycle facility is provided, the shoulders of major rural roads should be of an appropriate width to cater for cyclists (Guide to Road Design – Part 3: Geometric Design (Austroads 2009a)) and be carried through intersections so that cyclists do not have to travel along the traffic lane and be exposed to conflict with motor vehicles. It is suggested that all traffic islands should be set back at least 1.5 m from the edge of the traffic lane to facilitate safer cyclist movement through intersections.

On designated bicycle routes the shoulders should be sealed and a marked bicycle lane provided within intersections including the length of the auxiliary lane to ensure continuity of the facility.

4.2 Intersection Types

Intersections are generally defined by the type of turn treatments and the types of traffic islands provided. They are often also described as:

- unchannelised and unflared
- unchannelised and flared
- channelised (including roundabouts).

Flaring is a general term for the provision of additional lanes and/or tapers while channelisation is the provision of traffic islands. Flaring and channelisation may be applied to T-intersections or cross intersections although cross intersections are not favoured in high-speed situations.

Unchannelised and unflared intersections

This type of intersection is normally adequate where minor roads meet and where a major road intersects with a minor road and does not require turning lanes or traffic islands.

Unchannelised and flared intersections

Simple unchannelised intersections may be flared to provide additional through lanes or auxiliary lanes, such as speed-change lanes or passing lanes. Speed-change lanes allow left-turning or right-turning vehicles to reduce speed when leaving the through road without adversely affecting the speed of through traffic and permit through vehicles to pass another vehicle waiting to complete a turn at an intersection.
Channelised intersections

A channelised intersection is one where paths of travel for various movements are separated and delineated. Raised traffic islands, raised pavement markers, painted markings and safety bars can be used for channelisation.

The simplest channelisation on a major road involves a painted or raised island in the centre of a two-lane two-way road designed to shelter a stationary vehicle waiting to turn right and to guide through vehicles past the turning vehicle.

Channelisation applies to left-turning, right-turning, and crossing vehicles and consequently a particular intersection layout will have a combination of lanes and islands designed to cater for specific traffic movements within the intersection.

Channelisation utilises islands to ‘funnel’, direct and separate vehicles into the required paths through an intersection, and to shelter vehicles that are waiting or moving within an intersection. This gives rise to specific forms of channelised intersection such as staggered T-intersections, seagull treatments, wide median treatments and roundabouts that are provided to achieve particular design objectives.

Intersections may also be described by the type of control, which is discussed in the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007). Intersections may be priority controlled by regulatory signs (i.e. give-way, stop, or roundabout signs) or by traffic signals.

4.3 Types of Turn Treatments

The types of right-turn and left-turn treatments provided in a design usually define the type of intersection. There are essentially three types of turn treatments available, namely:

- a basic turn treatment (BA) where turning vehicles may share the lane with through traffic movements
- an auxiliary lane turn treatment (AU) where a separate lane is provided to enable the turn to be performed in an additional lane
- a channelised turn treatment which provides a traffic island to enhance the safety of right-turning or left-turning vehicles.

These turn treatments are available for both right-turn and left-turn movements. They are presented and discussed in Sections 4.5, 4.6 and 4.7 respectively. Warrants for the provision of these turn treatments are provided in Section 4.8. The layout of channelised turn treatments should be adequately illuminated by road lighting or defined by reflective pavement markers, signs etc.

The turn treatments are also used as the basis for the design of other specific types of intersections that are named on the basis of a type of movement (e.g. staged crossing) or the shape of the layout in plan view (e.g. seagull) which are also discussed in this section.

4.4 Intersection Selection

4.4.1 General Considerations

The selection of an appropriate type of intersection for a particular site may be influenced by:

- transport planning and environmental considerations
traffic management and road safety objectives
a range of road design considerations that are not necessarily related to traffic management
environmental considerations
economic considerations (costs and benefits).

In many cases there will be more than one option considered for the intersection treatment at a particular site. In these cases it will be necessary to list the relative advantages and disadvantages of the various options to assist in deciding between them. This may take the form of a balance sheet that compares all operational, safety, physical, environmental and economic considerations.

Broad transport or environmental considerations, and traffic management and road safety objectives may be fundamental to the selection of the appropriate intersection treatment at a particular site or sites. For example, some routes are designated as important traffic routes and therefore the movement of large volumes of traffic is a primary consideration. On the other hand, the objective may be to prevent or limit traffic from entering designated areas in which case the intersection should be designed and managed to achieve the desired outcome. Consequently, the type of intersection required may be influenced by transport planning and network management objectives (Guide to Road Transport Planning, (Austroads 2009)) and the (Guide to Traffic Management – Part 4: Network Management, (Austroads 2009i)).

The traffic management considerations are most important as they relate to the function of the intersection, its operation, and safety. Section 3 of Part 6 of the Guide to Traffic Management (Austroads 2007) also briefly describes principles for safe intersection operation and some environmental considerations.

Designers should be aware that the selection of a treatment may also require an economic evaluation and consideration of road safety and environmental aspects of competing options. The economic evaluation should include consideration of construction costs, and both crash costs and operating costs over the life of the treatment (Guide to Project Evaluation, Austroads 2005-2008).

Crash costs for intersections are usually determined by applying a crash rate (casualty crashes/100 million entering vehicles) for each type of treatment and average crash costs which are likely to be available from the relevant local jurisdiction. However, it should be noted that crash rates for similar treatments (e.g. roundabouts) can vary substantially depending on a number of factors such as volume, operating speed and the scale of treatment.

While consideration of traffic management aspects and evaluation is very important, the type of intersection adopted at a particular site may also be influenced by the road design considerations described in Section 3.3 of the Guide to Road Design – Part 4: Intersections and Crossings – General (Austroads 2009b).
4.4.2 Traffic Management Considerations

General

The *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossing* (Austroads 2007) summarises the key traffic management considerations involved in the selection of an appropriate type of intersection for any given situation. Section 2 of Part 6 of the *Guide to Traffic Management* (Austroads 2007) summarises the types of intersections and their characteristics (Table 2.1), intersection control options (Table 2.2 and 2.3) and key traffic management selection considerations (Table 2.4).

Wide median treatment

The wide median treatment (WMT) is discussed and illustrated in Section 4.13. The treatment was developed and designed to reduce the crossing and entering speed of side road traffic to a safe value on divided major roads in rural areas. Research (VicRoads internal report) has shown that there is a level of exposure beyond which WMTs develop safety issues and that they should only be considered for use at intersections where:

- for T-intersections the entering side road volume is not greater than 1000 vpd
- for cross intersections the sum of the entering volumes on the two side roads is not greater than 1000 vpd
- the exposure, given by the following formula, does not exceed 6000 vpd.

\[ 2\sqrt{V_1V_2} \leq 6000 \]

where:

- \( V_1 \) = Total volume of traffic entering the intersection from the minor roads
- \( V_2 \) = Total volume of traffic entering the intersection from the major road.

The above limitation can be used to determine the year in which a WMT will no longer be appropriate, and beyond which an alternative treatment will be required.

4.4.3 Layout Considerations

While the broader and traffic management considerations are very important, the choice of intersection is also determined by the type of turning treatments required for the safe and efficient operation of the intersection. Warrants determining the need for BA, AU and CH treatments on two-lane two-way roads are provided in Section 4.8.

The warrants in Section 4.8 essentially determine the need for auxiliary lanes and islands to shelter turning vehicles in situations where the arrival of traffic at the intersection is random (e.g. rural or outer urban sites). However, in urban areas the decision to provide auxiliary lanes and the determination of their length can be more complex and require a number of considerations that are discussed in Section 5. This may require a higher-order turn treatment to be used than that indicated by Section 4.8.

Furthermore, various types of intersections have relative advantages and disadvantages that may be important factors in selection of an appropriate type of intersection, and these are discussed in the relevant section for the particular treatment.
4.5 Basic Turn Treatments (Type BA)

BA turn treatments comprise:
- basic right-turn treatment (BAR) on the major road (two-lane undivided roads only)
- basic left-turn treatment (BAL) on the major road (two-lane undivided roads and multi-lane roads)
- basic left-turn treatment (BAL) on the minor road (lane also used for right-turn movements).

These type of turn treatments (Figure 4.1) are:
- the simplest layouts
- designed to be as compact (and inexpensive) as possible
- most appropriately used where the volume of turning and through traffic is low. The BAR turn treatment is only used on two-lane, two-way roads (i.e. it does not apply to multi-lane roads)
- comprised of carriageways that intersect with an appropriate corner radius and taper to suit the swept path of the design vehicle
- used with any wearing surface
- required to be located where good perception of the treatment is provided (e.g. BAR turn treatments should not be located on small to moderate sized crests as insufficient visibility to the treatment will be provided).

4.5.1 Rural Basic (BA) Turn Treatments

Figure 4.1 shows the features of rural BA turn treatments at T-intersections, namely:
- the BAR treatment features a widened shoulder on the major road that allows through vehicles, having slowed, to pass to the left of turning vehicles
- the BAL treatment on the major road has a widened shoulder, which assists turning vehicles to move further off the through carriageway making it easier for through vehicles to pass
- the BAL turn treatment on the minor road allows turning movements from a single lane with a shoulder that is too narrow to be used by left-turning vehicles (to prevent drivers from standing two abreast at the holding line).

Where the major road is sealed it is preferred that the widened shoulders are also sealed, unless the shoulders can be maintained with a sound and even surface in all weather conditions. Research (Arndt 2004) has shown that BAR turn treatments record a rear-end major vehicle crash rate 52 times higher than do CHR turn treatments. The research also found that the rear-end major vehicle crash rate decreases substantially with increased median width, regardless of the type of median (painted, raised or depressed). Commentary 3 provides some more information in relation to the findings in Arndt 2004.

For design details of rural basic turn treatments refer to:
- Figure 7.5 for a BAR treatment on the major road
- Figure 8.2 for BAL treatments on major and minor roads.
Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

Figure 4.1: Rural basic BA turn treatments

Figure 4.1 shows only basic T-intersection treatments because unsignalised and signalised crossroads should not be provided because of road safety risk in high speed situations (e.g. > 80 km/h) unless treated with channelisation (e.g. roundabout, wide median treatment) and/or traffic management devices. However, CHR treatments may be applied to existing crossroads where there is a need to shelter turning vehicles on the major road and the risk associated with crossing traffic is considered to be low (e.g. no crashes recorded, very low approach speeds, negligible traffic crossing). This treatment is implemented under extended design domain principles (Appendix A and the Guide to Road Design – Part 2: Design Considerations, Austroads 2006c).

4.5.2 Urban Basic (BA) Turn Treatments

Figure 4.2 shows the features of urban BA turn treatments. It can be seen that:

- the basic right-turn treatment and basic left-turn treatments are achieved by resuming parking space at and near the intersection
- a bicycle lane on the major road may be incorporated into the treatment and should always be continued through unsignalised intersections.
Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

**Figure 4.2:** Urban basic BA turn treatments

While Figure 4.2 shows only T-intersections the treatment may be adapted to cross intersections that are common in established urban areas.

For design details of urban basic turn treatments refer to:
- Figure 7.17 for a BAR treatment on the major road
- Figure 8.8 for BAL treatments on major and minor roads.

**4.5.3 Basic Right-turn Treatment – Multi-lane Undivided Road**

The basic right-turn treatment has occasionally been applied to multi-lane undivided roads. It is essentially a multi-lane undivided road with no right-turn facility (i.e. no separate right-turn lane) and is sometimes referred to as an MNR treatment. A layout of this type is shown in Figure 4.3.
Research (Arndt 2004), has found that MNR turn treatments record the highest rear-end major vehicle crash rate of all the turn treatments. They are intuitively unsafe in that the central lanes of a four lane undivided road attract the faster vehicles and are used for overtaking and, as a consequence, vehicles that stop in the central lane are particularly vulnerable. Consequently MNR treatments are not favoured and should not be included in designs for new roads or road improvements.

Where MNR treatments exist in rural areas provision of a right-turn lane should be considered. In lower speed areas (i.e. ≤ 70 km/h) it may be appropriate to merge the two through lanes into one and incorporate a right-turn lane or (as a last resort) a right-turn ban may be appropriate. In such cases islands should be considered to ensure that through traffic merges and that pedestrians have a refuge.

Notes:
1. This turn type is not to be used at new unsignalised intersections.
2. Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

Figure 4.3: Multi-lane undivided road with no specific right-turn facility, ‘MNR’

4.6 Auxiliary Lane Turn Treatments (Type AU)

The AU turn treatment has short lengths of auxiliary lane provided to improve safety, especially on high-speed roads. It comprises the following turn treatments:

- auxiliary right-turn treatment (AUR) on the major road
- auxiliary left-turn treatment (AUL) on the major road
- auxiliary left-turn treatment (AUL) on the minor road.

While AUR turn treatments exist at many locations and are safer than a basic treatment they are not as safe as channelised treatments (i.e. CHR) to protect right-turners. They are therefore not favoured by some jurisdictions (e.g. Queensland Department of Main Roads and the New Zealand Transport Agency) for use as new unsignalised intersections. As discussed below, the same situation applies with respect to the use of AUL turn treatments.

Often, not all of the treatments will be used together at a single intersection. The AUR right-turn treatment:

- allows traffic to bypass a vehicle waiting to turn right, or may provide a lane for left-turning traffic, or both
- can only be used on legs which have a sealed surface
• can be confused with an auxiliary lane for overtaking and should only be used at locations where the driver can appreciate the purpose of the lane. Situating such intersections near auxiliary lanes used for overtaking must be avoided
• has been used where an arterial road meets with sub-arterials, collectors, or local roads (particularly in rural areas where there is a low volume of high speed through traffic and the volume of turning traffic is sufficient to make a conflict likely)
• is more expensive than basic intersections, but can be more cost-effective when long-term crash costs are included in the economic analysis.

Research has shown that the crash rate for vehicles entering the major road from the minor road at an unsignalised intersection is significantly higher when there are two stand-up lanes on the minor road (i.e. when there is an auxiliary lane) because a vehicle standing in the right lane obscures the view of drivers in the left lane and vice versa (Figure 4.4). For this reason an AUL turn treatment on the minor road is not preferred at rural or urban sites, particularly at four-way unsignalised intersections. It is therefore desirable that the minor road approach has only one stand-up lane and, if sufficient traffic demand exists, that a channelised left-turn treatment is provided. Further information on this issue is provided in Commentary 4.

Each vehicle shown on the minor road restricts visibility to major road vehicles, for the vehicle in the adjacent stand-up lane.


Figure 4.4: Restricted visibility at an unsignalised intersection comprising two stand-up lanes on the minor road

Where additional lanes are required on minor road approaches to provide adequate capacity and reduce queuing and delays, consideration should be given as to whether a signalised intersection or a roundabout would provide a more suitable arrangement.

4.6.1 Rural Auxiliary Lane (AU) Turn Treatments

Figure 4.5 shows the features of rural AU turn treatments at T-intersections, namely:
• AUR turn treatment is created by the use of a short lane with standard painted stripes
• AUL turn treatment on the major road is a normal indented turn lane
• AUL turn treatment in the minor road is also a normal indented turn lane.
As mentioned previously for unsignalised intersections:

- the AUR treatment is not favoured by some jurisdictions (e.g. Queensland Department of Main Roads and the New Zealand Transport Agency) due to the exposure of right-turning vehicles to rear-end collisions, and this is particularly an issue in high-speed rural situations.
- an AUL treatment in the major road is not preferred as it is likely to be less safe than a CHL treatment. Consequently a CHL treatment should be used wherever practicable.
- the AUL treatment in the minor road at unsignalised intersections is not preferred as it is likely to be less safe than either a basic treatment or a CHL treatment. Consequently a basic treatment or a CHL treatment should be used wherever practicable.

AUL treatments are generally satisfactory in major roads in urban areas where the major road is straight and flat or on a uniform grade. However, the use of AUL treatments in major roads where the intersection is within a curve should be avoided because vehicles turning left from the major road can impede the sight distance for drivers waiting in the minor road and crashes can result. For this reason a CHL treatment should generally be preferred to an AUL treatment and, in particular, where the major road has a horizontal curve through the intersection or there are other factors that could lead to vehicles turning left from the major road impeding the sight distance of drivers waiting in the minor road (e.g. crest curve). This situation is also described as a practical example in Section 8.6 of the Guide to Road Safety – Part 6: Road Safety Audit (Austroads 2009).

For design details of rural auxiliary turn treatments refer to:

- Figure 8.2 for an AUL(S) treatment on the major road comprising a shorter turning lane
- Figure 8.3 for an AUL treatment on the major road comprising a full-length lane.
Notes:
1. Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.
2. Not used by the Queensland Department of Main Roads or the New Zealand Transport Agency.
Source: Based on QDMR (2006).

Figure 4.5: Rural auxiliary lane (AU) turn treatments

4.6.2 Urban Auxiliary Lane (AU) Turn Treatments

Figure 4.6 shows the features of urban AU turn treatments at T-intersections, namely:

- AUR turn treatment is created by the addition of a short section of traffic lane with standard painted stripes
- AUL turn treatment on the major road may be a normal indented turn lane or be shielded by a parking lane, depending on the situation
- AUL turn treatment in the minor road may also be a normal indented turn lane or be shielded by parked cars, depending on the situation.
Notes:
1. Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.
2. Not used by the Queensland Department of Main Roads or the New Zealand Transport Agency.

Figure 4.6: Urban auxiliary lane (AU) turn treatments

For design details of urban auxiliary turn treatments refer to:
- Figure 8.10 for an AUL(S) treatment on the major road comprising a shorter turning lane
- Figure 8.11 for an AUL treatment on the major road comprising a full-length lane.
4.7 **Channelised Turn Treatments (Type CH)**

The CH turn treatment has conflicting vehicle travel paths separated by raised, depressed, or painted medians and/or islands. Auxiliary lanes are often used in conjunction with channelisation.

Channelised turn treatments comprise (Figure 4.7):

- right-turn treatment (CHR) on the major road
- left-turn treatment (CHL) on the major road
- left-turn treatment (CHL) on the minor road.

Often, not all the treatments will be used together at a single intersection. A CHR treatment may have full-length deceleration turning lanes or it may have a reduced length in which case it is referred to as a CHR(S) treatment (see Section 4.8 for warrants).

The advantages of using CHR turn treatments in lieu of AUR treatments include:

- reduction in 'rear-end major road' crashes and 'overtaking-intersection' vehicle crashes (where a right-turn vehicle is hit by an overtaking vehicle (Appendix A). With an AUR treatment a stationary right-turning vehicle on a tight horizontal curve or over a crest is vulnerable whereas the island in a CHR treatment guides through drivers past the right-turning vehicle
- provision of fewer types of turn treatments and thus more consistent intersection layouts
- provision of a refuge for pedestrians crossing the major road
- increase in the average design life of turn treatments compared to AUR turn treatments; CHR(S) treatments will be able to function for longer periods before an upgrade is required
- allaying concerns from the motoring public that more CHR turn treatments should be provided on high-speed roads to improve safety.

CHR(S) turn treatments can only be used with linemarking. The good safety performance of the CHR(S) occurs by removing potentially stationary turning vehicles from the through traffic stream. This treatment is suitable where there are low to moderate through and turning volumes. For higher volume sites, and sites where there is limited visibility of the treatment (e.g. over smaller to moderate size crests), a full-length CHR turn treatment is preferred which should have the same longitudinal dimensions to a rural CHR as shown in Table 7.2 (these lengths being based on the application of Table 5.2 and Table 5.3).

The CHR(S) treatment is not intended to be used with raised or depressed islands. Right-turning drivers often travel onto the painted chevron to exit the through traffic stream as soon as possible. This is a desirable feature, as it reduces the likelihood of rear-end-major vehicle accidents as all through traffic is required to deviate through an alignment designed to suit the operating speed. Because of this deviation, parking limits are likely to be needed as shown in Figure 7.18.

**4.7.1 Rural Channelised (CH) Turn Treatments**

Figure 4.7 shows rural CH turn treatments at T-intersections.
Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

Source: Based on QDMR (2006).

**Figure 4.7:** Rural channelised (CH) intersection turn treatments

For design details of rural channelised turn treatments refer to:

- Figure 7.6 for a CHR(S) treatment on the major road comprising a shorter turning lane
- Figure 7.7 for a CHR treatment on the major road comprising a full-length lane
- Figure 8.5 for high entry angle CHL treatments on major and minor roads
- Figure 8.6 for CHL treatments with an acceleration lane on major and minor roads.
4.7.2 **Urban Channelised (CH) Turn Treatments**

Figure 4.8 shows channelised (CH) turn treatments for urban situations which may or may not be signalised. The treatments are similar to rural treatments except that the dimensions will reflect the lower speed environment, and kerb and channel, parking and bicycle lanes are likely to be included.

Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

Source: Queensland Department of Main Roads.

**Figure 4.8:** Urban channelised (CH) intersection turn treatments

For design details of urban channelised turn treatments refer to:

- Figure 7.18 a CHR(S) treatment on the major road comprising a shorter turning lane
- Figure 7.19 for a CHR treatment on the major road comprising a full-length lane
- Figure 8.12 for high entry angle CHL treatments on major and minor roads
- Figure 8.13 for CHL treatments with an acceleration lane on major and minor roads.
4.8 Warrants for BA, AU and CH Turn Treatments

These warrants apply to major road turn treatments for the basic, auxiliary lane and channelised layouts illustrated in Sections 4.5, 4.6 and 4.7 respectively. The warrants are shown in Figure 4.9 and provide guidance on where a full-length deceleration lane must be used and where a shorter lane, designated AUL(S) and CHR(S), may be acceptable based on traffic volume. Figure 4.9 contains two graphs for the selection of turn treatments on roads with a design speed:

- greater than or equal to 100 km/h. Figure 4.9(a) is appropriate for high speed rural roads
- less than 100 km/h. Figure 4.9(b) is appropriate for urban roads, including those on the urban fringe and lower speed rural roads.

If a particular turn from a major road is associated with some geometric minima (for example, limited sight distance, steep grade), consideration should be given to the adoption of a turn treatment of a higher order than that indicated by the warrants. For example, if the warrants indicate that a BAR turn treatment is acceptable for the relevant traffic volumes, but limited visibility to the right-turning vehicle is available, consideration should be given to the adoption of a CHR(S) or CHR turn treatment instead. Another example is a major road on a short steep downgrade where numerous heavy vehicles travel quickly down the grade, in which case it would not be appropriate to adopt a BAL turn treatment. Instead, an AUL(S) or an AUL would be a preferred treatment.

Development of the warrants in this section is detailed in Arndt and Troutbeck (2006) and briefly discussed in Commentary 5.
**Figure 4.9:** Warrants for turn treatments on the major road at unsignalised intersections

(a) Design speed ≥100 km/h

(b) Design speed < 100 km/h

In applying the warrants in Figure 4.9 designers should note that:

- Curve 1 represents the boundary between a BAR and a CHR(S) turn treatment and between a BAL and an AUL(S) turn treatment.

- Curve 2 represents the boundary between a CHR(S) and a CHR turn treatment and between an AUL(S) and an AUL or CHL turn treatment. The choice of CHL over an AUL will depend on factors such as the need to change the give way rule in favour of other manoeuvres at the intersection and the need to define more appropriately the driving path by reducing the area of bitumen surfacing.

- The warrants apply to turning movements from the major road only (the road with priority).

- Figure 4.10 is to be used to calculate the value of the major road traffic volume parameter ($Q_M$).

- Traffic flows applicable to the warrants are peak hour flows, with each vehicle counted as one unit (i.e. do not use equivalent passenger car units [pcus]). Where peak hour volumes or peak hour percentages are not available, assume that the design peak hour volume equals 8% to 10% of the AADT for urban situations and that the design hour volume equals 11% to 16% of AADT for rural situations.

- If more than 50% of the traffic approaching on a major road leg turns left or right, consideration needs to be given to possible realignment of the intersection to suit the major traffic movement. However, route continuity issues must also be considered (for example, realigning a highway to suit the major traffic movement into and out of a side road would be unlikely to meet driver expectation).

- If a turn is associated with other geometric minima, consideration should be given to the adoption of a turn treatment of a higher order than that indicated by the warrants.

- Some road authorities may consider that the CHR(S) treatment is not a suitable arrangement in all instances. Where this occurs, the Main Roads Western Australia AUR treatment may be used as an alternative. However the CHR(S) treatment is considered to be preferable for general use on major roads.

- Where the major road has four lanes (e.g. two in each direction) the value used for $Q_M$ is the volume in the closest through lane to the turning movement.

<table>
<thead>
<tr>
<th>Turn type</th>
<th>Splitter island</th>
<th>$Q_M$ (veh/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right</td>
<td>No</td>
<td>$= Q_{T1} + Q_{T2} + Q_L$</td>
</tr>
<tr>
<td>Right</td>
<td>Yes</td>
<td>$= Q_{T1} + Q_{T2}$</td>
</tr>
<tr>
<td>Left</td>
<td>No/Yes</td>
<td>$= Q_{T2}$</td>
</tr>
</tbody>
</table>


**Figure 4.10:** Calculation of the major road traffic volume parameter $Q_M$
4.9 Intersection Treatments – Rural Divided Roads

4.9.1 Two Staged Crossing

This layout is suitable on roadways with wide medians when the volume of right-turning traffic is small and the traffic volumes on the through route are high. Right-turning traffic from the minor road undertakes the turning manoeuvre in two stages. A simple two staged crossing is illustrated in Figure 4.11. For details of a two staged rural crossing treatment refer to Figure 7.11.

![Two staged crossing diagram](image)

Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

**Figure 4.11: Two staged crossing**

The treatment may not be suitable if a significant number of large heavy vehicles turn into the minor road as it may be difficult to accommodate the required swept path and a 30 m wide median will be needed to store a B-double, for example.

A disadvantage of the two staged crossing is that it is difficult to provide for large vehicles turning from the major road as the turning movements overlap within the crossing. To design for this occurrence would result in an excessive width of the crossing within the median. However, where a very wide median exists it may be practicable to provide an additional island in the median opening based on the swept path of the particular design vehicle.

The need to accommodate large vehicles in median openings, together with a desire to reduce the crossing speed at crossroads on rural divided highways led to the development and use of the wide median treatment in Victoria (Section 4.13), a treatment that may not be favoured in other places.

**Offset Right-turn Lanes**

Where a wide median exists at an intersection, a treatment involving offset right-turn lanes may be appropriate as shown in Figure 4.12. It is suitable for use on rural and urban roads and may be signalised where necessary.

A further advantage of offset right-turn lane treatments is that they provide improved sight lines for a right-turning driver to see past a vehicle waiting to turn right from the opposite direction. The treatment could also be advantageous to older drivers in order to accommodate their slower decision times and declining motion perception abilities (Veith 2004).
4.10 Intersection Treatments – Urban Divided Roads

4.10.1 Basic Median Opening

Figure 4.13 shows a typical arrangement for an unsignalised intersection between a divided major road and a minor road. In some cases the treatment may not have a bicycle lane, or it may have a bicycle/car parking lane treatment. The parking in the minor road should be set back in accordance with statutory regulations or traffic operational requirements.

Notes:
1. Depending on the available space it may not be practicable to provide bicycle lanes.
2. Also applies to six lane divided roads.
3. Where appropriate, parking lanes may also be provided adjacent to the bicycle lanes.
4. Median should be ≥ 7 m wide to shelter cars.
5. Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.
4.10.2 Urban Offset Right-turn Lanes

Urban offset right-turn lanes can have similar advantages to rural offset right-turn lanes (Section 4.4.2) when used at unsignalised intersections. However, they can also be used at signalised intersections and have the advantage of preventing overlapping of the right-turning movements within the median opening which results in a more efficient signal system (i.e. through the channelisation the opposing right turns become a diamond turn).

Figure 4.14 shows an example of offset right-turn treatment on an urban divided road. Where road space can be made available bicycle and parking lanes should be provided as shown in this example. While the channelisation indicates painted islands it is generally preferable to use raised islands on major urban roads.

![Offset right-turn lanes at an urban cross intersection](image)

Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.
Source: Queensland Department of Main Roads 2006.

4.10.3 Intersection Layouts with Service Roads

Purpose and use

Service roads are often provided adjacent to divided roads to separate local access traffic movements from traffic on the main carriageways, but are sometimes provided adjacent to undivided major roads. Service roads should be terminated at signalised intersections (and unsignalised intersections that have median openings) for safety and capacity reasons.

Service roads should generally operate as one-way carriageways because of the operational problems associated with intersections and headlight glare to the left of drivers on the major carriageways. Commentary 6 provides further explanation of these problems.

Two-way service roads may be used where:

- the outer separator is wide enough to ensure that operational problems do not eventuate at minor intersections and to accommodate a screen to prevent headlight glare
- they form short sections immediately prior to or beyond an intersection that functions as a property access.

A conceptual layout of a typical service road termination at an unsignalised intersection is shown in Figure 4.15, where it can be seen that various treatments may be adopted depending on site conditions and traffic characteristics. A treatment for a signalised intersection is shown in Section 10.
Exits from the service road to the major carriageway should desirably be angled at 70° so that drivers align their vehicles at the appropriate observation angle (as for the high entry angle left-turn). However, this may not be possible to achieve where the outer separator is narrow or larger vehicles use the opening.

Details for the design of service road treatments are given in Section 10.5.2.

![Diagram](image)

**Various treatments may be used depending on land use, access vehicles and parking requirements**

**Left turn slip lane optional**

**Access located to enable vehicle to conveniently cross to the turn lane when traffic flows permit**

Notes:
1. Simple left-turn treatment may be provided from minor road if volumes do not justify a CHL treatment.
2. Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

**Figure 4.15: Service road termination at an unsignalised intersection**

### 4.11 Staggered T-intersections

Unsignalised cross intersections (i.e. four legs) with one road having priority, record high crash rates for the through movements from the minor road, particularly if the minor legs are aligned. Staggered T-intersections are used as a safer alternative to four-way unsignalised intersections either by:

- setting out the alignment of the minor roads on new major roads to form a staggered T-intersection
- realigning one or both minor road legs of an existing intersection.

Commentary 7 provides some further information on this treatment.

There are two types of staggered T-intersections defined by the order of the turning movements of vehicles crossing the major road from the minor roads, namely:

- a right-left staggered T-intersection
- a left-right staggered T-intersection.
Traffic management considerations relating to the treatments are provided in the *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings* (Austroads 2007). There are no numerical volume warrants for the safe performance of staggered T-intersections, although experience suggests a volume limit exists for the right-left staggered treatment. A staggered T-intersection should not be provided where traffic analysis indicates that it is likely to operate at or near capacity early in its design life.

This layout stores crossing vehicles on the minor legs. As traffic on the minor legs has to give way to both directions on the major route, calculations to establish delay may be necessary. If excessive delay is anticipated an alternative treatment should be considered as drivers may take risks and crashes may result.

The right-left staggered T treatment (R-L) requires drivers to initially turn right into the major road, then left into the opposite minor road leg. This treatment is suitable only for low volume situations but is often more cost-effective than a left-right stagger if converting a four-way cross intersection into a staggered T-intersection.

A right-left staggered T-intersection treatment may be selected where:

- the potential for high-speed right angle crashes at a basic crossroad needs to be eliminated
- the intersection could be expected to operate below capacity throughout the intended design life of the treatment
- a low-cost treatment is required
- the aim is to minimise land acquisition from abutting property.

The right-left treatment has the relative advantages that less land is required (e.g. less acquisition) than that for a left-right stagger and it costs less, particularly when treating an existing intersection.

The right-left staggered T-intersection on a two-lane two-way road may be provided with a BAR or CHR treatment in the major road.

The left-right staggered T treatment requires drivers to initially turn left into the major road and then to turn right into the opposite minor road leg. Right-turn lanes should be introduced for the drivers turning right from the major road.

A left-right staggered T treatment may be selected where:

- the potential for high-speed right angle crashes at a basic crossroad needs to be eliminated
- the direction of stagger of side roads is conducive to its use
- it is planned to deviate the side road approaches to resolve other network issues
- analysis shows that a right-left staggered treatment would not have a satisfactory design life in terms of intersection capacity (and hence safety)
- the extent of land acquisition is acceptable.

The left-right staggered T is usually provided with auxiliary right-turn lanes in the major road. It may be safer than the right-left staggered T because:

- drivers moving from the minor roads across the major road do so by selecting gaps in two one-way traffic streams and crossing one lane at a time, rather than a gap in two-way traffic across a much larger distance
- the manoeuvres are relatively simple compared to the ‘reverse curve’ type manoeuvre required in the right-left stagger
- some right-left staggered treatments, where the stagger distance is minimal, may result in drivers adopting an illegal path to ‘straighten out the intersection’ by driving to the right of median islands.

While this treatment has some relative advantages for safety and traffic operation, it requires substantially more land acquisition when applied to an existing intersection and has a higher cost.

### 4.11.1 Rural Staggered T-Intersection Treatments

Preferred layouts for each type are illustrated in Figure 4.16 and Figure 4.17 respectively. Both types of staggered T-intersection can be provided on two-lane two-way roads or divided roads. Where it is desirable to minimise the stagger distance of a left-right staggered T-intersection due to site conditions or land availability, the right-turn lanes may be overlapped as shown in Figure 4.18.

The stagger distance is particularly important for the right-left stagger on a two-lane two-way road Figure 4.16 (a) as the distance should be:

- small enough to enable an efficient crossing manoeuvre in a single movement (i.e. not staged)
- great enough to cut off the possibility of high-speed crossing movements from the minor roads.

For a right-left staggered T on a divided road it is desirable to provide left-turn lanes for traffic turning into the minor roads as shown in Figure 4.16(b), as this arrangement does not require crossing traffic to travel along the through lane and reduces the risk of rear-end crashes.

For a two-lane two-way road the left-right staggered treatment in Figure 4.17(a) is preferred to that in Figure 4.18(a) because it results in less deviation of the through lanes on the major road. The stagger distance for a left-right treatment should be based on the deceleration and storage distance required for traffic turning right from the major road, either for back-to-back right turns (Figure 4.17) or overlapping right-turns (Figure 4.18). The required length of lanes is discussed in Section 5.
Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

Figure 4.16: Right-left staggered T-intersections

Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

Figure 4.17: Left-right staggered T-intersections with back-to-back right-turns
4.11.2 Urban Staggered T Treatments

The principles applied to rural staggered T treatments are also applied in urban situations, the main differences being the generally lower design speeds, the incorporation of bicycle and pedestrian facilities, the presence of parking and the use of kerbs. Staggered T treatments may be used on all roads from local to arterial.

On local roads staggered T treatments can be used as a measure to reduce the ‘permeability’ of the area for through traffic. However, on urban traffic routes a cross intersection may be a better arrangement if it is likely that traffic signals will be required in the future to improve capacity or reduce delays. Signalised staggered T-intersections are generally less efficient than signalised crossroads because of the ‘overlapping’ right turns and associated phasing.

4.12 Seagull Treatments

4.12.1 Rural Seagull Treatments

A diagram of a seagull layout is shown in Figure 4.19. Seagull intersections usually work well where right-turning traffic from the minor road would be delayed for extended periods due to the small number of coincident gaps on the major road, particularly if upstream events on both of the major road legs cause traffic to arrive at the intersection in platoons.
A decision to provide a seagull treatment should be based on traffic analysis that demonstrates the treatment would operate satisfactorily and be advantageous.

A seagull treatment may be appropriate where:

- a substantial volume of traffic turns right from the minor road of a T-intersection, to the extent that a two-stage right turn through a conventional median opening would not operate satisfactorily
- traffic turning right from the minor road has adequate gaps in traffic on the nearer carriageway, and is able to merge satisfactorily with the traffic on the other carriageway
- it is unlikely that an access (driveway or road) from a major traffic generator will be proposed adjacent to the major road and opposite the minor road within the design life of the treatment.

When the volume of right-turning traffic is small, it is preferable to store vehicles, one at a time, in the median. This requires a two-staged crossing treatment as shown in Figure 4.11.

![Seagull treatment (preferred)](image)

Notes:

1. Schematic sketch only. Refer to Figure 7.14 for design details.
2. Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

The treatment shown in Figure 4.19 is preferred in most cases. However, where the number of right-turning vehicles from the minor road is high relative to the number of through vehicles with which it must merge (i.e. a similar design hour flow in each stream) the layout in Figure 4.20 may be appropriate. This treatment can be advantageous where the carriageway on the major road increases from, for example, two lanes to three lanes at the seagull intersection. When this alternative layout is used and the cross-section of the major road does not change, the merge for through traffic should be located an appropriate distance downstream of the treatment (say 500 m to 700 m).
Notes:
1. Schematic sketch only. Refer to Figure 7.15 for design details.
2. Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.

Figure 4.20: Seagull treatment (alternate)

For details of rural seagull treatments refer to:
- Figure 7.14 for the preferred seagull layout that has a right side merge
- Figure 7.15 for the alternative seagull layout where right turners have a dedicated lane and a left side merge may be provided downstream of the intersection.

4.12.2 Urban Seagull Treatment

The principles applied to the design of seagull treatments are the same for urban and rural treatments (Section 7.6.4). However, urban treatments generally have kerbs rather than shoulder on the left edges, are generally designed for lower operating speeds, and may be signalised on one carriageway.

Signalised seagull treatments have been used at high-volume urban intersections where two right-turn lanes operate from the side road. In this case the double right-turn traffic has to merge within the median prior to entering a dedicated lane or prior to merging with the main carriageway traffic. Traffic analysis is necessary to confirm that the seagull is the most appropriate treatment in such situations.

An issue that limits the suitability of seagull treatments in urban areas is the provision for the movement of pedestrians and cyclists across the major road, and the possible need to provide access to major development opposite the minor road.

4.13 Wide Median Treatment

Wide median treatments (WMT) were developed for use on high-speed rural divided roads where it is necessary to retain a crossroad and therefore to physically control the speed of crossing traffic. The treatment is illustrated in Figure 4.21 and shows how the minor road entries are designed with horizontal curvature and large islands to reduce the speed of vehicles approaching and entering the intersection.

The WMT has some similar design features to roundabouts but the WMT provides priority for drivers on the major road whereas a roundabout requires major road drivers to give way to vehicles circulating on the roundabout. To ensure that there is no confusion created for drivers, WMTs and roundabouts should not be alternated along the same route nor used in close proximity to each other.
4.14 Channelised Intersections with Right-turn Restrictions

Right turns at urban intersections can be banned through the use of appropriate traffic control devices and/or restricted through geometric design. The assessment of intersection control options, including the banning of right turns, is discussed in the *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings* (Austroads 2007).

It is desirable to provide for all movements at intersections between arterial roads; however, it is often preferable to restrict right-turn movements at selected minor road intersections along arterial routes in order to provide an appropriate level of service for arterial road traffic. Figure 4.22 illustrates how channelisation can be used at urban intersections to restrict certain right-turn movements and to discourage wrong-way movements. These treatments require the appropriate traffic control devices to be installed (e.g. regulatory signs).
Note: Arrows indicate movements relevant to the turn type. They do not represent actual pavement markings.
Source: Based on Austroads (2005).

**Figure 4.22:** Channelisation to ban right turns

---

**Median**

**Single right turn ban**
(reinforce with signs)

**Double right turn ban**
(reinforce with signs)

**Right turn ban from side road**

**Right turn restricted by raised median**
5 AUXILIARY LANES

5.1 General

At an intersection an auxiliary lane is an additional lane or lanes, added to the through carriageway for safety and/or intersection capacity purposes. Auxiliary lanes can be added to the near and/or off-side, and on the approach and/or departure. On the approach side they are designed on the basis of deceleration models and on the departure side models of acceleration are used.

The two main types of auxiliary lanes related to intersection design are turn lanes (i.e. deceleration and acceleration lanes) and auxiliary through lanes.

Conversion of through lanes into turning lanes should only be used in existing extremely constrained locations because of the poor crash history associated with such treatments. They are not to be used for the design of new intersections.

Conversion of an approach through lane of a multi-lane road into an exclusive right-turn or left-turn lane should be avoided as it may cause some through traffic to change lanes at the last moment, creating a potential for crashes, particularly in areas with high tourist or visitor populations. This treatment is not to be used in the design of a new intersection. Should such a conversion be unavoidable at an existing intersection, advance warning and guidance signs should be erected informing drivers of what to expect. The signs should be supplemented by pavement arrows.

5.2 Determining the Need for Auxiliary Lanes

5.2.1 Deceleration Turn Lanes

The layouts of many intersections include turning lanes to ensure that deceleration and storage of turning vehicles occur clear of the through traffic lanes. The need for deceleration turn lanes cannot be stated definitively in all instances because of the many factors to be considered, such as speeds, traffic volumes, capacity, type of road, service provided, traffic control and crash history. However, the need is usually established on the basis of ensuring that turning traffic does not impede through traffic to the extent that:

- the operational efficiency of an intersection or intersection approach is compromised
- an unacceptable level of safety would result due to turning traffic slowing or stopping in a through lane.

The need for auxiliary lanes and the type of treatment should consider:

- the function of the road and its strategic significance
- the volume of heavy vehicles using the road
- operating speeds at the intersection
- available sight distance to drivers of turning vehicles
- consistency of treatment along a corridor to meet driver expectations
- traffic volumes.

Auxiliary lanes to accommodate right-turn or left-turn movements, or to improve the capacity of a through movement, may be provided across the range of available intersection types. Warrants for the provision of auxiliary lanes for AU and CH treatments are provided in Section 4.8.
Where volumes are substantial a need is usually established through traffic analysis *Guide to Traffic Management – Part 3: Traffic Studies and Analysis* (Austroads 2009h). At major signalised urban intersections it is common for two, and in some cases three, turn lanes to be required for right-turning or left-turning movements based on operational efficiency.

### 5.2.2 Acceleration Lanes

There are no simple numerical warrants for the provision of acceleration lanes. However, an auxiliary lane may be added on the departure side of a left turn or right turn if traffic is unable to join safely and/or efficiently with the adjacent through traffic flow by selecting a gap in the traffic stream.

Acceleration lanes may be provided at major intersections depending on traffic analysis. However, they are usually provided only where:

- insufficient gaps exist for vehicles to enter a traffic stream
- turning volumes are high (e.g. 300 to 500 vph)
- the observation angle falls below the requirements of the minimum gap sight distance model (for example, inside of horizontal curves)
- heavy vehicles pulling into the traffic stream would cause excessive slowing of major road vehicles.

Acceleration lanes should only be used where there is no demand for the turning drivers to weave over a relatively short distance across the carriageway once they leave the acceleration lane.

### 5.2.3 Auxiliary Through Lanes

At rural intersections an auxiliary through lane will be associated with the need to provide an overtaking lane or a climbing lane (*Guide to Road Design – Part 3: Geometric Design*, (Austroads 2009a)).

At urban intersections the need for an auxiliary through lane will relate to the need to increase the capacity or improve the level of service on an approach (*Guide to Traffic Management – Part 3: Traffic Studies and Analysis*, (Austroads 2009h)).

### 5.3 Deceleration Turn Lane Length

#### 5.3.1 Components of Deceleration Turn Lanes

The design of deceleration turn lane length is based on the performance of cars. It is generally accepted that a design based on the performance of trucks would not be cost effective and that it is generally acceptable for trucks to commence deceleration in the through lane. However, consideration should be given to providing a longer deceleration lane in situations where there is a high volume of trucks turning.

The length of a deceleration lane will be governed by one or more of the following:

- deceleration from the approach speed to a stop
- deceleration from the approach speed to a turning speed
- additional length required for storage of vehicles queuing while waiting to turn
- diverge distance
- additional length to enable turning vehicles to enter the turn lane when vehicles are queued in an adjacent through lane.
Deceleration from the approach speed to a stop condition is applicable to:

- right turns from two-way roads (all cases)
- right turns from one-way roads where the turn is controlled by a stop sign, give way sign or a traffic signal
- a left turn to a stop, give way or signalised approach
- left turn slip lanes without a protected acceleration lane on the departure.

Deceleration from the approach speed to a turning speed is applicable to unsignalised:

- right turns from a one-way priority road
- left turns with a protected acceleration lane on the departure
- left turns from a major road where there is no left-turn island (i.e. BAL and AUL turn treatments).

The components of an auxiliary lane are shown in Figure 5.1. They apply to both left-turn lanes and right-turn lanes as described previously. The components comprise:

- \( B \) = total length of auxiliary lane
- \( D \) = deceleration length (m)
- \( L_d \) = diverge length (m)
- \( S \) = storage length (m)
- \( T \) = physical lane taper length (m)
- \( P \) = length of parallel lane for deceleration (m).

![Figure 5.1: Components of a deceleration turning lane](source: Based on QDMR (2006).)
Total length of auxiliary lane (B)
The overall length of a deceleration auxiliary lane is determined by either the deceleration length plus storage length (D + S), or the diverge length depending on circumstances.

Deceleration length (D)
Where drivers are required to stop or give way as described previously, the overall length of deceleration lane will be determined by the deceleration distance for cars plus storage required for the queuing of vehicles (D + S) as shown in Figure 5.1(a). The deceleration length is determined from Table 5.2, the use of which is discussed below.

Diverge length (Ld)
When drivers enter turning lanes they will generally prefer to diverge from the through lane at a comfortable rate of lateral movement (i.e. 1.5 m/sec) from the centre of the through lane to the centre of the auxiliary lane. In the case of free-flow left-turn lanes, where the driver can drive on a left-turn roadway at a particular speed (i.e. exit speed), the value of D may be relatively small in which case the driver is likely to diverge directly toward the left-turn roadway as shown in Figure 5.1(b). In some situations the diverge length (Ld) will exceed the deceleration length (D), in which case Ld determines the length of lane required (Table 5.2).

In some cases a design may provide for right-turners to leave the road at an ‘exit speed’. Table 5.2 also shows values of Ld for two typical lane widths. However, Ld should be based on the distance that the diverging vehicle shifts sideways when undertaking the diverge manoeuvre and Equation 5 can be used to determine Ld in any given situation.

\[
L_d = \frac{VY}{3.6S}
\]

where:

- \(L_d\) = diverge length (metres)
- \(V\) = design speed (km/h). For normal length of deceleration lanes, use the mean free speed of the through road, about numerically equal to the posted speed limit (km/h).
- \(S\) = rate of lateral movement (1.5 m/sec)
- \(Y\) = width of lateral movement (metres).

Where short length deceleration lanes are used, the design speed V may be decreased to the value used at the start of the taper. For example, CHR(S) and AUL(S) turn treatments are based on a 20% reduction in through road speed at the start of the taper. Therefore, the design speed V in these cases may be taken as 80% of the mean free speed of the through road.

Storage length (S)
The storage length is the distance required to store vehicles in a lane while they are waiting to pass through the intersection. Storage lengths can be determined by simulating the operation of an intersection using computer programs. Unsignalised intersections, signalised intersections and roundabouts can be analysed. The analysis is usually undertaken by using computer software for which design traffic volumes and a preliminary intersection layout design are required as input.
The 95th percentile queue is usually used for the design of auxiliary turning lanes. This is the queue length that is exceeded on 5% of occasions (Guide to Traffic Management – Part 3: Traffic Studies and Analysis, (Austroads 2009h)).

Storage length is not necessary for the situation where traffic can turn and enter the intersecting road at speed (Figure 5.1(b)).

**Physical taper length T**

The taper length T is the physical taper to be constructed at the entry to the lane. It does not represent the path likely to be driven by drivers entering the lane (Lₜ). It is important that the taper length T is not too long to ensure that:

- the commencement of the auxiliary lane is well defined
- drivers do not inadvertently enter the lane during inclement weather, a situation that is more likely where a deceleration lane is on a horizontal curve
- additional storage capability is provided at urban locations for those times when the 95th percentile queue length is exceeded.

Recommended physical taper lengths for various design speeds in rural and urban areas are shown in Table 5.1. However, in rural situations a shorter taper (e.g. 20 to 30 m) can be used to provide clearer definition of turn lanes located on curves, and in urban situations a shorter taper (e.g. 10 to 20 m) should be used to maximise storage in the turn lane.

### Table 5.1: Length of physical taper T for a 3.5 m lane width

<table>
<thead>
<tr>
<th>Design speed of approach (km/h)</th>
<th>Taper length T (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>15</td>
</tr>
<tr>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>70</td>
<td>23</td>
</tr>
<tr>
<td>80</td>
<td>25</td>
</tr>
<tr>
<td>90</td>
<td>30</td>
</tr>
<tr>
<td>100</td>
<td>33</td>
</tr>
<tr>
<td>110</td>
<td>35</td>
</tr>
</tbody>
</table>

Note: Values of taper length are rounded.

The values in Table 5.1 assume a desirable lane width of 3.5 m. However, where a different lane width is provided Equation 6 should be used to compute the physical taper length.

\[
T = \frac{0.33VW_T}{3.6} \tag{6}
\]

where:

- \(T\) = taper length (m).
- \(V\) = design speed of major road approach (km/h).
- \(W_T\) = width of turn lane (m).
Length of parallel lane (P)
The parallel part of the deceleration length (P) is deduced from D – T.

5.3.2  Determination of Deceleration Turning Lane Length

Procedure
Table 5.2 shows the distances required for deceleration (including the physical taper) required for cars on a level grade and the diverge length required to change lanes, for a range of design speeds.

Table 5.2 should be used as follows:

- Where vehicles are required to stop or to give way the deceleration distance from the ‘stop condition’ column for a comfortable deceleration rate of 2.5 m/s should be used.
- The column for a maximum design deceleration rate of 3.5 m/s should only be used where it is impracticable to adopt the ‘comfortable’ rate. This usually involves situations where an intersection is located adjacent to a design constraint and it is not feasible to relocate either the intersection or the constraint (e.g. bridge abutment, bridge pier, utility that would be excessively expensive to modify or relocate) in order to achieve a deceleration lane length that provides for the 2.5 m/s rate.
- In situations where a turning vehicle does not have to stop or give way and is able to turn a corner at speed, less deceleration distance is required (shaded grey and pink in Table 5.2). Ld should be used where it exceeds the value shown in the area shaded grey.

Table 5.2: Deceleration distances required for cars on a level grade

<table>
<thead>
<tr>
<th>Design speed of approach</th>
<th>Length of deceleration D – including diverge taper T</th>
<th>Diverge length Ld3 for lane widths</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Stop condition1</td>
<td>Design speed of exit curve (km/h)2</td>
</tr>
<tr>
<td>Road (km/h)</td>
<td>Conf. 2.5 m/s²</td>
<td>Max. 3.5 m/s²</td>
</tr>
<tr>
<td>50</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>60</td>
<td>55</td>
<td>40</td>
</tr>
<tr>
<td>70</td>
<td>75</td>
<td>55</td>
</tr>
<tr>
<td>80</td>
<td>100</td>
<td>70</td>
</tr>
<tr>
<td>90</td>
<td>125</td>
<td>90</td>
</tr>
<tr>
<td>100</td>
<td>155</td>
<td>110</td>
</tr>
<tr>
<td>110</td>
<td>185</td>
<td>135</td>
</tr>
</tbody>
</table>

1. Rates of deceleration are: 2.5 m/s² for comfortable deceleration; 3.5 m/s² is the maximum for design purposes.
2. Speed of exit curve depends on radius and crossfall (Figure 5.2).
3. Distance Ld assumes a lateral rate of movement of 1.5 m/s.
4. Example lane widths – use actual lateral shift distance of vehicle.

Notes:
The pink shading indicates that the deceleration lengths given are greater than the diverge length. The length of the deceleration lane should be based on these values.
The grey shading indicates that the diverge length is greater than the deceleration length. In these cases, the length of the deceleration lane should be based on the diverge length (the values shown in yellow shading).
Adjust for grade using Table 5.3.
All lengths are in metres.
Source: Based on Austroads (2005).
The deceleration distance determined from Table 5.2 should be increased for a downgrade and may be reduced for an upgrade in accordance with Table 5.3.

**Table 5.3: Correction to deceleration distance \( D \) for grade**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Ratio of ‘length on grade’ to ‘length on level’</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upgrade</td>
</tr>
<tr>
<td>0 – 2%</td>
<td>1.0</td>
</tr>
<tr>
<td>3 – 4%</td>
<td>0.9</td>
</tr>
<tr>
<td>5 – 6%</td>
<td>0.8</td>
</tr>
</tbody>
</table>

Figure 5.2 is used to determine the design speed of the exit curve required in Table 5.2. The calculation method for Figure 5.2 is provided in Commentary 8.

As discussed previously, the length of auxiliary lane should be the larger of the diverge length \( (L_d) \) or the deceleration length \( (D) \). The distances for \( L_d \) in Table 5.2 are based on a rate of lateral shift of 1.5 m/sec and lane widths of 3.5 m and 3.0 m. Where a different lane width applies, or a designer has a case to use a different rate of lateral shift, Equation 5 can be used to determine \( L_d \).

Where a turning lane caters for a high percentage of heavy vehicles consideration may be given to increasing the length above that required for cars so that less interference to traffic flow occurs in the through lane as a result of trucks slowing. However, it is accepted that turning lanes should generally be designed for the deceleration of cars and that heavy vehicles may reduce speed in the through lane.
Notes:
1. A maximum crossfall of 8% should be adopted for turning roadways.
2. Adverse crossfall should be as flat as possible consistent with drainage requirements and should not be steeper than -3%. The ‘effective adverse crossfall’ should not be steeper than -5%. (Effective crossfall is the vectorial sum of the longitudinal grade and crossfall).
3. Graphs are based on the maximum side friction factors shown in Commentary 8

Source: Based on Austroads (2005).

Figure 5.2: Turning speeds for various combinations of radius and crossfall


**Practical application of the procedure**

This section provides guidance on the factors that influence the length of a deceleration lane and the process of determining the length. However, many situations arise in practice where engineering judgement must be applied by the designer in determining an appropriate length.

**High-speed rural and urban roads**

On high-speed rural and urban roads (≥ 90 km/h) with moderate to high traffic volumes it is important for road safety that turning vehicles do not impede through traffic. It is therefore most desirable that turning vehicles (i.e. cars) do not decelerate in the through lane, and that the deceleration lane is long enough to cater for deceleration and storage.

Generally in rural areas the storage length will not be large and the resulting length of lane (i.e. D + S) will be within practical limits. An exception is facilities on recreational routes which may periodically experience long queues. In these cases analysis should be undertaken to determine the queue length (S) likely to be experienced in the design year and the economic value of adopting a length that can accommodate the required storage.

**Low to moderate-speed urban arterial road intersections**

At major intersections on low to moderate speed urban arterial roads (< 90 km/h) it is desirable to provide for deceleration plus storage (D + S) for turning traffic. However, in situations where the road system is congested and queues are long it may not be practicable to provide for D + S. If this is the case designers should do everything practicable to at least accommodate the 95th percentile queue (i.e. storage length) within the turn lane as shown in Figure 5.3(a).

Another consideration at urban arterial road intersections is access to auxiliary lanes for turning vehicles. Many turning movements at signalised intersections are catered for by a 'leading' right-turn phase or a left-turn phase that runs concurrently with a right-turn phase from the intersecting road. A frustration occurs for some turning drivers when queues in the through lanes block access to the turning lanes and drivers are unable to utilise the green turn arrow (Figure 5.3(b)).
The inability of turning vehicles to access turn lanes can also adversely affect the capacity of an intersection and result in vehicles encroaching onto medians and causing maintenance issues.

The length of turning lanes possible at major urban intersections is often influenced by the existence of physical constraints on achieving a greater length. The constraints may include:

- other intersecting roads
- a railway crossing on an approach
- a road bridge
- the abutment or pier of an overpass.

In all cases the costs and benefits of removing the constraint should be investigated to determine the most cost-effective solution.

At intersections between low to moderate speed arterial roads (< 90 km/h) and collector roads it is desirable and usually practicable, because of the lower turning volumes, to provide a length equivalent to D + S for vehicles turning right and left from the major road and this should be achieved wherever practicable.
5.4 Determination of Acceleration Lane Length for Cars

5.4.1 General

While this section is concerned with the design of acceleration lanes provided for turning traffic, the principles may be applied to other road design situations such as acceleration distances required for drivers using ramp meters on freeway/motorway on-ramps.

The length of an acceleration lane is governed by the acceleration requirements from a stop or turning speed to the speed of the through traffic on the road being entered. The acceleration should occur wholly within the lane.

While the design of an acceleration lane is usually based on the performance of cars, situations may arise where the performance of trucks needs to be considered (Section 5.5).

An acceleration lane has two basic design requirements:
- acceleration length
- merge length.

Figure 5.4 shows a typical arrangement for an acceleration lane and an option where the lane continues as an additional through lane. This type of treatment may require the provision of a signalised crossing for pedestrians and cyclists to enable them to safely cross the turning roadway.

![Figure 5.4: Options for auxiliary acceleration lanes](image)

Source: Austroads (2005).

5.4.2 Acceleration Distance

The process to determine the minimum length of acceleration lane is:
- select the appropriate turning speed from Figure 5.2 for turn radius and crossfall
• using this turning speed, determine the overall acceleration lane length from Table 5.4 and adjust for grade using Table 5.5.

The values for the minimum length of an acceleration lane in Table 5.4 are based on the greater of:

• the length required to accelerate from the turning speed to the design speed of the road being entered
• the distance travelled in four seconds by the driver using the acceleration lane (to enable the driver time to observe potentially conflicting vehicles in the right side rear view mirror, and to prepare to merge) plus the required merge length.

The values shown in Table 5.4 apply to both urban and rural conditions and are:

• for cars and include the merge taper
• based on the data from research studies on instantaneous acceleration rates of a typical passenger car.

Acceleration rates for a typical passenger car are provided in Commentary 9.

While it is desirable in most cases that the accelerating vehicle reaches the mean free speed of the adjacent through lane (about numerically equal to the posted speed limit) before merging, in some situations where the site is constrained and the volume in the through lane is low it may be acceptable to design for a speed decrement of 20 km/h within the merge area (i.e. a merging vehicle travelling at 80 km/h enters a traffic stream of vehicles travelling at 100 km/h).
Table 5.4: Length of acceleration lanes for cars on level grade

<table>
<thead>
<tr>
<th>Design speed of road entered(^1) (km/h)</th>
<th>Length of acceleration lane A (m) (including length of merge taper)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design speed of entry curve (km/h)</td>
</tr>
<tr>
<td></td>
<td>0(^2)</td>
</tr>
<tr>
<td>50</td>
<td>105</td>
</tr>
<tr>
<td>60</td>
<td>125</td>
</tr>
<tr>
<td>70</td>
<td>165</td>
</tr>
<tr>
<td>80</td>
<td>235</td>
</tr>
<tr>
<td>90</td>
<td>330</td>
</tr>
<tr>
<td>100</td>
<td>450</td>
</tr>
<tr>
<td>110</td>
<td>610</td>
</tr>
</tbody>
</table>

1. For the purpose of calculating acceleration lane lengths at intersections, the speed reached is usually made equal to the mean free speed. In the absence of local data it can be assumed that the mean free speed is approximately equal to the speed limit.

2. Length required where a vehicle accelerates from zero speed.

Notes:
Values in the non-shaded areas are based on the distance required to accelerate from the turning speed to the design speed of the road being entered.
Values in the grey-shaded areas are based on the distance travelled in four seconds plus the merge length. In this area of the table these values are greater than the distance required to accelerate from the turning speed to the design speed of the road being entered.

Table 5.5: Correction of acceleration distances as a result of grade

<table>
<thead>
<tr>
<th>Design speed of road entered (km/h)</th>
<th>Ratio of length on grade to length on level(^*) for:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Design speed of turning roadway curve (km/h)</td>
</tr>
<tr>
<td></td>
<td>3 to 4% upgrade</td>
</tr>
<tr>
<td>Stop</td>
<td>30</td>
</tr>
<tr>
<td>50</td>
<td>1.3</td>
</tr>
<tr>
<td>60</td>
<td>1.3</td>
</tr>
<tr>
<td>80</td>
<td>1.3</td>
</tr>
<tr>
<td>100</td>
<td>1.3</td>
</tr>
<tr>
<td>110</td>
<td>1.4</td>
</tr>
</tbody>
</table>

* Ratio from this Table multiplied by length in Table 5.4 gives length of speed change lane on grade.

5.4.3 Merge Taper \(T_M\)

The merge length is the distance required for a vehicle to merge from the auxiliary lane into the adjacent through lane. The physical taper at the end of an acceleration lane should be equal to the desirable merge length (\(T_M\)). The taper is included in the overall acceleration length for an auxiliary lane shown in Table 5.4.
For an acceleration lane it is assumed that drivers are expecting that they will have to merge and can therefore comfortably merge at a lateral rate of 1.0 m/s (basis used for $T_M$ in Table 5.4). For most practical purposes the acceleration lane merge length $T_M$ approximates the design speed ($V$ km/h). However, if a lane width other than 3.5 m is proposed, or a different rate of lateral movement is considered to be appropriate, a specific value can be calculated for $T_M$ using the formula in Commentary 10.

### 5.4.4 Other Considerations

For safety reasons merges should never be installed:

- over a crest that has a sight distance less than ASD or on the inside of a horizontal curve where the radius of the right-side lane line is less than:
  - 185 m for a 60 km/h design speed
  - 330 m for a 80 km/h design speed
  - 515 m for a 100 km/h design speed
  - 620 m for a 110 km/h design speed.

This is based on a 3.5 m lane width and a 2 s gap. For 3.0 m wide lanes a 20% larger radius applies.

It is also important that:

- Approach sight distance (ASD) is available at all points along the merge length to allow drivers to observe the linemarking with sufficient time to react.

- Merge transitions around horizontal curves should be developed as for a straight alignment and transferred to the curved alignment by the distance and offset method. This is shown in Figure 5.5.

- A circular curve should not be used for the merge taper, as the rate of lateral movement and reduction in width will not be uniform. In plane geometry, concentric circular arcs cannot be joined tangentially by a third circular arc, unless they are joined over exactly $180^\circ$. The curve within the merge length in the bottom half of Figure 5.5 is obtained by linear interpolation only; it is not a circular arc.

Where an intersection is located downstream of the end of the acceleration lane it is important to verify that sufficient weaving distance is available for drivers using the acceleration lane who wish to turn right at that intersection. The same applies to drivers in the through lane who may wish to turn left at that intersection (Figure 5.4 (b)). This will require traffic analysis in accordance with the *Guide to Traffic Management – Part 3: Traffic Studies and Analysis* (Austroads 2009h).
5.5 Acceleration Lane Design for Trucks

The speed of heavy vehicles needs to be considered when designing acceleration lanes. For the design of new acceleration lanes it is preferable that the design heavy vehicle has sufficient length to accelerate to a speed no less than 20 km/h below the mean free speed of the through road, particularly if the acceleration lane is on a dedicated heavy vehicle route.

As trucks require very long acceleration distances, often to an extent that is not possible to accommodate in practice, a speed differential between general traffic and heavy vehicles will usually have to be accepted at the point of merging.

If the speed of trucks nearing the end of an acceleration lane is too low, it can be very difficult for drivers on the through road to determine whether to brake and follow a merging truck or accelerate and move ahead of the truck. For this reason, the speed at which heavy vehicles will merge should be determined and considered when designing the length of acceleration lanes.

If the speed of heavy vehicles at the merge is much lower than the speed of the through traffic (say 30–40 km/h difference or more) consideration should be given to extending the length of the acceleration lane. If this cannot be achieved consideration should be given to installing either:

- a basic left-turn treatment comprising a give way or stop situation (i.e. a BAL) or a high entry angle (CHL) treatment
- an acceleration lane length that is based on Table 5.6 or Table 5.7 (where practicable) or alternatively on the length required for cars to accelerate to the design speed of the through road.

---

Figure 5.5: Procedure for plotting a merge on a curved alignment using offsets from a straight road
Although the BAL and CHL treatments result in slow moving heavy vehicles on the through road, where the traffic volume on the road and the number of trucks entering is not high, it may be relatively easy for through drivers to perceive the slow movement of these vehicles and to slow for them. On the other hand, where traffic volumes on the road and the number of trucks entering are relatively high, it may be preferable to provide an acceleration lane in order to establish the presence of the entering truck on the major road, even though a higher than desirable speed differential between trucks and cars may occur near the merge area.

Table 5.6 provides a guide to the acceleration lane lengths that are required for semi-trailers to accelerate from rest to a specified decrement below the through lane speed. It should be noted that the table provides values only for flat conditions and downgrades. It can be seen that, depending on gradient, the lengths are generally within practicable limits.

<table>
<thead>
<tr>
<th>Downgrade (%)</th>
<th>100</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2.400</td>
<td>1.500</td>
<td>910</td>
<td>550</td>
<td>320</td>
</tr>
<tr>
<td>1</td>
<td>1.400</td>
<td>940</td>
<td>640</td>
<td>410</td>
<td>250</td>
</tr>
<tr>
<td>2</td>
<td>970</td>
<td>700</td>
<td>500</td>
<td>330</td>
<td>210</td>
</tr>
<tr>
<td>3</td>
<td>780</td>
<td>560</td>
<td>400</td>
<td>280</td>
<td>180</td>
</tr>
</tbody>
</table>

Note: For the purpose of calculating acceleration lane lengths at intersections, the through road speed is usually made equal to the mean free speed (which is often approximately equal to the speed limit).

Source: Based on Austroads (2002a).

It is seldom practical to provide an acceleration lane of sufficient length on upgrades to enable trucks to accelerate to the design speed for through lanes or even a reasonable decrement below the speed of a through lane. Graphs in Commentary 11 provide speed profiles for a semi-trailer on various gradients (Austroads 2002a) and reference to relevant computer software. Table 5.7 shows acceleration lengths scaled from the graphs for upgrades and various decrements relative to the through lane speed. Furthermore, it indicates that a decrement of 10 km/h or 20 km/h is generally not practicable in terms of an acceleration lane length where the through road speed is 100 km/h.

<table>
<thead>
<tr>
<th>Upgrade (%)</th>
<th>100</th>
<th>90</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-</td>
<td>-</td>
<td>2,000</td>
<td>890</td>
<td>480</td>
<td>230</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>890</td>
<td>-</td>
<td>320</td>
<td>130</td>
</tr>
</tbody>
</table>

Note: Dashes indicate that it is not practical to provide sufficient acceleration lane length for semi-trailers to reach the speeds indicated.

Source: Based on Austroads (2002a).

### 5.6 Auxiliary Through Lane Design

Auxiliary through lanes may be used at signalised intersections as a means of increasing capacity. They are often introduced on the immediate approach to an intersection and terminated on the departure. It is desirable that the lane commences far enough in advance of the intersection to accommodate a queue length that will enable saturation flow to be maintained across the stop line for the duration of the green time. The queue can be estimated from the maximum green time allocated to the approach in the signal timings. For example:
• assuming that the green time is 40 s and that traffic is discharged across the stop line of the auxiliary lane at 2 s headways (average) a total of \(40/2 = 20\) vehicles will be discharged during the green signal phase.

• the queue that can be discharged is therefore \(20 \times 8 \text{ m} = 160 \text{ m}\) which is a guide to the length of parallel lane that should be provided on the approach.

However, the signal analysis should be examined to assess the potential for the queue in the adjacent through lane to block access to the added short through lane.

It is also important that the departure lane is long enough to enable the capacity of the approach lane to be utilised. In order to satisfactorily discharge a queue similar to that described, it is suggested that the length of the parallel departure lane should be based on about 4 s to 6 s of travel time at the operating speed of the through lane plus a taper length.

For a through lane the physical diverge taper on the approach should be based on a lateral rate of movement of 1.0 m/sec. The merge taper on the departure \(T_m\) should be calculated on the basis of a lateral rate of movement of 0.6 m/sec which is more generous than the merge length associated with acceleration lanes. In practical terms this approximates the numerical value of the design speed, \(V\) (based on a 3.5 m wide lane and \(V\) is in km/h).
6 TRAFFIC ISLANDS AND MEDIANS

6.1 General

A traffic island is an area provided to separate and direct traffic. Medians are a dividing strip provided to separate traffic flowing in opposite directions. Traffic management aspects of traffic islands and medians are provided in the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007).

The width and type of median on a road leading into an intersection may influence its design. Designers should refer to the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) for guidance on the design of medians in mid-block situations.

Traffic islands and medians can be raised, depressed, painted, or defined by contrasting material on the pavement. There are no numerical warrants for the provision of the various types of islands or medians at intersections; however, there are a number of considerations that assist in the decision. The requirement for a traffic island or median tends to be site specific and consideration may depend on a subjective assessment of turning volumes, the percentage of trucks and the road authority’s knowledge of driver behaviour at other sites in the jurisdiction.

Painted medians and traffic islands do not have the same degree of physical control or conspicuity as raised treatments. Painted treatments are often used, particularly to define right-turn lanes, in constrained situations or where there are budgetary constraints.

Traffic islands and median noses at an intersection should be designed to suit the turning paths of the design vehicle and to maintain continuity of the major road through the intersection. The decision to use painted or raised medians and traffic islands often requires individual assessment and the relative advantages and disadvantages of raised medians and islands listed in Table 6.1 compared to flush or painted treatments may assist in decision making.

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
</table>
| A raised island or median:  
  • provides improved conspicuity of the median and islands, particularly during inclement weather  
  • physically restricts turning or crossing movements  
  • can safely accommodate signposting, traffic signal hardware and road lighting  
  • provides refuge areas for pedestrians  
  • provides positive guidance for turning and through vehicles  
  • can concentrate and direct rainfall runoff into channels and thus reduce the risk of hydroplaning  
  • provides an opportunity for landscaping | A raised island or median:  
  • requires lighting which can be expensive to install and maintain, especially in isolated areas  
  • may require a greater network of drainage systems, increased maintenance activities and cost to cater for the concentrated rainfall runoff  
  • could generate safety issues if struck by fast moving traffic  
  • may require more space due to greater lane widths to cater for broken down vehicles and the need for offsets to kerbs  
  • may block access for through traffic into a right-turn lane at traffic signals, whereas a painted median would assist right-turn manoeuvres by allowing drivers to drive over the median (within the limits of the road rules)  
  • may have traffic furniture which is prone to damage by errant and over-dimensional vehicles  
  • is often a more costly treatment. |
Traffic islands are used to:

- provide improved cues and conspicuity of the presence of an intersection where more important roads intersect (e.g. those with high traffic volumes)
- guide drivers into defined paths and hence to the correct position on the road to minimise conflict (e.g. to minimise ‘corner cutting’) at the intersection.

They should be designed and located with regard to the following considerations:

- The proper line of travel should be obvious and any changes in direction should be gradual and smooth.
- Approach sight distance (refer section 3.2.1), measured from 1.1 m to pavement level for painted medians and 1.1 m to 0.1 m for raised medians, must be provided on the minor road and is desirable on the major road.
- Small islands with the inherent problem of low target value should be avoided.

The most common form of traffic islands are splitter islands that may be provided on the approaches to intersections, left-turn islands and the central islands of roundabouts. The latter are discussed in the Guide to Road Design – Part 4B: Roundabouts (Austroads 2009c).

### 6.2 Raised Traffic Islands and Medians

#### 6.2.1 Raised Islands

Raised islands are preferred where there is a need to:

- physically control and direct traffic movement within an intersection (i.e. channelisation)
- control movements to or from property accesses in the vicinity of an intersection
- provide refuge for pedestrians and cyclists crossing the road
- locate traffic control devices in a prominent position for approaching drivers
- provide consistent treatments along a route.

Raised islands should be constructed of semi-mountable kerbs (Figure C12 1 in Commentary 12 for examples of kerb types). Barrier kerbs and other profiles are not favoured for use on islands. Depressed islands can also be outlined using kerbs, provided that adequate definition and delineation of the island can be achieved by other means (e.g. berm behind the kerb).

The size and shape of traffic islands vary according to site conditions and the design vehicles for various traffic movements. The size may also depend on the need to accommodate a number of pedestrians and/or cyclists, and roadside furniture within the island. In addition clearances to the edge of traffic lanes are necessary based on the traffic speed in the adjacent lane (Table 6.4).

Apart from functional aspects, a key consideration is that the island should be conspicuous to drivers approaching at the operating speed of the approach road. Rural sites with few constraints will have relatively large islands (e.g. ≥ 100 m² for a splitter island on an important approach to an arterial road) whereas an unsignalised urban intersection may have a small island.
Where raised islands are used:

- Island noses should be offset from the edge of the adjacent traffic lane to provide additional clearance to the kerb to enhance comfort for approaching drivers and prevent any tendency for them to shy away from the kerb. As a general guide it is suggested that the island nose be offset by 0.2 m per 10 km/h of approach speed but this guide is not used by all jurisdictions. On narrow islands where an offset to the approach nose is not practicable a fully mountable nose may be provided, which requires a smaller offset and nose radius than a kerb.

- ASD should be available to all island noses on the minor road.

- The radii at the ends or corners of islands will depend on the size of the island designed for the particular site.

### 6.2.2 Raised Medians

**General**

In this guide a median is considered to be any island that separates traffic travelling in opposite directions. Consequently, short islands on the approaches to intersections that are referred to as splitter islands in some jurisdictions are called median islands in this guide, and the term median suggesting a longer dividing strip. Median islands also include islands in the centre of a major (priority) road that are provided on the approaches to intersections (i.e. CHL treatment).

Raised median islands are used on approaches to intersections primarily to separate opposing traffic streams, but also to warn drivers of the presence of an intersection, provide refuge for pedestrians, reduce the number of points of crossing conflict and to shelter right-turning vehicles.

Wherever practicable, intersections should be designed to provide ASD to the pavement markings at the intersection (e.g. holding line). However, where this cannot be achieved because of limited visibility to intersections that are located on crests and relatively tight curves, raised median islands in the major road can be used to improve driver perception of the intersection. In such cases the island nose should be designed to a length that carries it over the crest or around the curve to a point where it can be easily seen.

Raised median islands and medians should preferably have semi-mountable kerbs. However, kerbs are an obstruction on the road so they must be highly visible and should have properly designed approach geometry and delineation (e.g. nose offsets, pavement markings and raised reflective pavement markers). Consequently, there are requirements for the length, area and offset from the edge of lanes for medians.

The following design aspects should also be considered for medians and splitter islands at intersections:

- A length of painted diagonal markings and barrier line should precede the approach nose to alert drivers to the presence of the median island and to guide them past the nose.

- Any short lengths of kerbed median island should be offset from the edge of the traffic lane.

- A median island in a side road should be set back from the prolongation of the through road (kerb or edge of traffic lane) to provide a clearance for major road vehicles and to assist heavy vehicle turning movements.

These aspects are illustrated in Figure 6.1 which shows a simple median island in a side road that is typical of urban situations and in Figure 6.2 which shows a rural example.
Note: It is preferable that a barrier kerb is not used for traffic islands or medians.
Source: Based on Austroads (2005).

Figure 6.1: An example of a layout of a simple median island in an urban side road
Notes:
Some jurisdictions may use a larger offset to the approach nose based on the speed of approaching vehicles.
For rural intersections or where the posted speed is more than 80 km/h, the minimum offset to the nose of the median island from the major roads through lane should be the greater of the shoulder width or 1.0 m.
Refer to Table 6.2 for L.

Figure 6.2: An example of a median island treatment at a rural unlit intersection

Minimum dimensions
The minimum area required for a median island depends on the speed environment and site conditions and is influenced by other design requirements (e.g. provision for turning vehicles, sight distance) and the need to accommodate road users and road furniture.

Median islands on major roads where the median accommodates a right-turn lane treatment are usually large in order to develop the transitions for vehicles to pass to the left of the turn lane. On the other hand median islands in local side streets may be relatively small. The geometry of median islands at rural intersections where two major roads intersect will generally be determined by the swept path of the design vehicle and the need to provide a conspicuous treatment on high-speed approaches. Consequently islands can be large as shown in Figure 6.2.
As an initial guide, designers may adopt the minimum length of raised median islands shown in Table 6.2. However, the required length, width and shape of median islands should be derived from traffic and site characteristics. For example, where an intersection must be placed around a horizontal curve or over a vertical crest it is good practice to extend the island to the start of the horizontal curve or prior to the crest in order to provide additional warning to drivers that they are approaching an intersection. In addition, it is often necessary to increase the width and provide curved sides to match the required turning path of the design vehicle.

These widths are measured to the line of the kerb. The full median width should be maintained for a distance of at least 2.0 m each side of a pedestrian ramp crossing.

For simple applications Table 6.2 and Table 6.3 can be used to determine a minimum area for median (splitter) islands, for example:

- urban unsignalised – 8.0 m² for a median island in a minor side road (e.g. island with small sign 1.2 m wide x 6.5 m long approx.)
- urban signalised – 20 m² for a median island to accommodate a traffic signal (based on 2.0 m wide to accommodate traffic signal x 10 m long)
- rural – 65 m² for a median island in a side road (based on 1.6 m wide (1.0 m offset to a 0.6 m radius nose) x 40 m long.

An example of a median island treatment for use at a rural site is shown in Figure 6.2. The widths and lengths of rural islands are generally greater than those used in urban situations because of the higher approach speeds that require greater offsets and the need for better conspicuity.

### Table 6.2: Minimum median island length (L)

<table>
<thead>
<tr>
<th>Speed prior to the intersection (km/h)</th>
<th>Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>80</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>40</td>
</tr>
</tbody>
</table>

### Table 6.3: Residual median island widths at urban intersections (W)

<table>
<thead>
<tr>
<th>Median function</th>
<th>Desirable minimum width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate traffic flows and a safety barrier</td>
<td>3.7²</td>
</tr>
<tr>
<td>Shelter a small sign</td>
<td>1.2</td>
</tr>
<tr>
<td>Shelter signal pedestals or lighting poles</td>
<td>2.0</td>
</tr>
<tr>
<td>Shelter pedestrians and traffic signals</td>
<td>2.5</td>
</tr>
<tr>
<td>Shelter pedestrians and TGSF provision in median cut-through</td>
<td>2.5</td>
</tr>
<tr>
<td>Shelter turning vehicles and traffic signals</td>
<td>6.0⁴</td>
</tr>
<tr>
<td>Shelter crossing cars</td>
<td>7.0³</td>
</tr>
</tbody>
</table>

Notes:

1. Width measured to centre of edge line of traffic lane for barriers, as there is no kerb and channel provided in front of barriers. Assumes 1.5 m shoulder width and 100 mm wide edge line and concrete barrier width of 570 mm. Single slope concrete barrier and steel beam barrier (back-to-back) are marginally wider i.e. 620 mm. Refer to AS/NZS 3845:1999 for details.
2. TGSF is a tactile ground surface indicator to assist vision-impaired pedestrians, often constructed of tiles with raised dots to indicate a hazard or raised ribs to indicate a direction.
3. Based on a 3.5 m wide turning lane and 2.5 m residual median to accommodate pedestrians and traffic signals.
4. Based on length of car plus clearance of about 0.9 m-1.0 m both front and back of car measured to line of kerb (length of 99.8th percentile car is 5.20 m and 85th percentile car is 4.91 m, refer to AS/NZS 2890.1:2004).
5. Widths for median functions other than barrier are measured to line of kerb.
6.2.3 Raised High-Entry Angle and Free-flow Left-turn Islands

High entry angle treatments and left-turn treatments with an acceleration lane (i.e. free-flow) can be used at rural and urban sites (Sections 8.2.4 and 8.2.5 for rural treatments and Sections 8.3.4 and 8.3.5 for urban treatments).

Figure 6.3 shows the key features of a raised high entry angle left-turn treatment for an urban intersection. The figure presents a signalised intersection approach but similar principles can be applied to an unsignalised approach.

![Diagram of Raised High-Entry Angle and Free-flow Left-turn Islands]

Note: For a description of LA and L1 see text below figure.

**Figure 6.3:** An example of the features of a high-entry angle left-turn treatment at an urban intersection (without bicycle lanes)

The key design features of an urban high entry angle treatment include the provision of:

- an adequate length of island (LA) on the approach to accommodate adequate clearances, the pedestrian marked foot crossing, and all road furniture in a safe location (i.e. clearance to traffic signals; signs not in nose)
- a left-turn roadway aligned so that left-turning drivers position their vehicles at an angle that results in a safe and convenient observation angle (i.e. 70°–90°)
- adequate width to accommodate a left-turning design vehicle
• kerbs ramps that are parallel to the traffic lane so that tactile ground surface indicators are also parallel to the kerb at crossing points

• a parallel offset on the approach where space is available and no bicycle lane is provided. Where a bicycle lane is provided equal the required width of the bicycle lane for the speed environment on the approach

• a length of island (L_I) on the intersecting road that is adequate to accommodate the pedestrian marked foot crossing, corner radii and signal pedestals.

It is desirable, although not always possible because roads intersect at angles other than 90°, that pedestrian crosswalk lines should be straight for the entire crossing of the road and at right angles to the kerbline. This design is desirable to ensure that the kerb ramp and associated tactile ground surface indicators are parallel to the kerb to provide a clear direction to vision-impaired pedestrians and for ease of construction.

Dimensions of traffic islands are site specific. At signalised sites, the side of a high entry angle left-turn island on the intersection approach should be a minimum of 10.0 m long to accommodate the pedestrian crosswalk and to ensure that signal poles and signs are not located in the vulnerable area near the approach nose of the island. A minimum clearance of 0.5 m from the line of kerb to a signal lantern target board is required. The side of the island adjacent to the departure should be at least 4.0 m long to accommodate the pedestrian crosswalk. These dimensions, together with an example of detailed offsets to both a high entry angle and a free-flow left-turn island are shown in Figure 6.4.

The desirable minimum area of an urban high entry angle left-turn treatment is approximately 40 m². Rural treatments may have a much larger area that will be a function of site conditions and the design vehicle.

Detailed information on the layout of high entry angle and free-flow left-turn island treatments is provided in Figure 6.4. However, as practice varies between jurisdictions, examples of acceptable treatments are also provided in Appendix D. In addition, treatments with bicycle lanes are illustrated in Section 8.3.6.
Notes:
1. Refer to Figure 6.3 for clearance to a raised median island.
2. Minimum offset 0.3 m where specific bicycle facilities are provided (e.g. bicycle lane, wide kerbside lane), 1 m where there is no other provision for bicycles. Where 0.3 m offset is used, apply a nominal 1 in 10 flare on the approach side of the island.
3. Some jurisdictions use different dimensions to those listed above. Examples of these are shown in Appendix D.
4. Pedestrian crossing (where provided). Width of pedestrian crossing (tw) and linemarking to be in accordance with Australian Standards.

Figure 6.4: An example of detailed island treatments showing offsets and crossing location

6.3 Painted Traffic Islands and Medians

6.3.1 General

Painted traffic islands and medians can be used:
- at rural or urban sites
- where space is limited (e.g. the resultant width between kerbs would be too narrow if a raised traffic island was used).

Painted islands require less space as no clearances are required between kerbs and the edge of adjacent traffic lanes or between kerbs and the swept path of design vehicles. While pedestrians can seek refuge in a painted island it is not intended that they do so. In addition, islands that are outlined in a single line may be encroached upon by the design vehicle. Painted islands may have various sizes and shapes but are often used as splitter islands and left-turn islands.
6.3.2 Painted Medians

Painted medians and median islands can be used where space is limited, where the aim is to provide a lower cost treatment or where a raised island would have some other relative disadvantage (Table 6.1).

Painted medians can be used:

- on approaches to raised or depressed medians
- where an intersection is unlit
- where space is limited and the resultant width between kerbs would be too narrow for a raised median.

Figure 6.5 shows the basic width dimensions of painted median islands or painted median markings. Reference should be made to AS 1742.2 or MOTSAM, Part 1: Traffic Signs, (Transit NZ 2007b) and Part 2: Markings (Transit NZ 2008) for further details. The minimum width of diagonal marking that is practicable is 300 mm giving a minimum overall width of painted island of 600 mm.

The minimum length of a painted median island at an intersection should be in accordance with Table 6.2. This length excludes any transition between the splitter island width and centreline pavement marking.

The edge of a painted median island should be coincident with the edge of the adjacent traffic lane (i.e. the clearance is 0.0 m). Provided that drivers do not cross a double line they may drive over a painted traffic island in order to enter a right-turn lane which may be a consideration when designing for heavy vehicles or to improve storage for heavily trafficked right-turning movements in urban areas.
Notes:

1. Based on AS 1742.2.
2. Pavement markers on the outside of an island are uni-directional retro-reflective raised pavement markers (RRPMs).
3. Diagonal rows of RRPMs within the marked median should be considered as an alternative to RRPMs along the outline. Two sets of RRPMs will not normally be required together.
4. N is generally 12 m for approaches to intersections.

Source: Austroads (2005).

Figure 6.5: Examples of painted medians

6.3.3 Painted Left-turn Islands

Examples of painted left-turn islands are shown in Figure 6.6. Larger traffic islands, as shown in Figure 6.6(a), will accommodate standard pavement markings. Smaller traffic islands, which will not accommodate standard pavement markings, should be fully painted as shown in Figure 6.6(b).

Painted traffic islands should be delineated with raised reflective pavement markers (RRPMs). Further information is available in AS 1742.2.
6.4 Desirable Clearances to Traffic Islands and Medians

The minimum recommended clearance from raised traffic islands to the edge of an adjacent traffic lane is provided in Table 6.4. This is the clearance from an island to a lane that is parallel to the island.

<table>
<thead>
<tr>
<th>Contest</th>
<th>Clearance from edge of traffic lane to CP on priority road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lit intersection, speed zone ≤ 80 km/h</td>
<td>0.0 m</td>
</tr>
<tr>
<td>Lit intersection, speed zone ≥ 90 km/h (for semi-mountable kerbs)</td>
<td>0.5 m</td>
</tr>
<tr>
<td>Unlit intersection, speed zone ≤ 80 km/h</td>
<td>0.3 m</td>
</tr>
<tr>
<td>Unlit intersection, speed zone ≥ 80 km/h</td>
<td>0.5 m</td>
</tr>
</tbody>
</table>

Notes:
1. Offset to the edge of a traffic lane from CP on the minor road approach should be 0.0 m.
2. These clearances may need to be increased for small radius turns. Design vehicle turning path swept widths should be used as a check.
3. The clearances presume that a 3.5 m lane is provided adjacent to the island or median.

Source: Austroads (2005).
Figure 6.7 shows the definition of AP and CP. The point ‘AP’ is used to compute the area of the island or median.

Notes:
1. The clearance point, marked CP, is used to apply clearance between the edge of the traffic lane and raised islands.
2. The area point marked AP is used to determine the areas of islands.

Figure 6.7: Reference points for clearance to raised traffic islands

6.5 Road Width between Kerbs and between Kerb and Safety Barrier

6.5.1 General

The width provided between kerbs or between kerb and safety barrier must be sufficient to accommodate the design vehicle swept path and possibly the check vehicle (especially between barriers) plus a 0.5 m clearance from both sides of their swept path to the line of kerb or barrier. Figure 6.8 shows how to provide for the design vehicle swept paths at an intersection comprising single-lane carriageways.

It is desirable to provide a width no less than 5.0 m between kerbs and between kerbs and roadside barriers to allow for the passing of broken-down vehicles. It is important to apply this width where long lengths of parallel kerbing (or kerbing and barrier) apply. In some cases, the widths required to cater for the design vehicle swept paths are greater than 5.0 m.

The width of 5.0 m is not mandatory if other provisions for passing broken-down vehicles are provided. Such provisions may include a very slow passing manoeuvre either partially or totally on an island or median. For this to occur, islands/medians require mountable or semi-mountable kerbing with sufficient offset to hardware (e.g. signs, light poles and traffic signal posts). In urban environments alternative routes to avoid ‘blockages’ are more likely to be available than in rural environments.
Where a safety barrier is placed close to the edge of the road it is important that the clearance available from the edge of the traffic lane to the barrier meets the 'shy line' requirements in the Guide to Road Design – Part 6: Roadside Design, Safety and Barriers (Austroads 2009e).

At locations where a raised traffic island is introduced it is important to provide satisfactory offsets and tapers to reduce the likelihood that drivers will shy away from the island nose (i.e. move laterally within the lane to increase clearance to it). Recommended offsets and tapers to urban and rural traffic islands and their noses are illustrated in Figure 6.1 and Figure 6.2, whilst Figure 6.4 provides details of offsets to left-turn islands.

A chevron or diagonal marking is provided in the space immediately in advance of the nose, details of which should be provided in accordance with AS1742.2 or MOTSAM, Part 1: Traffic Signs, (Transit NZ 2007b) and Part 2: Markings (Transit NZ 2008).

Notes

1. Minimum desirable width between kerbs to allow for a broken-down vehicle is 5.0 m. This width is not mandatory if other provisions for passing broken-down vehicles are provided. Such provisions may include mountable or semi-mountable kerbing on islands/medians with sufficient offset to hardware (e.g. signs, light poles and traffic signal posts) to allow a very slow passing manoeuvre.

2. Offsets between raised islands and adjacent edge lines are given in Table 6.4. As no specific bicycle facilities exist in this example, a minimum 1m offset should cater for bicycles in urban areas. The 1 m offset provides the capabilities listed in Note 3. On the major road in rural areas, the minimum offset must be the greater of the shoulder width and 1.0 m.

3. The 1 m offset provides:
   a. clearance from the kerb to the design vehicle swept path
   b. additional width for the check vehicle
   c. provision for cyclists

4. This diagram shows an intersection with no specific bicycle facilities. For diagrams of intersections with specific bicycle facilities (e.g. exclusive bicycle lanes), refer to Figure 8.7 for island for acceleration lane treatment and to Figure 8.14 and Figure 8.15 for unsignalised and signalised high-entry angle treatments respectively.


**Figure 6.8:** Example of island treatments showing clearances at an intersection with single lane carriageways and no specific bicycle facilities
6.6  Kerb and Channel

6.6.1  General

Kerbs may be used to separate areas used by vehicles from areas used by pedestrians or other modes of transport, or areas to be put to other uses.

Channels are used to collect and convey surface drainage and preferably should not be considered part of the traffic lanes.

The main uses of kerb and channel are to:
- collect surface drainage and to convey it to a point of discharge
- delineate the edges of carriageways
- separate carriageways from pedestrian areas
- control parking manoeuvres
- support the edge of the pavement
- reduce the width of the cut by substituting an underground drainage system in place of table drains.

6.6.2  Kerb and channel types

There are four basic types of kerb and channel combinations (or kerbs):
- fully mountable
- semi-mountable
- barrier
- channels.

Examples of each type are shown in Commentary 12.

It should be noted that some jurisdictions may prefer to use kerbs that do not have a channel (or gutter). Where the pavement slopes away from a raised island or median there is no need to have an integrated channel.

6.6.3  Use and restrictions on use

Guidelines, on the use and restrictions on the use of types of kerb and channel are summarised in
Table 6.5. Kerbs are an obstruction on the road (especially barrier kerbs), so the appropriate type of kerb should be used, be highly visible and have properly designed and adequately maintained approach delineation (e.g. painted lines and marking, and raised pavement markers).

While it is recognised that there may be a desire to construct kerb and channel from materials other than concrete in order to satisfy heritage or urban design requirements, the kerb and channel on arterial roads should be smooth so that it does not damage vehicle tyres, and light in colour to assist roadside delineation (e.g. kerb constructed of bluestone pitchers often has relatively sharp edges and offers poor delineation at night).

Generally the kerb and/or channel should preferably not be placed in front of safety barriers because it will adversely affect the operation of the barrier (Guide to Road Design – Part 6: Roadside Design, Safety and Barriers, Austroads 2009e). Where the situation is unavoidable safety barriers shall be placed either 200 mm behind the line of kerb or a substantial distance behind the kerb (say 3 m).
### Table 6.5: Use and restrictions on use of kerb and channel

<table>
<thead>
<tr>
<th>Type</th>
<th>Use</th>
<th>Restriction on use</th>
</tr>
</thead>
</table>
| **Semi mountable** | Preferred for use on medians, traffic islands and outer kerb lines of all intersections, particularly where the speed zone ≥ 80 km/h.  
  Can be driven over by slow moving vehicles passing a broken down vehicle, where insufficient width is available on the road surface. | Not recommended for use:  
  under guardrail on high speed routes because the rail deflects on impact and the barrier kerb and rail combination may form a ramp to launch errant vehicles.  
  on high speed roads (i.e. > 80 km/h, as it is more likely to trip and overturn a vehicle which is out of control |
| **Barrier**     | Should be considered:  
  where it is essential to prevent vehicles from moving upon areas used by pedestrians, typically during on-street parking manoeuvres, but also at sharp left-turn kerb returns  
  as protection for traffic signal poles  
  in car parks  
  in shopping areas  
  when matching into council kerbing  
  under or close to bridge barrier  
  where it is more suitable for drainage behind safety barrier. | |
| **Fully mountable** | May be used:  
  on leading nose of median or traffic island in order to extend the island nose where space or funding is limited  
  for heavy vehicle over-run areas within an intersection  
  at the interface of indented bus bays with the adjacent traffic lane. | Use to delineate encroachment areas for heavy vehicles may not be supported in some jurisdictions. |
| **Channel**     | Channel of semi-circular cross-section may be provided at the rear edge of shoulder in some rural situations.  
  May be used along the edge of through lane opposite a bus embayment. | Not to be provided:  
  where vehicle wheels may become trapped in semi-circular channel. |
7 RIGHT-TURN TREATMENTS – LAYOUT DESIGN DETAILS

7.1 Introduction

Right-turn treatments are provided to improve road safety and capacity, and to minimise delay. In rural high-speed areas capacity is often not an issue whereas safety is paramount. However, intersection capacity is often an important consideration for urban intersections, in addition to safety.

The types and selection of right-turn treatments are discussed in Section 4 of this guide. Right-turn treatments:

- vary according to traffic requirements and site conditions
- can vary from a simple T-intersection treatment to major channelisation with traffic signal control
- can be minimal (i.e. BAR) if no superior treatment is justified by volume warrants and there are no safety problems (real or perceived) associated with right-turning vehicles
- should desirably have the right-turn lane protected by a median to guide through vehicles clear of stationary right-turn traffic
- should enable turning traffic to decelerate clear of the through traffic, where a channelised treatment is warranted
- can be defined by raised or painted median islands and pavement markings including arrows.

Lower order right-turn treatments (e.g. BAR and CHR(S)) generally should not be used with other geometric minima (e.g. steep downgrades). This is particularly true where there is reduced visibility to the turn treatment (e.g. they should not be located on smaller to moderate size crest curves). This is because turning drivers on the major road need to perceive the location of the side road and make the necessary speed reduction (or sometimes stop in the case of a BAR) in the through lane before the intersection. In these situations, a CHR turn treatment with a full length deceleration lane should be used.

The various types of right-turn treatments are illustrated throughout Section 4 and often involve the provision of auxiliary lanes, usually for deceleration and storage and occasionally for acceleration and merging (e.g. seagull treatment). Detailed information on the design of auxiliary lanes is provided in Section 5 and Figure 5.1 illustrates the components of a turn lane to provide for deceleration and storage.

This section provides guidance and examples of layouts for common types of right-turn treatments. This information should enable designers to develop a shape and size for an intersection which can be used in conjunction with other information to develop a detailed layout that suits the particular site conditions. Where relevant to a site, the other information may include:

- topography
- motor traffic requirements (e.g. number of lanes)
- horizontal and vertical geometry
- design controls (e.g. watercourses, utilities)
- the need for public transport facilities
- other road user requirements (e.g. cyclists, pedestrians, trucks).
Depending on the characteristics of the particular site and the road users, designers may have to refer to a number of other Austroads guides including but not limited to:

- *Guide to Road Design – Part 2: Design Considerations* (Austroads 2006b)

The design principles for right-turn treatments are similar for urban and rural situations, except that rural treatments generally have shoulders on the approaches and kerbing at the intersection, whereas urban treatments are likely to be (but not always) on roads that are fully kerbed.

Conversion of through lanes into turning lanes should only be used in existing extremely constrained locations because of the poor crash history associated with such treatments. They are not to be used in greenfield sites. Conversion of an approach through lane of a multi-lane road into an exclusive right-turn or left-turn lane should be avoided as it may cause some through traffic to change lanes at the last moment, creating a potential for crashes, particularly in areas with high tourist or visitor populations. This treatment is not to be used in the design of a new intersection. Should such a conversion be unavoidable at an existing intersection, advance warning and guidance signs should be erected informing drivers of what to expect. The signs should be supplemented by pavement arrows.

**7.2 Opposed Right-turns**

*7.2.1 General*

Section 5 of the *Guide to Road Design – Part 4: Intersections and Crossings – General* (Austroads 2009b) provides guidance on the selection of design vehicles and the use of turning templates, including clearances that should be provided between opposing right-turning vehicles. The use of templates for single and double opposed right-turns and clearances is illustrated in Figure 7.1 and Figure 7.2 respectively.

Where it is necessary to apply separate templates to a multi-lane right-turn a clearance of at least 1.0 m should be provided between the swept paths of the templates. This situation is illustrated in Figure 7.3 and may occur where heavy vehicles are likely to turn two abreast for example at intersections that serve major industrial and freight areas such as seaports.

Multi-lane (e.g. double) right turns are not suitable for use at unsignalised intersections (excluding roundabouts) because:

- on the major road, vehicles in the leftmost right-turn lane obscure the view of drivers in the adjacent right-turn lane
- on side road approaches vehicles in the rightmost right-turn lane obscure the view of drivers in the adjacent leftmost right-turn lane.

Multi-lane right-turn lanes are therefore used only at signalised intersections.
Signalised intersections between arterial roads often require dual right-turn lanes to provide adequate capacity. The application of turning templates to this situation is depicted in Figure 7.2 and Figure 7.3. Figure 7.2 shows opposed right-turning movements where both turns have dual right-turn lanes whereas Figure 7.3 shows a dual turn opposed by a single turn.

Austroads (2006) provides turning templates for a range of vehicles but only one combination for a dual turning movement, a prime mover with semi-trailer and a car. The turn on the right-hand side of Figure 7.2 shows the prime mover with semi-trailer turning on the outside of the car, a situation that is common as many truck drivers choose to turn on a larger radius. The template provided in Austroads (2006) has the prime mover with semi-trailer turning on the inside of the car which, although less common, is required where the truck must turn right into a side street or property shortly after completing the right turn. The swept width of the template includes required separation between vehicles. The Austroads (2006) template is the more conservative of the two situations and may be used for both turns where space permits.

For some situations it may be desirable to design dual turns for different combinations of vehicles (e.g. a prime mover with semi-trailer and a single unit truck/bus. The need for this will be indicated by vehicle classification data for the site. Figure 7.3 shows a dual turning movement by two prime movers with semi-trailers which could occur at major intersections, particularly near transport terminals. Although manual templates can be used to approximate the overall swept width in such cases it is recommended that designers simulate the turning requirements using a computer software package.
Where a multi-lane right turn is provided it is important that turning markings are used to delineate the lanes through the intersection as illustrated in Figure 7.4.
Note: In some jurisdictions the lane line between the through lane and turning lane, and the turn lines, will be continuous rather than broken continuity lines.
Source: Austroads (2005).

Figure 7.4: Details of turn line treatments for multiple lanes

### 7.2.2 Design Procedure

In applying swept path turning templates to design an intersection for opposed right turns that operate concurrently, the following procedure is suggested:

1. The cross-section of each approach is plotted showing the road centreline or median kerbs, all traffic lanes and the left edge of the roads.

2. A trial location of the median noses in the side roads (i.e. roads which turning vehicles are entering) or the intersection point of the stop line/give way line and the side road centreline (where the side road has no median) is marked. The median noses in the side road should be located:
   - in rural situations in line with the back edge of shoulder or the stop line/give way line, whichever is the greater setback from the major road edge line (or edge of pavement)
   - in urban situations about 0.5 m – 1.5 m from the left edge of the road to provide an offset between the nose and the traffic lane.

3. Trial turning templates are placed in the opposed right-turn lanes and adjusted until they clear the median nose or marked point (see point 2 above) by 0.5 m and comply with the required clearance between swept paths (Figure 7.1, Figure 7.2 and Figure 7.3).

4. The location of median noses or stop lines in the major road (i.e. road from which the opposed vehicles are turning) is then plotted in relation to the design vehicle swept path.

5. The procedure is repeated for right turns from the side road.

It may be necessary to try various combinations of radii for the turning templates before the best layout is determined. During this iterative process it is necessary to ensure that the resulting pedestrian crosswalks can be accommodated close and preferably parallel to the roads.
7.3 **Right-turn Bans at Signalised Intersections**

Consideration should be given to banning a right turn where:

- a right-turn lane cannot be provided and the right-turning traffic would cause a safety and/or a capacity problem
- sight distance is poor and cannot be corrected, and other options such as erecting advance signs are not satisfactory.

If the right-turn can be banned, several options may be considered as described in Section 2.2.3 of the *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings* (Austroads 2007) and illustrated in Section 4.14 of this guide.

7.4 **Right-turn Lanes for Cyclists**

Right-turn lanes for cyclists are rarely used and should generally not be provided for cyclists at right-turn treatments on arterial roads or busy traffic routes because of the difficulty and crash risk for cyclists moving from the left of an intersection to the centre of the road in order to utilise such treatments. Conditions for the use of cyclist right-turn lanes and illustrations of their use at an intersection are provided in Section 10.6.4 of this guide.

7.5 **Rural Right-turn Treatments – Undivided Roads**

All the turn treatments described in this section are applicable to two-lane two-way rural roads. They can also be applied to multi-lane rural roads (divided and, less commonly, undivided), except for the BAR turn treatment.

7.5.1 **Rural Basic Right-turn Treatment (BAR)**

The basic right-turn treatment (BAR) shown in Figure 7.5 is the minimum treatment for right-turn movements from a through road to side roads and local access points. This treatment provides sufficient trafficable width for the design through vehicle to pass on the left of a stationary turning vehicle. This is achieved by widening the shoulder to provide a minimum width sufficient to allow the vehicles to pass. Substantial speed reduction (potentially half of the design speed) is a feature of this layout.

Other aspects of the design are:

- on a terminating intersection leg no special provision is usually made for right-hand turns when a BAR is used
- this layout can be used on both sealed and unsealed roads
- it is preferred that the widened shoulder at BAR turn treatments is sealed, unless the shoulder can be maintained with a sound and even surface
- this layout should not be used where there is reduced visibility to the turn treatment. Right turning drivers on the major road need to perceive the location of the side road and stop if necessary in the through lane before the intersection.

Where adequate through sight distance exists, BAR turn treatments will generally be marked with a broken centreline to allow overtaking on the major road through the intersection. This will not restrict overtaking opportunities, thereby minimising delays. However, there may be instances where a BAR turn treatment on a section of road with good overtaking opportunities will yield a high likelihood of crashes resulting from inappropriate overtaking through the intersection. In such cases, a barrier line should be used. Examples of such instances include the following:
- The turn treatment is located after a significant length of roadway that has no overtaking opportunities. This geometry would result in drivers often overtaking through the intersection because of the large amount of time spent following other vehicles prior to the intersection. The increased exposure of overtaking may result in an excessively high overtaking-intersection vehicle crash rate.

- There are reasonably high right-turning volumes.

- The warrants dictate that a higher-level turn treatment is appropriate.

It is suggested that BAR treatments should generally have a barrier line on the major road approaches to reduce the likelihood of overtaking vehicles colliding with vehicles entering from the side road. Consideration should only be given to the use of a broken centreline in situations where overtaking opportunities are limited and the volume on the side road is very low.

The BAR turn treatment on a two-lane rural road as shown in Figure 7.5 has limited applications. It is mainly applicable at the junction of side roads and rural arterial roads with lower traffic volumes. Such turn treatments can record high crash rates, especially in high-speed areas. A more desirable treatment at such sites is a CHR(S) turn treatment discussed in Section 7.5.2.
Guideline for Road Design – Part 4A: Unsignalised and Signalised Intersections

Notes:
1. This treatment applies to the right turn from a major road to a minor road.
2. The dimensions of the treatment are defined thus:

\[ W = \text{Nominal through lane width (m) (including widening for curves). Width to be continuous through the intersection.} \]

\[ C = \text{On straights} \quad 6.5 \text{ m minimum} \]

\[ C = \text{On curves} \quad 7.0 \text{ m minimum for Type 1 & Type 2 road trains} \]

\[ A = \frac{0.5VF}{3.6} \]

Increase length A on tighter curves (e.g. those with a side friction demand greater than the maximum desirable). Where the design through vehicle is larger than or equal to a 19 m semi-trailer the minimum speed used to calculate A is 80 km/h.

\[ V = \text{Design speed of major road approach (km/h).} \]

\[ F = \text{Formation/carrigeway widening (m).} \]

\[ S = \text{Storage length to cater for one design turning vehicle (m) (minimum length 12.5 m).} \]

\[ X = \text{Distance based on design vehicle turning path, typically 10–15 m.} \]


Figure 7.5: Basic right (BAR) turn treatment on a two-lane rural road

7.5.2 Rural Channelised T-junction – Short Lane Type CHR(S)

The CHR(S) turn treatment shown in Figure 7.6 is a more desirable treatment than the BAR treatment because it provides greater protection for vehicles waiting to turn right from the centre of the road. This treatment is suitable where there are low to moderate through and turning volumes. For higher volume sites, a full-length CHR turn treatment (Figure 7.7) is preferred.
This type of intersection can only be used with linemarking. It is not to be used with raised or depressed islands as the turn lane is short and it is desirable that right-turning drivers travel over the painted chevron to exit the through traffic stream as soon as possible.

For the CHR(S) turn treatment, all through traffic is required to deviate, hence the deviation must be designed to suit the operating speed. A minimum shoulder width of 1.0 m must be used on the through lane deviation.

The start of the right-turn taper occurs as a painted median width of 2.0 m, in lieu of the full turning lane width as per a full length CHR treatment.

The length of turn slot is based on a right-turning vehicle slowing to 80% of the design speed on the approach (i.e. a speed reduction of 20% in the through lane), prior to moving into the turn lane and decelerating. This is based on the assumption that drivers decelerate at a maximum value of 3.5 m/s\(^2\) from the start of the taper to the start of the storage length.

Although some deceleration of the right-turning vehicles occurs in the through lane, this treatment records far fewer rear-end crashes than do BAR turn treatments. The good safety performance occurs by removing stationary turning vehicles from the through traffic stream.

CHR(S) turn treatments should not be used where there is reduced visibility to the turn treatment. Right-turning drivers on the major road need to perceive the location of the deceleration lane and the side road in time to make the necessary speed reduction in the through lane prior to diverging.

Table 7.1 provides the dimensions of the CHR(S) treatment for various design speeds.

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Lateral movement length A (m)(^1)</th>
<th>Diverge/deceleration length D (m)(^2)</th>
<th>Desirable radius R (m)</th>
<th>Taper length T (m)(^3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>40(^4)</td>
<td>15</td>
<td>110</td>
<td>15</td>
</tr>
<tr>
<td>60</td>
<td>50(^4)</td>
<td>25</td>
<td>175</td>
<td>15</td>
</tr>
<tr>
<td>70</td>
<td>60</td>
<td>35</td>
<td>240</td>
<td>20</td>
</tr>
<tr>
<td>80</td>
<td>65</td>
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<td>280</td>
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</tr>
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<td>90</td>
<td>75</td>
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<td>25</td>
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<td>100</td>
<td>85</td>
<td>70</td>
<td>425</td>
<td>30</td>
</tr>
<tr>
<td>110</td>
<td>95</td>
<td>85</td>
<td>500</td>
<td>30</td>
</tr>
<tr>
<td>120</td>
<td>100</td>
<td>100</td>
<td>600</td>
<td>35</td>
</tr>
</tbody>
</table>

Notes:
1. Based on a diverge rate of 1 m/sec and a turn lane width of 3.0 m. Increase lateral movement length if the turn lane width >3 m. If the through road is on a tight horizontal curve (e.g. one with a side friction demand greater than the maximum desirable), the lateral movement length should be increased so that a minimal decrease in speed is required for the through movement.
2. Based on a 20% reduction in through road speed at the start of the taper to a stopped condition using a value of deceleration of 3.5 m/s\(^2\) (Table 5.2). Adjust for grade using the ‘correction to grade’ factor in Table 5.3.
3. Based on a turn lane width of 3.0 m.
4. Where Type 2 road trains are required, minimum A = 60 m.
Note: The dimensions of the treatment are defined below and values of A, D, R and T are shown in Table 7.1:

\[ W = \text{Nominal through lane width (m) (including widening for curves). For a new intersection on an existing road, the width is to be in accordance with the current link strategy.} \]

\[ W_t = \text{Nominal width of turn lane (m), including widening for curves based on the design turning vehicle = 3.0 m minimum.} \]

\[ B = \text{Total length of auxiliary lane including taper, diverge/deceleration and storage (m).} \]

\[ E = \text{Distance from start of taper to 2.0 m width (m) and is given by:} \]

\[ E = 2 \left( \frac{A}{W_t} \right) \]

\[ T = \text{Taper length (m) and is given by:} \]

\[ T = \frac{0.33 \times V \times W_T}{3.6} \]

\[ S = \text{Storage length to cater for one design turning vehicle (m).} \]

\[ V = \text{Design speed of major road approach (km/h).} \]

\[ X = \text{Distance based on design vehicle turning path, typically 10-15 m.} \]


Figure 7.6: Channelised right-turn treatment with a short turn slot [CHR(S)] two-lane rural road

7.5.3 Rural Channelised T-junction – Full Length (CHR)

For this layout, all traffic is required to deviate and therefore the road alignment for the through movement must be designed to suit the operating speed. This deviation requires the pavement to be widened to provide a full-length right-turn lane as shown in Figure 7.7.

The minimum lengths of deceleration (D) for different design speeds are shown in Table 5.2 and should be based on the comfortable deceleration rate of 2.5 m/s². The storage length (S) is usually determined through the use of computer programs such as aaSIDRA.

Details of the departure end of the right-turn lane should be determined using turning path templates (minimum radius 15.0 m). This will depend on the width and the angle of intersection of the road that the turning vehicle is entering.
There are no numerical warrants for the provision of raised medians in lieu of the painted medians, and some jurisdictions may require road lighting where raised medians are provided.

Pavement marking should be provided as shown in Figure 7.7. If the painted separation between opposing traffic flows is wider than a double white line, then the median should be delineated with diagonal markings and raised retroreflective pavement markers (Figure 6.5).

Table 7.2 provides the dimensions of the CHR treatment for various design speeds.

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Lateral movement length A (m) (1)</th>
<th>Desirable radius R (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Wₜ=3.5 m</td>
<td>Wₜ=3.0 m</td>
</tr>
<tr>
<td>50</td>
<td>50 (2)</td>
<td>40 (2)</td>
</tr>
<tr>
<td>60</td>
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<td>95</td>
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<tr>
<td>120</td>
<td>120</td>
<td>100</td>
</tr>
</tbody>
</table>

Notes:
1. Based on a diverge rate of 1 m/sec. If the through road is on a tight horizontal curve (e.g., one with a side friction demand greater than the maximum desirable), increase the lateral movement length so that a minimal decrease in speed is required for the through movement.
2. Where Type 2 road trains are required minimum A = 60.0 m.
Notes:
1. An alternative to the double white line on the offside edge of the right-turn slot is a 1.0 m painted median. The 1.0 m median is particularly useful when the major road is on a tight horizontal curve and oncoming vehicles track across the centreline. Provision of this median will require the dimension ‘A’ to be increased.
2. A raised concrete median on the minor road may be used with this treatment to minimise ‘corner cutting’, particularly for higher turning volumes.
3. The dimensions of the treatment are defined below and values of A, D, R and T are shown in Table 7.2:

\[
\begin{align*}
W &= \text{Nominal through lane width (m) (including widening for curves). For a new intersection on an existing road, the width is to be in accordance with the current link strategy.} \\
W_t &= \text{Nominal width of turn lane (m), including widening for curves based on the design turning vehicle. Desirable minimum = W, absolute minimum = 3.0 m.} \\
B &= \text{Total length of auxiliary lane including taper, diverge/deceleration and storage (m).} \\
D &= \text{Diverge/deceleration length including taper. Adjust for grade using the ‘correction to grade’ factor (Section 5)} \\
T &= \text{Physical taper length (m) and is given by:}
\end{align*}
\]

\[
T = \frac{0.33VW_r}{3.6}
\]

\[
S = \text{Storage length (m) should be the greater of:}
\begin{align*}
1. \text{ the length of one design turning vehicle} \\
2. \text{ (calculated car spaces –1) x 8 m (Guide to Traffic Management – Part 3: Traffic Studies and Analysis (Austroads 2009h), or use computer program e.g. aaSIDRA).}
\end{align*}
\]

\[
V = \text{Design speed of major road approach (km/h)} \\
X = \text{Distance based on design vehicle turning path, typically 10–15 m}
\]

Source: Based on QDMR (2006).

Figure 7.7: Channelised right turn (CHR) on a two-lane rural road

7.5.4 Rural Right-Left Staggered T

Basic two-lane two-way road

This layout should be designed to ensure that:

- the stagger distance between the minor legs is large enough to discourage drivers from ‘taking a short-cut on the wrong side of the traffic islands (e.g. at least 15 m to 25 m depending on the site characteristics)
- the island treatments in the minor roads are long enough to also discourage wrong way movements
- sufficient width is provided on the major road within the intersection to enable through vehicles to pass slowly to the left of vehicles waiting to turn right (e.g. 12 m), a similar principle to the BAR treatment.
Figure 7.8: Right-left staggered T-intersection on a two-lane rural road (low turning volume)

7.5.5 Left-Right Staggered T

Overlapping right turns on a two-lane two-way road

Figure 7.9 shows a diagram of a left-right staggered intersection where the right-turning lanes on the major road overlap. This layout may be suitable in situations where two existing minor roads are located relatively close to each other, or where constraints exist on both ends of the treatment which prevent it extending further along the major road.
Notes:
1. The stagger distance must be sufficient to ensure that deceleration and storage length can be accommodated. This should also ensure that the through design vehicle from the minor roads can store clear of the major road through lane when positioned in the right-turn lane.
2. The dimensions of the treatment are defined thus:

- \( W \) = Nominal through lane width (m) (including widening for curves).
- \( W_{r} \) = Nominal width of turn lane (m) including widening for curves based on the design turning vehicle. Desirable minimum = \( W \), absolute minimum = 3.0 m.
- \( A \) = Design the through lane alignments in accordance with the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a).
- \( D \) = Diverge/deceleration length including taper Table 5.2. Adjust for grade using the ‘correction to grade’ factor in Table 5.3.
- \( S \) = Storage length (m) is the greater of:
  - (a) the length of one design turning vehicle or
  - (b) (calculated car spaces –1) x 8 m (Guide to Traffic Management – Part 3: Traffic Studies and Analysis, Austroads 2009h, or use computer program e.g. aaSIDRA).
- \( V \) = Design speed of major road approach (km/h).
- \( X \) = Distance based on design vehicle turning path, typically 10–15 m.

Source: Based on QDMR (2006).

**Figure 7.9:** Rural left-right staggered T with overlapping turns on a two-lane road

The treatment requires a relatively wide pavement area and large islands at each end to shelter turning vehicles from both directions. This means that the transitions at each end required to guide through traffic may be relatively long. The islands may be raised or painted.

**Back-to-back right turns on a two-lane two-way road**

This treatment is shown in Figure 7.10. It results in a relatively narrow layout which requires shorter transitions than the overlapping layout. However, it requires a large stagger between intersections (e.g. about 300 m for a 100 km/h operating speed) which is often impracticable due to land acquisition and other constraints.
Note: The dimensions of the treatment are defined thus:

- **W** = Nominal through lane width (m) (including widening for curves).
- **W_t** = Nominal width of turn lane (m), including widening for curves based on the design turning vehicle. Desirable minimum = W, absolute minimum = 3.0 m.
- **A** = Design the through lane alignments in accordance with the Guide to Road Design – Part 3: Geometric Design, Austroads 2009a).
- **D** = Diverge/deceleration length including taper (Table 5.2). Adjust for grade using the 'correction to grade' factor in Table 5.3.
- **T** = Physical taper length (m) is given by:

\[
T = \frac{0.33VW_T}{3.6}
\]

- **S** = Storage length (m) is the greater of:
  1. the length of one design turning vehicle or
  2. (calculated car spaces –1) x 8 m (Guide to Traffic Management – Part 3: Traffic Studies and Analysis, Austroads 2009h, or use computer program e.g. aaSIDRA).
- **V** = Design speed of major road approach (km/h).
- **X** = Distance based on design vehicle turning path, typically 10–15 m.

**Figure 7.10:** Rural left-right staggered T with back-to-back turns on a two-lane road

### 7.6 Rural Right-turn Treatments – Divided Roads
#### 7.6.1 Two Staged Crossing on a Rural Road

The use of this treatment is discussed in Section 4.9.1 and illustrated in Figure 7.11. The width of the median should be sufficient to cater for the length of the turning design vehicle (denoted S in the figure). For the right turn from the major road, the median width should also cater for the calculated storage length. This is to provide drivers turning right from the minor road a clear view of approaching major road vehicles, although this may be difficult to achieve where a large heavy vehicle is used as the design vehicle. Turning paths are not to cross the centreline of the street being entered. The layout shown in Figure 7.11 may also be applicable in some urban situations.
Notes:

1. An offset right-turn lane, as shown in Figure 4.12 is a more preferable solution for a two staged crossing. The offset right-turn lane improves visibility for the rightturn vehicle from the side road, once stored in the median.

2. The dimensions of the treatment are defined thus:

   \[ W = \text{Nominal through lane width (m) (including widening for curves).} \]
   \[ W_r = \text{Nominal width of turn lane (m), including widening for curves based on the design turning vehicle. Desirable minimum = W, absolute minimum = 3.0 m} \]
   \[ D = \text{Diverge/deceleration length including taper – Table 5.2. Adjust for grade using the 'correction to grade' factor in Table 5.3.} \]
   \[ T = \text{Taper length (m) is given by:} \]
   \[ T = \frac{0.33VW_T}{3.6} \]
   \[ S = \text{Storage length (m) is the greater of:} \]
       
       1. the length of one design turning vehicle or
       2. (calculated car spaces –1) x 8 m (Guide to Traffic Management – Part 3: Traffic Studies and Analysis, Austroads 2009h), or use computer program e.g. aaSIDRA).

\[ V = \text{Design speed of major road approach (km/h).} \]


Figure 7.11: Two staged crossing on a rural road
7.6.2 Left-Right Staggered T – Divided Road

Overlapping right turns on a divided road

Notes:
1. The stagger distance must be sufficient to ensure that the ‘through’ design vehicle from the minor roads can store clear of the major road through lane when positioned in the right-turn slot.
2. The dimensions of the treatment are defined thus:

\[ W = \text{Nominal through lane width (m) (including widening for curves).} \]
\[ WT = \text{Nominal width of turn lane (m), including widening for curves based on the design turning vehicle. Desirable minimum = } W, \text{ absolute minimum = 3 m.} \]
\[ D = \text{Diverge/deceleration length including taper – Table 5.2 (adjust for grade using the ‘correction to grade’ factor in Table 5.3).} \]
\[ S = \text{Storage length (m) is the greater of:} \]
   1. The length of one design turning vehicle or
   2. (calculated car spaces –1) x 8 m or use computer program (e.g. aaSIDRA).
\[ X = \text{Distance based on design vehicle turning path, typically 10–15 m.} \]


Figure 7.12: Left-right staggered T-intersection on a divided rural road with overlapping right turns

7.6.3 Back-to-back Right Turns on a Divided Road

This treatment is shown in Figure 7.13. It is suitable for use where the side roads are sufficiently staggered to enable the required deceleration and storage lengths to be accommodated, or where only a relatively narrow median can be achieved within the road reservation. However, the large stagger required between intersections (e.g. about 300 m for a 100 km/h operating speed) is often impracticable due to land acquisition and other constraints. If this treatment is impracticable and a wider median can be achieved overlapping right-turn lanes may be required.
Note: The dimensions of the treatment are defined thus:

\[ W = \text{Nominal through lane width (m) (including widening for curves).} \]

\[ W_r = \text{Nominal width of turn lane (m), including widening for curves based on the design turning vehicle. Desirable minimum } = W, \]
\[ \text{absolute minimum} = 3.0 \text{ m.} \]

\[ D = \text{Diverge/deceleration length including taper – Table 5.2. Adjust for grade using the ‘correction to grade’ factor in Table 5.3.} \]

\[ T = \text{Physical taper length (m) is given by:} \]

\[ T = \frac{0.33VW_T}{3.6} \]

\[ S = \text{Storage length (m) is the greater of:} \]
\[ (a) \text{the length of one design turning vehicle or} \]
\[ (b) \text{calculated car spaces} – 1 \times 8 \text{ m (Guide to Traffic Management – Part 3: Traffic Studies and Analysis, Austroads 2009h, or use computer program e.g. aaSIDRA).} \]

\[ V = \text{Design speed of major road approach (km/h).} \]

\[ X = \text{Distance based on design vehicle turning path, typically 10–15 m.} \]

Figure 7.13: Left-right staggered T-intersection on a divided rural road with back-to-back right-turns

7.6.4 Rural Seagull Treatments

Preferred rural seagull treatment

A ‘seagull’ is a particular form of channelised layout that is only suitable for T-intersections. The preferred seagull treatment is shown in Figure 7.14. It is used in situations where traffic analysis confirms that there is an operational advantage in right turners from the minor road being able to accept a gap at the first carriageway and merge with major road traffic at the second carriageway. The paths for right turns into and from the minor road are channelised by a seagull island.

The key features of the treatment are:

- normal requirements for deceleration and storage apply to the turning lanes on the major road
- the provision of an adequate acceleration lane for the merge into the second carriageway is critical to the successful operation of the treatment. The length should allow for:
  - an adequate distance for acceleration
  - plus an observation time of 3 s to 5 s at the operating speed of the major road
  - plus a taper.

The safety of the treatment relies on the driver of the merging vehicle being able to observe vehicles in the median lane of the major road through the left-side rear-view mirror. Designers should ensure that road curvature and placement of road furniture in the seagull island do not impede the sight distance to the rear of the merging vehicle.
Seagull treatments require a minimum width of median to ensure that median and island noses are located to provide adequate control and guidance for traffic. With seagull layouts, a minimum width between semi-mountable kerbs of 5.0 m is required to enable traffic to pass a disabled vehicle and thus prevent a blockage in the acceleration area. However, such widths between kerbs may encourage drivers to form two lanes and the provision of edge lines may be necessary to prevent this from happening.

Semi-mountable kerbs should be used throughout the treatment. Painted medians and islands should generally not be used.

Alternative seagull layout

Where turning movements from the side road are high, or where the through traffic volumes and/or speed make gap acceptance in the merge area difficult, and a seagull treatment is still deemed to be the most appropriate treatment, then a dedicated exit lane should be provided. This alternative layout is shown in Figure 7.15.

Where a seagull treatment provides a dedicated lane for exiting vehicles, the adjacent through lane(s) should be extended past the seagull to allow a passenger car vehicle to accelerate to the speed of through vehicles before the left to right merge is required. It should be noted that providing a straight near-side edge line is not preferred as it lacks the visual queue of the edge line marking deviating for the merge manoeuvre.

It should be noted that acceleration of the joining vehicles can require a substantial length, particularly if it occurs on an upgrade (Table 5.4 and Table 5.5). Where the major road operating speed is high this may require the termination of the left lane to be 700 m or more from the intersection.
Figure 7.15: Alternative rural seagull layout (left side merge)

7.6.5 **Rural Wide Median Treatment**

Wide median treatments (WMT) may be provided on rural divided highways to reduce the speed of traffic crossing or entering the highway. The key design characteristics of the treatment (Figure 7.16) are:

- The divided road has priority and the alignment of it is straight (or on a very large radius curve if a straight alignment is not possible).
- A large island is provided in the median together with large islands on the minor roads so that crossing traffic has to follow a deflected path which limits the approach and crossing speeds (similar to roundabouts).
- The islands in the minor roads are designed to encourage vehicles to stand-up at the holding line at 70° to comply with the required observation angle.
- The large median island is designed to accommodate the design vehicle (e.g. B-double), both turning and crossing, which requires a median width of about 30 m.
- Raised or painted (depending on jurisdictional practice) over-run areas for heavy vehicles should be provided in the central roadways to encourage crossing traffic (i.e. smaller vehicles) to adhere to the ‘deflected’ path.
- The sides of the median island adjacent to the major road should be straight over a substantial distance to diminish the possibility of drivers mistaking the treatment for a roundabout layout.
- Vehicles are aligned to stand-up at the ‘second’ carriageway (or cross it at low speed) at an angle of about 85° which is particularly important to enable drivers of trucks and vans to have clear sight lines to the left from their vehicles.
- The islands in the minor road should be set back at least 1.5 m from the edge of the major road traffic lane to allow the safe passage of cyclists (i.e. cyclists should not encroach on the traffic lane).

It is preferable that the major carriageways at a WMT are at the same level as this assists drivers on the minor road approaches to comprehend the layout of the intersection. A difference in level may occur where an existing two-lane two-way road is duplicated and the new carriageway is constructed at a higher level (to comply with flood levels). In these cases, designers should ensure that the carriageways are designed to the same level through the intersection or that the design provides drivers intending to cross through the median with sufficient cues to enable them to follow the correct path and observe traffic control devices.
Note:
The dimensions of the treatment are defined thus:

\[ W = \text{Nominal through lane width (m) (including widening for curves).} \]

\[ W_r = \text{Nominal width of turn lane (m), including widening for curves based on the design turning vehicle. Desirable minimum = } W, \text{ absolute minimum = 3.0 m.} \]

\[ D = \text{Diverge/deceleration length including taper – Table 5.2. Adjust for grade using the 'correction to grade' factor in Table 5.3.} \]

\[ T = \frac{0.33}{W_r} \times \frac{1}{3.6} \]

\[ S = \text{Storage length (m) is the greater of:} \]

1. the length of one design turning vehicle or
2. (calculated car spaces –1) x 8 m (Guide to Traffic Management – Part 3: Traffic Studies and Analysis, Austroads 2009h, or use computer program e.g. aaSIDRA).

\[ L = \text{Nominal length so that drivers can perceive that the central island is not round – a measure to assist in minimising any confusion that the layout is a roundabout. The length should be at least the width of the through carriageway plus right-turning lane and preferably much longer. Suggested desirable minimum 25 m and absolute minimum 12 m.} \]

\[ V = \text{Design speed of major road approach (km/h).} \]

Source: VicRoads.

Figure 7.16: Rural wide median treatment
7.7 Urban Right-turn Treatments – Undivided Roads

7.7.1 Urban Basic Right-turn Treatment (BAR)

The BAR turn treatment shown in Figure 7.17 is applicable at intersections of two-lane urban roads and minor local roads where traffic volumes do not warrant a higher order treatment. It should provide sufficient pavement width for the design through vehicle to pass a vehicle waiting to turn right. The absolute minimum pavement width on a horizontal straight should be 6.0 m between the centreline and the edge of the pavement or kerb line while 6.5 m is the preferred minimum as it is adequate for heavy vehicles (excluding road trains) to pass right-turning vehicles.

![Diagram of Basic Right-turn Treatment (BAR)](image)

Notes:
1. This diagram does not show any specific bicycle facilities. Where required bicycle facilities should be provided in accordance with this guide.
2. The dimensions of the treatment are defined thus:

   \[ W = \text{Nominal through lane width (m) (including widening for curves). Width to be continuous through the intersection.} \]

   \[ C = \text{On straights} \]

   \[ - \quad 6.0 \text{ m minimum} \]

   \[ - \quad 6.5 \text{ m minimum for } 19 \text{ m semi-trailers and B-doubles} \]

   \[ - \quad 7.0 \text{ m minimum for Type 1 & Type 2 road trains} \]

   \[ \text{On curves} \]

   \[ - \quad \text{widths as above } + \text{ curve widening (based on widening for the design turning vehicle plus}} \]

   \[ - \quad \text{widening for the design through vehicle).} \]

   \[ A = \frac{0.5V(C-W)}{3.6} \]

   Increase length A on tighter curves (e.g. where side friction demand is greater than the maximum desirable). Where the design through vehicle is larger than or equal to a 19 m semi-trailer, the minimum speed used to calculate A is 80 km/h.

   \[ V = \text{Design speed of major road approach (km/h).} \]

   \[ S = \text{Storage length to cater for one design turning vehicle (m) (minimum length 12.5 m).} \]

   \[ X = \text{Distance based on design vehicle turning path, typically 10–15 m.} \]


Figure 7.17: Basic right-turn treatment (BAR) for a two-lane urban road

A turning radius of 10 m to 15 m should be used and the design turning vehicle's swept path should be used to determine the length of approach and departure widening for the site geometrics (i.e. angle of intersection, width of carriageways). No lane lines or right-turn arrows should be marked on the pavement for a BAR turn treatment. The provision of bicycle lanes should be considered.
This layout should not be used where there is reduced visibility to the turn treatment. Right-turning drivers on the major road need to perceive the location of the side road and stop if necessary in the through lane before the intersection.

7.7.2 Urban Channelised T-junction – Short Lane Type CHR(S)

A more desirable treatment than the BAR is a CHR(S) turn treatment as shown in Figure 7.18. CHR(S) turn treatments should not be used where there is reduced visibility to the turn treatment. Right-turning drivers on the major road need to perceive the location of the deceleration lane and the side road in time to make the necessary speed reduction in the through lane prior to diverging.

Notes:

1. This layout includes bicycle lanes. The layout may be used without providing bicycle lanes if insufficient space is available to accommodate them. If midblock bicycle lanes exist in the latter case, alternative treatments must be provided for cyclists to negotiate the intersection (e.g. a separate bicycle path on the nature strip).

2. Islands are to comprise linemarking only (i.e. no raised or depressed medians). Diagonal rows of raised reflective pavement markers within the painted island may be used to improve the delineation of the diagonal pavement markings.

3. The dimensions of the treatment are defined thus:

\[
\begin{align*}
W &= \text{Nominal through lane width (m) (incl. widening for curves). For a new intersection on an existing road, the width is to be in accordance with the current link strategy.} \\
W_t &= \text{Nominal width of turn lane (m) (incl. widening for curves based on the design turning vehicle) }\geq 3.0 \text{ m minimum.} \\
B &= \text{Total length of auxiliary lane including taper, diverge/deceleration and storage (m).} \\
E &= \text{Distance from start of taper to } 2.0 \text{ m width (m) } = (A/W_t) \times 2. \\
T &= \text{Physical taper length (m) given by:} \\
&= \frac{0.33W_t}{3.6} \\
S &= \text{Storage length to cater for one design turning vehicle (m).} \\
V &= \text{Design speed of major road approach (km/h).} \\
X &= \text{Distance based on design vehicle turning path, typically } 10–15 \text{ m.}
\end{align*}
\]

Values of A, D, R and T are shown in Table 7.3.

Source: QDMR 2006.

Figure 7.18: Urban CHR(S) treatment on a two-lane road
Table 7.3: Dimensions of urban CHR(S) treatment for various design speeds

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Lateral movement length A (m)</th>
<th>Diverge/deceleration length D (m)</th>
<th>Desirable radius R (m)</th>
<th>Taper length T (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>40$^2$</td>
<td>15</td>
<td>110</td>
<td>15</td>
</tr>
<tr>
<td>60</td>
<td>50$^2$</td>
<td>25</td>
<td>175</td>
<td>15</td>
</tr>
<tr>
<td>70</td>
<td>60</td>
<td>35</td>
<td>240</td>
<td>20</td>
</tr>
<tr>
<td>80</td>
<td>65</td>
<td>45</td>
<td>280</td>
<td>20</td>
</tr>
<tr>
<td>90</td>
<td>75</td>
<td>55</td>
<td>350</td>
<td>25</td>
</tr>
</tbody>
</table>

1. Based on a diverge rate of 1 m/sec and a turn lane width of 3.0 m. Increase lateral movement length if turn lane width >3 m. If the through road is on a tight curve (e.g. where side friction demand is greater than the maximum desirable), increase lateral movement length so that a minimal decrease in speed is required for the through movement.

2. Based on a 20% reduction in through road speed at the start of the taper to a stopped condition using a value of deceleration of 3.5 m/s$^2$ (Table 5.2). Adjust for grade using the ‘correction to grade’ factor in Table 5.3. Based on a turn lane width of 3.0 m.

3. Where Type 2 road trains use the major road the minimum $A = 60$ m.

7.8 Urban Right-turn Treatments – Divided Roads

7.8.1 Channelised Right-turn (CHR) on Divided Urban Roads

Right-turn treatments on urban divided roads involve the provision of indented turn lanes as shown in Figure 7.19. The auxiliary lane should be of an appropriate length (Section 5.3 and Table 5.2). It is important to design the median noses to assist turning movements of the design vehicle and to encourage the drivers of vehicles turning right from the minor road to stand at the appropriate angle in the median (i.e. not at a low observation angle).
Notes:
1. This diagram does not show any specific bicycle facilities. Where required bicycle facilities should be provided in accordance with this guide.
2. A raised concrete median in the minor road may be used with this treatment.
3. The dimensions of the treatment are defined thus:

- \( W \) = Nominal through lane width (m) (including widening for curves).
- \( W_t \) = Nominal width of turn lane (m), including widening for curves based on the design turning vehicle. Desirable minimum = \( W \), absolute minimum = 3.0 m.
- \( B \) = Total length of auxiliary lane including taper, diverge/acceleration and storage (m).
- \( D \) = Diverge/acceleration length including taper – Table 5.2 (adjust for grade using the ‘correction to grade’ factor in Table 5.3).
- \( T \) = Physical taper length (m) given by:
  \[
  T = \frac{0.333W_T}{3.6}
  \]
- \( S \) = Storage length (m) is the greater of:
  1. The length of one design turning vehicle
  2. (calculated car spaces –1) x 8 m or use computer program (e.g. asSidRA).
- \( V \) = Design speed of major road approach (km/h).
- \( X \) = Distance based on design vehicle turning path, typically 10–15 m.


Figure 7.19: Urban channelised right-turn treatment (CHR)

### 7.8.2 Two Staged Crossings on Divided Urban Roads

The use and design of basic median openings at minor road intersections on urban divided roads is discussed in Section 4.10.1. The basic treatment shown in Figure 4.13 is a form of two staged crossing, the geometry of which is determined by the median width. Where very wide medians exist on urban roads, intersection treatments with minor roads may take the form of the rural two staged crossing discussed in Section 4.9.1 and illustrated in Figure 4.11.

### 7.8.3 Seagull Treatments on Divided Urban Roads

The use of urban seagull treatments is discussed in Section 4.12.2. The geometric design principles are the same as those that apply to rural seagull treatments (Section 4.12.1) except that the carriageways would generally be kerbed on both sides.
8 LEFT-TURN TREATMENTS

8.1 General

8.1.1 Types of Treatment and Selection

The types of left-turn treatments, and volume warrants and safety considerations for their selection are discussed in Section 4.

The type of left-turn treatment used may depend on the:

- volume and type of traffic making the turn
- volume, speed and type of traffic with which the turn merges
- estimated speed at entry, and desirable speeds through and exiting from the turn
- local restrictions such as turn angles, property boundaries, service utilities and other structures
- provision for turning cyclists
- pedestrian movements.

These factors combine to determine the type of treatment to be adopted in any given situation. The types of treatments provided for left turns are similar for high and low-speed environments and for different volume demands; however, the geometry is usually more generous for higher speeds or higher volumes and an auxiliary lane may be required (Section 4).

Lower order left-turn treatments (e.g. BAL and AUL(S)) generally should not be used with other geometric minima (e.g. steep downgrades). This is particularly true where there is reduced visibility to the turn treatment (e.g. they should not be located on smaller to moderate size crest curves). This is because drivers on the major road need to perceive the location of the side road and make the necessary speed reduction in the through lane before the intersection. In these situations, an AUL or CHL turn treatment with a full-length deceleration lane should be used.

8.1.2 Return Radius

A basic element of a left-turn treatment is the return radius or radii. The return is the circular arc or arcs joining the kerb or edge lines of intersecting roads. The return radius or radii are determined by:

- consideration of the factors listed above
- the design vehicle (Section 4 of the Guide to Road Design – Part 4: Intersections and Crossings – General (Austroads 2009b))
- the width and direction of the approach and departure to the turn
- whether a single radius return or a return with compound radii is appropriate.

A single radius return is commonly used, with compound radii returns being used to a greater extent in urban areas, and three centred curves being used in free-flow left-turn treatments to better represent the tracking of heavy vehicles. Compound radii returns are generally only used to avoid obstructions (Appendix A). The radius, or radii, of a return should be designed using the appropriate design vehicle turning path.
The types of left-turn treatments that may be provided are:

- single radius left turn without a left-turn island
- single radius left turn with left-turn island
- multiple radii left turn
- high entry angle left turn
- free-flow left turn.

Having selected a return radius, designers should ensure that the turning treatment:

- enables adequate sight lines and sight distance to approaching vehicles
- minimises areas of conflict
- keeps crossing distances for pedestrians to a minimum (mainly urban conditions).

As the return radius increases to accommodate larger design vehicles it becomes increasingly difficult to satisfy observation angle requirements for drivers to be able to see and safely give way to approaching vehicles (Section 3.2.3). At some sites this requirement may determine the type of treatment.

### 8.1.3 Intersection Angle

Where kerb lines intersect in the range 70°-110° (e.g. at an existing intersection), and the design vehicle is a 19.0 m semi-trailer, a left-turn island of sufficient size cannot be provided in the residual area between intersecting kerb lines using a single, 11.0 m radius return. If the return radius is made larger, the observation angle requirement cannot be met. Accordingly, such a layout must be controlled by traffic signals. However, there are some exceptions as follows:

- legs entering on the outside of a horizontal curve
- entering traffic only needs to sight turning traffic (Figure 3.4).

The return radius should be reduced when:

- entering on the inside of a horizontal curve
- the design vehicle is 12.5 m long (or less).

When the intersection angle is 130° (or more), a left-turn island can be provided for a 19.0 m semi-trailer as long as the return radius is not greater than 11.0 m. This is illustrated in Figure 8.1 and can result in a relatively small island. Observation angles for the above conditions should be checked with criteria shown in Figure 3.6.

The left-turn island will assist in reducing pedestrian crossing widths and areas of uncontrolled pavement. If a marked foot crossing is provided in the left-turn slip lane, approach sight distance (ASD) should be provided for the approach to the crossing and the pavement markings should be clearly visible over the entire length of ASD for drivers approaching the crossing.
8.2 Rural Left-turn Treatments

8.2.1 Rural Basic Left-turn Treatment (BAL)

Figure 8.2 shows a minimum treatment for use in a rural situation (i.e. high-speed environment) which provides tapers leading into and out of the left-turn treatment in order to cater for the swept path of a large design vehicle. While the case illustrated in Figure 8.2 has a large articulated vehicle as the design vehicle, the size and detailed shape of the treatment will vary in accordance with the appropriate design vehicle for a particular site. Where the design vehicle is relatively small (e.g. car or service vehicle) a single radius turn may be adopted without tapers, provided that the design vehicle can perform the left turn without encroaching into an opposing traffic lane.

It should be appreciated that the:

- layout is the minimum form of treatment that should be applied to a rural left-turn
- layout has a single radius return, auxiliary lanes are not provided, and the layout is not channelised
appropriate design vehicle should be used

design vehicle should not cross the centreline of the side road

angle of the intersection may be in the range 70°-110°

distance $S_b$ is the setback distance between the centre of the major road and the give-way or stop line in the minor road

layout should not be used where there is reduced visibility to the turn treatment. Left turning drivers on the major road need to perceive the location of the side road in time to make the necessary speed reduction in the through lane prior to moving onto the widened shoulder.

New or reconstructed intersections must be designed to this requirement even if intersection legs have to be re-aligned. An exception is intersections that cater mainly for smaller vehicles (i.e. cars, vans and service vehicles), and only occasionally have to cater for a heavy vehicle. In these circumstances it may be considered appropriate to design a simple radius without tapers that is able to cater for the smaller design vehicles.

The dimension $S_b$ is an important feature and is measured from the centreline of the major road. When the return radius ($R_1$) exceeds 11 m, the give way or stop line needs to be placed to allow the observation angle of 120° to be achieved. Where the side road is located on:

- a straight, and its length is a minimum of 5 s travel at the design speed, the holding line (particularly a stop line) should be located at distance $S_b$ (note that 5 s is the critical gap for drivers turning left; Table 3.4).
- the back of a curve, the holding line may be located closer to the through road
- the inside of a curve, the holding line may need to be located further back (limited to 8 m from the centreline of a two-lane rural road).

Where $S_b$ exceeds 8 m other treatments (e.g. a high entry angle left-turn or a protected departure lane, should be considered in order to provide the 120° observation angle.
Notes:
1. R1 and R2 are determined by the swept path of the design vehicle.
2. The dimensions of the treatment are defined thus:
   - $W$ = Nominal through lane width (m) (including widening for curves).
   - $C$ = On straights – 6.0 m minimum.
     - On curves – 6.0 m plus curve widening (based on widening for the design turning vehicle plus widening for the design through vehicle).
   - $A = \frac{0.5V}{F} \times \frac{3.6}{V}$
   - $V$ = Design speed of major road approach (km/h).
   - $F$ = Formation/carriageway widening (m).
   - $P$ = Minimum length of parallel widened shoulder (Table 8.1).


**Figure 8.2: Rural basic left-turn treatment (BAL)**

**Table 8.1: Minimum length of widened parallel shoulder**

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Minimum length of parallel widened shoulder $P$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>0</td>
</tr>
<tr>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>70</td>
<td>10</td>
</tr>
<tr>
<td>80</td>
<td>15</td>
</tr>
<tr>
<td>90</td>
<td>20</td>
</tr>
<tr>
<td>100</td>
<td>25</td>
</tr>
<tr>
<td>110</td>
<td>35</td>
</tr>
<tr>
<td>120</td>
<td>45</td>
</tr>
</tbody>
</table>

Note: Adjust the length for grade using the ‘correction to grade’ factor in Table 5.3

8.2.2 Rural Auxiliary Left-turn Treatment – Short Turn Lane [AUL(S)] on the Major Road

An AUL(S) turn treatment is shown in Figure 8.3. This treatment is suitable where there are low to moderate through and turning volumes (Section 4.8). For higher volume sites, a full-length AUL turn treatment is preferred. The required length of treatment is shown in Table 8.2.

The AUL(S) layout should not be used where there is reduced visibility to the turn treatment. Left-turning drivers on the major road need to perceive the location of the deceleration lane and the side road in time to make the necessary speed reduction in the through lane prior to diverging.

Notes:
1. # for setting out details of the left-turn geometry, use vehicle turning path templates and/or Table 8.2.
2. Approaches to left-turn slip lanes can create hazardous situations between cyclists and left-turning motor vehicles. Treatments to reduce the number of potential conflicts at left-turn slip lanes are given in this guide.
3. The dimensions of the treatment are defined as follows. Values of D and T are provided in Table 8.2.

\[
W = \text{Nominal through lane width (m) (including widening for curves). For a new intersection on an existing road, the width is to be in accordance with the current link strategy.}
\]

\[
WT = \text{Nominal width of the turn lane (m), including widening for curves based on the design turning vehicle = 3.0 m minimum.}
\]

\[
T = \text{Physical taper length (m) given by:}
\]

\[
T = \frac{0.5VF}{3.6}
\]

\[
V = \text{Design speed of major road approach (km/h).}
\]


Figure 8.3: Rural AUL(S) treatment with a short left-turn lane
### Table 8.2: Dimensions for AUL(S) treatment on major leg

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Diverge/deceleration length D (m)¹</th>
<th>Taper length T (m)²</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>60</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>70</td>
<td>35</td>
<td>20</td>
</tr>
<tr>
<td>80</td>
<td>45</td>
<td>20</td>
</tr>
<tr>
<td>90</td>
<td>55</td>
<td>25</td>
</tr>
<tr>
<td>100</td>
<td>70</td>
<td>30</td>
</tr>
<tr>
<td>110</td>
<td>85</td>
<td>30</td>
</tr>
<tr>
<td>120</td>
<td>100</td>
<td>35</td>
</tr>
</tbody>
</table>

1. Based on a 20% reduction in through road speed at the start of the taper and a value of deceleration of 3.5 m/s² (Table 5.2). Adjust for grade using the ‘correction to grade’, Table 5.3.
2. Based on a turn lane width of 3.0 m.


### 8.2.3 Rural Auxiliary Left-turn Lane Treatment (AUL)

A diagram of an AUL turn treatment on the major leg of a rural road is shown in Figure 8.4. The length of the auxiliary left-turn lane should not be restricted to the minimum if there is little difficulty in making it longer and the demand warrants the treatment (Section 4.8).

![Diagram of AUL turn treatment on a rural road](image)

Notes:
1. # For setting out details of the left-turn geometry, use to vehicle turning path software or templates.
2. Approaches to left-turn slip lanes can create hazardous situations between cyclists and left-turning motor vehicles. Treatments to reduce the number of potential conflicts at left-turn slip lanes are given in this guide.
3. The dimensions of the treatment are defined thus:
   - \( W \) = Nominal through lane width (m) (incl. widening for curves). For a new intersection on an existing road, the width is to be in accordance with the current link strategy.
   - \( W_r \) = Nominal width of turn lane (m) (incl. widening for curves based on the design turning vehicle) = 3.0 m minimum.
   - \( D \) = Diverge/deceleration length including taper – Table 5.2. (Adjust for grade using the ‘correction to grade’ in Table 5.3).
   - \( T \) = Physical taper length (m) given by:
     \[
     T = \frac{0.33W_r}{3.6}
     \]
   - \( V \) = Design speed of major road approach (km/h).

**Figure 8.4:** Auxiliary left-turn treatment (AUL) on a rural road
8.2.4 Rural Channelised Left-turn Treatment (CHL) with High Entry Angle

Provision of a left-turn island with a single radius return where edge lines intersect in the range 70° to 110° requires a high entry angle treatment to achieve an island 50 m² (or more) in area and the observation sight requirements. Such a CHL left-turn treatment is shown in Figure 8.5 and is designed for use in high-speed environments (typically rural situations). The layout is similar to that shown for a low-speed environment with the exception that:

- the tracking of large vehicles is accommodated by a taper into the road being entered
- the left-turn island is considerably larger
- a left-turn auxiliary lane should be provided on major roads.

Alternative CHL layouts with high entry angles, which may be preferred by some road authorities, are given in Appendix D.

Notes:
1. Approaches to left-turn slip lanes can create hazardous situations between cyclists and left-turning motor vehicles. One treatment to reduce the number of potential conflicts at left-turn slip lanes is given in Figure 8.14 and Figure 8.15.
2. Figure 6.4 details minimum offsets to islands.
3. Figure 6.8 details clearances required at a CHL turn treatment where there are no specific cyclist facilities.
4. Refer to Figure 7.7 (CHR turn treatment) for details of the dimensions T, D, S, B, W, and W⁻¹.
5. Desirable minimum area of rural islands ≥ 50 m².
Source: QDMR 2006.

Figure 8.5: Rural (CHL) treatment with a high entry angle
8.2.5 Rural Channelised Left-turn Treatment (CHL) with an Acceleration Lane

A channelised left-turn treatment with an acceleration lane comprises multiple radii returns i.e. it consists of compound circular arcs having two or three radii. The acceleration lane is a protected left-turn lane. A layout of such a CHL turn treatment is shown in Figure 8.6.

A CHL with an acceleration lane (protected left-turn lane) can be useful where:

- the observation angle falls below guideline requirements (e.g. the intersection is located on the inside of a curve)
- insufficient gaps are available in the major road traffic stream for the left-turning movement
- left-turning heavy vehicles will cause excessive slowing of the major road traffic stream.

The left-turn island will help to reduce areas of uncontrolled pavement and define vehicle paths.

Figure 8.6 shows the geometric details of a free-flow left-turn treatment with a three centred curve, suitable for use in a high-speed environment. Guidance on the required length of deceleration lane and acceleration lane is provided in Sections 5.3 and 5.4 respectively.

A free-flow treatment enables drivers turning left from the major road to decelerate at a comfortable rate clear of following traffic, turn left at a designated speed and join the intersecting road at its operating speed. It is provided where:

- intersection capacity can be improved by using an exclusive free-flow left-turn lane
- a protected departure lane is required for safety reasons (e.g. observation sight distance less than required).

Free-flow left-turn treatments are generally not suited to locations where traffic turns at a moderate to high speed (e.g. ≥ 30 km/h) and cyclists and pedestrians need to cross the roadway, because of the risk to these vulnerable road users. They may not be suited to sites where a substantial proportion of the traffic turning left has to subsequently turn right at an adjacent intersection as operational problems may result in relation to weaving traffic streams.

A key feature of the treatment is the three centred curve that provides for the tracking of the design vehicle through the left-turn roadway (e.g. 19 m semi-trailer).

A three centred curve must not be used for unsignalised left-turn treatments that do not have a left-turn island. An appropriately designed island is necessary to:

- protect the departure lane
- control the path of exiting vehicles
- minimise crossing widths for pedestrians
- minimise the area of pavement that is not utilised by traffic.

Details of set-out parameters are provided in Figure 8.6. Commentary 13 illustrates the influence of incorrect and correct design on potential driver behaviour and protection of the acceleration lane on the departure from the treatment.

Alternative CHL layouts with acceleration lanes, which may be preferred by some road authorities, are given in Appendix D.
Notes:
1. Key distances:
   (a) \( A \) = See table 5.4 for length of the acceleration lane.
   (b) \( L \) = Minimum distance between end of chevron and start of merge taper to be based on 2 s of travel time.
   (c) \( C \) = Maximum length of chevron taper based on 1:50.
2. Approaches to left-turn slip lanes can create hazardous situations between cyclists and left-turning motor vehicles. One treatment to reduce the number of potential conflicts at left-turn slip lanes is given in Figure 8.7.
3. Figure 6.4 details minimum offsets to islands.
4. Refer to Figure 7.7 (CHR turn treatment) for details of the dimensions \( T \), \( D \), \( W \), and \( WT \).
5. Desirable minimum area of islands \( \geq 50 \text{ m}^2 \).
Source: QDMR 2006.

Figure 8.6: Rural CHL treatment with an acceleration lane

8.2.6 Provision for Cyclists at Rural Free Flow Left-turn Lanes on Bicycle Routes

Figure 8.7 illustrates how a bicycle lane may be designed to provide a safer treatment for cyclists at a rural free-flow left-turn island. The treatment discourages cyclists from travelling in a path between the auxiliary lane and the adjacent through lane and being caught between through traffic and merging traffic. The width of the lane should be in accordance with the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a). The shape of the island treatment should be based on Figure 8.6 for a rural island and Figure 8.13 for an urban island, amended where necessary to accommodate a bicycle lane as shown in Figure 8.7.
Figure 8.7: Provision for cyclists at rural free-flow left-turn treatments

8.3 Urban Left-turn Treatments

8.3.1 Urban Basic Left-turn Treatment (BAL)

Single radius left-turn and tapers – low-speed environment

This is a simple treatment where the kerb lines of the intersecting roads are joined by a single radius circular arc and tapers to accommodate the swept path of turning vehicles (Figure 8.8). At sites in both rural and urban situations the left turn should be designed to enable the design vehicle to turn from the left-hand lane into the minor road without crossing the centreline of the minor road. While Figure 8.8 shows a large design vehicle (e.g. B-double) which may apply where the minor road serves an industrial area, the design vehicle may be some other vehicle such as a single unit truck or bus. Designers should refer to Section 4 of the Guide to Road Design – Part 4: Intersections and Crossings – General (Austroads 2009b) for guidance on the choice of an appropriate design vehicle.

The BAL layout should not be used where there is reduced visibility to the turn treatment. Left-turning drivers on the major road need to perceive the location of the side road in time to make the necessary speed reduction in the through lane prior to turning.
Notes:
1. Where the approach is two lanes or more in width, heavy vehicles (12.5 m long or more) must turn from the kerbside or adjacent lane, unless otherwise controlled by signs and pavement arrows.
2. Where a side street approach and/or departure is not used by vehicles over 12.5 m long, a turning path for a bus/truck may be used.
3. This diagram does not show any specific bicycle facilities. Where specific bicycle facilities are required (e.g. exclusive bicycle lanes), designers should refer to Section 10.6.4.
Source: QDMR 2006.

Figure 8.8: Basic left-turn treatment (BAL) on an urban road

Single radius left-turn without tapers – low-speed environment

At low-speed urban intersections where a minor side road is predominantly used by cars, light trucks and service vehicles, and only used occasionally by larger vehicles, it may be appropriate to design for the occasional large vehicle to turn from the second lane from the left. Figure 8.9 shows the minimum treatment that may be used in a constrained low-speed, low-volume urban environment (e.g. built-up urban situation) where the design vehicle would normally be a service vehicle and a 19.0 m semi-trailer is the checking vehicle. This treatment is suitable only where very infrequent access would be required by this class of checking vehicle.

A return radius for an initial design for the side road can be selected from Table 8.3, which provides for a semi-trailer or truck/bus (12.5 m long) as the design vehicle. However, the radius of the turn is a function of the design vehicle and the design should always be checked using swept path turning templates.
Note: The design vehicle and the check vehicle will vary depending on the traffic characteristics at each site.

Source: Austroads (2005).

**Figure 8.9:** Application of a check vehicle swept path to a single radius treatment (BAL) for an urban intersection

The observation angle of 120° to approaching traffic will be exceeded when the kerb return radius exceeds 11 m and the approach on the through road is straight for a distance equal to or greater than that travelled in five seconds at the design speed of the through road (Figure 3.6). Hence, the kerb return radius of 11 m should only be exceeded when:

- entering on the outside of a horizontal curve
- leaving a through road without a slip lane
- entering traffic only needs to sight turning traffic (Figure 3.4(b)).

The kerb return radius should be reduced when entering on the inside of a curve.

Observation angles for the above conditions should be checked with criteria shown in Figure 3.4 and Figure 3.6.

Pedestrian crossing widths are generally not a problem if minimum kerb return radii are used. It should be noted that the narrower the departure, or approach lane width, the larger the return radius necessary. Hence, these two factors must be considered together.
Table 8.3: Minimum kerb radii for low speed environment

<table>
<thead>
<tr>
<th>Vehicle Type</th>
<th>Turning from lane adjacent to kerb side lane – approach width 6.4 m</th>
<th>Turning from kerb side lane – approach width 3.2 m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>W(m)</td>
<td>70°</td>
</tr>
<tr>
<td>Semi-trailer 19.0 m long</td>
<td>6.4</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>5.5</td>
<td>12</td>
</tr>
<tr>
<td>Bus/truck 12.5 m long</td>
<td>6.4</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>5.5</td>
<td>6</td>
</tr>
</tbody>
</table>

Notes:
1. Where approach and/or departure are curved, or widths vary from above, use turning templates to determine kerb radius and check observation sight distance.
2. Shaded area represents situations where the kerb radius exceeds 11.0 m and the observation angle will be exceeded.
3. A left-turn movement from the lane adjacent to the kerb side lane is permissible under National Transport Commission, Australian Road Rules and National Transport Commission. For new intersections, application of such movements should only be considered when applying swept paths of the check vehicle.

Source: Austroads (2005).

### 8.3.2 Urban Auxiliary Left-turn Treatment – Short Turn Lane [AUL(S)] Major Road

The BAL turn treatment from the major to minor road in Figure 8.8 is generally only suitable for lower turning volumes. A more desirable treatment at such sites is an AUL(S) turn treatment as shown in Figure 8.10. Although some deceleration of the left-turning vehicles occurs in the through lane, this treatment records very few rear-end vehicle crashes on the major road (generally rear-end type accidents resulting from a through driver colliding with a left-turning major road driver). This treatment is suitable where there are low to moderate through and turning volumes. For higher volume sites, a full length AUL turn treatment is preferred (Section 4.8).

The AUL(S) layout should not be used where there is reduced visibility to the turn treatment. Left-turning drivers on the major road need to perceive the location of the deceleration lane and the side road in time to make the necessary speed reduction in the through lane prior to diverging.
Notes:
1. For setting out details of the left-turn geometry, use vehicle turning path templates and/or the details in Table 8.4.
2. Approaches to left-turn lanes can create hazardous situations between cyclists and left-turning motor vehicles. Treatments to reduce the number of potential conflicts at left-turn slip lanes are given in this guide.
3. The dimensions of the treatment are defined as follows. Values of D and T are provided in Table 8.4.

\[
W = \text{Nominal through lane width (m) (incl. widening for curves). For a new intersection on an existing road, the width is to be in accordance with the current link strategy.}
\]

\[
W_r = \text{Nominal width of turn lane (m) (incl. widening for curves based on the design turning vehicle) = 3.0 m minimum.}
\]

\[
T = \text{Physical taper length (m) given by:}
\]

\[
T = \frac{0.33VW_r}{3.6}
\]

\[
V = \text{Design speed of major road approach (km/h).}
\]

Source: Queensland Department of Main Roads.

Figure 8.10: Auxiliary left-turn treatment [AUL(S)] on the major leg of an urban road

Table 8.4: Dimensions for D and T in AUL(S) treatment

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Diverge/deceleration length D (m)1</th>
<th>Taper length T (m)2</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>20</td>
<td>20</td>
</tr>
<tr>
<td>60</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>70</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>80</td>
<td>45</td>
<td>30</td>
</tr>
<tr>
<td>90</td>
<td>55</td>
<td>40</td>
</tr>
</tbody>
</table>

1. Based on a 20% reduction in through road speed at the start of the taper and a value of deceleration of 3.5 m/s² (Table 5.2). Adjust for grade using the 'correction to grade' factor in Table 5.3.
2. Based on a turn lane width of 3.0 m and a bicycle lane width of 1.5 m.

8.3.3 Urban Auxiliary Left-turn Treatment (AUL) on the Major Road

A diagram of an AUL turn treatment on the major leg of a divided urban road is shown in Figure 8.1. The length of the auxiliary left-turn lane should not be restricted to the minimum if there is little difficulty in making it longer and the traffic demand warrants the treatment.
Notes:
1. For setting out details of the left-turn geometry, use vehicle turning path templates.
2. Approaches to left-turn slip lanes can create hazardous situations between cyclists and left-turning motor vehicles. Treatments to reduce the number of potential conflicts at left-turn slip lanes are given in this guide.
3. The dimensions of the treatment are defined thus:
   \[ W = \text{Nominal through lane width (m) (incl. widening for curves).} \]
   \[ W_f = \text{Nominal width of turn lane (m) (incl. widening for curves based on the design turning vehicle) = 3.0 m minimum.} \]
   \[ D = \text{Diverge/deceleration length including taper – Table 5.2 (adjust for grade by applying the 'correction to grade' factor in (Table 5.3).} \]
   \[ T = \text{Physical taper length (m) given by:} \]
   \[ T = \frac{0.33V}{3.6}W_f \]
   \[ V = \text{Design speed of major road approach (km/h).} \]

Source: Austroads (2005).

**Figure 8.11:** Auxiliary left-turn treatment (AUL) on the major leg of an urban road

### 8.3.4 Urban Channelised Left-turn Treatment (CHL) with High Entry Angle

Figure 8.12 illustrates a high entry angle treatment for an intersection in a low-speed environment. The treatment is suitable for unsignalised or signalised intersections when appropriate road markings are provided and the medians are wide enough to accommodate signal hardware.

Where bicycle lanes pass through the intersection the design should be amended to accommodate them as indicated in Figure 8.14 and Figure 8.15, which relate to unsignalised and signalised intersections respectively.
The lengths of the island sides of a high entry angle left-turn island for a low-speed environment can be derived from first principles. Detailed information for setting out the islands is provided in Appendix D for cases with and without a bicycle lane.

Where kerb lines intersect in the range $70^\circ$ to $110^\circ$, and a left-turn island is required in conjunction with a single radius return, a high entry angle treatment is necessary. This is the only way to achieve a left-turn island that is adequate for lower speed environments, as well as an observation angle of $120^\circ$ (or less) to traffic approaching on a straight road of length not less than five seconds of travel at the design speed.

In some situations it may be necessary to adopt a multiple radii return to avoid an expensive design control (e.g. telecommunications pit). This is an acceptable treatment under EDD principles (Appendix A).

The left-turn island will assist in reducing pedestrian crossing widths and areas of uncontrolled pavement. If a marked pedestrian crossing is provided in the left-turn slip lane, approach sight distance (ASD) should be provided on the approach to the crossing so that the pavement markings should be clearly visible over the entire length of ASD on approach to the crossing.

Appropriate bicycle treatments may be required adjacent to the left-turn island. Such treatments include linemarking and logos for bicycle lanes and may be supported by warning signs for drivers using the slip lane to watch for cyclists.

Alternative CHL layouts with high entry angles, which may be preferred by some road authorities, are given in Appendix D.
Notes:
1. Approaches to left-turn slip lanes can create hazardous situations between cyclists and left-turning motor vehicles. One treatment to reduce the number of potential conflicts at left-turn slip lanes is given in Figure 8.14 and Figure 8.15.
2. Figure 6.4 details minimum offsets to islands.
3. Figure 6.8 details clearances required at a CHL turn treatment where there are no specific cyclist facilities.
4. Refer to Figure 7.19 (CHR turn treatment) for details of the dimensions T, D, S, B, W, and W_r.
5. Desirable minimum area of islands-25 m² for an unsignalised intersection and 40 m² for a signalised intersection.
Source: QDMR 2006.

Figure 8.12: Urban CHL treatment with high entry angle left-turn island

8.3.5 **Urban Channelised Left-turn Treatment (CHL) with Acceleration Lane**

Figure 8.13 shows the geometric details of a free-flow left-turn treatment with a three centred curve, suitable for use in a low-speed environment (urban situation with road lighting). This CHL treatment with an acceleration lane comprises multiple radii returns (i.e. it consists of compound circular arcs having two or three radii in order to best match the swept paths of turning trucks).

CHL treatments with acceleration lanes are useful where:
- the observation angle falls below guideline requirements (e.g. intersection located on the inside of a curve)
- insufficient gaps are available in the major road traffic stream for the left-turning movement
- left-turning heavy vehicles will cause excessive slowing of the major road traffic stream.
A three centred curve must not be used for unsignalised left turns without a left-turn island that:

- protects the departure lane
- controls the path of exiting vehicles
- minimises crossing widths for pedestrians
- minimises the area of uncontrolled pavement.

If the path of exiting vehicles is not controlled by the island nose the following will occur:

- the observation angle to approaching through traffic will be exceeded where the through approach is straight for a distance less than five seconds of travel at the design speed
- an inadequate acceleration taper will result.

Where the intersection is used by pedestrians, an island can reduce the width of pavement to be crossed. If a pedestrian crossing is provided in the left-turn slip lane, approach sight distance (ASD) must be available on the approach to the crossing, and pavement markings should be clearly visible over the entire length of ASD on the approach to the crossing.

Alternative CHL layouts with acceleration lanes, which may be preferred by some road authorities, are given in Appendix D.
Notes:
1. Key distances are:
   - A = See table 5.4 for length of acceleration lane.
   - L = Minimum distance between end of chevron and start of merge taper to be based on 2 s of travel time.
   - C = Maximum length of chevron taper based on 1:50.
2. Approaches to left-turn slip lanes can create hazardous situations between cyclists and left-turning motor vehicles. One treatment to reduce the number of potential conflicts at left-turn slip lanes is given in Figure 8.7.
3. Figure 6.4 details minimum offsets to islands.
4. Figure 6.8 details clearances required at a CHL turn treatment where there are no specific cyclist facilities.
5. Refer to Figure 7.19 (CHR turn treatment) for details of the dimensions T, D, W and W1.
6. Desirable minimum area of islands ≥ 50 m².
Source: Queensland Department of Main Roads.

**Figure 8.13:** Urban CHL with acceleration lane
8.3.6 Provision for Cyclists at Urban Channelised Treatments

General
Approaches to exclusive left-turn treatments may create serious conflict points between cyclists and left-turning motor vehicles. The bicycle treatments in this section show how bicycle lanes should continue through the intersection, between general traffic lanes if necessary, to provide cyclists with a safer treatment and equity.

On priority cycling routes where there are long deceleration or acceleration tapers, large radius curves and high speeds, it is particularly desirable that a bicycle lane be marked through the diverge areas and merge areas. These treatments provide space for cyclists and also warn drivers of the possible presence of a cyclist.

Bicycle lane treatments through intersections could also be considered at other locations where cyclists would be at risk due to the geometric design requirements for motor vehicles. A short marked bicycle lane through an intersection may provide safety advantages to cyclists provided that its termination point does not lead cyclists into an unsafe situation. Terminating near a sealed shoulder or in a wide kerbside lane would normally deliver adequate safety.

Figure 8.14 and Figure 8.15 respectively show bicycle lanes on the approaches to unsignalised and signalised intersections that have a high entry angle treatment.
Unsignalised intersection with high entry angle left-turn island

Notes:
1. Bicycle lanes on priority road must be continuous through unsignalised intersections and connect to bicycle facilities on the approach and departure.
2. In cases where a bicycle route turns the corner bicycle lanes may be accommodated within the minor road and within the left-turn roadway.
3. Green pavement surfacing may be used where high numbers of cyclists and motor vehicles interact. Where this is not the case normal surfacing, road markings and bicycle logos may be used to delineate the bicycle lane.
4. A minimum width of 5.0 m is required in the left-turn slip lane to enable vehicles to pass a disabled vehicle by mounting the semi-mountable kerb. It is therefore necessary to have a solid surface immediately behind the kerbs.

Figure 8.14: Provision for cyclists at an unsignalised CHL treatment in a low-speed environment
**Signalised intersection with high entry angle left-turn island**

![Diagram of signalised intersection with high entry angle left-turn island]

**Figure 8.15:** Provision for cyclists at a signalised CHL treatment in a low-speed environment

**Free flow left-turn island with acceleration lane**

The treatment illustrated in Figure 8.7 for rural sites can also be applied to urban sites. The treatment at urban sites will vary only in the detail of the dimensions of the treatment (Figure 8.13). At urban locations the intersection is likely to have lighting that will enhance the conspicuity of cyclists and their safety in dark conditions.

### 8.3.7 Left-turn Treatments for Large Vehicles

The extent of roadway required to accommodate large vehicles such as road trains at BAL turn treatments can become large, creating an undesirable situation for smaller vehicles (e.g. large undefined areas of pavement, accumulation of debris in areas of unused pavement). The correct path of travel for the smaller vehicles becomes unclear and the potential for two-lane operation is created.
A solution to this problem is to provide the normal turning roadway for a design vehicle (e.g. service truck or semi-trailer, as relevant) and provide an additional area for the larger vehicles, such as road trains, in a different material separated by a white line and diagonal markings. Some jurisdictions may prefer to have this additional area slightly raised above the turning roadway for the design vehicle (e.g. fully-mountable kerb 50 mm high to further discourage smaller vehicles from encroaching into the additional area.

Figure 8.16 and Figure 8.17 respectively show a normal and alternative treatment developed to cater for road trains using a CHL high entry angle turn treatment. Although these figures show urban intersections similar layouts can be developed for rural sites. It should be noted that the kerb line and widths of both treatments are identical as they are both designed for a left turning type 1 or type 2 road train. The difference is in the marking which is designed for the swept path of a design service truck in Figure 8.16 and for a design prime mover and semi-trailer in Figure 8.17. The shape of the marking in the former treatment covers more pavement area and would be more effective in encouraging drivers of cars to stand at the required angle of 70°.

Because the road trains have to travel over the marked areas in Figure 8.16 and Figure 8.17 and other vehicles may also traverse the area, these painted treatments at unsignalised urban left-turn roadways may pose a safety issue for pedestrians who may not be able to understand where to wait for a gap in the traffic. It is therefore suggested that in urban areas a signalised pedestrian crossing should be provided across the left-turn roadway and, if provided, the slightly raised kerb (say 50 mm) and contrasting pavement be flush with left-turn roadway within the crossing.

In deciding to use a raised area designers and jurisdictions should be mindful that the height of 50 mm may be hazardous to some pedestrians, cyclists and motorcyclists. This height is between a flat surface and a proper step height and may constitute a trip hazard for pedestrians. A possible solution is to define a pedestrian path through the diagonal markings and ensure that the raised area slopes to meet the road pavement where the pedestrians cross. The issue for cyclists and motorcyclists using the left-turn roadway is that they are highly likely to become unstable should their wheels strike the low kerb. For this reason it is desirable to provide road lighting and/or a high standard of delineation where these treatments are used.

Detailed further examples from Main Roads Western Australia of this type of treatment and the swept path provisions for the treatments illustrated in Figure 8.16 and Figure 8.17 are provided in Appendix E.
Notes:

1. This treatment:
   (a) is shown for an urban site but a similar layout is applicable to rural sites
   (b) provides a special pavement area for the passage of large single unit trucks, prime movers and semi-trailer combinations and B-doubles
   (c) promotes a desirable observation angle for all vehicle types if drivers of smaller vehicles minimise any encroachment onto the special pavement zone
   (d) assumes that road train operation has been allowed because there is sufficient sight distance to avoid the use of stop signs.

2. Where possible, sight distance requirements should be met at the point prior to the give way line where these vehicles have a desirable observation angle.

Figure 8.16: Set-out details for CHL for road trains – normal treatment
Notes:

1. This treatment:
   (a) is for areas where there is a high volume of large single unit trucks and prime mover and semi-trailer combinations (basic setting out details)
   (b) is shown for an urban site. A similar layout is also applicable to rural sites
   (c) may be used where the volume of large SU trucks and prime movers and semi-trailer combinations will cause unacceptable maintenance problems for the linemarking on the special pavement zone if the normal treatment in Figure 8.16 is used. However, cars and smaller trucks are more likely to describe a turning radius that results in a difficult observation angle if stopped at the give way line. Where possible, sight distance requirements should be met at the point prior to the give way line where these vehicles have a desirable observation angle
   (d) assumes that road train operation has been allowed because there is sufficient sight distance to avoid the use of stop signs.

2. For areas where there is a high volume of large SU trucks and prime mover and semi-trailer combinations (basic setting out details).

Figure 8.17: Set-out details for CHL for road trains – alternative treatment
9 U-TURN TREATMENTS

9.1 General

The provision of U-turn treatments relates to divided roads. On divided urban roads the need for vehicles to perform U-turns at median openings may require special provision to be made. This is particularly so where traffic regulations in some states prohibit U-turns at signalised intersections.

Drivers are permitted to U-turn at unsignalised intersections on divided roads unless a sign is erected to prohibit the turn. Unsignalised intersections are often spaced frequently enough on urban roads to remove the need for any additional special treatments for U-turning vehicles. Roundabouts provide a convenient means for drivers to U-turn on both divided roads and undivided roads. Where jurisdictional traffic regulations prohibit drivers from U-turning at signalised intersections, it is usually desirable to provide a U-turn lane before the intersection and completely separate it from the right-turn lanes so that delay is minimised for all turning vehicles.

Although cars, small trucks and vans may be able to U-turn at intersections the manoeuvre is problematic for larger heavy vehicles because it is generally impracticable to provide enough space for these vehicles. However, where industrial or commercial properties abut an arterial road it is often desirable and sometimes practicable to provide for heavy vehicles to access the properties a suitably located and designed U-turn treatment. U-turn lanes should have appropriate deceleration and storage lengths (Section 4).

9.2 Rural Roads

Rural divided roads that have at-grade intersections usually require very wide medians to provide sufficient storage in the median to safely accommodate heavy vehicles that are crossing the major road or turning into the major road from a side road (e.g. a B-double is 25 m to 27 m long and requires a 30 m wide median). These vehicles can generally U-turn in the space provided by such a wide median and shoulders. On freeways U-turns should only be permitted at interchanges.

9.3 Urban Roads

On urban divided roads where a demand exists for heavy vehicles to U-turn and space is available, the treatments illustrated in Figure 9.1 may be appropriate. These treatments comprise a jug handle layout suitable for semi-trailers and a treatment where auxiliary lanes enable a single unit truck/bus to U-turn.

On roads with relatively narrow medians, unsignalised intersections may be designed to allow cars to U-turn. Where intersections are a substantial distance apart and demand exists, the mid-block U-turn treatment shown in Figure 9.2 may be provided. Often the treatment can only cater for cars; however, they may also be strategically placed to enable trucks to U-turn into service roads.

It is desirable that U-turn treatments are located away from intersections; however, a signalised U-turn treatment may be provided on the approach to a signalised intersection adjacent to right-turn lanes as shown in Figure 9.3.
Figure 9.1: U-turn facilities for urban areas

(a) Jug handle U-turn facility (suitable for semi-trailers)

(b) U-turn facility - urban areas - restricted to single unit vehicles

Figure 9.2: Desirable U-turn treatment (mid-block or in advance of an intersection)
Figure 9.3: U-turn lane on approach to signalised intersection
10 SIGNALISED INTERSECTIONS

10.1 General

Generally, the treatments described in Section 4 can be signalised as an alternative form of control to give-way or stop signs with the exception that signalised intersections are generally not used on high-speed traffic routes.

Intersections are signalised either to address a road safety or a traffic/transportation operational issue. Signalised intersections on major arterial roads often require a number of through lanes and turn lanes to ensure that the intersecting routes have adequate capacity as a result of the various intersecting traffic movements that must share time. The Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007) provides information on the traffic management aspects of signalised intersections, for example:

- Section 2 includes traffic management considerations in the selection of traffic signals as the preferred method of control and provides general guidance on the signalisation of intersections.
- Section 5 provides discussion on road space allocation, lane management, signal phasing and timings, signal coordination and traffic detection. It also provides guidance on road user requirements at signalised intersections.

Consideration of traffic management and road safety issues and aspects is an essential part of developing conceptual and functional layouts for signalised intersections, and the subsequent development of a signal layout plan. Practitioners must ensure that, where practicable, the needs of all road users are identified (i.e. through developed plans/strategies or specific site investigations) and incorporated into the intersection design.

It is particularly important that the design of signalised intersections provides adequately for public transport, pedestrians including people who have impairments, and cyclists. Section 6 of the Guide to Road Design – Part 4: Intersections and Crossings – General (Austroads 2009b) describes some of the public transport facilities, and pedestrian and cyclist facilities that may need to be provided. These may include:

- pedestrian facilities (including treatments to assist people who have impaired vision or mobility)
- bicycle lanes, paths and crossings
- public transport lanes, stops and priority measures
- designs to assist heavy vehicle freight movement.

10.2 Design Process

The process of designing a signalised intersection is described in Section 2. It involves operational and geometric requirements that are inter-related and determine the information that is presented on functional design and signal layout plans.

10.3 Signal Operation Considerations

10.3.1 Traffic Operation at an Intersection

Traffic signal operation considerations are discussed in detail in the Guide to Traffic Management – Part 9: Traffic Operations (Austroads 2009j). However, it is important that designers recognise that the geometric layout and the operation of a signalised intersection are inter-related. For example:
Adequate space must be available within the intersection for concurrent right turns to occur from opposite directions (i.e. diamond turn).

In situations where roads intersect at oblique angles and space is constrained the geometry may lead to less efficient phasing. An example of this is illustrated and briefly discussed in Commentary 14.

10.3.2 Proximity to Other Intersections
Desirably intersections should be separated by at least five seconds of travel time at the design speed to provide time for drivers to process information relating to traffic, the road layout and traffic signs. However, it is preferable that signalised intersections be separated by a considerable distance so that:

- traffic queues from one intersection do not back up through an adjacent intersection and adversely affect traffic safety or operation
- inefficiencies do not result from the signal phasings at the intersections having to be inter-dependent
- safety issues do not arise because of the 'see through effect' whereby a driver approaching along the major road focuses on green lights at the second intersection rather than red lights at the first intersection.

Commentary 15 provides an example of how a traffic queue resulting from a signalised intersection can adversely affect sight distance and hence safety at an upstream intersection.

10.4 Sight Distance
The sight distance provided at signalised intersections should be in accordance with the general requirements for intersections as described in Section 3 of this guide. While the existence of illuminated signal aspects provides an additional cue to drivers that they are approaching an intersection, approach sight distance (ASD) is desirable so that these drivers can see the layout of the intersection approach, the pavement and traffic paths within the intersection.

It is desirable to provide ASD Minimum Gap Sight Distance (MGSD) and safe intersection sight distance (SISD) at both signalised and unsignalised movements at signalised intersections, as signals may not always function because of power outages or crash damage to the controller. Stopping sight distance (SSD) should be available at all points on each roadway. In constrained situations (e.g. some urban intersections) an EDD value for SSD and SISD may have to be considered (Appendix A).

10.5 Intersection Layouts

10.5.1 General
Signalised intersection layouts take many forms depending on the:

- reservation available
- classifications of the intersecting roads
- traffic volumes
- constraints such as public utilities, buildings and other road use (e.g. parking, pedestrian malls on one leg)
- the angles of the intersecting roads.
The typical signalised intersections are usually at crossroads or T-intersections where the roads intersect at a right angle.

Figure 10.1 is an example of a signalised intersection and shows the type of detail provided on a signal layout plan that would be prepared to assist in the specification and installation of traffic signals. Lane arrangements vary depending on the space available on the intersection approaches, the movements to be accommodated or permitted and the volume of traffic (e.g. double right-turn and double left-turn lanes).

A further example of a signalised intersection that has complementary double right-turn and left-turn lanes is shown in Figure 10.2.
Figure 10.1: Example of a signalised intersection on a divided arterial road
Figure 10.2: An example of a signalised intersection with double left and right-turn lanes, dual carriageway and bicycle facility in both roads.

Source: Adapted from Main Roads Western Australia (MRWA) (2007).
10.5.2 Service Road Treatments

Section 4.10.3 discusses service roads at unsignalised intersections and the same principles apply to signalised intersections. Figure 10.3 shows examples of service road terminations at a major signalised intersection. It is desirable that the access from the service road is located so that drivers can conveniently move across to the right-turn lane when possible during lower traffic flows on the major road. During peak periods drivers may have to turn left from the service road and seek an alternative route.

![Diagram of service road terminations at a signalised intersection]

Figure 10.3: Typical service road treatments at a signalised intersection

10.6 Traffic Lanes

10.6.1 General

Traffic lanes at signalised intersections generally comprise either through lanes, right-turn lanes and left-turn lanes as discussed in Section 4, Section 7 and Section 8. In addition U-turn lanes may be accommodated in medians on the approaches to signalised intersections. The U-turn movement can be unsignalised or incorporated into the signal phasing with U-turn signal aspects and lanterns.

10.6.2 U-Turning Lanes

U-turns may be permitted at traffic signals in some jurisdictions subject to local guidelines which may require a U-turn lane and signal phase to be provided.

At sites where a U-turn facility is not to be provided at the signals, a separate U-turn lane could be located a sufficient distance in advance of the signalised intersection to ensure that:

- it is clear to right-turning drivers that it is a U-turn lane and not a right-turn lane
Guideline to Road Design – Part 4A: Unsignalised and Signalised Intersections

- U-turning drivers have time to perform the manoeuvre without conflicting with left-turning vehicles from the intersecting road.

Where a jurisdiction allows U-turning from right-turn lanes (i.e. on divided roads) it should be recognised that the U-turners do cause delay for the right-turners which may be an issue, especially if they have to give way to pedestrians or left-turning traffic.

There is often a need to provide for traffic to U-turn from the major road into a service road and this can sometimes be facilitated by a signalised U-turn lane indented into the residual median part way along the right-turn lane/s. Such a treatment is illustrated in Figure 9.3 and an example is shown in Figure 10.4.

![Figure 10.4: U-turn lane combined with a double right-turn lane](image)

10.6.3 Pedestrian Treatments

Pedestrian crossings

Pedestrian crossings that may have to be incorporated into signalised intersections include:

- a marked foot crossing located across approaches between the stop lines and the intersecting road (most common)
- a pedestrian (zebra) crossing marked across left-turn roadways (at the discretion of the relevant road authority)
- an exclusive (scramble) pedestrian phase whereby vehicular traffic on all approaches is stopped and pedestrians can walk across all approaches and diagonally within the intersection.

It is most desirable that, wherever practicable, marked foot crossings should:

- provide a straight path across the road to assist vision-impaired pedestrians (i.e. crosswalk lines do not change direction through a median)
- be at right angles to the road in order to
  - assist vision-impaired pedestrians
  - minimise crossing distance and hence pedestrian phase time
facilitate the orientation of tactile ground surface indicators

- pass behind median noses so that very slow-moving pedestrians (physically impaired or aged) have a secure refuge if they become stranded in the centre of the road. However, it is common practice at intersections that have heavy pedestrian flows and low approach speeds (e.g. inner urban areas) and where pedestrians can cross in one movement to mark the crosswalk lines in front of median noses.

- have appropriately designed kerb ramps (i.e. smooth, flat and correct orientation).

At signalised intersections the width between crosswalk lines should:

- be at least 2.0 m
- be desirably in the range 2.4 m to 3.0 m
- where necessary, should be wide enough (e.g. ≥ 5.0 m) to accommodate high pedestrian demands.

Where pedestrian flows are significant at signalised intersections it may be appropriate to have left-turning traffic pass through the signals rather than provide a left-turn island and roadway. However, in situations where pedestrian flow is moderate and a left-turn roadway beneficial, a pedestrian (zebra) crossing may be marked across the left-turn roadway. Figure 10.5 shows a pedestrian crossing without flashing lights on a left-turn slip lane. It is important to place the crossing a distance equivalent to one or two car lengths back from the holding line so that the crossing is coincident with a space between queued cars (i.e. usually 6 m or 12 m).

Details of a typical pedestrian (zebra) crossing are illustrated in the Guide to Road Design – Part 4: Intersections and Crossings – General (Austroads 2009b). At these facilities traffic regulations require a driver to give way to pedestrians on the crossing and therefore approach sight distance should be available to the crossing and pedestrians waiting to cross. The size and location of signs and vegetation are therefore important factors.

Notes:

1. For details of left-turn island design refer to Sections 6 and 8.
2. Storage length for vehicles should be 6 m or 12 m.
3. If the pedestrian sign would obscure drivers’ view of traffic signals, it may be placed on the signal pole.

Figure 10.5: An example of an urban left-turn slip lane with a pedestrian crossing
Turning vehicles

Potential issues relating to conflict between pedestrians and turning movements at signalised intersections are generally resolved through signal phasing by providing full signal control of traffic movements. The design of left-turn treatments should therefore limit the turning speed to 30 km/h (say 20 m radius) if an unsignalised pedestrian crossing is to be used. Where the design provides for higher turning speeds (e.g. a free-flow slip lane) a signalised pedestrian crossing should be provided.

Pedestrian storage areas

Pedestrian storage areas commensurate with the demand should be provided within signalised intersections (i.e. on medians, left-turn islands and footpaths). The layout should also provide for people walking with prams or bicycles and for people in wheelchairs.

Where appropriate consideration should be given to the provision of ‘blisters’ or ‘kerb outstands’ that reduce pedestrian crossing distances and place pedestrians in a position where they are more easily seen by approaching drivers. The kerb outstands are beneficial where parallel parking exists and pedestrians can emerge from behind parked cars.

Adequate space and accessible all-weather paths should be provided at bus and tram stops.

Footpaths

All footpaths around signalised intersections should be designed to be easily negotiated by pedestrians, including people with a vision or mobility impairment. Appropriate areas, widths, ramp gradients and surfacing should be provided. Poles, solid pit lids, grated pit lids and other street furniture should be located so that they are not obstructions for pedestrians. Reference should be made to AS 1428 and the Guide to Road Design – Part 6A: Pedestrian and Cyclist Paths (Austroads 2009f) for further information.

Pedestrian fences, bollards and barriers

A significant number of pedestrian deaths and injuries occur as a result of pedestrians crossing roads between and close to intersections. Barriers and fences of various types can be used to deter pedestrians from crossing at inappropriate locations and thus reduce mid-block crashes, particularly outside hotels, night clubs, shops and schools. This use is common in conjunction with pedestrian crossing facilities and intersection approaches where fences can be used to channel pedestrians to safe crossing locations (e.g. signalised intersections or crossings, or overpasses). Designers should ensure that the need for pedestrian barriers is considered in the design process. Austroads Guide to Road Design – Part 6B: Roadside Environment (Austroads 2009g) provides further information on infrastructure that needs to be accommodated in the roadside including fences.

Common situations at or between signalised intersections that require fences are:

- Median fences, which are usually chain link or weld mesh fences, prevent pedestrians from crossing dual carriageway roads at mid-block locations. This type of barrier may be added solely for pedestrian purposes, or may be incorporated with vehicle barriers (e.g. steel or concrete safety barriers).
- Footpath fences, railings, or bollards are located between the footpath and the roadway to prevent pedestrians from crossing at hazardous locations, and to channel pedestrians to crossing locations. Footpath fences are typically constructed of chain link, weld mesh, post or bollard and chain, concrete or other treatments.
Designers should refer to standard drawings for the relevant jurisdiction in selecting and locating an appropriate fence or barrier. However, there are several types of pedestrian barriers that may be considered, including:

- numerous varieties of architectural metal railings
- concrete, brick, timber or other fabricated (low) walls as used in many off-road situations
- chain-link, weld-mesh or other commercially available fencing
- bollards and other forms of posts supporting a chain catenary.

Design considerations include:

- Maintenance of sight lines to other vehicles and pedestrians.
- People with impaired vision and who use a cane and/or a sound reflection device for guidance can be confused by the post and chain arrangement (continuous solid edge at pavement level preferred).
- A safe system approach to minimise the risk to drivers posed by the provision of fencing (Guide to Road Design – Part 6: Roadside Design, Safety and Barriers, (Austroads 2009e)).
- Installations should be finished with no sharp edges or protrusions which could be a danger to those who use the railing for support or guidance.
- Post and rail fencing such as galvanised pipe and timber rails and treated pine post and rail fencing with horizontal rails should not be used for pedestrian guidance near vehicle roadways as rails can spear vehicles and occupants.
- Designs where components can be dislodged and projected through the air upon vehicle impact with the barrier should not be used.

Other considerations

In some situations other pedestrian facilities or crossings will exist or be planned in close proximity to a signalised intersection. Practitioners should ensure that the design and operation of these facilities is compatible with the design for the intersection.

10.6.4 Cyclist Facilities

General

Signalised intersections are often associated with traffic routes and are therefore utilised by commuter cyclists. Wherever practicable, traffic routes and signalised intersections should provide the space and operational conditions to support cycling as a viable alternative mode of transport. The needs of cyclists should be considered in relation to detection, signal phasing and timing and road space. Off-road paths are often provided for non-commuter cyclists (e.g. the young and novice cyclists) and these paths often have to be incorporated into the functional layouts of signalised intersections. Traffic management considerations for cyclists at intersections are discussed in the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007).
Illustrations of exclusive right-turn lanes for cyclists are shown in this section. However, these right-turn lanes are rarely used and should generally not be provided for cyclists at right-turn treatments on arterial roads or busy traffic routes because of the difficulty and crash risk for cyclists moving from the left of the road on an intersection approach to the centre of the road in order to utilise such treatments. Exclusive right-turn lanes for cyclists would only be provided where:

- It can be demonstrated that the volume of traffic on an arterial road/traffic route is low enough for cyclists to be able to safely access the cyclist right-turn lane, and there is sufficient cyclist demand to justify the facility.
- The speed environment is very low (e.g. 50 km/h limit) and cyclist demand is significant. These conditions may exist within the business centres of cities or activity centres and may be associated with particular precincts (e.g. universities or sporting recreational areas).

**Bicycle lanes on signalised intersection approaches**

The types of lanes that may have to be incorporated into traffic routes, and therefore signalised intersections, include:

- wide kerbside lanes
- bicycle lanes adjacent to car parking lanes
- exclusive bicycle lanes.

Wide kerbside lanes provide additional width for cyclists to share the left lane with motor vehicles but without any designated space being marked on the road surface. It is desirable that wide kerbside lanes be carried through intersections as a reduction in the width of the left lane at intersections to allocate space for other uses (e.g. provide a painted right-turn lane) creates a squeeze point for cyclists.

Where a bicycle lane exists or is planned on roads leading up to a signalised intersection the design should assist the safe passage of cyclists through the intersection. Ideally, visually separated operating space should be provided within each of the six elements illustrated in Figure 10.6. However, where space is constrained and all elements cannot be satisfactorily addressed designers should meet as many of the requirements as possible. Design options for the six elements are shown in Figure 10.7 and Figure 10.8. Further information on application of the six elements is contained in Commentary 16.
Figure 10.7: Design options for signalised intersections (mid-block, transition and approach)

Figure 10.8: Design options for signalised intersections (waiting, through and departure)

Figure 10.9 shows two common examples of bicycle lanes marked through signalised intersections where the width between kerbs is approximately 13 m and parking is provided. In the car side option no separate left-turn lane is provided for cyclists resulting in them having to make the left-turn from the vehicle lane and the expanded storage box. Cyclists using the kerbside option can turn left or proceed straight through the intersection from the bicycle lane.
Figure 10.9: Bicycle lanes through signalised intersection – car side and kerbside

Head start and expanded storage areas

These storage areas are provided to position cyclists in a highly visible location while they are waiting to proceed through the intersection thereby improving safety. Figure 10.10 shows four combinations of head start and expanded storage areas at signalised intersections. The treatments in each of the four examples can be used in isolation or in any combination. A summary of the various treatments is given below.

Example (a)

The purpose of the treatment in this example is to store a cyclist in advance of a motor vehicle driver in the adjacent left-turn lane or through lane so that the cyclist can be easily seen by a stationary driver at the stop line. This is particularly important where the vehicle is a van or truck in which case the cyclist would otherwise be hidden from view below the left-hand side window. This treatment:

- reduces the potential for conflict between cyclists and traffic using the left lane
- is suitable where cyclist numbers are relatively low
- allows cyclists to pass on the left side of a queue of vehicles waiting to turn left
- has an area that is only as wide as the bicycle lane on the approach
- has a bicycle stop line that is located 0.2 m in advance of the pedestrian crosswalk line and 2.0 m (i.e. storage length for one bicycle) beyond the motor vehicle stop line
- may be placed to the left of a left-turn lane, a through lane, or a combined through and left-turn lane.

Example (b)

This treatment locates the bicycle lane between the left-turn lane and through lane and provides additional storage width and length. Cyclists travelling straight ahead travel to the right of queued or moving left-turning vehicles. However, left-turning vehicles are required to change lanes across the bicycle lane at the start of the left-turn lane. Cyclists intending to turn left should desirably share the left-turn lane with motor vehicles. However, it is likely that some left-turning cyclists will use the bicycle lane to pass the queue and access the storage box.

Example (c)

This illustration includes two treatments, the first being a bicycle lane for cyclists travelling straight through the intersection. In this case left-turning cyclists are expected to share the left-turn lane with motor vehicles. The second treatment is a right-turn expanded storage area for high volumes of bicycle turning traffic. These are rarely used and are not intended for use in higher speed zones (> 60 km/h) because of the difficulty and conflict associated with cyclists crossing traffic lanes to access the right-turn bicycle lane. However, these treatments may be appropriate in lower speed zones (≤ 60 km/h) where bicycle volumes are high and the turn is made into a single lane mixed function road that does not have marked bicycle lanes (e.g. inner city areas).

Where bicycle lanes are provided in the intersecting road and bicycle turning volumes are not high, it is more acceptable to install a head start storage area only in the right-turn bicycle lane. In this instance it is also necessary to include additional turning lines within the intersection to guide right-turning cyclists and delineate the cyclists’ path for drivers.
Example (d)

This example also shows two treatments. The hook turn storage area, provided to accommodate cyclists in a safe position while they are waiting for a green traffic signal phase for the intersecting road, can be used generally throughout the road system. The second treatment, an expanded storage area shared by left-turning, through and right-turning cyclists is suitable only for lower speed areas (e.g. 50 km/h).

Note: $L_{HS}$ denotes length of head start area.

Source: Adapted from NSW bicycle guidelines, version 1.2, RTA (2005).

Figure 10.10: Head start and expanded storage areas
In high traffic locations or where the number of bicycle turning movements is significant, or compliance by motor vehicle drivers is poor (i.e. encroachment into bicycle storage area) it may be necessary to improve the delineation of the storage area by paving it with a green surface.

It should be noted that:

• not all jurisdictions use head start areas across multiple lanes, particularly through lanes
• a head start area may be used where there is no bicycle lane on the intersection approach.

The treatment in Example (a) is not suitable for use where a green left-turn arrow is provided on the approach as the treatment encourages cyclists to store at the stop line. Even without the treatment left-turn phases are problematic for through cyclists waiting in the vicinity of the stop line. The bicycle lane for the through cyclist movement depicted in Example (c) can remove this conflict and should be used where a left-turn phase is provided.

In practice many cyclists intending to turn right ride to the left of motor vehicles which are turning or intending to turn right in order to avoid conflict with this traffic stream. This means that they may be exposed to conflict with through motor traffic. The right-turn bicycle lane shown in Figure 10.10(c) creates space for cyclists, providing protection from moving motor vehicles and enabling cyclists to easily advance to the head of the right-turning queue.

If the volume of cyclists is high then consideration may be given to providing a larger storage area as shown in Figure 10.10(b) and (c).

**Hook turn storage boxes and hook turn restrictions**

Under the Australian Road Rules, National Transport Commission, cyclists on an approach at a signalised intersection can use a hook turn as an alternative to a conventional right-turn from the centre of the road. Cyclists undertake a hooked turn by travelling straight at the intersection and waiting at the far corner of the intersecting road. Where the aim is to encourage the use of hooked turns, or to ban a conventional right-turn that may be hazardous to cyclists, a hook turn storage box can be provided as illustrated in Figure 10.10(d) and Figure 10.11.

The hook turn box should not be located as illustrated if the left-turn lane has a signalised left-turn arrow. In this case the box may be placed in front of the adjacent lane if the signal phasing permits. Additional in-ground signal detection in the hook turn box should be considered where the box is placed at a side street approach to a major road to ensure that cyclists can call a phase.

It should be noted, however, that the box turn may be illegal in some states and the traffic signal phasing at some intersections may not suit a hook turn. For instance, waiting cyclists who have performed the first stage of a hook turn manoeuvre could be in conflict with an exclusive left-turn phase for the intersecting road or a diagonal pedestrian crossing phase.
Notes:
In this case the hook turn box is located in the area between the crossing line or vehicle stop line and the crossroad kerb line.

The hook turn box should not be located in this position if the left lane has a signalised turn phase. In this case the bay may be located in front of the adjacent traffic lane if signal phasing permits.

Additional in-ground signal detection should be installed in hook turn boxes where the box is located at a side street entrance to a major arterial road with signal priority.


**Figure 10.11: Bicycle hook turn box detail**

*Left-turn bypass treatment*

Left-turn access through signals may be provided for cyclists where a major bicycle route turns left through a signalised intersection as shown in Figure 10.12. This treatment has a bicycle lane in the intersecting road. Where there is no bicycle lane in the intersecting road the bypass should be designed as a free-flow arrangement where the bicycle lane is directed into an off-road path parallel to the intersecting road to join it with a protected transition (kerb extension).


**Figure 10.12: Bicycle lane left-turn bypass at a signalised intersection**
**Bypass of T-intersection**

In order to limit the delay to cyclists at T-intersections, circumstances may permit the construction of a bypass of the intersection for cyclists opposite the discontinuing leg of an intersection, as shown in Figure 10.13. The bypass may be separated by channelisation as shown or a separated path treatment can be used where the bicycle path is raised and adjacent to the footpath. A disadvantage of the channelised treatment may be the accumulation of debris and the consequent maintenance.

This treatment may be appropriate where:

- property access does not exist opposite the discontinuing leg of the intersection
- pedestrian activity in the vicinity of the intersection is limited and the number of pedestrian crossing movements of the bicycle path is low
- the proportion of elderly, vision-impaired, and other disabled pedestrians is low.

Where the bypass lane/path passes over a pedestrian crossing, the crossing should be designated in a manner that is consistent with local practice and should incorporate one or a combination of:

- warning signs
- zebra crossing (AS 1742.10)
- raised platform
- give-way controls.

![Figure 10.13: Cyclist bypass lane at a signalised T-intersection](image-url)
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**Australian and New Zealand Standards**

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APPENDIX A  EXTENDED DESIGN DOMAIN (EDD) FOR INTERSECTIONS

A.1 General

This section provides extended design domain (EDD) values for intersection design criteria. These are values outside of the normal design domain (NDD) that through research and/or operating experience, particular road authorities have found to provide a suitable solution in constrained situations (typically at brownfield sites).

EDD may be considered when:

- reviewing the geometry of existing intersections
- new intersections are being retrofitted on existing roads in constrained locations
- improving the standard of existing intersections in constrained locations
- building temporary intersections.

Application of EDD involves identification and documentation of driver capability. Ultimately, the capabilities that are accepted may have to pass the test of what is reasonable capability (the capability that a court decides a driver can reasonably be expected to have when they are taking reasonable care for their own safety). The decision to use EDD should not be taken lightly.

In applying this guide:

- NDD values given in the body of this guide should be used wherever practical.
- Design values outside of NDD are only to be used if approved in writing by the delegated representative from the relevant road authority. The relevant road authority may be a state road authority, municipal council or private road owner.
- If using EDD values, the reduction in standard associated with their use should be appropriate for the prevailing local conditions. Generally, EDD should be used for only one parameter in any application and not be used in combination with any other minimum or EDD value for any related or associated parameters.

Through collective experience it has been accepted for a very long time that the use of minimum values for several parameters at the same location does not constitute good practice and generally leads to an inferior or unsafe design.

Designers may refer to the Guide to Road Design – Part 2: Design Considerations (Austroads 2006c) and Cox and Arndt (2005) for further information on EDD. The following sections deal with EDD for specific road design parameters and situations.

A.2 EDD for Sight Distance at Intersections

A.2.1 Application of EDD for Sight Distance at Intersections

EDD for sight distance at intersections is calculated by the same process as that used for the NDD intersection sight distance. The main difference with EDD is that less-conservative values are used for some of the terms (e.g. coefficient of deceleration, observation time), where justified based on an acceptable level of driver capability being provided. The development of EDD for sight distance at intersections has included checks for safety involving the relationship between sight distance and crash rate that was established in Arndt (2004).
EDD for sight distance at intersections is primarily for assessing the sight distance capability at existing intersections. However, it can be applied to special cases of new work, for example:

- upgrading sight distance at existing intersections
- where a new intersection must be installed on an existing road and it is impractical to achieve the normal design domain criteria.

**Compliance with EDD for sight distance at intersections**

Sight distance at an intersection is deemed to comply with EDD if all of the following conditions are met:

1. EDD approach sight distance (ASD) capability is provided for the base cases given in Table A.1. Section A.2.3 ‘EDD approach sight distance’ provides the criteria for determining appropriate EDD approach sight distance capability for the base cases. Application of ASD is always applied on the minor road at unsignalised intersections. It is normally only required on the major road at unsignalised intersections if:
   - sufficient cues are not provided through other means
   - drivers may be distracted by other features at the intersection
   - the intersection is complex or non standard.

2. EDD Minimum Gap Sight Distance (MGSD). Is applied in accordance with the Normal Design Domain MGSD criteria, except that an object height of 1.25 m is used (top of a passenger car) instead of 0.65 m (indicator height).

3. EDD Safe Intersection Sight Distance (SISD) capability is provided for the base cases and any relevant check case given in Table A.1. Section A.2.5 ‘EDD Safe Intersection Sight Distance’ provides the criteria for determining appropriate EDD Safe Intersection Sight Distance capability for the base cases and provides guidance for assessing the check cases.

4. EDD Stopping Sight Distance is provided at all locations throughout the intersection. Refer to the criteria in Section A.3 of Appendix A of the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a).

5. The ‘General Considerations’ given below.

**General considerations**

The following apply under EDD for sight distance at intersections:

- Application of EDD sight distance at intersections is only appropriate when crash data indicates that there are no sight distance related crashes.
- Because EDD uses less conservative values, there is less margin for error (although some margin is still provided in the EDD values). Design issues such as choosing the correct operating speed and allowing for the effect of grade become more critical.
- Generally, an EDD value should not be combined with any other lower order geometric value for the same element.
- Zones clear of obstructions, defined by ‘sight triangles’ for each of the appropriate sight distance models, are required at intersections and must be maintained.
- Future arrangements/planning must be satisfied (e.g. allow for future fencing, safety barriers).
- Geometric and other features of the road should not be misleading and should not distract drivers.
Horizontal curves and vertical curves should not be considered in isolation. Sight distances/lines should be checked in both the vertical and horizontal planes taking into account both the horizontal and vertical curvature.

Particular attention must be given to checking truck requirements on routes with high numbers of heavy vehicles. Some capability for trucks should be provided on all roads.

**Formulae**

Section 3.2.1 of this guide provides the formula for the calculation of approach sight distance.

Section 3.2.2 of this guide provides the formula for the calculation of safe intersection sight distance.

Section 5.4 of the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a) provides the formula for the calculation of offsets required to obtain stopping sight distance around horizontal curves. It also has a graph that can be used to determine this offset.

Section 8.6 of the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a) provides formulae for the calculation of vertical curve radii required to obtain stopping sight distance for a crest or sag curve.

Where horizontal and vertical curves overlap or coincide it is usually necessary for the designer to determine and check stopping sight distance via plots or Computer Aided Drafting and Design (CADD) packages (rather than formulae).

**A.2.2 Base and Check Cases**

**Base cases**

For EDD approach sight distance and EDD safe intersection sight distance, it is mandatory to provide sufficient driver capability for cars and trucks during daylight hours (Norm-Day and Truck-Day base cases respectively) as shown in Table A 1. These are the same conditions used for the Normal Design Domain.

**Table A 1: Case types used for EDD sight distance**

<table>
<thead>
<tr>
<th>Case Type</th>
<th>Case code</th>
<th>Case description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base case (mandatory application)</td>
<td>Norm-day</td>
<td>Normal car driver travelling at the 85th percentile speed in daylight hours.</td>
</tr>
<tr>
<td></td>
<td>Truck-day</td>
<td>Truck in daylight hours.</td>
</tr>
<tr>
<td>Check case (ensure that adequate capability exists under these conditions, as relevant)</td>
<td>Norm-night</td>
<td>Normal car driver travelling at the 85th percentile speed on an unlit road at night</td>
</tr>
<tr>
<td></td>
<td>Truck-night</td>
<td>Truck travelling on an unlit roadway at night</td>
</tr>
<tr>
<td></td>
<td>Mean-day</td>
<td>Car driver travelling at the mean free speed in daylight hours (about 0.85 times the 85th percentile speed).</td>
</tr>
<tr>
<td></td>
<td>Mean-night</td>
<td>Car driver travelling at the mean free speed on an unlit roadway at night (about 0.85 times the 85th percentile speed).</td>
</tr>
<tr>
<td>Optional check case to confirm borderline cases</td>
<td>Skill-day</td>
<td>Skilled car driver travelling at the 85th percentile speed in daylight hours.</td>
</tr>
<tr>
<td></td>
<td>Skill-night</td>
<td>Skilled car driver travelling at the 85th percentile speed on an unlit roadway at night</td>
</tr>
</tbody>
</table>
Check cases

Because the EDD base cases may well use less conservative values for some of the terms, it becomes important to provide suitable capability for other combinations of driver and lighting conditions. For example, that suitable capability is provided for car and truck drivers at night (norm-night and truck-night check cases in Table A 1) and that suitable capability is provided for drivers travelling at the mean free speed (mean-day and mean-night). The check cases are particularly important for EDD SISD.

Sufficient capability for the night-time check cases will not be needed if the road has continuous route lighting.

Generally, the check cases in Table A 1 are not applied to EDD ASD because of the large sight distances, and associated costs that would result. In addition, Arndt (2004) showed that provision of ASD was not a significant predictor of any crashes at unsignalised intersections. The reason given for this result was that good perception of intersections can often be provided even when ASD fell below the NDD values.

Optional check cases

The optional checks in Table A 1 are used to ascertain whether skilled drivers have sufficient safe intersection sight distance capability. This may be helpful when analysing borderline cases. For example, if the skill-day and skill-night check case capabilities are not available, it would not be a suitable solution under EDD. These optional check cases may even be used when determining if any capability exists under a design exception.

A.2.3 EDD Approach Sight Distance (ASD)

EDD approach sight distance values and corresponding crest curve sizes for the base cases are calculated using the following:

- Eye height ($h_1 = 1.1$ m for cars and $2.4$ m for trucks) and object height ($h_2 = 0$ m) as per Table A 4 of Appendix A of the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a).
- Reaction times ($R_T = 1.5$ s / $2.0$ s / $2.5$ s) as per Table A 5 of Appendix A of the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a).
- Longitudinal deceleration ($d = 0.61 / 0.46$ for cars and $0.29$ for trucks) as per Table A 6 of Appendix A of the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a).

EDD approach sight distance values and corresponding crest curve sizes are given in the following tables:

- Table A 2 for the norm-day base case, which uses a coefficient of deceleration of 0.61, is suitable for sealed roads in predominantly dry areas with an AADT <4000 veh/d. In order to be classified as a predominantly dry area, the average number of days per year with rainfall greater than 5 mm should be less than 40. Refer to the Bureau of Meteorology website for the amount of rainfall at any particular site.
- Table A 3 for the norm-day base case, which uses a coefficient of deceleration of 0.46, is suitable for sealed roads with normal road conditions i.e. wet roads. This table should be used for the norm-day base case for all roads other than those in the previous dot point.
- Table A 6 for the truck-day base case.
Grade corrections for \( d = 0.61 \), \( d = 0.46 \) and \( d = 0.29 \) are provided in Table A 4 and Table A 5 and Table A 7 respectively.

The approach sight distances given in Table A 2, Table A 3 and Table A 6 are based on the sight distance being measured on a horizontal straight or a horizontal curve with a side friction factor less than or equal to the desirable maximum value. If this does not apply, individual calculations are required to determine the approach sight distance.

The vertical crest curve sizes given in Table A 2, Table A 3 and Table A 6 are based on the:

- sight distance being less than the length of the crest curve
- average grade over the braking length being zero
- horizontal alignment at the particular location results in passenger car drivers using a side friction factor less than or equal to the desirable maximum value.

If any of the above does not apply, individual calculations are required to determine the vertical crest curve size.

Generally, the check cases in Table A 1 are not applied to EDD approach sight distance because of the large sight distances, and associated costs that would result.

### Table A 2: Minimum EDD approach sight distance and corresponding crest vertical curve size for the norm-day base case for sealed roads with level grades in predominantly dry areas (m)

| Design speed (km/h) | Based on the norm-day base case 1\( h1 = 1.1 \quad h2 = 0 \)
|---------------------|---------------------------------------------------------------|
|                     | Roads in predominantly dry areas with AADT<4000veh/d 2\( d = 0.61 \)
|                     | (\( d = 0.61 \))3 \( \text{RT} = 1.5 \) s | \( \text{RT} = 2.0 \) s | \( \text{RT} = 2.5 \) s
<table>
<thead>
<tr>
<th>ASD (m)</th>
<th>K</th>
<th>ASD (m)</th>
<th>K</th>
<th>ASD (m)</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>27</td>
<td>3.3</td>
<td>33</td>
<td>4.8</td>
<td>-</td>
</tr>
<tr>
<td>50</td>
<td>37</td>
<td>6.2</td>
<td>44</td>
<td>8.8</td>
<td>-</td>
</tr>
<tr>
<td>60</td>
<td>48</td>
<td>10.6</td>
<td>57</td>
<td>14.5</td>
<td>-</td>
</tr>
<tr>
<td>70</td>
<td>61</td>
<td>16.8</td>
<td>71</td>
<td>22.6</td>
<td>-</td>
</tr>
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<td>80</td>
<td>75</td>
<td>25.3</td>
<td>86</td>
<td>33.4</td>
<td>-</td>
</tr>
<tr>
<td>90</td>
<td>90</td>
<td>36.6</td>
<td>102</td>
<td>47.5</td>
<td>115</td>
</tr>
<tr>
<td>100</td>
<td>106</td>
<td>51.3</td>
<td>120</td>
<td>65.6</td>
<td>134</td>
</tr>
<tr>
<td>110</td>
<td>124</td>
<td>69.8</td>
<td>139</td>
<td>88.1</td>
<td>154</td>
</tr>
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<td>120</td>
<td>-</td>
<td>-</td>
<td>160</td>
<td>116</td>
<td>176</td>
</tr>
<tr>
<td>130</td>
<td>-</td>
<td>-</td>
<td>181</td>
<td>149</td>
<td>199</td>
</tr>
</tbody>
</table>

1. If the average grade over the braking length is not zero, calculate the approach sight distance values using the correction factors in Table A 4 (or use Equation 1 in Section 3.2.1) by applying the average grade over the braking length.
2. In order to be classified as a predominantly dry area, the average number of days per year with rainfall greater than 5mm should be less than 40. Refer to the Bureau of Meteorology website for the amount of rainfall at any particular site.
3. On any horizontal curve with a side friction factor greater than the desirable maximum value for cars, calculate the stopping sight distance with the coefficient of deceleration reduced by 0.05.

**Notes:**
Generally, check case capability is not required under EDD approach sight distance.
Combinations of design speed and reaction times not shown in this table are generally not used.
The crest vertical curve sizes are based on the sight distance being less than the length of crest curve.
Table A 3: Minimum EDD approach sight distance and corresponding crest vertical curve size for the norm-day base case for sealed roads with level grades for normal road conditions (m)

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Based on the norm-day base case1</th>
<th>RT = 1.5 s</th>
<th>RT = 2.0 s</th>
<th>RT = 2.5 s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ASD (m)</td>
<td>K</td>
<td>ASD (m)</td>
<td>K</td>
</tr>
<tr>
<td>40</td>
<td>30</td>
<td>4.2</td>
<td>36</td>
<td>5.9</td>
</tr>
<tr>
<td>50</td>
<td>42</td>
<td>8.1</td>
<td>49</td>
<td>11.0</td>
</tr>
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<td>60</td>
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<td>14.2</td>
<td>64</td>
<td>18.7</td>
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<td>70</td>
<td>71</td>
<td>23.0</td>
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<td>29.7</td>
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<td>127</td>
<td>73.6</td>
<td>141</td>
<td>90.6</td>
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<tr>
<td>110</td>
<td>149</td>
<td>101</td>
<td>165</td>
<td>123</td>
</tr>
<tr>
<td>120</td>
<td>-</td>
<td>-</td>
<td>190</td>
<td>164</td>
</tr>
<tr>
<td>130</td>
<td>-</td>
<td>-</td>
<td>217</td>
<td>214</td>
</tr>
</tbody>
</table>

1. If the average grade over the braking length is not zero, calculate the approach sight distance values using the correction factors in Table A 5 (or use Equation 1 in Section 3.2.1) by applying the average grade over the braking length.

2. On any horizontal curve with a side friction factor greater than the desirable maximum value for cars, calculate the stopping sight distance with the coefficient of deceleration reduced by 0.05.

Notes:
Generally, check case capability is not required under EDD approach sight distance.
Combinations of design speed and reaction times not shown in this table are generally not used.
The crest vertical curve sizes are based the sight distance being less than the length of crest curve.

Table A 4: Grade corrections to stopping sight distance for d = 0.61

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Upgrade</th>
<th>Correction (m)</th>
<th>Downgrade</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>40</td>
<td>0</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>50</td>
<td>-1</td>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td>60</td>
<td>-1</td>
<td>-1</td>
<td>-2</td>
</tr>
<tr>
<td>70</td>
<td>-1</td>
<td>-2</td>
<td>-3</td>
</tr>
<tr>
<td>80</td>
<td>-1</td>
<td>-3</td>
<td>-4</td>
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<tr>
<td>130</td>
<td>-3</td>
<td>-7</td>
<td>-10</td>
</tr>
</tbody>
</table>
Table A 5: Grade corrections to stopping sight distance for d = 0.46

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Correction (m)</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upgrade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Downgrade</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
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<td>2</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>2</td>
</tr>
<tr>
<td>60</td>
<td>-1</td>
<td>-1</td>
<td>-2</td>
<td>-2</td>
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<tr>
<td>130</td>
<td>-6</td>
<td>-12</td>
<td>-17</td>
<td>-21</td>
</tr>
</tbody>
</table>

Table A 6: Minimum EDD approach sight distance and corresponding crest vertical curve size for the truck-day base case for sealed roads with level grades (m)

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Based on the truck-day base case  (^{(1)})</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(R_T = 1.5 \text{ s} )</td>
</tr>
<tr>
<td></td>
<td>ASD (m)</td>
</tr>
<tr>
<td>40</td>
<td>38</td>
</tr>
<tr>
<td>50</td>
<td>55</td>
</tr>
<tr>
<td>70</td>
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<tr>
<td>100</td>
<td>117</td>
</tr>
<tr>
<td>110</td>
<td>210</td>
</tr>
</tbody>
</table>

1. If the average grade over the braking length is not zero, calculate the approach sight distance values using the correction factors in Table A 7 (or use Equation 1 in Section 3.2.1) by applying the average grade over the braking length.
2. On any horizontal curve with a side friction factor greater than the desirable maximum value for trucks, calculate the stopping sight distance with the coefficient of deceleration reduced by 0.05.

Notes:
- Generally, check case capability is not required under EDD approach sight distance.
- Combinations of design speed and reaction times not shown in this table are generally not used.
- The crest vertical curve sizes are based on the sight distance being less than the length of crest curve.
Table A 7: Grade corrections to stopping sight distance for \( d = 0.29 \)

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Upgrade</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
<th>2</th>
<th>4</th>
<th>6</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
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<td>-6</td>
<td>-8</td>
<td>-11</td>
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<tr>
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<td>-8</td>
<td>-11</td>
<td>-14</td>
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<td>11</td>
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</tr>
<tr>
<td>80</td>
<td>-6</td>
<td>-11</td>
<td>-15</td>
<td>-19</td>
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<td>14</td>
<td>23</td>
<td>33</td>
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</tr>
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<td>90</td>
<td>-7</td>
<td>-13</td>
<td>-19</td>
<td>-24</td>
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<td>18</td>
<td>29</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>-9</td>
<td>-16</td>
<td>-23</td>
<td>-29</td>
<td>10</td>
<td>22</td>
<td>35</td>
<td>52</td>
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</tr>
<tr>
<td>110</td>
<td>-11</td>
<td>-20</td>
<td>-28</td>
<td>-36</td>
<td>12</td>
<td>26</td>
<td>43</td>
<td>63</td>
<td></td>
</tr>
</tbody>
</table>

A.2.4 Observation Times for EDD Safe Intersection Sight Distance

The observation times used for the base cases under EDD safe intersection sight distance are given in Table A 8. A range of values are given depending on factors such as the complexity of the intersection and traffic volume. The observation times used for the check cases are given in the note to Table A 8.

Table A 8: Driver observation time for safe intersection sight distance under EDD

<table>
<thead>
<tr>
<th>Observation time ( O_T ) (s)</th>
<th>Typical use</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.5</td>
<td>T-intersections on single carriageway roads (two-lane, two-way roads and one-way roads) that have a traffic volume &lt;4000 veh/d. Cross intersections on single carriageway roads (two-lane, two-way roads and one-way roads) that have a traffic volume &lt;400 veh/d. Simple intersection arrangements e.g. left in, left out on all roads.</td>
</tr>
<tr>
<td>2.0</td>
<td>T-intersections on single carriageway roads (two-lane, two-way roads and one-way roads) that have a traffic volume ≥4000 veh/d. Cross intersections on single carriageway roads (two-lane, two-way roads and one-way roads) that have a traffic volume ≥400 veh/d.</td>
</tr>
<tr>
<td>2.5</td>
<td>T-intersections and cross intersections on multi-lane roads. Intersections in overtaking lanes. Complex intersection layouts. Situations in which drivers may be distracted by other features.</td>
</tr>
</tbody>
</table>

Note: The observation times in this table are applicable to the norm-day and truck-day base cases. The minimum observation times for the check cases are given below:

- mean-day and skill-day as per this table.
- norm-night, truck-night, mean-night and skill-night use 1.0s less than the values given in this table. Use of the lower observation times is associated with the additional cues drivers are given by observing the glow of the oncoming vehicle’s headlights.

A.2.5 EDD Safe Intersection Sight Distance (SISD)

EDD safe intersection sight distance values and corresponding crest curve sizes for the base and check cases are calculated using the following:

- Eye height and object height as per Table A 4 of Appendix A of the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) – refer Note 3 for the check cases.
  - \( h_1 = 1.1 \) m and \( h_2 = 1.25 \) m for norm-day and mean-day
  - \( h_1 = 2.4 \) m and \( h_2 = 1.25 \) m for truck-day
— $h_1 = 0.65 \text{ m and } h_2 = 1.25 \text{ m for norm-night and mean-night}$
— $h_1 = 2.4 \text{ m and } h_2 = 0.8 \text{ m for truck-night (minimum acceptable)}$.

- Reaction times as per Table A 5 of Appendix A of the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a) – refer to Note 5 for the check cases.
  — $RT = 1.5 \text{ s / } 2.0 \text{ s / } 2.5 \text{ s for norm-day, truck-day, norm-night and truck-night}$
  — $RT = 2.0 \text{ s / } 2.5 \text{ s for mean-day and mean-night}$

- Longitudinal deceleration as per Table A 6 of Appendix A of the *Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a) – refer to Note 3 for the check cases. Dry weather only stopping is not used under SISD because the primary hazard at intersections is other vehicles, which are prevalent in wet as well as dry conditions.
  — $d = 0.46 \text{ for norm-day and norm-night}$
  — $d = 0.29 \text{ for truck-day and truck-night}$
  — $d = 0.41 \text{ for mean-day and mean-night}$.

- Observation times as per Table A 8 – refer to the note for the check cases.

**Application of the base cases**

EDD safe intersection sight distance values and corresponding crest curve sizes for the base cases are given in the following tables:

- Table A 9, Table A 10 and Table A 11 for the norm-day base case, which use observation times of 1.5 s, 2.0 s and 2.5 s respectively
- Table A 12, Table A 13 and Table A 14 for the truck-day base case, which use observation times of 1.5 s, 2.0 s and 2.5 s respectively.

Grade corrections for $d = 0.46$ and $d = 0.29$ are provided in Table A 5 and Table A 7 respectively.

The safe intersection sight distances given in Table A 9 to Table A 14 are based on the sight distance being measured on a horizontal straight or a horizontal curve with a side friction factor less than or equal to the desirable maximum value. If this does not apply, individual calculations are required to determine the safe intersection sight distance.

The vertical crest curve sizes given in Table A 9 to Table A 14 are based on the:

- sight distance being less than the length of the crest curve
- average grade over the braking length being zero
- horizontal alignment at the particular location results in passenger car drivers using a side friction factor less than or equal to the desirable maximum value.

If any of the above does not apply, individual calculations are required to determine the vertical crest curve size.
Application of the check cases

Appropriate check case capability is obtained when the minimum observation times listed in the note to Table A 8 are met.

When evaluating sight distance in the horizontal plane only (i.e. where there are no restrictions to visibility in the vertical plane), the provision of:

- Norm-Day base case SISD values given in Table A 9 to Table A 11 will usually provide satisfactory sight distance capability for the norm-night, mean-day and mean-night check cases.
- Truck-Day base case SISD values given in Table A 12 to Table A 14 will provide satisfactory sight distance capability for the truck-night check case.

Table A 9 to Table A 14 show that suitable check case capability has been provided for the crest curve sizes listed. Particular combinations of speeds and reaction times in the tables will produce greater check case capability than that shown.

Individual calculations are required to determine the crest curve sizes for the check cases where the:

- sight distance is greater than the length of the crest curve
- average grade over the braking length is not zero
- horizontal alignment at the particular location results in passenger car drivers using a side friction factor greater than or equal to the desirable maximum value.
### Table A 9: Minimum EDD safe intersection sight distance and corresponding crest vertical curve size for sealed roads with level grades for the norm-day base case using an observation time of 1.5 seconds (m)

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Based on norm-day Safe Intersection Sight Distance (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$h_1 = 1.1$  $h_2 = 1.25$  $d = 0.46$  $O_T = 1.5$ s</td>
</tr>
<tr>
<td></td>
<td>$R_T = 1.5$ s $SISD (m)$</td>
</tr>
<tr>
<td>--------------------</td>
<td>-------------------------------------------------------</td>
</tr>
<tr>
<td>40</td>
<td>47  2.4  53  2.9 - -</td>
</tr>
<tr>
<td>50</td>
<td>63  4.2  70  5.2 - -</td>
</tr>
<tr>
<td>60</td>
<td>81  7.0  89  8.5 - -</td>
</tr>
<tr>
<td>70</td>
<td>100 10.7 110 12.9 - -</td>
</tr>
<tr>
<td>80</td>
<td>121 15.7 133 18.7 - -</td>
</tr>
<tr>
<td>90</td>
<td>144 22.2 157 26.2 169 30.5</td>
</tr>
<tr>
<td>100</td>
<td>169 30.4 183 35.6 197 41.2</td>
</tr>
<tr>
<td>110</td>
<td>195 40.8 211 47.2 226 54.3</td>
</tr>
<tr>
<td>120</td>
<td>- - 240 61.3 257 70.1</td>
</tr>
<tr>
<td>130</td>
<td>- - 271 78.2 289 89.0</td>
</tr>
</tbody>
</table>

Do all of the crest curve sizes listed provide acceptable car check case capability (3)  

- Norm-night (4) Yes ($d = 0.46$, $h_1 = 0.65$ m, $h_2 = 1.25$ m, $O_T = 0.8$ s).
- Mean-day Yes ($d = 0.41$, $h_1 = 1.1$ m, $h_2 = 1.25$ m, $O_T = 1.7$ s).
- Mean-Night (4) Yes ($d = 0.41$, $h_1 = 0.65$ m, $h_2 = 1.25$ m, $O_T = 1.2$ s).

1. If the average grade over the braking length is not zero, calculate the safe intersection sight distance values using the correction factors in Table A 5 or use Equation 2 in Section 3.2.2 by applying the average grade over the braking length.

2. On any horizontal curve with a side friction factor greater than the desirable maximum value for cars, calculate the stopping sight distance with the coefficient of deceleration reduced by 0.05.

3. This part of the table identifies whether the crest curve sizes listed provide acceptable check case capability in accordance with Section A.2.5, Subsection ‘Application of the Check Cases’. The minimum capabilities listed for the check cases assume the same combination of design speeds and reaction times as those listed in the table, except:
   - Where particular check cases use a different speed according to Table A 1.
   - Where particular check cases use a different reaction time according to Note 5 of Table A 5 of Appendix A of the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a).

4. Drivers will usually be alerted by the glow from the other vehicle’s headlights before seeing the vehicle.

Notes:
- Combinations of design speed and reaction times not shown in this table are generally not used.
- The crest vertical curve sizes are based on the sight distance being less than the length of crest curve.
### Table A 10: Minimum EDD safe intersection sight distance and corresponding crest vertical curve size for sealed roads with level grades for the norm-day base case using an observation time of 2.0 seconds (m)

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Based on norm-day Safe Intersection Sight Distance (1)</th>
<th>R_T = 1.5 s</th>
<th>R_T = 2.0 s</th>
<th>R_T = 2.5 s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h_1 = 1.1 h_2 = 1.25 d = 0.46 (2) O_T = 2.0 s</td>
<td>SISD (m)</td>
<td>K</td>
<td>SISD (m)</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>53</td>
<td>2.9</td>
<td>58</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>70</td>
<td>5.2</td>
<td>77</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td>89</td>
<td>8.5</td>
<td>97</td>
</tr>
<tr>
<td>70</td>
<td></td>
<td>110</td>
<td>12.9</td>
<td>120</td>
</tr>
<tr>
<td>80</td>
<td></td>
<td>133</td>
<td>18.7</td>
<td>144</td>
</tr>
<tr>
<td>90</td>
<td></td>
<td>157</td>
<td>26.2</td>
<td>169</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td>183</td>
<td>35.6</td>
<td>197</td>
</tr>
<tr>
<td>110</td>
<td></td>
<td>111</td>
<td>47.2</td>
<td>226</td>
</tr>
<tr>
<td>120</td>
<td></td>
<td>-</td>
<td>-</td>
<td>257</td>
</tr>
<tr>
<td>130</td>
<td></td>
<td>-</td>
<td>-</td>
<td>289</td>
</tr>
</tbody>
</table>

Do all of the crest curve sizes listed provide acceptable car check case capability (3)  
Norm-night (4) Yes (d = 0.46, h_1 = 0.65 m, h_2 = 1.25 m, O_T = 1.1 s).  
Mean-day Yes (d = 0.41, h_1 = 1.1 m, h_2 = 1.25 m, O_T = 2.8 s).  
Mean-night (4) Yes (d = 0.41, h_1 = 0.65 m, h_2 = 1.25 m, O_T = 1.8 s).

Notes:  
(1), (2), (3), (4) – refer to notes (1) – (4) respectively in Table A 9.  
Also refer to the general notes for Table A 9.

### Table A 11: Minimum EDD safe intersection sight distance and corresponding crest vertical curve size for sealed roads with level grades for the norm-day base case using an observation time of 2.5 seconds (m)

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Based on norm-day Safe Intersection Sight Distance (1)</th>
<th>R_T = 1.5 s</th>
<th>R_T = 2.0 s</th>
<th>R_T = 2.5 s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h_1 = 1.1 h_2 = 1.25 d = 0.46 (2) O_T = 2.5 s</td>
<td>SISD (m)</td>
<td>K</td>
<td>SISD (m)</td>
</tr>
<tr>
<td>40</td>
<td></td>
<td>58</td>
<td>3.6</td>
<td>64</td>
</tr>
<tr>
<td>50</td>
<td></td>
<td>77</td>
<td>6.3</td>
<td>84</td>
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<tr>
<td>60</td>
<td></td>
<td>97</td>
<td>10.1</td>
<td>106</td>
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<tr>
<td>70</td>
<td></td>
<td>120</td>
<td>15.3</td>
<td>129</td>
</tr>
<tr>
<td>80</td>
<td></td>
<td>144</td>
<td>22.0</td>
<td>155</td>
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<td>90</td>
<td></td>
<td>169</td>
<td>30.5</td>
<td>182</td>
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<td>197</td>
<td>41.2</td>
<td>211</td>
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<tr>
<td>110</td>
<td></td>
<td>226</td>
<td>54.3</td>
<td>241</td>
</tr>
<tr>
<td>120</td>
<td></td>
<td>-</td>
<td>-</td>
<td>273</td>
</tr>
<tr>
<td>130</td>
<td></td>
<td>-</td>
<td>-</td>
<td>307</td>
</tr>
</tbody>
</table>

Do all of the crest curve sizes listed provide acceptable car check case capability (3)  
Norm-night (4) Yes (d = 0.46, h_1 = 0.65 m, h_2 = 1.25 m, O_T = 1.5 s).  
Mean-day Yes (d = 0.41, h_1 = 1.1 m, h_2 = 1.25 m, O_T = 2.9 s).  
Mean-night (4) Yes (d = 0.41, h_1 = 0.65 m, h_2 = 1.25 m, O_T = 2.3 s)

Notes:  
(1), (2), (3), (4) – refer to notes (1) – (4) respectively in Table A 9.  
Also refer to the general notes for Table A 9.
Table A 12: Minimum EDD safe intersection sight distance and corresponding crest vertical curve size for sealed roads with level grades for the truck-day base case using an observation time of 1.5 seconds (m)

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Based on truck-day Safe Intersection Sight Distance (^{(1)})</th>
<th>( R_t = 1.5 ) s</th>
<th>( R_t = 2.0 ) s</th>
<th>( R_t = 2.5 ) s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( h_1 = 2.4 ) ( \ h_2 = 1.25 ) ( d = 0.29 ) (^{(2)})</td>
<td>SISD (m)</td>
<td>K</td>
<td>SISD (m)</td>
</tr>
<tr>
<td>40</td>
<td>55</td>
<td>2.1</td>
<td>61</td>
<td>2.6</td>
</tr>
<tr>
<td>50</td>
<td>76</td>
<td>4.0</td>
<td>83</td>
<td>4.8</td>
</tr>
<tr>
<td>60</td>
<td>99</td>
<td>6.9</td>
<td>107</td>
<td>8.1</td>
</tr>
<tr>
<td>70</td>
<td>125</td>
<td>11.0</td>
<td>135</td>
<td>12.7</td>
</tr>
<tr>
<td>80</td>
<td>154</td>
<td>16.6</td>
<td>165</td>
<td>19.1</td>
</tr>
<tr>
<td>90</td>
<td>185</td>
<td>24.0</td>
<td>197</td>
<td>27.4</td>
</tr>
<tr>
<td>100</td>
<td>219</td>
<td>33.7</td>
<td>233</td>
<td>38.1</td>
</tr>
<tr>
<td>110</td>
<td>256</td>
<td>46.0</td>
<td>271</td>
<td>51.7</td>
</tr>
</tbody>
</table>

Do all of the crest curve sizes listed provide acceptable truck-night check case capability \(^{(3)} \) \(^{(4)}\)? Yes \((d = 0.29, \ h_1 = 2.4 \text{ m}, \ h_2 = 0.8 \text{ m}, \ O_T = 0.7 \text{s})\).

Notes:
1. If the average grade over the braking length is not zero, calculate the safe intersection sight distance values using the correction factors in Table A 7 (or use Equation 2 in Section 3.2.2) by applying the average grade over the braking length.
2. On any horizontal curve with a side friction factor greater than the desirable maximum value for trucks, calculate the stopping sight distance with the coefficient of deceleration reduced by 0.05.
3. This part of the table identifies whether the crest curve sizes listed provide acceptable check case capability in accordance with Section A.2.5, Subsection ‘Application of the Check Cases’. The minimum capabilities listed for the check case assumes the same combination of design speeds and reaction times as those listed in the table.
4. Drivers will usually be alerted by the glow from the other vehicle’s headlights before seeing the vehicle.

Notes:
- Combinations of design speed and reaction times not shown in this table are generally not used.
- The crest vertical curve sizes are based on the sight distance being less than the length of crest curve.

Table A 13: Minimum EDD safe intersection sight distance and corresponding crest vertical curve size for sealed roads with level grades for the truck-day base case using an observation time of 2.0 seconds (m)

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Based on truck-day Safe Intersection Sight Distance (^{(1)})</th>
<th>( R_t = 1.5 ) s</th>
<th>( R_t = 2.0 ) s</th>
<th>( R_t = 2.5 ) s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( h_1 = 2.4 ) ( h_2 = 1.25 ) ( d = 0.29 ) (^{(2)})</td>
<td>SISD (m)</td>
<td>K</td>
<td>SISD (m)</td>
</tr>
<tr>
<td>40</td>
<td>61</td>
<td>2.6</td>
<td>66</td>
<td>3.1</td>
</tr>
<tr>
<td>50</td>
<td>83</td>
<td>4.8</td>
<td>89</td>
<td>5.6</td>
</tr>
<tr>
<td>60</td>
<td>107</td>
<td>8.1</td>
<td>116</td>
<td>9.4</td>
</tr>
<tr>
<td>70</td>
<td>135</td>
<td>12.7</td>
<td>144</td>
<td>14.6</td>
</tr>
<tr>
<td>80</td>
<td>165</td>
<td>19.1</td>
<td>176</td>
<td>21.7</td>
</tr>
<tr>
<td>90</td>
<td>197</td>
<td>27.4</td>
<td>210</td>
<td>31.0</td>
</tr>
<tr>
<td>100</td>
<td>233</td>
<td>38.1</td>
<td>247</td>
<td>42.8</td>
</tr>
<tr>
<td>110</td>
<td>271</td>
<td>51.7</td>
<td>286</td>
<td>57.7</td>
</tr>
</tbody>
</table>

Do all of the crest curve sizes listed provide acceptable truck-night check case capability \(^{(3)} \) \(^{(4)}\)? Yes \((d = 0.29, \ h_1 = 2.4 \text{ m}, \ h_2 = 0.8 \text{ m}, \ O_T = 1.1 \text{s})\).

Notes:
- \(1\), \(2\), \(3\), \(4\) – refer to notes \((1)\) – \((4)\) respectively in Table A 12.
- Also refer to the general notes for Table A 12.
### Table A 14: Minimum EDD safe intersection sight distance and corresponding crest vertical curve size for sealed roads with level grades for the truck-day base case using an observation time of 2.5 seconds (m)

<table>
<thead>
<tr>
<th>Design Speed (km/h)</th>
<th>Based on truck-day Safe Intersection Sight Distance (1)</th>
<th>SISD (m)</th>
<th>K</th>
<th>SISD (m)</th>
<th>K</th>
<th>SISD (m)</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$R_T = 1.5 \text{s}$</td>
<td>$h_1 = 2.4$</td>
<td>$h_2 = 1.25$</td>
<td>$d = 0.29$ (2)</td>
<td>$O_T = 2.5 \text{ s}$</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>66</td>
<td>3.1</td>
<td>72</td>
<td>3.6</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>89</td>
<td>5.6</td>
<td>96</td>
<td>6.5</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>116</td>
<td>9.4</td>
<td>124</td>
<td>10.8</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>70</td>
<td>144</td>
<td>14.6</td>
<td>154</td>
<td>16.7</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>80</td>
<td>176</td>
<td>21.7</td>
<td>187</td>
<td>24.5</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>90</td>
<td>210</td>
<td>31.0</td>
<td>222</td>
<td>34.8</td>
<td>235</td>
<td>38.8</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>247</td>
<td>42.8</td>
<td>261</td>
<td>47.8</td>
<td>275</td>
<td>53.0</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>286</td>
<td>57.7</td>
<td>302</td>
<td>64.0</td>
<td>317</td>
<td>70.6</td>
<td></td>
</tr>
</tbody>
</table>

Do all of the crest curve sizes listed provide acceptable truck-night check case capability (3)(4) Yes ($d = 0.29$, $h_1 = 2.4$ m, $h_2 = 0.8$ m, $O_T = 1.6$ s).

**Notes:**
(1), (2), (3), (4) – refer to notes (1) – (4) respectively in Table A 12.
Also refer to the general notes for Table A 12.

#### A.2.6 Sight Distance at Constrained Urban Intersections

The desirable criteria for signalised and unsignalised intersections are ASD and SISD (refer to Section 3.2.1 and Section 3.2.2 respectively). However, at some urban intersections where provision of ASD is not possible due to severe restrictions on sight lines it is necessary to ensure that stopping sight distance (SSD) can be provided to the tail lights of cars that may queue on the approach.

The stopping sight distance should be available to any point in the queue up to the back of the 95th percentile peak hour queue (Figure A 1) for:

- an approaching car, SSD measured from car driver eye height to tail-light (1.1 m to 0.8 m)
- an approaching truck measured from truck driver eye height to tail-light (2.4 m to 0.8 m).

![Figure A 1: Sight distance to back of the queue](image-url)
A.3 EDD for Sight Distance at Domestic Accesses

A.3.1 Application of EDD for Sight Distance at Domestic Accesses

EDD for sight distance at domestic accesses is calculated by the same process as that used for the NDD access sight distance. The main difference with EDD is that less conservative values are used for some of the terms where justified based on an acceptable level of driver capability being provided for entering and exiting drivers.

A domestic access is one that services three or less domestic units.

EDD for sight distance at domestic accesses is primarily for assessing the sight distance capability at existing accesses. However it can be applied to special cases of new work, for example:

- upgrading sight distance at existing accesses
- where a new access must be installed on an existing road and it is impractical to achieve the normal design domain criteria.

Under EDD for sight distance at domestic accesses, it is necessary to provide sufficient driver capability for cars and trucks stopping during daylight hours (norm-day and truck-day base cases respectively) as shown in Table A 1 (Section A.2.1 of this Appendix). These are the same conditions used for the NDD. In addition to these base cases, designers should ensure that adequate capability exists for any check case listed in Table A 1 that is deemed relevant. For example, sufficient capability for the night-time check cases will not be needed if the road has continuous route lighting. For borderline cases, the optional checks in Table A 1 may be used.

EDD sight distance at domestic accesses requires mandatory application of the following:

- EDD MGSD Apply in accordance with the NDD MGSD criteria, except use an object height of 1.25 m (top of a passenger car) instead of 0.65 m (indicator height).
- EDD SISD using an observation time (O_T) of 0.5 s less than the values given in Table A 8 of this appendix.
- EDD SSD. At all locations on a roadway, stopping sight distance to hazards is required. Refer criteria in Section A.3 of Appendix A of the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a).

Normally, the provision of ASD at domestic accesses is not necessary due to the familiarity of their location by users.

Application of EDD sight distance at domestic assesses is only applicable when crash data indicates that there are no sight distance related crashes.
A.4 EDD for Minor Road Approaches

If the desirable treatment shown in Figure 2.3 of this guide cannot be achieved then designers may consider using the minimum alignment treatment shown in Figure A.2.

![Diagram of minimum minor road approach alignment at rural sites](Source: Austroads (2005).)

Figure A 2: Minimum minor road approach alignment at rural sites

A.5 EDD for Intersection Turn Treatments

A.5.1 Intent of EDD Turn Treatments

The intent of using the EDD turn treatments in this section is to maximise the use of channelised right-turn (CHR) and auxiliary left-turn (AUL) treatments at existing intersections in order to improve safety. Arndt (2004) has shown that these turn types are considerably safer than other types of turn treatments, namely BAR, AUR and BAL. This is especially true for the right-turn treatments.

In some situations, the EDD turn treatments may be used to justify retaining existing geometry.

A.5.2 Use of EDD Turn Treatments

This guide presents EDD dimensions for CHR and AUL turn treatments that are smaller than the minimums used for the NDD (i.e. those used for a new intersection in a greenfield site). In general, these treatments are intended to replace lower order turn types (e.g. linemarking an existing AUR turn treatment to form a CHR turn treatment). The EDD dimensions have been found to operate effectively in practice, providing a higher level of safety than any of the lower order treatments.

The treatments shown in this guide are predominantly for application to existing intersections, where sufficient area of pavement exists for them to be incorporated. Sometimes, they may be applied as new construction at existing intersections, where insufficient length is available to introduce a turn-slot with dimensions as per the NDD.
A.5.3 General Considerations

The use of the EDD turn treatments can only be justified provided they meet the following conditions:

- They are not combined with other minima such as:
  - very tight horizontal curves (e.g. horizontal curves with a side friction demand near or greater than the absolute maximum)
  - reduced visibility to the treatment (e.g. smaller to moderate size crest curves)
  - major road on a steep downgrade.
- Future arrangements/planning must be satisfied (e.g. allow for future traffic growth, which may well affect storage lengths).
- Geometric features and other features of the road do not distract drivers.
- For existing layouts meeting the EDD criteria, the crash data indicates that there is not a high crash rate related to the use of the shorter dimensions e.g. not a high rear-end crash rate at the start of the turn lanes.
- The length of left and right turn bays should not be restricted to the minimum length if there is little difficulty in making them longer and the demand warrants the treatment.

A.5.4 Minimum EDD Channelised Right-turn Treatment for Two-lane Two-way Roadways without Medians

Figure A 3 shows a minimum EDD channelised right-turn treatment for two-lane, two-way roadways without medians.

The primary intent of this treatment is to enable an AUR turn treatment to be linemarked as a CHR turn treatment. This is only possible if full depth pavement exists under the original auxiliary lane and, if required, the shoulder. In this treatment, the through road deviates by the width of the turn lane. The dimensions of the lateral movement length ‘A’ are deemed suitable for horizontal straights and larger radius horizontal curves. On smaller curves, ‘A’ will need to be increased above the lengths given in Figure A 3 so that the resulting alignment of the through lane means that a minimal decrease in speed is required for through drivers. To determine whether a minimal decrease in speed is achieved, draw vehicle paths along the through road for the proposed layout and use the operating speed model to calculate the operating speed on each segment. Table A 15 provides dimensions for various terms listed in Figure A 3.
Notes:
1. Diagram shown for a rural intersection layout. The dimensions shown are also suitable for an urban intersection layout which may include bicycle lanes and parking.
2. The dimensions of the treatment are defined as follows. Values of A, R and T are provided in Table A 15.

- \( W \) = Nominal through lane width (m), including widening for curves.
- \( W_T \) = Nominal width of turn lane (m), including widening for curves based on the design turning vehicle = 2.8 m minimum.
- \( E \) = Distance from start of taper to 2.0 m width (m) = \( \frac{2A}{W_T} \)
- \( S \) = Storage length (m) is the greater of:
  a. the length of one design turning vehicle
  b. (calculated car spaces –1) x 8 m (Guide to Traffic Management – Part 3: Traffic Studies and Analysis (Austroads 2009h), or use computer program e.g. asSIDRA).
- \( T \) = Physical taper length given by:

\[
T = \frac{0.2VW_T}{3.6}
\]

- \( V \) = Design speed of major road approach (km/h).
- \( X \) = Distance based on design vehicle turning path, typically 10 m to 15 m.

Figure A 3: Minimum extended design domain channelised right-turn treatment for two-lane, two-way roadways without medians

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Minimum lateral movement length A (m) (^{(1)})</th>
<th>Desirable radius R (m)</th>
<th>Taper length, T (^{(2)}) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>40 (^{(3)})</td>
<td>175</td>
<td>10</td>
</tr>
<tr>
<td>70</td>
<td>50 (^{(3)})</td>
<td>240</td>
<td>15</td>
</tr>
<tr>
<td>80</td>
<td>55 (^{(3)})</td>
<td>280</td>
<td>15</td>
</tr>
<tr>
<td>90</td>
<td>60</td>
<td>350</td>
<td>15</td>
</tr>
<tr>
<td>100</td>
<td>70</td>
<td>425</td>
<td>20</td>
</tr>
<tr>
<td>110</td>
<td>75</td>
<td>500</td>
<td>20</td>
</tr>
<tr>
<td>120</td>
<td>80</td>
<td>600</td>
<td>20</td>
</tr>
</tbody>
</table>

1. Based on a diverge rate of 1.25 m/s and a turn lane width of 3.0 m. Increase lateral movement length if turn lane width >3 m. If the through road is on a tight horizontal curve (eg one with a side friction demand greater than the maximum desirable) increase lateral movement length so that a minimal decrease in speed is required for the through movement.
2. Based on turn lane width of 3 m.
3. Where Type 2 road trains are required, minimum \( A = 60 \) m.

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A.5.5 Minimum EDD Channelised Right-turn Treatment for Roadways with Medians

Figure A 4 shows a minimum EDD channelised right-turn treatment for roadways with medians.

This treatment can be used at intersections on existing roads where sufficient area of pavement already exists to introduce a right-turn slot. Alternatively, the treatment may be applied as new construction at existing intersections where insufficient length is available to introduce a right-turn slot with dimensions as per the NDD.

Table A 16 provides dimensions for various terms listed in Figure A 4.

![Diagram of Minimum EDD Channelised Right-turn Treatment for Roadways with Medians](image)

Notes:

1. Variables are defined thus:
   - \(W\) = Nominal through lane width (m), including widening for curves.
   - \(W_T\) = Nominal width of turn lane (m), including widening for curves based on the design turning vehicle = 2.8 m minimum.
   - \(B\) = Total length of auxiliary lane (m), including taper, diverge/acceleration and storage.
   - \(S\) = Storage length (m), greater of:
     - (a) the length of one design turning vehicle or
     - (b) (calculated car spaces –1) x 8 m (refer to Austroads Guide to Traffic Management – Part 3: Traffic Studies and Analysis (Austroads 2009h), or use computer program e.g. asSIDRA).
   - \(T\) = \(\frac{0.2VW_T}{3.6}\)
     - \(T\) = Physical taper length
   - \(V\) = Design speed of major road approach (km/h).
   - \(X\) = Distance based on design vehicle turning path, typically 10 m to 15 m.
2. Values of \(D\) and \(T\) are shown in Table A 16.
3. Diagram shown for an urban intersection layout. The dimensions shown are also suitable for a rural intersection layout.

**Figure A 4:** Minimum extended design domain channelised right-turn treatment for roadways with medians
Table A 16: Dimensions relating to Figure A 4

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Minimum diverge / deceleration length D$^{(1)}$ (m)</th>
<th>Taper length T$^{(2)}$ (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>60</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>70</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>80</td>
<td>35</td>
<td>15</td>
</tr>
<tr>
<td>90</td>
<td>45</td>
<td>15</td>
</tr>
<tr>
<td>100</td>
<td>55</td>
<td>20</td>
</tr>
<tr>
<td>110</td>
<td>65</td>
<td>20</td>
</tr>
<tr>
<td>120</td>
<td>80</td>
<td>20</td>
</tr>
</tbody>
</table>

1. Based on a 30% reduction in through road speed at the start of the taper to a stopped condition using a value of deceleration of 3.5 m/s². Adjust for grade by
   • decreasing length D by 10% for upgrades of 3 to 4% and by 20% for upgrades of 5 to 6%
   • increasing length D by 20% for downgrades of 3 to 4% and by 35% for downgrades of 5 to 6%.

2. Based on a turn lane width of 3.0 m.

**A.5.6 Minimum EDD Auxiliary Left-turn Treatment**

Figure A 5 shows a minimum EDD auxiliary left-turn treatment. This treatment can be used at intersections on existing roads where sufficient area of pavement already exists to introduce an indented left-turn lane. Alternatively, the treatment may be applied as new construction at existing intersections where insufficient length is available to introduce a left-turn lane with dimensions as per the NDD.

Table A 17 provides dimensions for various terms listed in Figure A 5.
Notes:

1. Variables are defined thus:
   \[ W = \text{Nominal through lane width (m), including widening for curves.} \]
   \[ W_T = \text{Nominal width of turn lane (m), including widening for curves based on the design turning vehicle = 2.8 m minimum.} \]
   \[ W_B = \text{Appropriate width of bicycle lane for operating speed.} \]
   \[ T = \frac{0.2VW_f}{3.6} \]
   \[ T = \text{Physical taper length} \]
   \[ V = \text{Design speed of major road approach (km/h).} \]

2. Values of D and T are shown in Table A 17.

3. Diagram shown for a rural intersection layout. The dimensions shown are also suitable for an urban intersection layout, except that the shoulder width criterion does not apply and kerbs are provided.

4. Approaches to left-turn slip lanes can create hazardous situations between cyclists and left-turning motor vehicles. Figure 8.6 shows a treatment that may be provided to reduce the number of potential conflicts at left-turn slip lanes.

Figure A 5: Minimum extended design domain auxiliary left-turn treatment
Table A 17: Dimensions relating to Figure A 4

<table>
<thead>
<tr>
<th>Design speed of major road approach (km/h)</th>
<th>Minimum diverge/deceleration length D(1) (m)</th>
<th>Taper length T(2) (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>15</td>
<td>10</td>
</tr>
<tr>
<td>60</td>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>70</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>80</td>
<td>35</td>
<td>15</td>
</tr>
<tr>
<td>90</td>
<td>45</td>
<td>15</td>
</tr>
<tr>
<td>100</td>
<td>55</td>
<td>20</td>
</tr>
<tr>
<td>110</td>
<td>65</td>
<td>20</td>
</tr>
<tr>
<td>120</td>
<td>80</td>
<td>20</td>
</tr>
</tbody>
</table>

1. Based on a 30% reduction in through road speed at the start of the taper to a stopped condition using a value of deceleration of 3.5 m/s².
2. Adjust for grade by:
   - decreasing length D by 10% for upgrades of 3 to 4% and by 20% for upgrades of 5 to 6%.
   - increasing length D by 20% for downgrades of 3 to 4% and by 35% for downgrades of 5 to 6%.

Note: Based on a turn lane width of 3.0 m.

A.6 EDD Treatment of a Constrained Left-turn Radius

In some situations it may be necessary to adopt a multiple radii return to avoid an expensive design control (e.g. telecommunications pit). In such cases in a low-speed environment it may be acceptable to adopt a multiple radius curve which consists of compound circular arcs having two or three radii. Figure A 6 illustrates how a two centred curve may be advantageous in avoiding physical restrictions, such as utilities in the footway. This treatment is most effective for acute angle turns.

The width of the traffic lane being entered should be large enough to enable a vehicle following the projection of the larger radius to remain on the correct side of the centre line.

![Figure A 6: Use of compound curves to avoid expensive relocation of an obstruction](image.png)

Source: Austroads (2005).
A.7 EDD for Existing Channelised Four-way Intersection – Right-turn CHR

It is undesirable to build new four-way unsignalised intersections in rural situations. However, many four-way rural unsignalised intersections exist. At some of these intersections, traffic volumes and other considerations may dictate the need to retrofit CHR(S) or CHR turn treatments.

There are various options for applying the through lane deviation to retrofit these turn treatments at four-way intersections. Some of these options are shown in Figure A 7 for a CHR(S) turn treatment) and Figure A 8 for a CHR turn treatment. The deviation can be fully on one side of the intersection, as shown in the two upper diagrams in these figures, or partly on each side, as shown in the lower diagram of these figures. Site details will generally dictate which option is the best.

The layouts shown in Figure A 7 and Figure A 8 may also be applicable to existing four-way urban intersections, except that the intersection will usually be kerbed and parking lanes (rather than shoulders) may exist on the intersection approaches and departures.

The definition of the notated dimensions and the key features of Figure A 7 and Figure A 8 are the same as those that relate to the T-intersections shown in Figure 7.6 and Figure 7.7 respectively.
Note: Refer to Figure 7.7 for the dimensions labelled in these diagrams.

Figure A 7: Retrofitting CHR(S) treatments to a rural four-way intersection
Note: Refer to Figure 7.7 for the dimensions labelled in these diagrams.

Figure A 8: Retrofitting CHR treatments to a rural four-way intersection
A.8  EDD for Median Widths

Table A 18 provides EDD median widths for intersections for various median functions.

Table A 18:  EDD median widths at intersections

<table>
<thead>
<tr>
<th>Median function</th>
<th>Absolute minimum width (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Separate traffic flows and a safety barrier†</td>
<td>1.9</td>
</tr>
<tr>
<td>Shelter a small sign</td>
<td>1.0</td>
</tr>
<tr>
<td>Shelter signal pedestals or lighting poles</td>
<td>1.4</td>
</tr>
<tr>
<td>Shelter pedestrians and traffic signals</td>
<td>2.0</td>
</tr>
<tr>
<td>Shelter turning vehicles and traffic signals</td>
<td>5.0</td>
</tr>
<tr>
<td>Shelter crossing vehicles</td>
<td>6.0</td>
</tr>
</tbody>
</table>

Note: Widths measured to edge of traffic lane for concrete barriers, as there is no kerb and channel associated with concrete barriers. Other widths are measured to line of kerb.

A.9  Adverse Crossfall for Turning Movements

Crossfall, particularly in conjunction with a longitudinal grade can be problematic for heavy vehicles turning at an intersection. Where speeds on the approach to an intersection are low, turning speeds are very low (i.e. \( \leq 10 \text{ km/h} \)), and it is not possible to achieve a crossfall within desirable limits (Section 2.2.4) an absolute maximum adverse crossfall up to -7% may be considered. In this situation traffic management devices such as appropriate warning signs may be required on the approach.
APPENDIX B  CRASH TYPES AT UNSIGNALISED INTERSECTIONS

B.1  Australian Study

Arndt (2004) is a study of the effect of unsignalised intersection geometry on crash rates. This appendix lists the various crash types used in the study, which are referenced in the body of the chapter.

A total of 1091 crashes were recorded for the 206 intersections in the study. An analysis period of five years was selected for the majority of the intersections, with a period of 10 years for several lower volume intersections.

The sample generally included crashes within 200 m of each intersection but excluded crashes at nearby intersections or other features. The crashes were classified as shown in Table B 1. Diagrams of the high-frequency and low-frequency intersection crash types are shown in Figure B 1 and Figure B 2 respectively.

Intersection crashes are those where the physical presence of the intersection directly influenced the crash. Through crashes are those where the intersection did not directly influence the crash.
### Table B 1: Accident categories in Arndt (2004)

<table>
<thead>
<tr>
<th>Broad accident category</th>
<th>Major accident type</th>
<th>General accident description</th>
<th>No.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High frequency intersection accidents</strong></td>
<td></td>
<td></td>
<td></td>
<td>694</td>
</tr>
<tr>
<td></td>
<td>Angle-minor</td>
<td>A vehicle on the minor road fails to give way and collides with a vehicle on the major road.</td>
<td>466</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rear-end-major</td>
<td>A through vehicle on the major road collides with a turning vehicle on the major road.</td>
<td>121</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Angle-major</td>
<td>A right-turning vehicle on the major road collides with an oncoming major road vehicle.</td>
<td>107</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rear-end-minor</td>
<td>A vehicle on the minor road runs into another vehicle on the minor road.</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single-minor-turn</td>
<td>A vehicle turning from the minor road loses control.</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single-major-turn</td>
<td>A vehicle turning from the major road loses control.</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Incorrect turn</td>
<td>A vehicle undertakes an incorrect turn at the intersection and collides with another vehicle.</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overtaking-intersection</td>
<td>An overtaking major road vehicle collides with a right-turning major road vehicle.</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Sideswipe-major- auxiliary</td>
<td>A major road vehicle moves from a deceleration lane and collides with another major road vehicle.</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
<td>8</td>
<td></td>
</tr>
<tr>
<td><strong>Low frequency intersection accidents</strong></td>
<td></td>
<td></td>
<td></td>
<td>109</td>
</tr>
<tr>
<td></td>
<td>High frequency through accidents</td>
<td>A through vehicle loses control and is involved in a single vehicle accident.</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td></td>
<td>Single-through</td>
<td></td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td></td>
<td>Head-on</td>
<td>A through vehicle loses control and collides with an oncoming vehicle.</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pedestrian</td>
<td>A vehicle collides with a pedestrian or cyclist crossing the road.</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td></td>
<td>U-turn</td>
<td>A vehicle undertaking a U-turn (not at the intersection) collides with another vehicle.</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changed lanes</td>
<td>An accident resulting from an unsafe lane change.</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Single-object</td>
<td>A vehicle collides with or avoids an object or animal.</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Overtaking</td>
<td>An accident resulting from unsafe overtaking.</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td></td>
<td>10</td>
<td></td>
</tr>
<tr>
<td><strong>Low frequency through accidents</strong></td>
<td></td>
<td></td>
<td></td>
<td>121</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>1091</td>
<td></td>
</tr>
</tbody>
</table>

Note: The term ‘accident’ has been used instead of ‘crash’ in order to be consistent with the terminology used in Arndt (2004).
B.2 New Zealand Study

Substantial research has also been undertaken in New Zealand in the modelling of crashes at different types of intersections. In the first instance practitioners are referred to a paper entitled *Crash prediction modelling down-under: Some key findings* that provides information on various types of intersections (Turner & Wood 2009).
APPENDIX C TRUCK STABILITY AT INTERSECTIONS

C.1 Introduction

Truck stability is an important consideration in design because the rolling over of trucks or the loss of loads can have serious safety issues for road users in addition to the delays and costs to the community.

As discussed in Section 2.2.4 adverse crossfall within an intersection can lead to instability for heavy vehicles, particularly those with high loads. This Appendix discusses the parameters associated with truck stability in design and provides a table of critical truck turning speeds as a function of radius and superelevation. The source of the information is the VicRoads Road Design Guidelines – Part 2: Horizontal and Vertical Geometry (Appendix 2.4B and 2.4C).

C.2 Lateral Friction Force on Vehicles

Depending on the circumstances at a site a truck turning at a particular speed can slide on the road surface or tend to overturn. On wet surfaces, trucks tend to lose stability by sliding. On dry, low radius curves, high trucks are more likely to roll which is sometimes an issue at intersections.

When a truck travels around a curve that has no superelevation (i.e. a flat surface) sufficient lateral friction usually develops at the tyre/road interface to force the truck to turn in a circular path. Without this force, the truck would travel in a straight line and Equation 7 in Section C.3 describes this condition.

For design purposes, friction factors have to be defined which are less than the maximum at which vehicles lose control. The side friction factors (i.e. lateral) that should be used in design are discussed and provided in Section 7.6 of the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a).

Some friction factors for cars and trucks on sealed roads are shown in Figure C1. It is emphasised that these lateral friction factors were calculated from field measurements of 85th percentile speeds and superelevation on dry sealed rural roads. These friction factors are therefore more a measure of the 85th percentile driver comfort level than of the friction developed at the tyre/road interface. This information is therefore provided only to assist discussion on heavy vehicle stability and should not be used for design purposes.

Figure C1 specifies the lateral friction which is being utilised when truck instability is imminent. In most cases it is not necessary to know whether this instability is caused by sliding or by rolling.

If, for analysis purposes, the moving truck is deemed to be a static point mass located at the centre of mass and the horizontal component of the force at the tyre/road interface is \( F = mv^2/R \), there is a moment at which the truck tends to overturn as illustrated in Figure C2.
Notes:
1. Car friction factors.
   (a) Car friction factors apply also to small single unit trucks.
   (b) Friction factors from A to B are based on measured speeds on roundabouts.
   (c) The figures from B to C are based on measurements reported in McLean.
2. High truck friction factors
3. Point D was fixed to permit a maximum speed of 15 km/h on a 15 m radius curve as shown on AUSTROADS turning templates (E = -0.05 assumed).
4. Points E and F are based on the rollover threshold for a large truck with homogeneous load. (See Table C 1).
5. Points G and H were fixed to provide radii consistent with car requirements at 100 km/h taking into account the speed differential between car speeds and truck speeds.

Source: VicRoads Road Design Guidelines – Part 2: Horizontal and Vertical Geometry (Appendix 2.4B).

**Figure C 1:** Variation of friction factors with speed

Source: VicRoads Road Design Guidelines – Part 2: Horizontal and Vertical Geometry (Appendix 2.4B).

**Figure C 2:** Overturning moment on a turning truck

Source: VicRoads Road Design Guidelines – Part 2: Horizontal and Vertical Geometry (Appendix 2.4B).
### C.3 Other Factors that Affect Truck Stability

Other effects which tend to reduce the stability of trucks include:

- Adverse superelevation which reduces the horizontal distance between the centre of gravity and the hinge point.
- The dynamic affects associated with wheel bounce tend to reduce the stability of trucks on curves.
- The rigidity of the fifth wheel linkage between the prime mover and the trailer on articulated vehicles directly affects the stability of the rig.
- The changes in geometry which occur on low radius curves.

When these factors are taken into account, the critical lateral acceleration (also known as the rollover threshold) at which instability occurs for a large vehicle with a homogeneous load is approximately 0.24 g. Critical lateral accelerations for other vehicle body types on level surfaces are shown on Table C 2.

#### Table C 2: Stability parameters for trucks

<table>
<thead>
<tr>
<th>Loading</th>
<th>Rollover Threshold</th>
<th>Centre of gravity height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Homogenous load</td>
<td>0.24g</td>
<td>2.67 m</td>
</tr>
<tr>
<td>30% load</td>
<td>0.28g</td>
<td>2.41 m</td>
</tr>
<tr>
<td>70% load</td>
<td>0.34g</td>
<td>2.12 m</td>
</tr>
<tr>
<td>Full gross</td>
<td>0.32g</td>
<td>2.25 m</td>
</tr>
<tr>
<td></td>
<td>0.26g</td>
<td>2.54 m</td>
</tr>
</tbody>
</table>

Source: Ervin et al.

Equation 7 shows that the lateral friction developed at the tyre/road interface as vehicles turn is directly related to the square of the vehicle speed. A speed can be reached at which the force required to maintain a circular path exceeds the force which can be developed by friction and superelevation. At this point, the vehicle starts to slide tangentially to the alignment of the road.

\[
E + F = \frac{v^2}{gR}
\]

\[
E + F = \frac{a}{g}
\]

On flat surfaces, \( E = 0 \) and therefore \( F = \frac{a}{g} \) (special case).

But as the critical lateral acceleration ‘a’ = 0.24 g from Figure C 1 and \( F = 0.24 \).

This shows that the numeral before g in the rollover thresholds in Table C 2 can be construed as a friction factor at which the vehicle is likely to overturn. This value of F fixes the upper limit to friction factors for trucks on Figure C 1. Variations from this limit occur at speeds above 50 km/h and speeds below 30 km/h.
The reduction in friction factors above 50 km/h are consistent with observed operating speeds in the field, that is, truck speeds should be approximately 10 km/h below cars speeds. This speed range above 50 km/h is also the range where instability is generally initiated by sliding.

The deviation from the friction factor of 0.24 value below 30 km/h is necessary to match limiting speeds shown on the AUSTROADS truck turning templates (Austroads 2006). In the speed range involved, curve radii are sufficiently low to influence the geometry of articulated vehicles and this effect could explain the low stability of trucks at low speeds.

Use of the truck friction factors in Figure C.1 provides for the majority of trucks. There have been some trucks which have rolled at lower friction factors. Rollovers at low speed can be initiated by a range of factors including:

- **Tripping.** Vehicles sliding sideways can overturn at speeds below 10 km/h when tripped by a kerb or pothole. For this reason road surfaces must be kept in good condition where critical turning movements occur.

- **Loading.** Small lateral offsets of the centre of gravity of the load significantly reduce the lateral stability of the truck. Uneven longitudinal loading also reduces the vehicle’s stability.

- **Load shift.** As for example liquid in tankers or cattle on high trucks.

- **Dynamic forces.** Associated with tyre and suspension bounce. These forces are related to the speed of the vehicle and the condition of the pavement.

- **Aquaplaning.** Leading to loss of control and rollover.

- **Braking.** As the brakes are applied, the friction available in the radial direction decreases. If the wheels lock, lateral stability and steering is lost.

- **Rearward amplification.** A ‘whiplash’ effect; specifically it is the ratio of the maximum lateral acceleration at the rear axle over the lateral acceleration on the prime mover.

- **Speed.** The indications are that critical lateral accelerations (or friction forces) are speed-dependent as shown by Figure C.1.

## C.4 Critical Turning Speeds for Trucks in Intersections

Turning paths within intersections are designed using turning templates for the appropriate design vehicle. Once the turning paths have been established, the minimum crossfall (or maximum adverse crossfall) may be calculated for each turning path. Critical speeds for high trucks (i.e. speeds at which the least stable are at the point of overturning) can then be obtained from Table C.3. The least stable truck in was used as a basis for design friction factors for the critical turning radii. The source of the table is VicRoads Road Design Guidelines – Part 2: Horizontal and Vertical Geometry (Appendix 2.4C).
### Table C 3: Critical truck turning speeds

<table>
<thead>
<tr>
<th>Radius (m)</th>
<th>Critical speeds for high trucks within intersections (km/h)</th>
<th></th>
<th>Negative superelevation (i.e. adverse)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positive superelevation (m/m)</td>
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<td>-0.01</td>
<td>-0.02</td>
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<tr>
<td>0.07</td>
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<td>Negative superelevation (i.e. adverse)</td>
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APPENDIX D

SET-OUT DETAILS FOR A HIGH ENTRY ANGLE CHL

D.1 Introduction
Road authorities apply similar principles to design left turn islands with respect to observation angles and the application of swept paths templates for a design vehicle. However, the detailed approach to the design can vary between road authorities. This Appendix describes a layout design process for setting out a simple high entry angle left-turn island and also presents alternative design layouts used by road authorities.

D.2 Simple High Entry Angle Design Process
This section describes a process for deriving the minimum size required for a high entry angle left-turn treatment from first principles. A basic requirement is that the designer has a clear understanding of the facilities and users that have to be accommodated by the island. The example in Figure D.1 is based on accommodating pedestrian marked foot crossings and signal hardware and signs in a position where they are less likely to be damaged by vehicles. The parallel offset to the island on the approach to the stop line is to provide an informal space for cyclists.

Figure D.1: Set-out details for a high entry-angle CHL with no bicycle lane on the approach
The various dimensions shown in Figure D 1 are used to determine the size and shape of the island which can be set out graphically or computed. The various dimensions are:

\[ L_A = \text{Length of the island on the intersection approach from the edge of the traffic lane on the intersecting road to the nose of the island.} \]

\[ L_I = \text{Length of the island on the intersecting road departure from the edge of the traffic lane on the approach to the edge of traffic lane in the left-turn slip lane.} \]

\[ O_I = \text{Offset from median nose to the edge of the traffic lane in the intersecting road or to the tangent point on } R_I \text{ where there is no median. Desirable offset is 0.5 m to 1.0 but may have to be greater to accommodate a design vehicle swept path into the road.} \]

\[ C_X = \text{Clearance between the nose of the median and the pedestrian crosswalk line.} \]

\[ W_P = \text{Width of the pedestrian crosswalk, minimum 2.0 m (AS 1742.2), generally 2.4 m – 3.0 m.} \]

\[ C_S = \text{Clearance between stop line and pedestrian crosswalk line, generally 1.2 m, minimum 0.8 m.} \]

\[ O_A = \text{Offset from median nose to the edge of the traffic lane on the approach road. Generally 1.0 m for urban islands. However, some jurisdictions prefer to use 0.2 m per 10 km/h of approach speed (e.g. for approach speed of 60 km/h, } O_A = 1.2 \text{ m); Exception: for 80 km/h use 2.0 m.} \]

\[ R_I = \text{Radius of leading nose on left-turn island. Desirable minimum 0.5 m to 1.0 m.} \]

\[ W_M = \text{Width of median on approach.} \]

\[ R_M = \text{Radius of median nose adjacent to intersecting road.} \]

\[ A = \text{Distance that is a function of } L_A \text{ and the angle of intersection of the left-turn slip lane.} \]

\[ B = \text{Distance that is a function of approach nose offsets and the diameter of the approach nose (i.e. } 2 \times R_M). \]

The procedure for setting out the island is to:

- Use the intersection point of the edge lines on the approach road and intersecting road as a reference point as shown in Figure D 1.

- Starting at the intersection point plot the distances \( O_I + C_X + W_P + 6.0 \) along the edge of traffic lane on the approach. The 6.0 m is a nominal distance (one car storage length) from the stop line to the tangent point of the approach nose to ensure that signal hardware is set back from the nose which can be a vulnerable area for road furniture.

- Locate point 1 by marking the distances \( O_A, 2 \times R_M \), and the 1.0 m offset.

- Draw a line through point 1 so that the edge line of the left-turn slip lane intersects the intersecting road at 70°.
• Check to ensure that $L_A$ is sufficient to accommodate the pedestrian crosswalk and results in an island large enough to accommodate any other necessary road furniture.

It can be seen that:

• $L_A = (O_I + C_X + W_P + C_S + 6.0)$
• $L_I = A + B = (L_A - R_I) \tan 20^\circ + (O_A + 2 \times R_I + 1.0)$ m.

**Example:**
Assuming that the approach speed is 60 km/h and that the median is 2.0 m wide to accommodate traffic signal hardware, in which case $C_X = R_M = 1.0$ m and $O_A = 0.2 \times 60/10 = 1.2$ m, and:

$L_A = (O_I + C_X + W_P + C_S + 6.0)$

$= (1.0 + 1.0 + 2.4 + 1.2 + 6.0)$

$= 11.6$ m

$L_I = A + B = (L_A) \tan 20^\circ + (O_A + 2 \times R_I + 1.0)$ m

$= 11.6 \times 0.364 + (1.2 + 2.0 + 1.0)$

$= 4.2 + 4.2$

$= 8.4$ m

Knowing the distances $L_I$ and $L_A$, and the various offsets, the raised island can be designed within the painted outline that has been defined through the process.

Figure D2 illustrates a high entry angle left-turn treatment with bicycle lanes on both intersecting roads at a signalised intersection. A similar procedure to that described previously can be used to set out the island and compute its size.

The bicycle lanes provided adjacent to high entry angle left-turn islands also perform the function of an offset to the leading noses of the island. This results in the sides of the island being parallel to the traffic lanes, with the advantage that kerb ramps are at right angles to the crosswalks.
Notes:
1. A head start treatment may be provided for cyclists as illustrated and where provided CS should be 2.0 m.

Figure D 2: Set-out details for a high entry angle CHL with a bicycle lane on the approach

D.3 Alternative Layout Designs
This section presents alternative layout arrangements

D.3.1 Alternative A
The method shown in Figure D 1 and Figure D 2 are from the Austroads Guide to Traffic Engineering Practice – Part 5: Intersections At-Grade (NAASRA 1988) and is preferred by designers in some road authorities.
**Alternative A1 – High-entry angle CHL turn treatment**

This high entry angle treatment should be regarded as the minimum treatment. Where approach speeds are higher (≥ 80 km/h) increased island length should be considered to improve island conspicuity.

![Diagram of High-entry angle CHL turn treatment](image)

**NOTES**

1. $A^\circ = 70^\circ$ desirably to enhance stand-up angle for give way condition.
2. $W = 4.5\text{m}$, unless a greater width is required for turning trucks.
3. $\star$ – offset of 0.2 m per 10 km/h of approach speed.
4. Kerbing to be semi-mountable. Barrier kerb should generally not be used.
5. The radius of the left turn approach curve should be at least 4 times greater than that of the departure curve.
6. The only benefit in increasing the island dimensions above those shown would be in rural areas where island conspicuity would be a consideration.

For left turn lane and taper treatment see Figure 5.18

Note: Reference in this figure relates to source document


**Figure D 3:** High-entry angle CHL turn treatment – alternative A1
Alternative A2 – CHL turn treatment with acceleration lane

The free-flow treatment provides an acceleration lane for traffic entering the intersecting road and may have an auxiliary lane on the approach to the treatment.

![Diagram of CHL turn treatment with acceleration lane]

**NOTES**
- Radius of turn ($R_t$) based on desirable speed of left turn of 80% (50% min.) of through road speed. A radius of 50m should be regarded as an absolute minimum value in high speed rural areas.
- The departure nose should always be located adjacent to the shift point.
- $W$ – width of turn lane. See para 5.6.5 and Table 5.4
  - where the radius $R_t \geq 100m$, the left hand kerb of the turning roadway may be deleted in which case a width sufficient for single lane flow ($W_t$ – from Table 5.4 and preferably in a sealed shoulder 1.0 to 1.5m wide) should be provided.
- $\#$ – 4.6m width at departure nose for single lane flow, or 7.0m for two lane flow. Where outer kerb is not provided these widths may be reduced slightly.
- $R_n$ – the radius of the turning roadway;
- $R_0$ – a curve of radius appropriate to achieve the width at the departure nose. Typically $R_0 = 3R_t$ where the road being entered has a straight alignment.
- $R_n = R_t + W$
- $S$ – shift distance between the curve of radius $R_t$ and the outer edge of the acceleration lane ($S = 3.0m$ for acceleration lane width of 3.5m)
- $\#$ – offset of 0.2m per 10 km/h of approach speed.
- All dimensions are in metres

Note: Reference in this figure relates to source document


**Figure D4**: CHL turn treatment with acceleration lane – alternative A2

**D.3.2 Alternative B**

The methods shown in this section are from the Guide to Traffic Engineering Practice – Part 5: Intersections At-Grade (Austroads 2005) and is preferred by some road authorities.
Alternative B1 – High-entry angle CHL turn treatment – urban


Figure D 5: High-entry angle CHL turn treatment for an urban site – alternative B1
Alternative B2 – CHL turn treatment with acceleration lane – urban

Figure D 6: CHL turn treatment with acceleration lane for an urban site – alternative B2
Alternative B3 – High-entry angle CHL turn treatment – rural

NOTES:
(c) - start of departure taper
(d) - end of departure taper

<table>
<thead>
<tr>
<th>Ø</th>
<th>70°</th>
<th>90°</th>
</tr>
</thead>
<tbody>
<tr>
<td>$O_1$</td>
<td>6.0</td>
<td>6.5</td>
</tr>
<tr>
<td>$R_1$</td>
<td>17</td>
<td>15</td>
</tr>
</tbody>
</table>

Offset between edge line and island widened from 0.3m min to 1.5m to allow for B-double turning path.

Minimum area of island - 50m²

# Lane width 3.0 to 3.5m

Auxiliary Lane refer to Section 6.8


Figure D 7: High entry angle CHL turn treatment for a rural site – Alternative B3
Alternative B4 – CHL turn treatment with acceleration lane – rural


Figure D 8: CHL turn treatment with acceleration lane for a rural site – alternative B4
APPENDIX E  SWEPT PATHS FOR ROAD TRAINS AT HIGH ENTRY ANGLE LEFT-TURN TREATMENTS

E.1  Introduction
This appendix contains illustrations of the left-turning paths necessary for road trains at ‘normal’ and ‘alternative’ high entry angle left-turn treatments illustrated in Figure 8.16 and Figure 8.17 of this guide.

E.2  Swept Paths for Examples in Figure 8.16 and 8.17.

E.2.1  Normal Treatment

Note: This treatment is shown for an urban site. A similar layout is also applicable to rural sites.


Figure E 1:  Swept path provisions for road trains at channelised left-turns – normal treatment
E.2.2 Alternative Treatment

Notes:
1. This treatment is shown for an urban site. A similar layout is also applicable to rural sites.
2. To be used for sites where there is a high volume of large single unit trucks and prime mover and semi-trailer combinations.

Figure E 2: Swept path provisions for road trains at channelised left-turns – alternative treatment

E.3 Detailed Examples from Main Roads Western Australia

The following examples are from Main Roads Western Australia Guideline Drawing number 200031-0015-4. They are provided for general guidance only as the details within figures may not be applicable in other jurisdictions.
Figure E 3: Example of corner treatment on heavy combination vehicle route
Figure E 4: Example of corner treatment on heavy combination vehicle route median allows carriageway widening.
COMMENTARY 1

ESD is the sight distance required for minor road drivers to enter a major road via a left or right-turn, so that traffic on the major road is unimpeded. It defines the most desirable set of circumstances that could be provided for traffic entering a major road. If the use of ESD were a practicable proposition, it would be applied and measured in the same way as Safe intersection sight distance (SISD).

For design speeds equal to or greater than 100 km/h the ESD is 500 m and experience has shown that sight distance of this magnitude is rarely able to be achieved in practice due to the expense and practicality of providing a commensurate road alignment on the major road. Furthermore, previous guidelines applied a limiting value of 500 m for ESD based on the assumption that drivers are unlikely to be able to identify and hence seek gaps greater than 500 m.

The consequence of providing SISD or a sight distance between SISD and ESD is that the vehicles involved will not be able to operate under the ideal assumptions of ESD. However, SISD has proven to be an adequate basis for design and should be used as the desirable minimum, the implication being that a distance greater than SISD should be considered where there are no consequences relating to cost or other considerations (e.g. roadside environment).

COMMENTARY 2

There are no design rules dealing with visibility from vehicles. Ackerman (1989) provides the visibility angles shown in Figure C2.1. At each point where a vehicle has to give way (e.g. give-way or stop lines) or is about to enter a traffic stream (e.g. merge situation), the vehicle paths, and orientation should be developed with these visibility angles in mind. The maximum desirable angles are shown by the dotted lines.

Road centrelines should be designed to intersect at between 70° and 110° in both urban and rural situations. For a curved alignment the angle should be measured to an approaching vehicle at a distance from the intersection equal to the design intersection sight distance. The orientation of vehicles prior to all points of conflict, including movements such as left and right merges, should comply with the visibility requirements of Figure C2.1.

The acceptable maximum observation angle for a left-turning driver is 120°. This means that a driver would not be required to significantly change driving position to sight approaching traffic. An angle greater than 120° can result in a driver losing stereo vision, i.e. only being able to sight approaching traffic with the right eye thus losing depth of field vision. This makes it very difficult for a driver to accurately detect the position and speed of approaching traffic.

Arndt (2004) found that larger observation angles increased angle-minor vehicle accident rates (accidents resulting from minor road drivers failing to give way and colliding with drivers on the major road). The observation angle was measured between a line representing the instantaneous direction of travel of minor road drivers 4 m behind the holding line and a line tangential to the major road. This relationship is shown in Figure C2.2 and confirms the need to limit the observation angle, and therefore, the skew of the intersection.
Figure C2.1: Visibility angles and sight restrictions due to vehicle design

Figure C2.2: Effect of observation angle on angle-minor vehicle accident rates
COMMENTARY 3

Arndt (2004) found that:

- Some BAR turn treatments (and AUR treatments) in the study included a narrow median. The rear-end major vehicle crash rate was found to decrease substantially with median width, regardless of the type of median (painted, raised or depressed). The median enables the right-turning vehicle to be positioned further away from the point of conflict in the through lane, lowering the probability of the vehicle being struck.

- Providing a median at a BAR turn treatment is unlikely to be a practical design consideration in many cases. However, there may be scope at some existing BAR treatments to consider introducing such a median by reducing the shoulder width. This may be a low-cost option of achieving a reduction in the rear-end major vehicle crash rate.

- MNR turn treatments record the highest rear-end-major vehicle crash rate of all the turn treatments (100 times higher than CHR turn treatments). This result likely reflects the fact that MNR turn treatments, unlike any other turn treatment, provide no specific facilities for through vehicles to avoid turning vehicles.

- Type AUR turn treatments record a rear-end major vehicle crash rate 30 times higher than do CHR [and CHR(S)] turn treatments.

COMMENTARY 4

C4.1 Number of Stand-up Lanes on the Minor Road at Unsignalised Intersections

Arndt (2004) showed that the angle-minor vehicle crash rate at unsignalised intersections with two stand-up lanes on the minor road is significantly higher than for one stand-up lane. A free left-turn lane did not constitute an additional stand-up lane. The higher crash rate can be attributed to vehicles in the offside stand-up lane blocking visibility for vehicles in the nearside lane, and vice versa as illustrated in Figure 4.4 in the body of this guide.

The angle-minor vehicle crash rate was found to be 1.5 times higher for those conflict points where there was an adjacent minor road stand-up lane in the direction of the relevant oncoming major road vehicles.

At T-intersections, this may not be a major problem because angle-minor vehicle crash rates for the various conflicts are generally low (except for one conflict type which is not affected by the visibility restrictions due to adjacent vehicles).

At cross intersections, however, visibility restrictions due to adjacent vehicles will substantially increase an already high angle-minor vehicle crash rate for conflicts involving through movements from the minor road.

For the above reasons, only one stand-up lane should be provided on minor road approaches at unsignalised intersections, particularly at four-leg intersections with heavy through movements from the minor legs. Where two lanes are required for capacity reasons, installation of a left-turn slip lane or signalisation of the intersection should be considered.
COMMENTARY 5

Warrants for Unsignalised Intersection Turn Treatments

This section briefly discusses the development of warrants for turn treatments on the major road at unsignalised intersections (excluding roundabouts and seagull treatments) as detailed in Arndt and Troutbeck (2006). The warrants are for both urban and rural roads.

C5.1 Development of the Warrants

According to Arndt and Troutbeck (2006) the warrants were created to:

- Improve the limitations and ambiguity of the previous warrants in Austroads (2005).
- Base the warrants directly on the measured safety performance of each turn type.
- Ensure that higher-order turn treatments are not warranted until higher traffic volumes occur on lower-speed roads. This is because turn treatments on lower speed roads record far fewer rear-end-major vehicle accidents (generally rear-end type accidents resulting from a through driver colliding with a driver turning right from the major road (Appendix B for more details) than do turn treatments on high speed roads.
- Ensure that higher-order right-turn treatments are provided at lower traffic volumes than for higher-order left-turn treatments. This is because lower-order right-turn treatments record far more rear-end-major vehicle accidents than lower-order left-turn treatments.
- Incorporate CHR and AUL turn treatments with short length right-turn slots as such treatments have significant safety benefits over lower-order turn treatments.

The warrants have been produced by identifying the location at which the benefits of providing a higher-level treatment (the reduction in estimated accident costs) are made equal to a proportion of the additional construction costs. This proportion is the benefit cost ratio (BCR) and applies for an assumed design life. The benefits and costs of a higher-level treatment are compared to the base case (the minimum turn treatment).

For the right-turn treatments, a design life of 10 years and a BCR equal to one is assumed in the calculations. For the left-turn treatments, however, using BCR values of one with a design life as high as 50 years, the warrants produced are such that traffic flows, on even the busiest roads, would never be high enough to justify using higher-level left-turn treatments. Omitting higher-level left-turn treatments in all circumstances would not meet driver expectation and would cause operational problems, especially on the busier roads. Therefore, an alternative method of determining warrants for left-turn treatments was developed.

For the left-turn warrants, the curves produced for the right-turn treatments are adopted. As the major road traffic volume on the X-axis of the warrants is based on all relevant major road traffic flows, higher-order right-turn treatments are required at lower traffic volumes than for higher-order left-turn treatments. This process ensures that these warrants reasonably match driver expectations set through the previous warrants.

The warrants show that it is not beneficial to provide AUR turn treatments. Instead, channelised right-turn treatments with reduced length of right-turn slots [CHR(S)] are the preferred treatment. Basically, CHR(S) treatments offer significantly better value for money (in terms of the safety benefits versus the construction costs) than do AUR turn treatments.
C5.2 Application of the Warrants

The warrants are based on the construction of intersections on new roads (i.e. greenfield sites). Therefore, their most appropriate application is to the selection of turn types for intersections on new roads. However, the warrants may also be used for the following:

- as a reference for the construction of new intersections on existing roads
- as a reference for intervention levels when upgrading existing intersection turn treatments
- although not intended for direct application to accesses and driveways, they may be used as a reference for such.

COMMENTARY 6

Service roads should not generally be carried through signalised intersections because they cause a reduction in:

- road safety due to the greater number of conflict points, the larger conflict area and the difficulty for right-turning drivers to select appropriate gaps in opposing traffic on two carriageways
- capacity because of increased pedestrian and vehicle clearance times.

Where there is insufficient separation between a major carriageway and a service road, two-way service roads cause operational issues at intersections with side roads that also intersect with the major carriageway, for example:

- insufficient space for turning vehicles
- turning manoeuvres interlock
- queues at the major carriageways block through movement on the service road.

In addition, narrow outer separators cannot be satisfactorily treated to avoid glare and confusion that may arise from the headlights of vehicles travelling along the service road in the opposite direction to the traffic flow on the major carriageway and to the left of it.

COMMENTARY 7

The realignment of minor road approaches at a staggered T-intersection requires drivers travelling through from a minor leg to initially turn onto the major road followed by turning onto the opposite minor road leg. Conflict points (involving through movements from the minor legs) generated by staggered T-intersections are deemed to be safer than those generated by four-way intersections.

At four-way intersections where the minor legs are fully aligned, drivers can overlook the presence of the intersection and can perceive the minor road continuing straight ahead. This can be especially true in a rural setting.

Arndt (2004) suggested that a left-right stagger may be safer than right-left stagger, due to less hazardous conflict points being generated.
COMMENTARY 8

Turning speeds for various radii ($R_i$) and crossfall are calculated from the formula:

$$R_i = \frac{V^2}{127(e + f)}$$

where:

- $R_i$ = curve radius (m)
- $V$ = speed (km/h.)
- $e$ = superelevation (m/m)
- $f$ = side friction factor between vehicle tyres and the pavement.

Table C7.1 provides values of side friction factors ($f$) for various turning speeds that may be used in applying the above formula.

<table>
<thead>
<tr>
<th>$V$ (km/h)</th>
<th>$f$ – maximum</th>
<th>$f$ – desirable</th>
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</thead>
<tbody>
<tr>
<td>25</td>
<td>0.36</td>
<td>0.30</td>
</tr>
<tr>
<td>30</td>
<td>0.36</td>
<td>0.30</td>
</tr>
<tr>
<td>40</td>
<td>0.36</td>
<td>0.30</td>
</tr>
<tr>
<td>50</td>
<td>0.35</td>
<td>0.30</td>
</tr>
<tr>
<td>60</td>
<td>0.33</td>
<td>0.24</td>
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<td>80</td>
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<td>0.13</td>
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<td>0.12</td>
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<tr>
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<tr>
<td>130</td>
<td>0.11</td>
<td>0.11</td>
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COMMENTSARY 9

Table C9 1 provides acceleration rates for a typical passenger car (RTA 1999) that may be of interest to road designers.

Table C9 1: Acceleration rates of a typical passenger car

<table>
<thead>
<tr>
<th>Travel speed (km/h)</th>
<th>Acceleration rate</th>
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</thead>
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<tr>
<td></td>
<td>Acceptance rate</td>
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<tr>
<td></td>
<td>(km/h/sec)</td>
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<tr>
<td></td>
<td>(m/sec2)</td>
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<tr>
<td>40</td>
<td>11.11</td>
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<td>4.7</td>
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<td></td>
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<tr>
<td></td>
<td>1.2</td>
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<td>60</td>
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<td>1.8</td>
</tr>
<tr>
<td></td>
<td>0.5</td>
</tr>
</tbody>
</table>

Source: RTA 1999.

COMMENTSARY 10

The merge length for an acceleration lane or an auxiliary through lane can be calculated from the formula:

$$T_m = \frac{VY}{3.6S}$$

where:

Tm = merge length (m)

V = design speed (km/h)

S = rate of lateral movement

acceleration lane merge – 1.0 m/s

through lane merge – 0.6 m/s

Y = width of lateral movement.
COMMENTARY 11

The following graphs show the speed profile of a semi-trailer on nominal upgrades and downgrades. They provide an indication of the speed decrement that could be expected for heavy vehicles on gradients merging with through traffic, and also indicate the length of acceleration lane that would be required to achieve that decrement.

![Graphs showing speed profile of a semi-trailer](image)

Source: Austroads (2002a).

**Figure C11 1: Profiles for a semi-trailer starting from rest on constant grades**

The computer software package VEHSIM (QLD DMR) can be also used to determine truck speed at the end of an acceleration lane. Inputs required include the start speed, the vertical alignment, and the heavy vehicle type. This program is particularly useful where the design heavy vehicle is other than a semi-trailer and/or the vertical alignment does not comprise a single grade.
COMMENTARY 12

Examples of kerb and channel are shown in Figure C12.1 the purpose of which is to illustrate the most common forms of kerb and channel. The dimensions are provided only to indicate typical sizes. Individual road authorities often have a broader range of kerb and channel types for specific applications and their guidelines should be referred to during design.

![Example kerbs](image)

Source: Austroads (2005).

Figure C12.1: Examples of semi-mountable and barrier kerbs used on medians and traffic islands

COMMENTARY 13

If the island nose does not control the path of exiting vehicles the following will occur:

- the observation angle to approaching through traffic will be exceeded where the through approach is straight for a distance less than five seconds of travel at the design speed
- an inadequate acceleration taper will result.

These points are illustrated in Figure C13.1.
Notes:
1. Observation angle exceeded.
2. No acceleration lane.
3. High relative speed at point of conflict.
4. Observation angle requirements.
5. Adequate and protected acceleration lane.
6. Low relative speed at point of contact.
7. Details of nose treatment are given in Appendix D, Section D.3.

Source: Austroads (2005).

Figure C13 1: Incorrect and correct treatment of an unsignalised three centred kerb return using an island

**COMMENTARY 14**

Figure C14 1 shows an intersection where one approach intersects at an oblique angle, space is limited and a minor fifth leg has to be accommodated. The oblique leg complicates the design in that the through movement is not obvious from the layout and a shared right-turn/through lane is created. This geometric layout requires the use of the four signal phases as illustrated in Figure C14 1 and the use of appropriate signal displays (e.g. arrows inclined in the direction of the movements).
COMMENTARY 15

Arndt (2004) found that angle-major vehicle crash rates (crashes resulting from a right-turning major road driver failing to give way and colliding with an oncoming vehicle – refer to Appendix B) can be up to three times higher on multi-lane roads where queuing occurred on the opposite major road leg. Such queues typically formed due to a blockage downstream of the unsignalised intersection (e.g. an intersection with traffic signals). A diagram of this scenario is shown in Figure C15 1.
Figure C15 1: Queuing through an unsignalised intersection due to a downstream blockage

The higher crash rate can be attributed to the queue in the offside lane obstructing the view to vehicles travelling at speed in the nearside lane.

To mitigate this problem, queuing from downstream blockages on multi-lane roads should not extend through upstream intersections. This may require an analysis of the downstream blockage to identify treatments to prevent the queue extending into the intersection (e.g. if the downstream blockage is a signalised intersection, change the phasing or increase the number of stand-up lanes).

**COMMENTARY 16**

Figure C16 1 provides details relating to the design of the six intersection elements presented in Section 10.6.4 of this guide.
**Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections**

**Figure C15 1: Designing for the six intersection elements**


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The six intersection elements provide guidance on bicycle facilities with an understanding of how to provide bicycle lanes at intersections. The concept provides a framework for solving complex design problems into six smaller design cases. Designers can now actively try to include each of the elements in their design.

**Depature**
- Bicycle lanes provide for cyclists as they leave the intersection. The lanes can be provided by:
  - Kerbside: bicycle lanes adjacent to the kerb.
  - Carriageway: bicycle lanes adjacent to the carriageway.
- A bicycle movement sign and bicycle lane sign should be located on the departure side of the intersection to advise motorists of the bicycle lane.

**Through**
- Element occurs when cyclists pass through the intersection in any direction. The movements are:
  - Left movements, where cyclists either move left or turn left.
  - Straight movements, where cyclists proceed straight ahead from one side to the other.
  - Right movements, where cyclists move right from the centre of the road.
  - Hook right movements, where cyclists undertake a right turn from the left to a right turn movement.
- In more complex intersections or where deliberation of motor vehicle lanes occurs through the intersection, consideration should be given to also delineating bicycle lanes through the intersection.

**Waiting**
- Cross arms are required where cyclists are stopped at intersections. Waiting space can be provided by:
  - Advanced waiting space, where the stop line of the approach bicycle lane is in advance of the motor vehicle stop line.
  - Expanded waiting space, provided by moving the motor vehicle stop line back to create a larger waiting area.
  - Hook emergency waiting space, provides an area adjacent the pedestrian crossing designating where cyclists wait for the clearance of traffic signals before undertaking a hook turn.
- When cyclists wait in the form of the traffic queue, they are safe immediately to move safely out of it.

**Approach**
- Bicycle lanes are installed back-up to the intersection and are located between the motor vehicle lanes. Approach bicycle lanes may be:
  - Kerb-side: where the approach bicycle lane is adjacent to the kerb.
  - Carriageway: where the approach bicycle lane is in the right of a motor vehicle left turn lane.
  - Mid-block: where the approach bicycle lane is in the left of a motor vehicle right turn lane.
- Approach lanes should be provided for at least the through movement. If there is high cyclic demand for left or right turns, bicycle lanes for these movements should also be considered.

**Transition**
- Movement undertaken to travel from a mid-block bicycle lane to the intersection approach bicycle lane. Transition may be:
  - Straight kerb-side, where the bicycle lane moves in the kerb-side position.
  - Straight carriageway, where the bicycle lane moves from a carriageway position.
  - Weave right, where bicycle lane overlap to allow cyclists to move across a motor vehicle lane to be in the appropriate approach position.

**Mid-block**
- Provides for cyclists to use a bicycle lane that will be either:
  - Kerb-side: bicycle lane where cyclists travel adjacent the kerb.
  - Carriageway: bicycle lane where cyclists travel adjacent to the carriageway.
- Mid-block bicycle lanes should continue through signalised motor intersections using continuity lines.