GUIDE TO ROAD DESIGN

Part 4: Intersections and Crossings – General
Guide to Road Design
Part 4: Intersections and Crossings – General
Guide to Road Design Part 4: Intersections and Crossings – General

Summary

The Guide to Road Design – Part 4: Intersections and Crossings – General contains guidance that provides road designers and other practitioners with information that is common to the geometric design of all at-grade intersections. However, Part 4 alone does not provide all the information that is necessary to design a satisfactory intersection and should therefore be used in conjunction with other parts of the Austroads Guide to Road Design, in particular:

- Part 4A: Unsignalised and Signalised Intersections (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.

Road designers have to consider many factors and disciplines that may affect, or be affected by, the design of roads and intersections. Therefore, reference should also be made to the all other parts of the Austroads Guide to Road Design as required by the situation.

Part 4 covers topics that are common to intersection design such as road design considerations, design process, choice of design vehicle, provision for public transport and property access. It also provides guidance and information on the design of pedestrian and cyclist crossing treatments.

Keywords

Design domain, normal design domain, extended design domain, types of intersection, road design considerations, design process, location of intersections, design vehicle, pedestrian crossings, cyclist crossings, public transport, bus facilities, tram facilities, property access, rail crossings

First Published August 2009

© Austroads Inc. 2009

This work is copyright. Apart from any use as permitted under the Copyright Act 1968, no part may be reproduced by any process without the prior written permission of Austroads.

ISBN 978-1-921551-54-3

Austroads Project No. TP1566

Austroads Publication No. AGRD04/09

Project Manager

David Hubner, DTMR Qld

Prepared by

Gary Veith, ARRB Group
Owen Arndt, DTMR Qld


**Austroads profile**

Austroads purpose is to contribute to improved Australian and New Zealand transport outcomes by:

- providing expert advice to SCOT and ATC on road and road transport issues
- facilitating collaboration between road agencies
- 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.

**Austroads membership**

Austroads membership comprises the six state and two territory road transport and traffic authorities, the Commonwealth Department of Infrastructure, Transport, Regional Development and Local Government in Australia, the Australian Local Government Association, and New Zealand Transport Agency. It is governed by a council consisting of the chief executive officer (or an alternative senior executive officer) of each of its 11 member organisations:

- Roads and Traffic Authority New South Wales
- Roads Corporation Victoria
- Department of Transport and Main Roads Queensland
- Main Roads Western Australia
- Department for Transport, Energy and Infrastructure South Australia
- Department of Infrastructure, Energy and Resources Tasmania
- Department of Planning and Infrastructure Northern Territory
- Department of Territory and Municipal Services Australian Capital Territory
- Department of Infrastructure, Transport, Regional Development and Local Government
- Australian Local Government Association
- New Zealand Transport Agency.

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

The authors acknowledge the role and contribution of the Austroads Road Design Reference Panel in providing guidance and information during the preparation of this guide. The panel comprised the following members:

Mr Pat Kenny  
Roads and Traffic Authority, New South Wales

Mr David Barton  
Roads Corporation, Victoria (VicRoads)

Mr Anthony Barton  
Roads Corporation, Victoria (VicRoads)

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

Mr Rob Grove  
Main Roads Western Australia (MRWA)

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
CONTENTS

1 INTRODUCTION......................................................................................................................... 1
1.1 Purpose .................................................................................................................................. 1
1.2 Scope of this Part ............................................................................................................... 2
1.3 Road Safety.......................................................................................................................... 2
  1.3.1 Safe System Approach ............................................................................................... 2
  1.3.2 Contribution of Intersection Design to Road Safety ............................................. 3
1.4 Design Criteria in Part 4 .................................................................................................... 3
1.5 Road Design Objectives ....................................................................................................... 4
1.6 Other Considerations ......................................................................................................... 4
  1.6.1 Pavement Markings and Signs .................................................................................... 4
  1.6.2 Road Lighting ............................................................................................................. 5
  1.6.3 Landscaping ............................................................................................................... 5
  1.6.4 Maintenance Considerations ..................................................................................... 5

2 TYPES OF INTERSECTION ...................................................................................................... 7
2.1 General .................................................................................................................................. 7
2.2 Basic Forms of Intersection ............................................................................................... 7
2.3 Specific Types of Intersections ........................................................................................... 8

3 ROAD DESIGN CONSIDERATIONS FOR INTERSECTIONS ........................................... 10
3.1 General ................................................................................................................................ 10
3.2 Road Users .......................................................................................................................... 11
3.3 Provision for Large/Special Vehicles ............................................................................... 14
3.4 Topography and Land Availability ................................................................................... 14
3.5 Environment and Heritage ............................................................................................... 15
3.6 Physical Constraints ......................................................................................................... 15
3.7 Occupational Health and Safety ...................................................................................... 15

4 DESIGN PROCESS ............................................................................................................... 16
4.1 General ................................................................................................................................ 16
4.2 Basic Data for Design ........................................................................................................ 18
4.3 Location of Intersections ................................................................................................... 20
4.4 Design Speed ..................................................................................................................... 22
4.5 Road Cross-section .......................................................................................................... 23
  4.5.1 Cross-section Elements ............................................................................................. 23
  4.5.2 Traffic Lanes ............................................................................................................... 23
  4.5.3 Medians ....................................................................................................................... 25
  4.5.4 Roadside Areas .......................................................................................................... 25

5 DESIGN VEHICLE ............................................................................................................... 26
5.1 General ................................................................................................................................ 26
5.2 Design Vehicles .................................................................................................................. 26
5.3 Checking Vehicles ............................................................................................................. 27
5.4 Restricted Access Vehicles .............................................................................................. 30
5.5 Visibility from Vehicles .................................................................................................... 30
5.6 Design Vehicle Swept Path ............................................................................................... 30
  5.6.1 General ....................................................................................................................... 30
  5.6.2 Radius of Turn .............................................................................................................. 31
  5.6.3 Clearances to Swept Paths of Turning Vehicles .......................................................... 31
  5.6.4 Using Templates to Prepare and Check Designs ......................................................... 32
TABLES

Table 3.1: Key differences between urban and rural intersections .................................. 11
Table 3.2: Considerations for road users in intersection design .................................. 13
Table 4.1: Factors to consider regarding function, current situation and the future .... 19
Table 4.2: Considerations in the location of intersections ......................................... 21
Table 5.1: Selection of design and checking vehicles and typical turning radii in
Australia .............................................................................................................. 29
Table 5.2: Selection of design and checking vehicles and recommended turning
radii in New Zealand .......................................................................................... 29
Table 6.1: Minimum length required for bus lane termination on departure side of
an intersection .................................................................................................... 35
Table 6.2: Minimum width of bus lanes and bicycle lanes in various speed zones .... 38
Table 6.3: Desirable distance of bus bay from tangent point near intersection ....... 45
Table 7.1: Property access considerations on urban roads ..................................... 53
Table 7.2: Property access considerations on rural roads ...................................... 55
Table 7.3: Considerations relating to the design of median openings .................... 61
Table 8.1: Crossing features and considerations .................................................. 64
Table 10.1: Variation in superelevation at railway level crossings ....................... 101
Table 10.2: Permitted variations in grade between road and rails at level crossings ... 102

FIGURES

Figure 1.1: Flow chart of the Guide to Road Design .............................................. 1
Figure 2.1: Basic forms of intersections ............................................................... 7
Figure 4.1: Design flow chart in the modelling process to produce a set of working
drawings for construction or modification of an intersection ......................... 17
Figure 4.2: Design lane widths ............................................................................ 24
Figure 5.1: Example of using a template for a checking vehicle ......................... 28
Figure 6.1: Potential conflict between buses and cars ....................................... 34
Figure 6.2: Potential conflict points between trams and cars at signalised
intersections ...................................................................................................... 34
Figure 6.3: Full bus lane and queue jump lane treatments ................................ 36
Figure 6.4: A left-turn slip lane and short bus lane to create a queue jump lane .... 37
Figure 6.5: Wide kerbside bus lane ................................................................. 39
Figure 6.6: Separated bus lane and bicycle lane treatment .............................. 40
Figure 6.7: Median bus lanes with bus signals on Causeway Bridge, Perth, WA .... 41
Figure 6.8: An example of a bus stop in the kerbside traffic lane ....................... 43
Figure 6.9: An example of a kerbside bus stop with parking on approach and exit .. 43
Figure 6.10: An example of a kerbside stop with footpath extension ................. 43
Figure 6.11: An example of a kerbside bus stop on the departure side of pedestrian
signals .............................................................................................................. 44
Figure 6.12: Proximity to departure side of intersection .................................... 44
Figure 6.13: Proximity to approach side of intersection ...................................................... 44
Figure 6.14: Bus bay on inside of curve.............................................................................. 45
Figure 6.15: An example of bus bay geometry at an unconstrained site ............................ 45
Figure 6.16: Desirable crossfall at bus bays ....................................................................... 46
Figure 6.17: Preferred pit location....................................................................................... 46
Figure 6.18: An example of a bus stop layout with a shelter .............................................. 47
Figure 7.1: Upstream functional intersection area (based on right-turning vehicles)....... 51
Figure 7.2: Example of a rural property access – single or dual carriageway (conditional) ........................................................................................................... 56
Figure 7.3: Example of a rural property access specifically designed for articulated vehicles on high-speed dual carriageway ....................................................... 57
Figure 7.4: Example of a rural property access specifically designed for articulated vehicles on a two-lane two-way road ........................................................................ 58
Figure 7.5: Typical mid-block median opening .................................................................. 59
Figure 7.6: Example of an emergency median openings on rural freeways .................... 62
Figure 7.7: Example of a general median opening for access on divided roads .............. 62
Figure 8.1: An example of a pedestrian refuge ................................................................. 66
Figure 8.2: An example of a median crossing for pedestrian operated signals ........................................................................................................................................ 68
Figure 8.3: An example of a footpath kerb extension ....................................................... 69
Figure 8.4: An example of a pedestrian (zebra) crossing ................................................. 71
Figure 8.5: An example of pedestrian – actuated traffic signals (mid-block) .................. 73
Figure 8.6: An example of a kerb ramp design .................................................................. 75
Figure 9.1: Bicycle path crossing of a two-way two-lane road and separated paths ....... 77
Figure 9.2: Example of a cyclist and pedestrian refuge at a mid-block location ............... 78
Figure 9.3: Refuge within an intersection for pedestrians and cyclists in bicycle lanes ........................................................................................................................................ 80
Figure 9.4: Cyclist priority treatment for use at low volume street crossings ................... 81
Figure 9.5: Signalled crossing with separate pedestrian and cyclist areas ..................... 82
Figure 9.6: Shared path and one-way bicycle path at a signalised intersection .............. 84
Figure 9.7: Right turn from an off-road bicycle path to an on-road bicycle lane ............. 85
Figure 9.8: Example of kerb ramp and holding rail layout .............................................. 87
Figure 9.9: Bicycle path crossing bent-out at side road .................................................... 90
Figure 9.10: Bicycle path crossing not bent-out at side road .......................................... 91
Figure 9.11: One-way bicycle path crossing bent-in at side road ..................................... 93
Figure 10.1: Sight triangles for give-way and stop sign control ........................................ 96
Figure 10.2: Approach visibility angles .............................................................................. 98
Figure 10.3: Crossing visibility angle for drivers looking left and right ......................... 98
Figure 10.4: Crossing of a road running parallel to a railway ........................................... 99
Figure 10.5: General guide to grading limitations ............................................................. 100
Figure 10.6: Minimum method of grading the road from above and below rails in difficult situations ............................................................................................................. 101
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 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 4: Intersections and Crossings – General
- Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b)
- 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.

As shown in Figure 1.1, Part 4 is one of eight guides that comprise the Austroads Guide to Road Design and 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)

Note: Part 6 of the Guide to Road Design comprises three parts, namely:

- Part 6: Roadside Design, Safety and Barriers (Austroads 2009e)
- Part 6A: Pedestrian and Cyclist Paths (Austroads 2009f)
- Part 6B: Roadside Environment (Austroads 2009g).

Figure 1.1: Flow chart of the Guide to Road Design
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, interchanges and crossings, including railway crossings. 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.

The Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) provides specific details relating to geometric design principles and their application which will be relevant to the design of roads on the approaches to and passing through intersections.

1.3 Road Safety

The Guide to Road Design – Part 4: Intersections and Crossings – General should be considered in the broad context of road safety and the contribution that the guide can make to the design of safer roads.

1.3.1 Safe System Approach

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.

Safer road user behaviour, safer speeds, safer roads and safer vehicles are the four key elements that make a safe system. In relation to speed the Australian Transport Council (2006) reported that the chances of surviving a crash decrease markedly above certain speeds, depending on the type of crash i.e.:
• pedestrian struck by vehicle → 20 to 30 km/h
• motorcyclist struck by vehicle (or falling off) → 20 to 30 km/h
• side impact vehicle striking a pole or tree → 30 to 40 km/h
• side impact vehicle to vehicle crash → 50 km/h
• head-on vehicle to vehicle (equal mass) crash → 70 km/h

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 Austroads Guide to Road Safety (Austroads 2006–2009).

1.3.2 Contribution of Intersection Design to Road Safety
A key component of the safe system approach is safer roads. A large percentage of crashes on road networks occur at intersections and therefore the installation of appropriate types of intersections and the application of best practice in intersection design has the potential to make a significant contribution to crash and injury reduction on road networks.

Different types of intersections may have different safety performances and this factor should be considered in the selection of an intersection type for any given situation, along with other important objectives such as the need to provide adequate capacity for traffic movement on the road network.

1.4 Design Criteria in Part 4
The Guide to Road Design – Part 2: Design Considerations (Austroads 2006c) discusses the concept of normal design domain (NDD) and extended design domain (EDD). Guidance on the application of this concept to intersections is provided in this guide and the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b).

In the context of road design:
• a greenfield site is a location on which a new road is being built where there is no development that prevents the use of design values within the guidelines relating to NDD
• a brownfield site is a location where development (e.g. roads and buildings) exist and may influence the design to the extent that use of values outside the NDD for one or more elements of the design may be necessary.

The body of this guide contains NDD values. These are road design values suitable for the design of all unsignalised and signalised intersections, including the installation of new intersections on new roads (greenfield sites). In most cases, these design values will also be suitable for new intersections on existing roads and for modifications to existing intersections (both are examples of brownfield sites).

In constrained locations (particularly at brownfield sites), it may not always be practical or possible to achieve all of the relevant NDD values. In these constrained locations, road authorities may consider the use of values outside of the NDD.
Appendix A of Part 4A contains extended design domain (EDD) values. These are values outside of the NDD domain that through research and/or operating experience, particular road authorities have found to provide a suitable solution for constrained situations in brownfield sites. EDD values have only been developed for particular parameters, where considerable latitude exists within the NDD values.

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

In applying this guide:

1. NDD 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.

1.6 Other Considerations

Road designers should establish the types and location of all features, road furniture including traffic control devices, markings and landscaping, and consider road maintenance requirements. In some cases the effectiveness of these elements may be influenced by the intersection design and, conversely, they may influence the design.

1.6.1 Pavement Markings and Signs

Signs and markings are provided at intersections to warn, regulate and guide traffic, and the extent of the devices used varies depending on the importance of the intersection in the road network and the particular site characteristics.

A properly designed intersection should not rely on pavement markings and signs to ensure safe and efficient operation. However, appropriate pavement markings and signs are an integral part of intersections and the guidance provided to road users.

For information on pavement markings and signs for signalised intersections practitioners should refer to:

- Australian Standard AS 1742 – Manual of uniform traffic control devices
1.6.2 Road Lighting

Standards and guidance on the design of road lighting are provided respectively in AS/NZS 1158 and the Guide to Road Design – Part 6B: Roadside Environment (Austroads 2009g). Whether an intersection is provided with lighting or not is determined by jurisdictional policy.

AS/NZS 1158 specifies requirements applicable where intersections, junctions and other specified locations form part of a substantially continuous road lighting system. Where an intersection involves roads that are lit or proposed to be lit to different standards, the overall intersection should be lit to the higher lighting standard.

In general, the lighting layout should provide the highest levels of illumination on critical areas such as:

- points of traffic conflict, e.g. merges, diverges, crossings and entry points
- noses of medians, separators and traffic islands
- pedestrian crossing areas including the immediate traffic approach where illegal movements are most likely
- bus/tram stops and areas where pedestrians congregate within the intersection area.

Other non-critical locations within the intersection area as defined in AS/NZS 1158 should be lit to the required standard.

1.6.3 Landscaping

Landscaping and streetscape treatments should be designed to complement road safety objectives. Road safety considerations will determine the placement and control of roadside vegetation and any built landscape elements within the road reserve. Rocks and other solid obstacles should not be provided within medians and traffic islands or within clear zones.

It is imperative that landscaping does not interfere with any sight lines for vehicles approaching, entering, or passing through an intersection. Adequate sight lines and sight distance should be provided. Furthermore, vegetation should not be placed where it will impede a driver’s ability to read and safely respond to road signs. Guidelines for landscaping are provided in the Guide to Road Design – Part 6B: Roadside Environment (Austroads 2009g).

1.6.4 Maintenance Considerations

The design of intersections and the assessment of options should consider the implications for maintenance activities and personnel. The following matters should be considered.

**Rural intersections**

Factors to consider are:

- avoid ‘dead’ areas of pavement that will collect refuse and gravel
- prevent gravel from being washed onto the road or strewn onto the road by tyres by providing kerb and channel, implementing measures to control runoff from verges, and sealing the bell mouths of gravel roads
- ensure that batters are flat so that the required maintenance machinery can operate clear of traffic
• provide adequate clearance between the toe of the embankment and reservation boundary to enable access by maintenance machinery
• wherever possible, do not provide junction pits for drainage within the road pavement
• only provide low growing species of plants within sight lines and maintain other vegetation to keep lines clear
• provide only low maintenance species of plant within medians and traffic islands
• consider use of innovative and attractive surfaces instead of vegetation on medians and traffic islands to remove the need for maintenance (often under traffic) and thereby improve road safety and the safety of maintenance workers.

Urban intersections
In addition to the rural factors:
• where possible, provide sufficient space to enable signal maintenance personnel to safely maintain signal hardware
• provide a safe area for the signal controller and adjacent parking space for the maintenance vehicle
• note that pedestrian footpath cut-through design of urban medians and islands at pavement level provides a flat even surface but may result in the accumulation of debris.
2 TYPES OF INTERSECTION

2.1 General
An intersection is formed wherever two or more roads cross or meet. Intersection treatments may be described by:
• the number of legs and the angle of intersection
• the type of traffic control
• the way in which right-turning and left-turning movements are accommodated
• the presence and shape of traffic islands.

2.2 Basic Forms of Intersection
The basic forms of intersections that exist on road networks are shown in Figure 2.1. The number of legs at an intersection, and the angle at which they meet, can vary. In addition, one or more of the legs may be curved.

A particular form of intersection may exist because of historical decisions associated with the establishment of road reservations and may not be satisfactory unless it is treated with some type of channelisation or intersection control. Forms of intersection control are discussed in Part 6 of the Guide to Traffic Management (Austroads 2007).

Notes:
Some or all legs may be curved.
Combinations of these basic elements are often used, e.g. a staggered T.
Source: Based on Austroads (2005)

Figure 2.1: Basic forms of intersections
In selecting an appropriate form of intersection a designer should appreciate that:

- T-intersections are generally safe
- unsignalised Y-intersections are not a safe form because of the potential for high angle impacts and the provision of poor observation angles
- unsignalised crossroads generally are not safe in high-speed situations (> 80 km/h)
- signalised crossroads may not be safe in high-speed situations (> 80 km/h)
- unsignalised multi-leg intersections can lead to confusion with priority
- a Y-intersection or multi-leg intersection should generally not be adopted when setting out new road networks or new links in an existing network.

Issues associated with these basic forms of intersection may be addressed by treatments that involve realignment of intersection legs, for example to convert:

- a Y-intersection to a T-intersection
- a crossroad to a staggered T-intersection
- a multi-leg intersection to a crossroad and adjacent T-intersection.

### 2.3 Specific Types of Intersections

Issues associated with the basic forms of intersection may also be addressed by:

- addition of right-turn or left-turn auxiliary lanes
- channelisation, for example:
  - a traffic island in the minor road (e.g. splitter island)
  - a right-turn lane and traffic island or a left-turn roadway and island
  - a staggered T-intersection (right-left and left-right types)
  - a seagull intersection
  - a wide median treatment
  - a roundabout
- signalisation.

All types of intersection can be used in urban or rural environments with the exception that signalised intersections are generally not used on high-speed traffic routes.

The design principles for intersections are the same irrespective of the type of intersection control. Generally, with the exception of roundabouts and wide median treatments all types of intersections can be signalised. The difference is in the detail with signalised layouts usually being provided in urban areas where:

- kerb and channel is provided rather than shoulders
- parking may have to be accommodated on the intersection approaches
- bus, transit and bicycle lanes and facilities may be required
- pedestrians have to be accommodated.
Guidelines for the design of unsignalised and signalised intersection treatments are provided in the *Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections* (Austroads 2009b). This Part also provides guidance on variations to these layouts and on the design and use of several layouts that are less commonly used.

Guidelines for the design of roundabouts are provided in the *Guide to Road Design – Part 4B: Roundabouts* (Austroads 2009c). A single-lane roundabout (i.e. one circulating lane and single-lane entries) is suitable for use at any of the basic forms of intersection. Multi-lane roundabouts are suitable for use at T-junctions and four-way intersections that intersect at or close to 90°. However, multi-lane roundabouts are generally unsuitable at sites where roads intersect at oblique angles (e.g. Y-junction or multi-leg intersection) as they can result in conflicts at exits and drivers can experience difficulty in anticipating the appropriate lane choice required for left, through or right-turns on some of the approaches (Section 4.6.2 and Commentary 18 of the *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings* (Austroads 2007)) for more information).

An interchange on freeways or major arterial roads is also a form of intersection. Guidelines for the design of interchanges are provided in the *Guide to Road Design – Part 4C: Interchanges* (Austroads 2009d). However, interchanges often include at-grade intersections at ramp terminals which should also be designed in accordance with Parts 4, 4A and 4B of the *Guide to Road Design*.

The *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings* (Austroads 2007) provides guidance on traffic management aspects of intersections including:

- traffic control options and selection criteria (Section 2.2.3)
- the suitability of types of traffic control to different road types (Table 2.3)
- key traffic management considerations in the selection of an appropriate intersection type (Table 2.4).
3 ROAD DESIGN CONSIDERATIONS FOR INTERSECTIONS

3.1 General

Parameters that are important in road design are covered in Guide to Road Design – Part 2: Design Considerations (Austroads 2006c) and these same parameters should be considered when designing any type of intersection or interchange. This section briefly covers some of the parameters most relevant to intersection design.

The location and design of an intersection will be affected by many factors including the alignment and grade of the approach roads, the need to provide for drainage, the extent of interference with public utilities, property access and the presence of local features, both man-made and natural. Natural features may involve the topography or vegetation that is environmentally sensitive. Some features may have heritage value or it may be otherwise impracticable to remove or alter them.

The same principles apply to the design of intersections in urban areas and rural areas. However, a key distinction between them is that drivers in rural areas may be less alert and require longer reaction times, and vehicle speeds are often relatively high on rural roads.

Urban areas can be defined as developed sites within boundaries set by the responsible state and local authorities. Urban areas have fundamentally different characteristics from rural areas with regard to land use, density of road network, nature of travel patterns, and the way in which these elements are related. Table 3.1 provides a summary of key differences between urban and rural intersections which may affect the type of intersection selected or the layout of the intersection.
### Table 3.1: Key differences between urban and rural intersections

<table>
<thead>
<tr>
<th>Feature</th>
<th>Urban site</th>
<th>Rural site</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road space</td>
<td>Arterial road intersections may require several lanes on each approach including dual turn lanes to cater for traffic demands.</td>
<td>Rural road intersection approaches generally have the basic number of lanes (i.e. two-lane two-way or one-way carriageway with or without single turning lanes).</td>
</tr>
<tr>
<td>Land acquisition</td>
<td>Often not feasible to acquire additional land due to cost and impact on abutting property.</td>
<td>Land can often be relatively inexpensive and acquisition less disruptive to abutting land holders.</td>
</tr>
<tr>
<td>Utilities</td>
<td>Generally need to accommodate a range of utilities in limited space.</td>
<td>Usually fewer utilities and sufficient road reservation available; however, higher vehicle speeds necessitate greater clearance to fixed roadside objects.</td>
</tr>
<tr>
<td>Kerbs</td>
<td>Usually fully kerbed except for outer urban intersections awaiting full development.</td>
<td>Generally, rural intersections are associated with shoulders in lieu of kerbing, the shoulders also allowing for cycling clear of motor traffic (assuming surface is suitable). The immediate environs of arterial road intersections (rural and urban) should desirably be kerbed to provide edge definition and prevent shoulder gravel from accumulating on pavement. At rural intersections, the kerbing is often only used throughout the left turn to assist in controlling traffic paths, to avoid damage to shoulders, and to avoid gravel being strewn onto the road. Lightly trafficked rural local road intersections are often not kerbed.</td>
</tr>
<tr>
<td>Drainage</td>
<td>Usually underground pipes and pits that need to be located with reference to pedestrian kerb ramps, utilities and traffic signal foundations and pits.</td>
<td>Usually open drains within road reservation that require considerable space.</td>
</tr>
<tr>
<td>Topography</td>
<td>Usually constrained to existing topography.</td>
<td>Often greater scope to choose an alternative alignment or alter an existing intersection approach alignment.</td>
</tr>
<tr>
<td>Cost</td>
<td>Relatively high due to costs of land acquisition, relocation of utilities, traffic control devices and traffic management during construction. Construction materials readily available.</td>
<td>Land acquisition cost relatively low. Materials may be relatively expensive due to haulage distances.</td>
</tr>
<tr>
<td>Road users</td>
<td>May have to cater for relatively high numbers of cyclists and pedestrians, including those people who have impairments. Design likely to be influenced by other factors such as parking, bus and tram stops, public transport priority measures, property access and adjacent T-intersections.</td>
<td>Pedestrian and cyclist numbers are often very low requiring no special provision. Design not usually influenced by as many factors as is the case in an urban environment.</td>
</tr>
</tbody>
</table>

### 3.2 Road Users

A primary requirement of road design practitioners is that they:

- remember that intersections must cater for road users varying from a driver to cyclist and pedestrian
- have an appreciation of the characteristics of the various road users and their vehicles.

The application of this requirement should result in a design that satisfies the principle that road users:

- especially strangers to an area, are not surprised by the location of the intersection, or the layout
- are not severely disadvantaged for making errors, nor rewarded for deliberately committing unsafe acts.
The first of these principles requires actions such as:

- the provision of adequate approach sight distance
- close attention to advance signposting, particularly where lane drops occur
- consistency of treatment along routes so that drivers can have reasonable expectations about intersection treatments.

The second requires designers to imagine the actions of those drivers who have made an error at the intersection and ensure that recovery action is not unduly hazardous. However, the layout should also discourage unsafe acts, such as overtaking through narrow intersections on the near side.

Considerations for various road users are summarised in Table 3.2.
## Table 3.2: Considerations for road users in intersection design

<table>
<thead>
<tr>
<th>Road user</th>
<th>Considerations</th>
</tr>
</thead>
</table>
| **Motor vehicle drivers** | Adequate sight distance  
• on all approaches to intersections  
• from a position at stop lines or give-way lines to other potentially conflicting vehicles, including those turning  
• at lane drops  
• to pedestrians waiting to cross the road and on the road.  
Avoid grading that will cause discomfort or require heavy braking.  
Provide for deceleration appropriate to the circumstances and adequate storage in turning lanes. |
| **Pedestrians including people who have an impairment** | Provide paths and road crossings at all urban intersections and at rural intersections where pedestrian movements are expected.  
Locate paths on pedestrian desire lines or install fencing or other barriers to guide them along the preferred route.  
Provide adequate path width.  
Provision of obstruction free paths (e.g. poles, street furniture, footpath cafes, trees); particularly important for people with vision and other physical impairments.  
Place side entry pits and grated pits clear of pedestrian paths (including those in traffic islands) and ramps.  
Crossings should be direct and straight to assist vision-impaired pedestrians.  
Avoid staged crossings wherever practicable.  
Design kerb ramps to assist vision-impaired people.  
Ensure pedestrian detectors are readily accessible for all users (e.g. people in wheelchairs).  
Provide generous setback between road traffic lanes and paths wherever practicable.  
Provide adequate vertical clearance above all pedestrian facilities.  
Do not exceed a ramp gradient of 1:10 if possible (maximum of 1:8 in AS 1428.1 should be regarded as an absolute maximum).  
Avoid steps and stairs as they form a barrier for impaired pedestrians.  
Limit path crossfall to 1:100 (may provide steeper crossfall, up to 1:40, if drainage problems are expected).  
Place signs so that they do not obscure pedestrian from motorist’s view.  
Specify even, skid resistant surfacing materials that will not be hazardous to aged pedestrians or those with vision and other physical impairments. |
| **Cyclists** | Consider the need for bicycle lanes on routes and at intersections; bicycle lanes are preferred to wide kerbside lanes.  
Avoid termination of bicycle lanes on the approaches to intersections.  
If provided, carry bicycle lane through intersection on major road at unsignalised intersections.  
Assess the need for a ‘head start’ storage area and advanced stop line for cyclists at signalised intersections.  
Consider storage space for ‘hook turns’, and other bicycle storage requirements. |
| **Heavy vehicle drivers** | Where practicable provide a flat grade on intersection approach to facilitate acceleration of heavy vehicles and acceptance of gaps by the drivers.  
Avoid steep downgrades on approaches to intersections.  
Provide space for the design vehicle movements to occur within the turning lanes and pavement area without the vehicle body overhanging kerbs or traffic islands.  
Ensure that the checking vehicle can turn within the intersection from lane adjacent to turning lanes if necessary.  
Avoid excessive adverse crossfall and significant variations in crossfall throughout turning paths.  
Ensure adequate space for concurrent right-turns to occur (i.e. swept paths) with adequate clearances.  
Adequate lane widths. |
| **Bus drivers and passengers** | Bus lanes.  
Approach and departure side bus lanes at intersections.  
Queue jump lanes.  
Signal priority.  
Adequate lane widths.  
Access to and from bus stops.  
Provide adequate space for buses to turn within pavement area without encroaching on other lanes or overhanging kerbs and traffic islands.  
Provide stops that are accessible for people with vision and other physical impairments. |
| **Tram drivers** | Tram priority.  
Provide stops that are accessible for people with vision and other physical impairments. |
3.3 Provision for Large/Special Vehicles

A functional layout based on the characteristics of a design vehicle should represent an economical level of design that caters safely and comfortably for at least 85% of vehicles operating in accordance with normal traffic regulations. Larger vehicles (e.g. 33 metre B-triple and 30 metre super B-double) may be selected as the design vehicle, in which case they should enter and depart from the intersection in the correct lane/s. However, where these vehicles and other vehicles operating under restricted access conditions only use the intersection occasionally, it may be acceptable for the design to be based on them encroaching into other traffic lanes. This may cause some inconvenience to other road users, but may be acceptable where there is a low frequency of occurrence together with the effect of special conditions associated with the permit.

It is also important that practitioners should be aware, through traffic data or local knowledge, whether the location is subjected to seasonal cartage where the number of large vehicles may be very high for a relatively short period of time (e.g. harvesting of crops). In such cases the typical seasonal cartage vehicle should be considered for use as the design vehicle.

Where the route is designated for the use of special vehicles that fall outside the three general classes (other freight efficient vehicles, over-length buses, type 1 or 2 road trains), or where regular use of the route by these vehicles could reasonably be expected (access to industrial areas, bus routes), the design should satisfy the needs of such vehicles. The operation of these vehicles should not be compromised by having to encroach into other traffic lanes.

The geometric design should be checked for B-doubles and special vehicles where the need is demonstrated and at the areas where problems are most likely to occur. Most arterial rural roads are likely to have some B-double operation even if they are not specific B-double routes. Section 5 describes the provisions that need to be made for trucks. These can also be used for special vehicles. Design guidelines for the various geometric issues in the table are discussed in subsequent sections.

For large or special vehicles it is important to:

- provide for the swept paths of large/special vehicles (Austroads 2006a). Refer to Section 5.6.
- provide truck stopping sight distance
  - understanding that lateral sight distance restrictions are often critical, particularly at T-intersections in hilly terrain or near bridge piers
  - for intersections on or near crest vertical curves
  - to allow large/special vehicles to turn safely into each road
  - to railway crossings, speed change areas and merge areas such as lane drops
- consider vehicle stability for turning movements by providing radii appropriate for the turning speeds and providing a satisfactory crossfall and a uniform rate of change for crossfall.

3.4 Topography and Land Availability

The topography at intersection sites is an important consideration in the selection of an alignment for a new road because it can:

- affect the safety and efficiency of the approaches to the intersection
- affect the extent of the earthworks to achieve an acceptable standard and hence the cost of the intersection
require benching of slopes around the intersection in order to ensure batter stability and hence increase the footprint of the intersection in terms of its environmental effect including its appearance.

The availability of land can determine the form of an intersection, particularly in urban areas where the cost of land is high. For example, in inner urban areas a roundabout or a left-turn slip lane may not be an option because of the inability to acquire land or the expense of acquisition.

3.5 Environment and Heritage
The design of intersections may be influenced by a range of environmental considerations that include the effect of the various options on:

- flora and fauna (habitats)
- watercourses
- foreshore reservations
- parkland
- erosion of the surrounding area
- visual amenity of the landscape
- noise levels for abutting landowners.

The effects for heritage can include historic buildings, bridges or fountains, aboriginal sites and other places that have historic significance.

3.6 Physical Constraints
Physical constraints that may influence an intersection design, apart from those previously mentioned, include a broad range of items such as:

- utility services such as telecommunication pits, power reticulation plant and large water mains
- nearby intersections
- adjacent existing bridges
- transport infrastructure such as tram lines and railway tracks.

3.7 Occupational Health and Safety
Intersections should provide for the occupational health and safety of road maintenance workers and others who have to undertake vocational responsibilities at or near intersections, for example:

- adequate clearances should be provided between public utility plant (e.g. telecommunication pits) and the traffic lanes
- traffic signal controllers should be located in areas that are unlikely to be traversed by errant vehicles, and an area should preferably be available next to the controller for parking the maintenance vehicle
- poles should not be located immediately behind the kerb and close to the turning envelope of heavy vehicles and buses
- landscaping and plant species should be chosen with a view to minimising maintenance to also minimise the exposure to traffic of maintenance personnel.
4 DESIGN PROCESS

4.1 General

This section summarises the planning and design procedures to be followed, and provides guidance on the data and parameters that should be considered in the development of detailed working drawings, specifications and cost estimates for intersections at grade. The procedure is outlined in the design flow chart in Figure 4.1.

The chart illustrates:

- the importance of town planning considerations together with current and future transport and traffic requirements in determining the intended function and form of an existing or new intersection or whether an intersection is required at all
- the way in which data, topography, user characteristics, policy, budgets and local issues combine to influence the development of intersection design options
- the iterative nature of the design process whereby design options are evaluated and refined until the most appropriate design is approved.

The development of a final design is facilitated by drawings that become progressively more detailed throughout the process (Guide to Road Design – Part 8: Process and Documentation (Austroads 2009h)). Some important aspects of the process are described below.

Roads are one form of land use and one element in the transport system. In developing areas and existing urban road networks the role of roads is influenced by the type of land use and the other modes of transportation available. The development of new roads and road networks therefore requires input from specialists in town planning, transport modelling and traffic engineering (traffic modelling, estimation and analysis).

While the current traffic situation is relevant in many cases (particularly at brownfield sites) designs for new roads and major upgrades of existing roads will require estimations of traffic flows, traffic movements and traffic composition in a future design year (or years where staged development is appropriate).

In some cases the need for an intersection may be questioned. A decision not to provide a new intersection or to remove an existing intersection should be taken only after an analysis of the likely impacts on other roads and intersections in the surrounding road network. These impacts could involve traffic congestion or crashes at other intersections, or traffic intrusion into local streets.

For new intersections, possible locations will have to be identified taking topography, natural and man-made features, and many other considerations into account. It may also be appropriate to consider a range of layout options and to evaluate them in terms of traffic performance, environmental impact and cost.

The process also involves an approval process that is preceded by consultation with other stakeholders (e.g. local municipalities; service authorities), the outcome of which may influence the design and final recommendation.
Figure 4.1: Design flow chart in the modelling process to produce a set of working drawings for construction or modification of an intersection
4.2 Basic Data for Design

Three questions have to be answered before the design of an intersection is possible. These questions attempt to establish the purpose of the intersection in the road network and they generate the basic data required for detailed design to commence. They are:

- What function should the intersection fulfil?
- What is the current situation at the intersection site?
- What changes could occur in the future?

Factors to consider in relation to each of these questions are listed in Table 4.1.

While many of the considerations in Table 4.1 relate to road planning and traffic management, it is important that road designers have an understanding of the factors that influence the functional design. Austroads Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007) provides information on traffic management considerations that influence road design including:

- intersection control options and selection criteria (Table 2.2 of the Guide to Traffic Management – Part 6)
- suitability of different types of traffic control to different road types (Table 2.3 of Guide to Traffic Management – Part 6)
- key traffic management selection considerations for the various types of intersection (Table 2.4 of Guide to Traffic Management – Part 6)
- issues for different road user categories for intersection and crossing design.
### Table 4.1: Factors to consider regarding function, current situation and the future

<table>
<thead>
<tr>
<th>Question</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>What function?</strong></td>
<td>Identify the:</td>
</tr>
<tr>
<td></td>
<td>- function of each leg</td>
</tr>
<tr>
<td></td>
<td>- conflict points with non-motorised transport modes.</td>
</tr>
<tr>
<td></td>
<td>Determine whether each leg should be provided/remain.</td>
</tr>
<tr>
<td></td>
<td>Examine network consequences on motor vehicles, pedestrians, cyclists, public transport and freight of:</td>
</tr>
<tr>
<td></td>
<td>- not providing an intersection</td>
</tr>
<tr>
<td></td>
<td>- deleting an intersection leg</td>
</tr>
<tr>
<td></td>
<td>- banning a motor traffic movement</td>
</tr>
<tr>
<td></td>
<td>- not providing for or allowing a pedestrian, cyclist or public transport movement.</td>
</tr>
<tr>
<td></td>
<td>The output from this step is a series of decisions about:</td>
</tr>
<tr>
<td></td>
<td>- which movements or legs should form the intersection (if any)</td>
</tr>
<tr>
<td></td>
<td>- the function of each leg in the road hierarchy</td>
</tr>
<tr>
<td></td>
<td>- the movements which should have priority.</td>
</tr>
<tr>
<td></td>
<td>For more information regarding the function of intersections, refer to Commentary 1.</td>
</tr>
</tbody>
</table>

| **Current situation?** | With the composition of the intersection defined and the function of each leg clarified, the current situation must be quantified at the likely site(s). Basic data that should be collected includes:  |
| | - topography at the site(s)  |
| | - land use, access points to properties and special site constraints (e.g. the location of public utilities, awnings and balconies, trees, monuments, property boundaries, buildings, and drainage structures including pipes)  |
| | - compilation and analysis of crash data for the most recent five-year period (for example)  |
| | - the current traffic (including bicyclists and pedestrians) defined in terms of:  |
| | - hourly through and turning movements during peak, inter-peak and non-business times  |
| | - volumes during special, regular events (holiday periods, sporting fixtures etc.)  |
| | - approach speed during each of these times (taking into account speed limits)  |
| | - movements currently given priority or denied  |
| | - details of public transport, especially bus and taxi desire lines  |
| | - proportions of through and local traffic  |
| | - performance (e.g. acceleration, braking, turning, walking speed) of the various users  |
| | - composition or mix of traffic (i.e. numbers of different vehicle classes, including trucks)  |
| | - special network functions existing, or proposed, such as freight routes and bus routes  |
| | - values of economic factors (e.g. operating and delay costs, rates for construction and maintenance work, property values, utility adjustment costs) to be used in the analysis stage  |
| | - budget limits  |
| | - special constraints (e.g. political commitments, flood levels).  |

| **Changes in the future?** | The objective here is to scan the possible future to define likely events which will have an impact on the operation of the intersection. Issues include:  |
| | - major new roads in the corridor  |
| | - changes in traffic volumes or composition  |
| | - changes to vehicle characteristics  |
| | - alterations to the road hierarchy  |
| | - alterations in turning movement volumes  |
| | - changes in land use  |
| | - adjustments to the speed zones  |
| | - changes in the form of traffic control (e.g. will traffic signals ever be installed?)  |
| | - foreshadowed amendments to traffic regulations  |
| | - planned route changes for trucks, buses and bicycles.  |

**THE CONSIDERATIONS LEAD TO OUTPUTS WHICH BECOME DESIGN INPUTS**
Table 4.1: Factors to consider regarding function, current situation and the future (continued)

<table>
<thead>
<tr>
<th>Question</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outputs</td>
<td>The completion of the three-stage process outlined above will yield the following outputs:</td>
</tr>
<tr>
<td></td>
<td>- a decision as to whether an intersection is required at all</td>
</tr>
<tr>
<td></td>
<td>- a determination about the legs which are to form the intersection and the function of each leg (especially the type of access controls and parking which will apply at the intersection site, and on each approach/departure leg)</td>
</tr>
<tr>
<td></td>
<td>- confirmation of the speed zoning which will apply on the approach and departure side of each leg in the immediate and longer term, and the desirable speed of turning movements, particularly during times of low traffic flow</td>
</tr>
<tr>
<td></td>
<td>- the hourly traffic volumes for vehicles, bicycles and pedestrians to be used for the design, the movements which should receive preference, and the movements which are to be positively discouraged or denied</td>
</tr>
<tr>
<td></td>
<td>- definition of public transport requirements (e.g. movements, where services should stop, priority)</td>
</tr>
<tr>
<td></td>
<td>- special provisions for movements which should be incorporated, especially emergency services</td>
</tr>
<tr>
<td></td>
<td>- site, or other constraints which apply</td>
</tr>
<tr>
<td></td>
<td>- need for future changes in the form of traffic control</td>
</tr>
<tr>
<td></td>
<td>- details of network influences, such as upstream and downstream intersections, which will affect the operation of the intersection at the site.</td>
</tr>
</tbody>
</table>

While many of the considerations in Table 4.1 relate to road planning and traffic management, it is important that road designers have an understanding of the factors that influence the functional design. Austroads *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings* (Austroads 2007), provides information on traffic management considerations that influence road design including:

- intersection control options and selection criteria (Table 2.2 of the *Guide to Traffic Management – Part 6*)
- suitability of different types of traffic control to different road types (Table 2.3 of *Guide to Traffic Management – Part 6*)
- key traffic management selection considerations for the various types of intersection (Table 2.4 of *Guide to Traffic Management – Part 6*)
- issues for different road user categories for intersection and crossing design.

### 4.3 Location of Intersections

The location of an intersection is primarily determined by land use and the transport (including roads) networks required to serve the activity associated with various land uses (*Guide to Transport Planning* (Austroads 2009n); *Guide to Traffic Management – Part 4: Network Management* (Austroads 2009j)). However, the location of an intersection can also be influenced by environmental and road design considerations. In terms of road design the broad considerations associated with choosing a preferred general alignment for a new road may tend to dictate the location of intersections, but designers should always consider the implications for intersections when establishing an alignment for a new road or for the deviation of an existing road (*Guide to Road Design – Part 3: Geometric Design* (Austroads 2009a)).

In urban situations, the choice of location of the intersection is usually limited by the layout of streets and the constraints of property development. In rural areas, the choice of location is also influenced by the existing road network; however, the absence of development and other constraints may result in a greater choice of location.
The location and spacing of intersections and property access can affect the safety and operation of a road, and road authorities may determine the appropriate degree of access according to a roads classification through the application of access management categories (Section 2 of the Guide to Traffic Management – Part 5: Road Management (Austroads 2008a)). An example of this approach to intersection and access spacing is provided in Commentary 2.

Road design is an iterative process and designers should expect road design alignments and intersection locations and layouts to be modified as the design progresses from conceptual to final drawings. Considerations that may affect the location of intersections are summarised in Table 4.2.

Table 4.2: Considerations in the location of intersections

<table>
<thead>
<tr>
<th>Context</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport</td>
<td>New intersections are created through a need to provide:</td>
</tr>
<tr>
<td></td>
<td>• a new road link within the network to overcome a network operational deficiency (e.g. new urban or rural freeway/motorway)</td>
</tr>
<tr>
<td></td>
<td>• a deviation of an existing road to overcome a safety or operational issue</td>
</tr>
<tr>
<td></td>
<td>• access to a major or minor land development.</td>
</tr>
<tr>
<td></td>
<td>In urban areas the location of new intersections is often constrained by the availability of land or the cost to acquire property.</td>
</tr>
<tr>
<td></td>
<td>The location of interchanges on new urban freeways/motorways is usually determined by the existing road network with which it must interact</td>
</tr>
<tr>
<td></td>
<td>and the level of service required on both the road in question and for community access.</td>
</tr>
<tr>
<td></td>
<td>On new rural freeways/motorways or duplicated roads there may be greater scope to choose the location of interchanges or intersections,</td>
</tr>
<tr>
<td></td>
<td>a key factor being the development of existing or new local roads for freeway access or the creation of frontage (i.e. service) roads.</td>
</tr>
<tr>
<td>Environment</td>
<td>The location of an intersection may be influenced by a range of environmental factors including:</td>
</tr>
<tr>
<td></td>
<td>• topography</td>
</tr>
<tr>
<td></td>
<td>• watercourses (rivers, streams)</td>
</tr>
<tr>
<td></td>
<td>• waterways (lakes, inlets)</td>
</tr>
<tr>
<td></td>
<td>• railways</td>
</tr>
<tr>
<td></td>
<td>• environmentally sensitive areas (swampland, habitats)</td>
</tr>
<tr>
<td></td>
<td>• heritage buildings and sites.</td>
</tr>
</tbody>
</table>
Table 4.2: Considerations in the location of intersections (continued)

<table>
<thead>
<tr>
<th>Context</th>
<th>Considerations</th>
</tr>
</thead>
</table>
| Road design   | Intersections must be located so that required driver and pedestrian sight distances are met. Ideally, it is desirable that T-intersections are located on straight and generally flat sections of road. Provided that the approach gradients are moderate the best site for an intersection is in a sag vertical curve, with a straight alignment on each approach leg. Where this is not possible it is desirable that the horizontal alignment for the major movements should be as constant as possible (i.e. a generous and constant curve through the intersection). This is particularly important at wide intersections to maintain good lane discipline. It is important to provide speed reducing treatments on minor legs with high approach speeds, particularly those where driver alertness or awareness is low as these approaches have been shown to have twice the crash rate as low-speed approaches (Arndt 2004). This may involve applying reverse curves on the approach or other treatments. Discussion of these treatments is provided in the Guide to Road Design – Part 4B: Roundabouts (Austroads 2009c). Due to potential problems with sight distances, operational issues and safety issues, wherever practicable the following sites should be avoided in locating intersections:  
  - Near crests: If an intersection must be located within a crest vertical curve, it should be on the top of the crest (not either side) and preferably on a straight horizontal alignment.  
  - Horizontal curves:  
    - on the inside of small radius horizontal curves as this can make it difficult to achieve adequate horizontal safe intersection sight distance and minimum gap sight distance, and produce difficult observation angles for drivers  
    - on the outside of smaller radii horizontal curves as this can make it difficult to provide approach sight distance to the pavement and road markings within the intersection because of the superelevation (unless the side road is on a downgrade to the intersection), and may result in oncoming major road vehicles being obscured to an entering driver by the vehicles travelling in the opposite direction on the major road.  
  - Steep gradients:  
    - a steep upgrade combined with a vertical curve on the approach to an intersection can adversely affect approach sight distance  
    - a steep upgrade on the immediate approach from a side road can adversely affect heavy vehicles starting up to enter the major road  
    - a steep downgrade on the approach to a stop or give-way line makes it more difficult for heavy vehicles to stop  
    - a steep downgrade within an intersection results in adverse crossfall for turning movements and this can be a safety issue for heavy vehicles (truck roll-over).  
  - In cuttings: Large volumes of additional excavation can result if adequate sight distance is to be provided for through and entering traffic.  
  - On high embankments: Large quantities of fill may be required to obtain the required geometry and to provide sight lines past crash barriers and signs.                                                                                                                                                                                                                       |

4.4 Design Speed

The design speed for traffic on a priority road at intersections will generally depend on the alignment standard adopted for the road in general (Guide to Road Design – Part 3: Geometric Design (Austroads 2009a)).

The design speed adopted for side roads that must give way to priority road traffic will also depend on the general road alignment. In rural areas where the alignment is curved along the road leading to the intersection it is desirable that the approach curve/s be designed to progressively slow vehicles and that the immediate approach is straight to facilitate good sight distance and controlled braking of vehicles. In addition, it is highly desirable that the intersection is able to be seen from before the first approach curve (Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b)).
4.5 Road Cross-section

4.5.1 Cross-section Elements

General

The selection of cross-section elements for roads is an iterative process that considers road function and safety, environmental impact, economy and aesthetics in order to determine the most appropriate arrangement for the particular situation. The allocation of space to various road users is an important factor that is discussed in of the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007).

The mid-block cross-section on roads leading into an intersection may also influence the cross-sections required on the intersection approaches (Guide to Road Design – Part 3: Geometric Design (Austroads 2009a)).

Traffic capacity should also be considered in determining the number and width of lanes required on the approaches to intersections (Guide to Traffic Management – Part 3: Traffic Studies and Analysis (Austroads 2009i)).

4.5.2 Traffic Lanes

General

Generally, important intersections should be defined by kerbs, including rural sites, to improve conspicuousness of the intersection and to prevent shoulder gravel from being strewn on the road pavement by vehicle tyres.

Lane width is generally measured from the centre of lane marking to centre of lane marking for inner lanes, and from the centre of lane marking to the centre of the edge line (or line of kerb) for outer lanes (Figure 4.2). However, some jurisdictions may measure the lane width to the lip of channel and designers should therefore become familiar with local practice.

This convention also applies to auxiliary lanes, bicycle lanes and other special use lanes. Where a shoulder exists adjacent to an intersection, the lane width should be measured to the centre of the edge line (where provided) or to the edge of the road pavement.

It should be noted that construction drawings usually show dimensions from the lip of the kerb and channel, defined as the point at which the kerb or kerb and channel meets the road pavement surface.
Types of cross-sections and lanes


The cross-sections of roads that pass through at-grade intersections can be urban or rural and fall into the following categories:

- two-lane two-way roads
- multi-lane undivided roads
- duplicated arterial roads.

At rural sites the lanes are usually through lanes, auxiliary lanes for turning from or onto the priority road, and stand up lanes on side roads. In some cases overtaking lanes may also pass through an intersection.

Intersections in urban areas generally have to accommodate through lanes and protected turning lanes. However, they may also have to accommodate special purpose lanes such as:

- transit lanes (AS 1742.12)
- bus lanes (AS 1742.12)
- bicycle lanes (AS 1742.9)
- parking lanes (AS 1742.11)
- clearways (AS 1742.11).

While truck lanes are included in AS 1742.12 they have not been implemented in Australia. However, it is important to provide adequate lane widths for trucks on freight routes or wherever there is a significant number of heavy vehicles using an intersection.
In some jurisdictions tram routes may have to be accommodated through intersections by the provision of appropriate road space and turning clearance between trams and vehicles in adjacent lanes.

Lane widths

This section provides advice on lane widths that should be provided at greenfield sites. The desirable lane width to be used for all lanes that are provided for the movement of motor vehicles is 3.5 m.

Parking lane widths provided on intersection approaches are the same as those adopted for mid-block parking lanes – refer to the Guide to Road Design – Part 3: Geometric Design, (Austroads 2009a).

The exclusive bicycle lane width (or sealed shoulder widths) used at intersections should match the bicycle lane width provided on the approach to the intersection, which depends on the speed environment. Designers should refer to the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) for guidance on bicycle lane widths.

Turning roadways should be wide enough to accommodate the swept path of the design vehicle (Section 5) and desirably a minimum of 5.0 m between kerbs (Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b)).

4.5.3 Medians

Medians at intersections are provided to:
- separate opposing flows
- provide a refuge for right-turning traffic
- control the speed of turning traffic
- provide a refuge for pedestrians
- accommodate essential traffic control devices (e.g. signs and signals)
- accommodate roadway lighting poles
- accommodate drainage.

The widths required for medians to fulfil particular functions are provided in the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b) where traffic islands and medians are discussed. Rural medians are often very wide (e.g. 20 m) and this raises particular issues and requires suitable treatments that are also discussed in Part 4A.

4.5.4 Roadside Areas

Adequate clear zones should be provided around intersections as there are a significant number of off-road crashes associated with intersections. Batters and drains adjacent to rural intersections should be flat and smooth to enable the safe passage of errant vehicles. Considerations relating to roadside design are covered in the Guide to Road Design – Part 6: Roadside Design, Safety and Barriers (Austroads 2009e).
5 DESIGN VEHICLE

5.1 General
Intersections should be designed to ensure that:

- the design vehicle for any particular turning movement can turn from the appropriate approach lane to an appropriate departure lane/s with adequate clearances to features such as kerbs and roadside furniture
- a checking vehicle for any particular turning movement can legally perform the movement
- where required, restricted access vehicles that exceed normal legal dimensions and operate under special permit arrangements can pass through the intersection.

In general the choice of design vehicles and checking vehicles for on-road facilities will depend on the functional classification of the road or roads involved (e.g. at an intersection or driveway), the composition of the traffic and design economics.

While the road network hierarchy has both functional and descriptive definitions, it is important that the land use, and hence the vehicle types that will be negotiating the intersections, are considered when determining appropriate design vehicles. For example, some local and collector roads may serve residential development, industrial development or bus routes and therefore an appropriate design vehicle and checking vehicle must be used to suit each particular case. Designers should refer to the Austroads guide entitled Design Vehicle and Turning Path Templates (Austroads 2006a) for more comprehensive information on design vehicles and corresponding vehicle turning templates.

5.2 Design Vehicles
The physical and operating characteristics of vehicles using the road control some specific elements in geometric design. The classification and function of the road may determine the type of vehicle operating on a length of road.

The design vehicle is a hypothetical vehicle whose dimensions and operating characteristics are used to establish lane width and road geometry intersection layout. Historically, four general classes of vehicles have been selected for design purposes, namely:

- design prime mover and semi-trailer (19.0 m)
- design single unit truck/bus (12.5 m)
- design service vehicle (8.8 m)
- design car (5.0 m).

Details of these and other potential design vehicles (e.g. length, width, axle spacing and overhangs) are provided in Austroads (2006a). Although these vehicles are generally appropriate for the design of many intersections on road networks it is necessary for designers to establish the appropriate design vehicle for any particular route, section of road or intersection. In the case of intersections different design vehicles may apply to different traffic movements within the intersection.
The design vehicle is therefore the largest vehicle likely to regularly perform a movement at an intersection. The choice of a particular vehicle as the design vehicle depends on the number of those vehicles expected to use the movement. The types of vehicles likely to use an intersection may be estimated from traffic data at the site or other locations along the route, or from the type of existing and planned future development on the intersecting roads. Where acceptable data is available it is suggested that a particular type of heavy vehicle should be adopted as the design vehicle if at least one of those vehicles is expected to use the movement each day.

In the absence of data or reliable information to the contrary, the selection of the appropriate design vehicle for a particular intersection or turning movement should be based on the functional classification of the intersecting roads as this reflects the composition of traffic expected at the intersection. Consequently, Table 5.1 and Table 5.2 should be used to choose design vehicles for movements at various intersection types in Australia and New Zealand respectively.

On most arterial roads the design vehicle would be a 19.0 m long articulated vehicle or a B-double depending on the traffic composition and road environment. However, a ‘road train’ may be appropriate as the design vehicle at some locations, and in some urban areas a 14.5 m restricted route bus may be the appropriate design vehicle.

In situations where it is appropriate to design for a car only, the Austroads design passenger vehicle (based on the B99 dimensions of AS 2890.1-2004) should be used. The B99 dimensions represent the 99.8th percentile class of all cars and light vans on the road, and the rationale for adopting these is to ensure that the majority of passenger vehicles are considered when this design vehicle is used.

Designers should also be aware that in Australia heavy vehicle designs are being developed under a performance-based standards (PBS) scheme to meet a government objective of ‘continuous productivity gains … whilst meeting reasonable safety, road asset protection and environmental standards’ (NTC 2008). ‘Blueprints’ for SMART heavy vehicles have been published on the NTC website and some blueprint heavy vehicles have been approved, one of which is an 82.5 t B-triple for use on a B-triple network. Consequently, these developments will influence the choice of design vehicle for intersections for relevant routes and road networks.

5.3 Checking Vehicles

The design vehicle for a particular case is not necessarily the largest of the vehicles that may operate at that location but is intended to represent the majority of the vehicles allowed to operate there. A larger vehicle may not be precluded from the road, but may need to operate with reduced clearances or encroach into adjacent lanes (where legal within a jurisdiction). While this may inconvenience some road users, the low frequency of the occurrence of these vehicles makes this acceptable.

An appropriate checking vehicle must be used in order to ensure satisfactory operation of these larger vehicles. The checking vehicle will be chosen according to the potential for such vehicles to use the facility and will be at least the next larger vehicle to the design vehicle. Typical checking vehicles are shown in Table 5.1 and Table 5.2.

The checking vehicle may be permitted to run over kerbs and encroach on adjacent lanes. ‘Permit’ vehicles (i.e. over-width or over-length vehicles travelling with a permit) are not to be used as a design vehicle unless they regularly use the route. Instead, permit vehicles are often used as the checking vehicle.
As an example, the intersection of two arterial roads could be expected to carry significant proportions of commercial vehicles and a semi-trailer or a B-double would often be chosen as the design vehicle (depending on the traffic composition and road environment) and used to determine the shape of pavement edges or locations of kerbs for small radius turns. The intersection should be checked to ensure that a larger restricted access vehicle (e.g. 25 m long prime mover and semi-trailer) can turn legally within the pavement area and to identify any 'over-run' areas that should be specially constructed or marked. Figure 5.1 shows an example of the provision for a checking vehicle.

Source: Based on Austroads (2006a)

Figure 5.1: Example of using a template for a checking vehicle
### Table 5.1: Selection of design and checking vehicles and typical turning radii in Australia

<table>
<thead>
<tr>
<th>Intersecting road types</th>
<th>Typical Austroads standard vehicle for design</th>
<th>Typical Austroads standard vehicle for checking design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial/Arterial</td>
<td>Single articulated (19.0 m)1</td>
<td>Appropriate restricted access vehicle e.g.</td>
</tr>
<tr>
<td></td>
<td>Radius 15 m</td>
<td>• B-double (25 m)1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Long single articulated (25 m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Road train3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Arterial/Collector</td>
<td>Single unit truck/ bus (12.5 m)</td>
<td>Single articulated (19.0 m)1</td>
</tr>
<tr>
<td></td>
<td>Radius 12.5 m</td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Arterial/Local (residential)</td>
<td>Service vehicle (8.8 m)</td>
<td>Single articulated (19.0 m)1</td>
</tr>
<tr>
<td></td>
<td>Radius 12.5 m</td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Collector/Collector (industrial)</td>
<td>Single articulated (19.0 m)1</td>
<td>Single articulated (19.0 m)1</td>
</tr>
<tr>
<td></td>
<td>Radius 15 m</td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Collector/Collector (residential)</td>
<td>Single unit truck/ bus (12.5 m)</td>
<td>Single articulated (19.0 m)1</td>
</tr>
<tr>
<td></td>
<td>Radius 12.5 m</td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Collector/Local (residential)</td>
<td>Service vehicle (8.8 m)</td>
<td>Single articulated (19.0 m)1</td>
</tr>
<tr>
<td></td>
<td>Radius 9 m</td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Local/Local (industrial)</td>
<td>Single articulated (19.0 m)1</td>
<td>Appropriate restricted access vehicle e.g.</td>
</tr>
<tr>
<td></td>
<td>Radius 12.5 m</td>
<td>• B-double (25 m)2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Long single articulated (25 m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Road train3</td>
</tr>
<tr>
<td>Local/Local (residential)</td>
<td>Service vehicle (8.8 m)</td>
<td>Single articulated (19.0 m)1</td>
</tr>
<tr>
<td></td>
<td>Radius 9 m</td>
<td>Radius 15 m</td>
</tr>
</tbody>
</table>

**Notes:**
1. Select the appropriate restricted access vehicle for the design of sites that are frequently used by such vehicles.
2. B-double length may vary between jurisdictions (e.g. 26 m in South Australia; 27.5 m in Western Australia).
3. Select appropriate road train from the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) or from relevant jurisdictional guide.
4. Also for intersections with industrial land use for collector/local intersections.
5. Simulations show that for this radius the maximum steering angle occurs at the exit of the turn and not applied at the crawl speed.

Source: Based on Austroads (2005).

### Table 5.2: Selection of design and checking vehicles and recommended turning radii in New Zealand

<table>
<thead>
<tr>
<th>Intersection type</th>
<th>Typical standard design vehicle</th>
<th>Typical standard vehicle for checking design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection of two or more arterial or sub-arterial roads</td>
<td>Semi-trailer (17.0 m)</td>
<td>B-train (20.0 m)</td>
</tr>
<tr>
<td></td>
<td>Radius 15 m</td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Intersections of an arterial road or sub-arterial road, and a minor road</td>
<td>Large rigid single unit truck/tour bus (12.5 m)</td>
<td>Semi-trailer (17.0 m) or B-train (20.0 m) depending on local traffic requirements</td>
</tr>
<tr>
<td></td>
<td>Radius 12.5 m</td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Intersections of local collectors</td>
<td>Large rigid unit rigid truck/tour bus (12.5 m)</td>
<td>Semi-trailer (17.0m)</td>
</tr>
<tr>
<td></td>
<td>Radius 12.5 m</td>
<td>Radius 15 m</td>
</tr>
<tr>
<td>Intersections of minor local streets</td>
<td>Medium single unit rigid truck (8.0 m)</td>
<td>Large single unit rigid truck/tour bus (12.5 m)</td>
</tr>
<tr>
<td></td>
<td>Radius 9 m</td>
<td></td>
</tr>
</tbody>
</table>

Source: Based on Austroads (2005).
5.4 Restricted Access Vehicles

Restricted access vehicles (sometimes referred to as over-dimensional vehicles) are included in Austroads (2006a) for the purpose of checking intersection designs on relevant routes. These vehicles may operate under permit arrangements that generally nominate the appropriate routes and are likely to be a checking vehicle on routes where they operate. Alternatively, specific routes are designated for operation by certain vehicle types without a permit. In this case, the largest type (e.g. A-triple) is likely to be the design vehicle for that route.

Restricted access vehicles exceed legal limits and operate under permits that specify conditions under which special loads (e.g. power station generators, temporary school classrooms) are able to use the road system. The characteristics of these vehicles (e.g. height, width and weight) can vary significantly and it is usual for permits to be issued that specify trip details such as the route, time of day and special requirements (e.g. temporary removal and replacement of traffic signs, traffic signals or overhead utility cables). Designers should consider the accommodation of these vehicles when designing intersections on routes designated for their use.

5.5 Visibility from Vehicles

There are no design rules dealing with visibility from vehicles. However, research has suggested that there is a range of angles through which a driver of a car can readily observe other traffic and areas that are not readily observed. This information is the basis for guidelines for the angle at which roads should intersect and the angle at which drivers should position their vehicle on intersection approaches in order to see potentially conflicting traffic (Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b)).

5.6 Design Vehicle Swept Path

5.6.1 General

Turning paths of design vehicles form the basis of the turning widths required at intersections. All intersection layouts must be checked to ensure that they can accommodate the turning path envelope (swept path) for the design vehicle plus necessary clearances. The swept path is the dynamic envelope traversed by the outer extremities of the vehicle. Vehicle swept paths can be checked by using a turning path template or a computer program. A wide range of turning path templates, at various scales, is available in Austroads (2006) and Land Transport NZ (2007).

The fundamental principles in the development of turning path templates and designing for turning vehicles are:

- the design vehicle should be able to turn (left or right) from a marked lane without crossing adjacent marked lanes
- the tendency for the rear of articulated vehicles to move backwards at some point through the turn should be prevented. This may occur when turning on a small radius through large angles (i.e. greater than 120°)
- all vehicles that are considered in designing the intersection can negotiate the intersection without the rear wheels of the vehicle describing a small radius such that pavement surfacing is damaged.
Turning path templates are:

- marked with a turning radius and the operating speed of the turning vehicle expressed as a range (e.g. 15–20 km/h). The radius is measured to the path of the outer front wheel
- restricted to specific turn radii less than 30 m
- set out to provide a number of specific angles of turn although other angles can be assessed by rotating the template at the centre of the turning circle
- presented for left-turning manoeuvres but are applied to right-turns by turning the transparency over
- an appropriate guide to the width necessary to cater for the tracking of long vehicles in smaller radius turns. For larger radius turns, the geometry specified in the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) should be used.

Further information in relation to design vehicles and turning templates, including Austroads standard templates, is provided in Austroads (2006). The templates can be imported into most computer drawing packages. Some information and examples of turning templates are provided in Commentary 3.

Computer programs such as Autoturn, Autotrack or Vehicle/Path (VPATH) are often used instead of vehicle turning path templates. These programs are particularly useful for checking complex combinations of geometric elements and vehicles that have unusual configurations (e.g. axle spacing, body overhang, over-width and over-length). Also, turning radii of any magnitude can be readily applied, whereas swept path templates are constrained to standard values (usually 12.5 m, 15 m, 20 m and 30 m).

5.6.2 Radius of Turn

The desirable minimum radius turning path is given by the template covering turning speeds of 5 km/h to 15 km/h (Austroads 2006). The minimum radii of turns for intersections between roads of various functional classifications in Australia are shown in Table 5.1 and for New Zealand in Table 5.2. Turning movements at all intersections between two arterial roads or important traffic routes should be designed for a minimum turning radius of 15 m.

General use of an absolute minimum 12.5 m radius for heavy vehicles should be avoided as this can only be achieved with full lock steering at very low speeds. A 12.5 m turning radius should only be used in low-speed environments such as intersections with collector roads and local streets, and in off-road areas where demand is low. Conversely, large curve radii at intersections may promote higher than desirable approach and turning speeds. Consequently, it is essential that the desirable speed for each turning movement be established early in the intersection design process.

5.6.3 Clearances to Swept Paths of Turning Vehicles

*Edge of pavement/kerb/centrel ine*

Design vehicle turning path templates should be applied to road intersection layouts to accommodate the swept path with a minimum offset of 0.5 m from the extremities of the vehicle path (i.e. vehicle extremity, not wheel tracks) to a kerb, pavement edge or centreline.
It should be understood that turning templates do not represent a particular vehicle but an envelope in which a range of vehicles can operate. They do not include allowances for variation in tracking by individual drivers, which is why adequate clearances must be applied between the swept path and kerbs or pavement edges.

**Between swept paths – turns in the same direction**

The following turning path templates should generally be used to design intersection geometry for turns in the same direction at arterial road intersections:

- single turn – the design vehicle, in accordance with Section 5.2
- double turn – design vehicle and car abreast.

Where it is necessary to apply two separate turning templates in the same direction of travel then a clearance of 1.0 m should be provided between the templates. This may occur where it is necessary to provide for heavy vehicles turning two or three abreast, a case not covered in Austroads (2006a) and which may occur at accesses to port facilities or major industrial complexes.

The radius of turn will depend on the geometry of the intersecting roads.

**Between swept paths – opposed turns**

Where opposed right-turns operate simultaneously, the following clearances should be provided between the left sides of opposing vehicles (i.e. not wheel tracks) as illustrated in:

- single turns – 1.0 m
- one single, one double – 2.0 m
- double turns – 2.0 m.

These clearances are illustrated in Section 7.2.1 of the *Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections* (Austroads 2009b).

### 5.6.4 Using Templates to Prepare and Check Designs

Turning path templates, which are generally reproduced on transparent film as a design tool, are used to:

- establish the width of pavement required at locations where vehicles execute significant turns (i.e. large angles of turn at relatively small radii)
- define the shape of the edge of the roadway, traffic islands, median ends, turning roadways and the alignment of traffic lanes, etc., at intersections, median and separator openings, channelisation, entrances, etc.
- establish the areas adjacent to turning roadways, traffic lanes and in traffic islands, etc., which are likely to be encroached upon by the swept path of checking vehicles including the area outside a vehicle’s wheel path (due to the front and rear overhang) which needs to be kept clear of road furniture and other fixed objects
- define areas within traffic islands or on the road verge which may need to be strengthened or otherwise designed to carry the occasional heavy wheel loads when checking or restricted access vehicles are permitted to encroach outside the normal roadway limits.
6 PUBLIC TRANSPORT AT INTERSECTIONS

6.1 General

Road design principles and standards are concerned with the safe, efficient and comfortable passage of all road users, and this is particularly important for road-based public transport services.

When designing road layouts and traffic management systems, it is important that traffic engineers and road designers appreciate that public transport is not simply another set of vehicles operating independently on the road network. Public transport is a comprehensive integrated service system that involves vehicles, infrastructure, systematically planned strategic routes and schedules, operational systems, and, most importantly, passengers.

Passengers travelling on road-based public transport are usually unrestrained, often standing and therefore more susceptible to dynamic forces than the occupants of cars. Public transport vehicles also have limitations that do not apply to cars. Therefore, roads and special public transport facilities must not only be designed to physically accommodate the types of vehicles that are intended to use them, but also to ensure that passengers using the service (particularly those standing) are not subjected to excessive forces as the vehicle moves through the system.

When designing new roads, it should be established whether bus services are likely to use the route. If so, the road alignment should be designed to provide acceptable ride quality for passengers and minimal delay to the progress of the bus or tram. This applies equally to horizontal and vertical alignments, intersection layouts, and to mid-block curves and gradients.

Ideally, public transport would be located in its own right-of-way and have exclusive use of that space. Some notable examples of separate rights-of-way for buses, trams and light rail vehicles do exist. However, the reality is that public transport vehicles usually have to be accommodated within road reservations either in a separate space (e.g. median) or by mixing with general traffic.

Many priority measures for public transport at intersections are achieved through traffic management initiatives and systems. These measures and treatments are discussed in the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007) and also in the Guide to Traffic Management – Part 9: Traffic Operations (Austroads 2009k).

The facilities and treatments for on-road public transport that may need to be incorporated into an intersection layout include:

- bus lanes (full lane, queue jump lane, or setback lane)
- bus stops on intersection approaches or departures
- tram lines
- tram stops on approaches or departures.

Taxis also provide an important public transport resource and where necessary should be considered in the design of intersections. Public transport facilities may be provided adjacent to the road or within medians.
6.2 Design Vehicle

Design vehicles are discussed in Section 5. In some instances the design vehicle for an intersection will be one of the Austroads standard bus configurations. However, designers should ensure that the intersection can satisfactorily accommodate the swept path of the appropriate bus or tram that will pass through the intersection. For example, because of the length of the vehicle and front and rear overhang, designers should be mindful during the design of the potential for conflict between buses or trams and adjacent vehicles or pedestrians (Figure 6.1 and Figure 6.2).

Source: VicRoads (1999a)

Figure 6.1: Potential conflict between buses and cars

Note: Points 1, 2, 3 and 4 represent locations where the swept path of a tram may encroach a centreline or lane line resulting in potential for conflict between a tram and a vehicle in an adjacent lane.
Source: VicRoads (1999b)

Figure 6.2: Potential conflict points between trams and cars at signalised intersections
6.3  Bus Facilities

6.3.1  Bus Lanes

A bus lane simply becomes an additional lane on the approach to the intersection and should be signed, marked and delineated in accordance with AS 1742.12. The bus lane is usually located to the left of the road although where a bus route turns right at an intersection, a right-turn bus lane may be provided.

A dedicated bus lane at an intersection may be:

- The continuation of a full bus lane, that is, a mid-block lane that extends over a considerable distance (Figure 6.3(a)).
- A queue jump lane that is long enough to enable buses to pass a queue of general traffic and obtain an early start at traffic signals (Figure 6.3(b)).
- A set-back lane with short mid-block bus lane on the approach enables a bus to pass through the intersection during the green time (Figure 6.3(c)).
- A short bus lane at traffic signals to allow buses to bypass queues at the approach to signalised intersections (Figure 6.4). Where this facility is not required initially, but is expected to be required at some future time, the left-turn island should be large enough to accommodate the lane. In the intervening period the island should be fully constructed as a permanent island (i.e. an additional space should not be ‘painted out’ or formed using a ‘spike down’ kerb.

The width of a bus lane should comply with the guidance in the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a).

Where a bus lane or queue jump lane treatment is provided on the approach to an intersection it is desirable that the lane continues for some distance on the departure side of the intersection. In some cases the treatment will lead into a continuous bus lane which is the ideal situation. However, where this is not necessary or practicable and the bus facility must end beyond the intersection, the terminal treatment should comprise a section of parallel lane and a generous taper. Suggested desirable minimum lengths for termination of the lane are provided in Table 6.1. The operating speed shown in the table is the maximum speed at which a bus is likely to travel on the departure road from the intersection.

<table>
<thead>
<tr>
<th>Operating speed on departure (km/h)</th>
<th>Overall length 1 (m)</th>
<th>Taper length 2 (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60</td>
<td>165</td>
<td>100</td>
</tr>
<tr>
<td>70</td>
<td>190</td>
<td>110</td>
</tr>
<tr>
<td>80</td>
<td>220</td>
<td>130</td>
</tr>
</tbody>
</table>

Notes:
1. Based on four seconds of travel time for the bus driver to observe traffic in the adjacent lane in order to accept a gap plus the taper length (see note 2) and is measured from the pedestrian crosswalk across the intersection departure.
2. Based on a rate of lateral shift for the bus of 0.6 m/sec.
Figure 6.3: Full bus lane and queue jump lane treatments

(a) Setback peak period bus lane with mid-block bus lane
(b) A queue jump bus lane to bypass the peak hour queue length
(c) Setback peak period bus lane with short mid-block bus lane

Source: Based on VicRoads (2003); figure updated 2009
6.3.2 Providing for Buses and Bicycles

Where space is constrained it may be necessary to provide a wide kerbside bus lane that is wide enough for cyclists to share with buses, see Figure 6.5. At sites where space is available it is preferable to provide a separated bus lane and bicycle lane treatment as shown in Figure 6.6 or a high-standard off-road bicycle path or shared path.
The choice of treatment will depend on the user groups that have to be accommodated. If there is strong demand for commuting by bicycle an on-road bicycle lane is likely to be preferred. If design constraints prevent the provision of an on-road bicycle lane or cyclists are likely to be at risk on a high-speed road it may be preferable to provide a high-standard off-road bicycle path. If there are moderate demands for both bicycle travel and walking then a shared path should be considered. Further guidance on the selection of bicycle treatments is provided in the Guide to Road Design – Part 6A: Pedestrian and Cyclist Paths (Austroads 2009f).

Guidance on the widths of bicycle lanes and bus lanes is provided in the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a) whereas the widths of paths is covered in the Guide to Road Design – Part 6A: Pedestrian and Cyclist Paths (Austroads 2009f) and designers should use these guides to develop a treatment suitable for the particular site. However, Table 6.2 is provided to show the minimum width of bicycle lanes and bus lanes along roadways and through intersections.

Table 6.2: Minimum width of bus lanes and bicycle lanes in various speed zones

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Speed zone</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>60 km/h</td>
<td>70 km/h</td>
<td>80 km/h</td>
</tr>
<tr>
<td>Bus lane only</td>
<td></td>
<td>3.5</td>
<td>3.5</td>
<td>3.5</td>
</tr>
<tr>
<td>Bicycle lane only</td>
<td></td>
<td>1.2</td>
<td>1.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Bus lane plus bicycle lane</td>
<td></td>
<td>4.7</td>
<td>5.0</td>
<td>5.3</td>
</tr>
</tbody>
</table>
Figure 6.5: Wide kerbside bus lane

Source: VicRoads (2007a); figure updated 2009.
Figure 6.6: Separated bus lane and bicycle lane treatment
6.3.3  **Bus Facilities in Medians**

Special bus facilities are not normally provided in the medians of arterial roads because of the space required to:

- accommodate bus stops and allow buses to overtake
- provide a safe clearance between buses travelling at substantial speeds in opposite directions.

There are also operational consequences in catering for the bus movements at major intersections. However, where a median is wide enough a facility such as a busway or a bus interchange may be provided (Figure 6.7).

![Median bus lanes with bus signals on Causeway Bridge, Perth, WA](image)

Source: MRWA.

**Figure 6.7:** Median bus lanes with bus signals on Causeway Bridge, Perth, WA

The provision of bus facilities in medians is usually restricted to:

- express services on freeways
- medians on large bridges at critical river crossings
- queue jump facilities over relatively short lengths
- a separate right-turn facility where a bus route turns at a major intersection
- provision of a ‘centre of the road’ bus stop where this is advantageous to bus services.

The median width will vary in accordance with the service required and site constraints.
6.3.4 **Bus Stops**

*Location*

When considering whether to locate a bus stop on the approach or departure side of a signalised intersection a number of factors should be considered, such as:

- bus stops on the approach to intersections can cause detection difficulties when designing bus priority schemes
- if located on the approach side, a stationary bus may adversely reduce the sight distance available to a waiting motorist on the side road
- if provided on the departure side the stop should be indented to ensure that stationary buses do not cause traffic to queue back into the intersection at the change of phase
- for safety reasons, bus stops should be located on the departure side of facilities such as intersections and pedestrian crossings
- in some situations a stop may have to cater for buses travelling straight through the intersection and turning at the intersection, in which case an approach stop may be desirable
- ‘through’ buses may have considerable difficulty in re-entering the traffic flow on an intersection approach that has a double left-turn lane, in which case a departure stop may benefit bus operations
- if the bus has to turn right at an intersection a departure stop will negate the need for the bus to weave across from a kerbside intersection approach stop to the right-turning lane at complex junctions
- if a bus service enters from the intersecting road, a departure stop may suit services on both intersecting roads
- a departure stop may be appropriate where a major generator of bus patrons exists on that corner (e.g. shopping centre, school)
- the effect that buses using a bus stop may have on general traffic flow at the intersection.

In order to maintain traffic flow and reduce delay, bus stops should be located outside the traffic lanes (e.g. within a parking lane or within a bus bay that is indented into the kerb). An issue that often arises with indented bus bays is that bus drivers often have difficulty in safely re-entering the traffic stream where traffic volumes and speeds are relatively high, in spite of a road rule requiring other drivers to give way to buses displaying a give way to buses sign. Policy on the appropriate type of bus stop may vary between jurisdictions and under specific conditions some jurisdictions may prefer to provide bus stops in the left traffic lane so that buses do not suffer the delays that may occur if the stop was in an indented bay (an example is shown in Figure 6.8).
Where parking is banned to accommodate a bus stop, the length should provide adequate run-in and run-out tapers for the design vehicle (Figure 6.9). An alternative is to have the footpath extended and the bus stopping in the traffic lane (Figure 6.10).
Bus bays are often required near pedestrian crossings and should be located on the departure side so that passengers are not obscured from view by the bus, and are readily seen by approaching drivers (Figure 6.11).

![Figure 6.11: An example of a kerbside bus stop on the departure side of pedestrian signals](source: VicRoads (2006))

Similarly, where a bus bay is required in close proximity to an intersection, the preferred location is for it to be placed on the departure side of the intersection, as shown in Figure 6.12 and at the offset shown in Table 6.3. Alternatively, the bus bay can be placed in advance of the intersection if the type/origin/destination of the passengers using the service warrants this (Figure 6.13 and Table 6.3).

As a general rule bus bays should not be combined with acceleration or deceleration lanes.

![Figure 6.12: Proximity to departure side of intersection](source: MRWA (2006))

![Figure 6.13: Proximity to approach side of intersection](source: MRWA (2006))
Table 6.3: Desirable distance of bus bay from tangent point near intersection

<table>
<thead>
<tr>
<th>Bus bay on departure (preferred)</th>
<th>Bus bay on approach (alternative)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desirable (m)</td>
<td>Minimum (m)</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
</tr>
</tbody>
</table>


The bus bay should be located so that following drivers have adequate stopping sight distance to a bus exiting the bus bay. Ideally, intersections should not be located on curves. However, where this is unavoidable it should be noted that drivers of buses departing from bus bays located on left-hand curves have problems sighting vehicles approaching from the rear due to the curvature of the alignment. It is therefore not desirable to locate bus bays on left curve alignments unless it can be demonstrated that this problem has been overcome with modified bus bay geometry (Figure 6.14).

![Figure 6.14: Bus bay on inside of curve](source)

**Geometric design**

Figure 6.15 illustrates the preferred components of a bus bay. The geometry is an example only and designers should consult local jurisdictional guides and standard drawings for bus bay layout details.

![Figure 6.15: An example of bus bay geometry at an unconstrained site](source)

Note: All dimensions are in metres.

Note: Use barrier kerb on parallel section where buses stop to assist passengers as semi mountable kerb can cause uneven surface.

It is important that bus passengers should not have to contend with ponding of water when embarking or alighting from buses. Therefore, the crossfall on the bus bay should normally be 2% towards the traffic lane. Where the bus bay is located on a right curved superelevated road alignment, the bus bay crossfall should be the same as the traffic lanes. These aspects are shown in Figure 6.16. In situations where an invert results at the edge of the traffic lane, it is desirable that grated drainage pits are not located within the length of the bus bay (Figure 6.17).

Figure 6.16: Desirable crossfall at bus bays

Figure 6.17: Preferred pit location
Bus stop layout

All new bus stops must comply with the requirements of the Australian Commonwealth Disability Discrimination Act 1992 and the Disability Standards for Accessible Public Transport 2002. The Standards outline the requirements in areas such as access path, manoeuvring areas, ramps, waiting areas, surfaces and tactile ground surface indicators (TGSI).

The design of layouts may vary depending on the jurisdiction and site but as far as possible at greenfield sites the passenger waiting area at bus stops should have a consistent and predictable layout as this will particularly assist people with vision or other physical impairments.

The design should provide:

- sufficient manoeuvring space for a wheelchair adjacent to the doors, as low floor buses may have ramps at either the front or rear doors
- a wider clear area at the rear door to enable passengers to easily alight in a number of directions once they are off the bus
- a rear area that caters for the location of the rear door for various length buses.

Figure 6.18 shows an example of a desirable minimum layout determined within one jurisdiction to adequately provide for bus passengers and pedestrians passing the bus stop. It is desirable to provide a barrier kerb within bus bays to give a flatter surface where passengers are required to step onto and off the bus compared to a semi-mountable kerb. Where semi-mountable kerbs are provided either side of the bus bay a smooth transition should be provided between the semi-mountable and barrier kerb profiles.

Note:
1. All dimensions in mm
2. Where a stationary bus impedes the passage of cyclists on the road, and space is available, consideration should be given to the management of cyclist movements past the stop.

Source: VicRoads (2006); figure updated 2009.

Figure 6.18: An example of a bus stop layout with a shelter
6.4 Tram Facilities

6.4.1 Tram Tracks
Trams and light rail vehicles (LRV) are not used extensively for public transportation in Australian cities, except in Melbourne. Generally, much of the tram network is in existing urban areas. Nevertheless, new intersections may have to accommodate tram and LRV services and should desirably provide a separate reservation for trams and LRVs. These services are often provided in the medians of major divided roads (VicRoads 2004).

The relevant tram and LRV company or authority should be consulted regarding the basic design parameters to be used in designing a separate tram/LRV reservation. Key geometric elements include limits for uphill and downhill gradients, horizontal and vertical curves and tolerances for the difference in the level of rails.

Although road authorities may not be involved in the detailed design of separate tram/light rail reservations they will have an interest in the interface between these facilities and the road system. The design of roads may be affected where exclusive public transport facilities join or cross the road system, either through an at-grade or grade separated intersection treatment. In addition, where a tram/LRV reservation is to be provided close to a road and parallel to it, connections for pedestrians and cyclists should be retained or provided.

6.4.2 Tram Lanes
Tram tracks are usually located in the centre of the road. If a new road provides for trams to be accommodated without general physical separation from other traffic, tram lanes may be provided on the approaches to the intersection. In this case the tram lane is simply a special lane on the approach and should be signed, marked and delineated in accordance with AS 1742.12, Part 12: Bus, transit, tram and truck lanes. The tram lane is almost always located in the centre of the road and therefore relatively wide islands are required to separate trams at intersections and accommodate tram stops and platforms that comply with the Australian Commonwealth Disability Discrimination Act 1992.

6.4.3 Tram Stops
Melbourne has an extensive tram network and its authorities have extensive experience in tram facility design, including the retro-fitting of existing roads and development of treatments for ‘new’ roads that comply with the Commonwealth Disability Discrimination Act 1992. Should a jurisdiction plan to implement a tram service it is suggested that VicRoads be contacted for current design guidelines.

6.5 Taxi Ranks
It may be necessary to accommodate a facility for taxis within or adjacent to a new intersection. Taxi zones are created by the appropriate use of road signs and markings defined in the National Transport Commission (Road Transport Legislation – Australian Road Rules) Amendment Regulations 2006 and AS 1742.11. Reference should also be made to the Guide to Traffic Management – Part 11: Parking (Austroads 2008b). New Zealand designers are referred to Land Transport Rule, Traffic Control Devices 2004 – Schedules, Rule 54002 for guidance on signs for taxi stands, and to the Traffic Control Devices Manual – Part 13 – Parking Control (Land Transport NZ 2007b) and MOTSAM Part 2 Section 2.12 (Transit NZ 2008) for layout and markings.
Taxi ranks usually comprise parallel parking adjacent to the kerb and are defined by taxi zone signs. At areas where there is a very high demand for taxi services, consideration may be given to taxi zone layouts that increase the service rate for patrons. Such layouts should be based on sound traffic management principles and practice. For example, a parallel parking zone with longer bays and a supervising officer may facilitate the efficient arrival and departure of taxis, and angled drive-through bays may be more efficient at modal interchanges.

6.6 Proximity of Public Transport Reservations to Intersections

Intersections should be located a sufficient distance from railway or tramway crossings to ensure that the safety of public transport and other road users is not compromised. The separation should be sufficient to ensure that traffic queues on the approach to a signalised intersection do not extend through the railway or tramway crossing, as this has been found to cause serious safety issues. Similarly, the separation should be sufficient to ensure that a queue at the railway or tramway crossing does not extend into nearby intersections to the detriment of intersection operational efficiency and safety.
7 PROPERTY ACCESS AND MEDIAN OPENINGS

7.1 General

Roads provide for both traffic movement and access to abutting property. Increased frequency and the degree of access are invariably associated with reduced level of service for traffic movement along a road. Access management is discussed in the Guide to Traffic Management – Part 5: Road Management (Austroads 2008a), which discusses the application of access management categories to achieve a level of access along a road that is in accordance with the function of the road.

Designers in New Zealand are referred to the Planning Policy Manual – for integrated planning and development of state highways (Transit NZ 2007) which covers a range of subjects including access way standards and guidelines.

The principles of intersection design defined in previous parts of this guide also apply to median openings and property access. Sight distance, design vehicle turning paths and interference to through traffic by decelerating and accelerating vehicles should be considered at all sites.

7.2 Property Access

7.2.1 Access Spacing and Proximity of Driveways to Intersections

The spacing of accesses (intersections and driveways) is important, and relates to the road classification and the way in which traffic and access should generally be managed on each road. Intersection design may therefore be influenced by the access management strategy for the road which may have been assigned an access management category (Guide to Traffic Management – Part 5: Road Management (Austroads 2008a)). In designing major intersections, the proximity of other intersections and driveways can have a significant effect on the operation of the intersection and the geometry that can be achieved.

Access spacing

Traffic signal spacing should be optimised to enable suitable progression through a series of intersections. The preferred spacing is 800 m with major arterials spaced at 1.6 km. This assumes that signalised intersections are provided only where arterials and sub-arterials intersect. It is possible for an intermediate intersection of a sub-arterial and a collector to occur, thereby creating a spacing of 400 m between intersections. However, at this spacing, traffic signal coordination will be necessary to achieve the best result. Reference should be made to the Guide to Traffic Management – Part 9: Traffic Operations (Austroads 2009k).

The spacing of unsignalised access (streets and driveways) can be assessed by considering:

- safety
- stopping sight distance
- intersection sight distance
- functional area
- left-turn conflict overlap
- influence distance
- egress capacity.
In addition, the spacing of intersections can be examined from the perspective of the blockage of an intersection due to vehicles queued to enter an adjoining driveway, the need for vehicles to move diagonally across a road on leaving an access and the simultaneous entry to the through road from two adjoining accesses.

These parameters are defined and discussed in Appendix A. Different distances are derived from the application of each and it is a matter for the relevant road authority to provide policy guidance on the appropriate distances on different types of road.

**Functional area of an intersection**

The location of an access close to a major intersection is often an issue in the design of major intersections as it has the potential to adversely affect both safety and capacity. The functional area of an intersection is the area beyond the physical intersection of two roads that comprises decision and manoeuvre distances on the approaches and departures, plus any required vehicle storage length. Wherever possible, this area should be protected from interference by traffic from accesses.

The upstream dimensions of the functional area are illustrated in Figure 7.1 and comprise:

- \( d_1 \) – distance travelled during perception-reaction time of driver
- \( d_2 \) – distance travelled while driver manoeuvres laterally and decelerates to a stop (lateral movement of 1.5 m/sec)
- \( d_3 \) – length required to store turning vehicles.

![Figure 7.1: Upstream functional intersection area (based on right-turning vehicles)](image)

Source: Queensland Department of Transport and Main Roads (1975).

**7.2.2 Urban Roads**

Urban property accesses vary from entrances to major developments, such as regional shopping centres, to driveways for individual residential houses. The treatment of access should be consistent with the function of the road and any access management strategy.

The right of access to the property and the subsequent entry and exit layout is dependent on:

- type of frontage road
- land use of the property
• type of vehicle likely to use the access
• average daily traffic using the access.

Entrances to major developments such as shopping centres should:
• be analysed thoroughly to minimise their effect on the through traffic flow (*Guide to Traffic Management – Part 3: Traffic Studies and Analysis* (Austroads 2009i))
• where they intersect a major road, be designed in accordance with this guide (i.e. the same as the intersection of two public roads).

The width of an entrance or driveway, and the layout of the turn out should:
• provide single manoeuvre turns by the design vehicle
• provide adequate clearance between the design vehicle’s turning path and physical constraints within the property
• avoid reversing movement into or out of the development, except in the case of individual single residential houses
• provide safety for pedestrians by ensuring adequate sight distance
• minimise pedestrian/vehicle conflict areas and control vehicle speed across footways.

Aspects that should be considered with property accesses are summarised in Table 7.1. In addition to these considerations, it is particularly important that adequate sight distance is provided for all traffic movements associated with property accesses. For guidance on sight distance designers should refer to Section 3 of the *Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections* (Austroads 2009b).

Reference should also be made to AS 2890.1 and the *Guide to Traffic Management – Part 12: Traffic Impacts of Developments* (Austroads 2009m).
### Table 7.1: Property access considerations on urban roads

<table>
<thead>
<tr>
<th>Type of road</th>
<th>Considerations</th>
</tr>
</thead>
</table>
| Urban divided arterial road                      | Consistency with access management strategy.  
|                                                 | Traffic flow and safety.  
|                                                 | Pedestrian safety across accesses.  
|                                                 | Preferably locate new accesses on service roads or side roads.  
|                                                 | Locate new entrances away from intersections (Appendix A).  
|                                                 | Provide grade separation where justified.  
|                                                 | For narrow road reserve with direct access consider provision of a left-turn in/left-turn out layout (preferred treatment) and indirect right-turn entry and exit movements via detours around the block or U-turn movements from sheltered turn lanes or at adjacent roundabouts.                                                                                                                                                                                                                                           |
| Urban undivided multi-lane road                  | On arterial roads with high through traffic volumes control the number of access points along the route through the planning process.  
|                                                 | Right turns can be prohibited by:  
|                                                 | - the provision of a double unbroken dividing line which prohibits right turns (under the Australian Road Rules)  
|                                                 | - no right-turn signs.  
|                                                 | A physical barrier, such as a minimum width raised median, can provide some assurance that the manoeuvre will not be made.  
|                                                 | Access via side streets and/or service roads abutting the rear of properties is preferred. This reduces vehicle conflict points and enhances pedestrian safety in areas of high pedestrian activity (i.e. commercial centres and strip shopping zones).  
|                                                 | For roads with abutting industrial land use, or on the outskirts of rural cities and towns where pedestrian activity is relatively low and speeds may be relatively high, it is important to ensure that through and turning lanes are of adequate width for heavy vehicles.                                                                                                                                                                                                                     |
| Urban two-lane two-way road                       | On arterial roads passing through commercial centres, vehicular access to properties is undesirable due to the potential for conflict with pedestrians using the footpaths.  
|                                                 | Restrictions should be placed on right-turning movements where minimum gap sight distance is unavailable. This can be achieved through:  
|                                                 | - linemarking with double dividing lines or painted medians, to an extent  
|                                                 | - by providing isolated raised medians as a physical barrier to the turn.                                                                                                                                                                                                                                                                                                                                                             |
| Local street                                      | It is preferred that road networks are planned and designed so that property access points are located on local streets rather than arterial roads.  
|                                                 | Low travel speed and driver expectation of interference reduces the likelihood of conflict.  
|                                                 | Potential conflict with pedestrian movement must be identified and appropriate solutions adopted. However, the low-speed environment should ensure that both the likelihood of conflict and the severity of crashes are minimised.                                                                                                                                                                                                                     |

#### 7.2.3 Rural Roads

Although rural roads are usually characterised by relatively low turning traffic volumes to and from widely spaced access points, high-speed crashes occur due to low driver expectation of turning vehicles.

Treatment of access to rural properties is dependent on several factors including:

- through traffic volume
- turning volume
- vehicle type
- single or divided carriageway
- land use
- general topography.
To enhance safety for the turning vehicle and minimise interference to through traffic it is common to widen the shoulder or provide an auxiliary lane. This is usually achieved by providing indented turning lanes on divided roads or a basic (BA) or channelised (CH) treatment on a two-lane two-way road (Section 4 of the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b)).

The location for the point of access will be governed by the following:

- sight distance (Section 3 of the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b))
- median width/storage space
- largest design vehicle to utilise the facility
- distance to intersection
- possible confusion with intersections
- deceleration/acceleration movements
- drainage
- topography.

The number of access points off a high-speed road should be reduced either by consolidating them or by using existing side roads and service roads.

The minimum design vehicle for a rural access should be the single unit truck. However, accesses should be designed for the largest vehicle likely to use them (e.g. milk tanker, semi-trailer, B-double).

The minimum layout for a rural property access is shown in Figure 7.2. The layout caters for a single unit truck to undertake left turns without crossing the centreline of the road. It will allow for turns by articulated vehicles (providing they use two lanes of a carriageway). This minimum layout is suitable for the following conditions:

- accesses not used by articulated vehicles on single carriageway roads (e.g. two-lane two-way roads)
- left-in, left-out accesses not used by articulated vehicles on dual carriageway roads
- dedicated commercial vehicle accesses with infrequent use by articulated vehicles (no more than about one turning articulated vehicle per day) on single carriageway roads with an AADT of less than 2000, provided that the access is not associated with other minimum design criteria (e.g. sight distance restrictions or tight horizontal curves).

Any dedicated commercial vehicle access used by articulated vehicles that does not meet the conditions in the third dot point must be designed to allow for a 19 m semi-trailer to undertake left turns without crossing the centreline, as shown in the layouts in Figure 7.3 and Figure 7.4.

At locations where there is a high demand for articulated vehicles (e.g. timber mill, quarry, transport facility) a road intersection layout should be adopted.
Vehicle storage is important so that vehicles entering property can stand clear of the road. Where a gate restricts access to a property there should be sufficient length between the edge of the road and the gate to store the parked design vehicle to allow for the occupants attending a gate.

Storage lengths are:
- 8 m – car as design vehicle (only applicable to some rural residential properties)
- 15 m – single unit truck as design vehicle
- 22 m – articulated vehicle as design vehicle.

A stock grid is the preferred control on the boundary where storage is unavailable as shown in Figure 7.2 and Figure 7.4.

Where an access on a dual carriageway incorporates a median cross-over, there should be provision for storage of the design vehicle as shown on Figure 7.3 so that it does not protrude onto the through lanes.

<table>
<thead>
<tr>
<th>Type of road</th>
<th>Consideration</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-speed divided road</td>
<td>A left-in left-out layout is the preferred option on a dual carriageway road with connection to and from the opposing carriageway via U-turn facilities at adjacent median openings. Ideal location of median openings is based on those side roads and accesses with higher demand and the need for additional cross median accesses should be minimal. Direct right-turn access should only be provided at access points where the daily trip demand is high (e.g., a dairy farm or a right of way serving several properties) or there is an expectation by regular articulated vehicle drivers. Direct access can be considered where safety factors justify an additional access within 3 km of a U-turn facility. Such a factor could be to allow for easier manoeuvrability for articulated vehicles in contrast to a 180° turn on a minimum 12.5 m turning path radius available at the U-turn facility. At locations where there is high demand for articulated vehicles (e.g., timber mill, quarry, truck station), a road intersection layout should be adopted, to enhance safety, incorporating a channelised right-turn treatment (CHR) for the right-turn movement and a basic left-turn treatment (BAL) for the left-turn movement.</td>
</tr>
<tr>
<td>High-speed single carriageway</td>
<td>Figure 7.2 and Figure 7.4 show layouts that are suitable for single carriageway roads. To enhance safety or cater for higher volumes, consideration can be given to the inclusion of BAR and BAL layouts.</td>
</tr>
</tbody>
</table>
Note: This rural property access treatment may be used where articulated vehicles:

- do not use the driveway on single and dual carriageway roads
- infrequently use the driveway on two-lane two-way roads that have an AADT <2000.

Source: Austroads (2005).

Figure 7.2: Example of a rural property access – single or dual carriageway (conditional)
Where road train access is required, the desirable width of 8 m should be provided (minimum width is 6 m)

Use median pits in preference to headwalls for median drainage within the clear zone

Widened shoulder for vehicle storage

Taper 1 in 10

OPTION:
Provide Layby on departure side of property access to be used also as school bus stop / mail service shelter

Headwalls and non-frangible roadside furniture to be located outside clearzone

1 in 10 taper

R10

5.5

10

R13

3

4

R15

21

22

R12

4m grid (preferable) or inward opening 3.6m gate located min 22m from edge line

Where road train access is required, the desirable width of 8 m should be provided (minimum width is 6 m)

Note: Two-way carriageway – design AADT ≥2000 or dual carriageway left-in – left-out access minimum requirements for semi-trailer access.
Source: Based on Austroads (2005).

Figure 7.3: Example of a rural property access specifically designed for articulated vehicles on high-speed dual carriageway
7.3 Median Openings

7.3.1 General

The spacing of median openings is an integral part of access management planning. A typical mid-block median opening is shown in Figure 7.5. The justification for a median opening is an economic issue, requiring comparison of the cost of providing the opening with the cost of extra travel and inconvenience. The increase in the number of potential conflict points must also be considered in comparison with the traffic manoeuvres likely to occur without median openings.

The desirable spacing of median openings is a complex question to which there is no definitive answer. On the one hand it is desirable to space openings as far apart as possible, keeping the number of potential conflict points to a minimum. On the other hand, infrequent openings can significantly increase travel distances for local traffic and the demand for turning manoeuvres at intersections. Where the median is too narrow to accommodate a sheltered right-turn lane, a good design practice is to provide openings at most, if not all, intersecting streets with an important local service function. Where the median width is sufficient to accommodate right-turn lanes, a spacing of 120 m will permit successive development of right-turn lanes. Greater spacing is required where high storage demands occur.
On freeways, median openings are provided for use by emergency services and maintenance vehicles, and should be signposted as such. On rural non-freeway divided roads, they operate as a general U-turn facility allowing access to the opposing carriageway for property owners as well as emergency services.

The dimensions and treatment of the median opening is governed by:
- the median width
- the presence of a median safety barrier
- the type of vehicle using it
- whether the site is in a high-speed or low-speed environment.

### 7.3.2 Location

In determining the location of a median opening the following points should be considered:
- desirable locations are sags and straights where sight distance is the greatest
- it is undesirable for median openings to be located on horizontal curves or crests
- on high-speed rural roads median openings should be located at a maximum spacing of 5 km, and not be within 3 km of an intersection or interchange
- median openings should be located immediately downstream of median drainage pits, thus eliminating the necessity for installation of a pipe and associated headwalls
- the preferred location is a distance downstream (for traffic flow) of emergency telephone bays on freeways, and of property access points on non-freeway type roads, that is sufficient to enable drivers to join the traffic stream and weave across to a deceleration lane in the median.

Ideally, on urban roads it is desirable to coordinate the openings with street intersections at 400 m to 800 m intervals and provide signalisation. Shorter spacing reduces indirect travel but creates more conflicts, while longer spacing improves safety and operation but can make trips more circuitous. The minimum distance between intermediate median openings should be 150 m.
In general, to determine the location of median openings on urban roads a designer should:

- identify the most important intersecting roads to determine where median openings must be provided, and where it is desirable that they should be provided
- select intermediate openings to provide adequate local service, to comply with the functional requirements of the road and adjacent development
- examine the proposed geometric alignment, cross-section and visibility to ensure that chosen locations will satisfy the geometric design and safety guidelines.

Other factors to consider include:

- on new projects, the adjacent median planting should be restricted to relatively low vegetation to enhance driver sight distance
- median openings of heavily planted medians on existing roads should only be installed where corrective measures can be undertaken to ensure that sight distance requirements are met
- on wide medians, a desirable slope of 10:1 (6:1 maximum) between the median opening and the median invert (measured longitudinally) should be used.

A driver having a need to use a median opening should be able to recognise that the opening exists from at least 300 m in either direction.

### 7.3.3 Design Requirements

To ensure that median openings operate satisfactorily without safely or operational issues designers should ensure that:

- turn lanes are provided at all median openings as the absence of a lane will lead to rear-end and side-swipe collisions
- turn lanes are sufficiently based on storage, deceleration and vehicle access (Section 9 of the Guide to Road Design –Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b))
- median openings that are not signalised allow only for right-turn movements but no crossing movements
- median openings are not provided across right-turn lanes
- median opening designs that encourage two or more vehicles to stop side by side while waiting to complete a right-turn or crossing manoeuvre are avoided (i.e. not excessively large so as to create unsafe conditions, since multiple vehicles interfere with each driver’s sight lines).

Considerations relating to median openings and their design for various types of road are summarised in Table 7.3.
Table 7.3: Considerations relating to the design of median openings

<table>
<thead>
<tr>
<th>Road type</th>
<th>Context</th>
<th>Considerations</th>
</tr>
</thead>
</table>
| High-speed rural roads      | Includes rural freeways/motorways and rural arterial roads with access control. Median openings are required to enable emergency vehicles to access adjacent carriageways:   | On rural freeways the median openings should be:  
- designed for articulated vehicles as the only alternative for turning round broken-down heavy vehicles or allowing for emergency procedures may be at the closest multi-directional interchange which could be 10–20 km away  
- should be located adjacent to emergency telephone bays or lay-bys. On access controlled rural arterial roads with medians, efforts should be made to incorporate the median opening with a property access point, T-intersection, or a widened section of road (lay-by). A 27.0 m offset covering the median and the adjacent carriageway is the minimum width required to allow an emergency vehicle to turn. This also allows a 19.0 m semi-trailer to turn at the minimum radius required for a speed up to 5 km/h. Greater dimensions are required for higher turning speeds. Where the median is narrow, a lay-by will need to be constructed on the adjacent carriageway’s left shoulder and verge. In situations where a significant number of semi-trailer or B-double trucks require access to a divided, high-speed, rural road it may be necessary to provide a wider median to safely store trucks within the median opening (e.g. a B-double requires approximately 30 m). Generally rural roads with divided carriageways have wide medians. |
| High-speed urban freeways   | Median openings are required to enable emergency vehicles to access the adjacent carriageway:  
- attend motor vehicle crashes/medical emergencies  
- tow away broken-down vehicles  
- clean/retrieve spill loads including chemicals. Urban freeways often have narrower medians than rural freeways. The carriageways are usually separated by median safety barrier (concrete, steel or wire rope). | The treatment of the break in the safety barrier is important. May incorporate:  
- for a concrete barrier, an approved crash attenuating device or opening system  
- for non-rigid systems, positioning the terminals to minimise the gap thus allowing access to the adjacent carriageway (Guide to Road Design – Part 3: Geometric design (Austroads 2009a)). Due to the closer frequency of interchanges in urban areas and the need to restrict the width of median openings, median openings at these sites are designed for a single unit truck (fire engine, ambulance, tow truck). The crossover should be located adjacent to a lay-by, bus zone or emergency telephone bay so that the turning vehicle can take advantage of the widened formation. |
| High-speed urban divided roads | High-speed (≥ 80 km/h speed limit) urban arterial roads serve as main connectors between suburban centres. Intersections are widely spaced. Direct property access is usually controlled and where available is often limited to left-turn entry and exit. | Where intersections are spaced over 1 km apart and there is a high volume AADT, median openings should be provided at 400–800 m intervals. On roads abutted by large industrial enterprises that attract a significant flow of large trucks, it may be necessary to examine the consequences of not providing access through the median to particular properties (e.g. trucks having to travel excessive distances or perform U-turns). Where the median does not incorporate a physical restraint (e.g. safety barrier, pedestrian fence) and the kerb is semi-mountable, median breaks with low ground cover plants can be made within the landscaping at 100–200 m intervals to allow emergency vehicles to access properties that abut the opposing carriageway. |
| Moderate-speed urban divided roads | Moderate-speed urban roads (60–70 km/h speed limit roads) serve residential, commercial and industrial zones. Emergency vehicles require access to the adjacent carriageway to attend motor vehicle crashes, overtake queued traffic and access adjacent properties for medical emergencies, fires, evacuations etc. | Due to the proximity of intersections, formed median openings are not required. Except where a pedestrian fencing/safety barrier is installed or there is a significant level difference, the median should be traversable with flattened batters, semi-mountable kerb and low growth vegetation. |
Figure 7.6: Example of an emergency median openings on rural freeways

Figure 7.7: Example of a general median opening for access on divided roads
8 PEDESTRIAN CROSSINGS

8.1 Introduction

8.1.1 General

This section provides guidance on the design of pedestrian crossing facilities. The traffic management considerations for the use of pedestrian crossings are provided in the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007). From a road safety perspective it is critical that the correct devices are provided and that they are designed in a uniform and consistent manner, particularly for people who have a disability as described in Commentary 4.

Designers should be aware of local pedestrian or cycling planning and design guides. These guides generally provide the policy and network planning context in which pedestrian facilities are provided within a jurisdiction. For pedestrians, examples of these guides include:

- How to Prepare a Pedestrian and Mobility Plan: An easy three stage guide (RTA 2002)
- Easy Steps (Queensland Transport 2005)
- Pedestrian Planning and Design Guide (Land Transport NZ 2007a).

8.1.2 Types of Crossings

Traffic engineering techniques which may be used to assist pedestrians to cross roads, and to control pedestrian/vehicle interaction include:

- general crossing treatments
- time separation (traffic controlled) treatments
- grade (or spatial) separation
- integrated treatments.

Formal crossings may be provided at signalised intersections (e.g. as part of a signalised intersection treatment, refer to Section 5 of the Guide to Road Design – Part 4A: Unsignalised and signalised intersections (Austroads 2009b), or take the form of mid-block signalised crossings (pedestrian-operated signals), school crossings or zebra crossings. Informal crossings may be established and reinforced through the provision of pedestrian refuges in the middle of the road, as it is much easier for pedestrians to cross the road in stages. Signalised crossings are preferred for use by people with disabilities, as they provide a greater guarantee of right-of-way for the pedestrian and provide the opportunity for audible and tactile cues as to when it is safe to cross.

It may be necessary to provide tactile ground surface indicators (TGSIs) in conjunction with pedestrian crossings in order to warn and direct vision-impaired people. Designers should refer to local jurisdictional guidelines regarding the provision and design layout of TGSIs.

8.2 Mid-block Crossings on Roads

8.2.1 General Considerations for Design

Table 8.1 lists important design features of pedestrian crossings and provides a summary of the aspects that should be considered in design.
### Table 8.1: Crossing features and considerations

<table>
<thead>
<tr>
<th>Feature</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crossing width</td>
<td>A marked crosswalk at a mid-block signalised pedestrian or children’s crossing should not be less than 3.0 m between the lines. Crossings that are too narrow may result in congestion and interference with pedestrians passing in opposite directions and result in longer than desirable pedestrian phase times with the possibility of pedestrians being caught on the crossing when the traffic signals change. Where heavy movements of pedestrians occur, a footway capacity analysis (Guide to Traffic Management – Part 3: Traffic Studies and Analysis (Austroads 2009i)) can be used to determine the crossing width required to provide an acceptable level of service for pedestrians.</td>
</tr>
<tr>
<td>Crossing length</td>
<td>It is good design practice to provide the shortest crossing of the road that is practicable in the circumstances (i.e. considering the safety of pedestrians, for the benefit of the elderly or infirm (security) and to minimise delay to vehicles). The acceptable length of a crossing will be determined by the overall carriageway width to be crossed and the nature of traffic control (e.g. the amount of time allotted at a traffic signal). In general, the crossing distance should be minimised. The crossing length can be reduced by extending the footpath (i.e. narrowing the carriageway), and/or by providing pedestrian refuges within the roadway to facilitate a staged crossing. A pedestrian refuge is desirable on all roads with moderate to high traffic volumes (e.g. two-lane two-way roads). This is especially important where there is a high pedestrian crossing volume or a high proportion of people with disabilities.</td>
</tr>
</tbody>
</table>
| Crossing orientation | Wherever practicable the crossing should be at right angles to the carriageway as this:  
- assists vision-impaired pedestrians to cross the road within the marked crosswalk; vision-impaired people to obtain cues from the orientation of the kerb ramps and it is more difficult to achieve a satisfactory arrangement where a crossing is at an angle to the kerb  
- minimises the crossing distance.  
Where a crossing at right angles is not possible:  
- access points to a crossing should be oriented so that people using them are able to cross the road without changing direction. Abrupt changes of direction should not be required once the user is on the roadway. This is particularly important for people with limited vision as the orientation of the crossing access point is a major cue to the necessary crossing direction.  
- Some form of directional guidance, such as tactile tiles and audio-tactile devices is recommended. |
| Surfaces | It is important that changes in a footpath’s surface, particularly at crossings, be easily detectable (especially important for vision-impaired pedestrians). Use of standard guidance devices is recommended, for example:  
- audible cues that range from audio-tactile devices at pedestrian crossings to public address systems  
- visual cues that include signs, lighting, visually contrasting surfaces and guide lines, physical cues that include audio-tactile devices at pedestrian crossings, surface texture changes, guide strips, kerbs and other surface level changes. |
| Sight distance | Refer to the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b), Section 3 of which covers sight distance requirements.  
It is important that pedestrian crossing facilities should:  
- be located where there is a clear view between approaching motorists and pedestrians on the crossing or waiting to cross a roadway  
- not be located immediately over the crest of vertical curves or on horizontal curves.  
It is essential to ensure that motorists have sufficient sight distance available after noticing the presence of the crossing to enable them to react to the presence of a pedestrian on or about to enter the crossing and stop their vehicle before entering the crossing (i.e. approach sight distance). |
| Stop line location | Stop lines are essential at crossings controlled by traffic signals and at children’s crossings to minimise the encroachment of vehicles onto the pedestrian crossing area. Such encroachment:  
- is a direct hazard to pedestrians  
- is a physical barrier to their movement  
- obstructs the line of sight between adjacent vehicles stopped on the approach and pedestrians already on the crossing.  
Stop lines should be located in accordance with the guidelines given in AS 1742:10 or MOTSAM Part 2: markings (Transit NZ 2008). |
Table 8.1: Crossing features and considerations (Continued)

<table>
<thead>
<tr>
<th>Feature</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access to roadway crossings</td>
<td>Where a road or street is kerbed a kerb ramp is essential to assist pedestrians in moving between the footpath and roadway. Kerbs present a significant barrier to many people; people in wheelchairs cannot mount a kerb at all and may have difficulty using ramps if they are too steep. People with limited vision need an indication of good places to cross and of the direction in which they should travel. These should be provided at mid-block pedestrian crossings, at all intersections, and at other points where access is needed to and from a footway. Where there are no kerbs, a drain usually borders the roadway and it is necessary to provide a culvert or other bridging to enable pedestrians to access the roadway at crossing points.</td>
</tr>
</tbody>
</table>

8.2.2 **General Crossing Treatments**

Physical separation of pedestrians from vehicles within the roadway may be achieved by providing:

- pedestrian refuges
- footpath (kerb) extensions
- medians.

Reference should be made to the installation guidelines and detailed design provisions provided in Australian Standards (AS 1742.10 and AS 1742.2) or in MOTSAM Part 1: Traffic signs (Transit NZ 2007); Part 2: Markings (Transit NZ 2008).

**Pedestrian refuges**

A typical pedestrian refuge for a two-way two-lane road is shown in Figure 8.1. Where it is necessary to stage pedestrians on the island (e.g. at crossings serving school children) because the road is wider (e.g. four-lane undivided or duplicated) the length and width of the island treatment will have to be increased in order to store the necessary number of pedestrians within the island. In such cases the island will have to be wide enough to accommodate pedestrian fencing designed to prevent pedestrians from moving directly into the second carriageway and orient them to face the direction of approaching vehicles. In some cases it may be appropriate to stage pedestrians within a larger refuge, in a similar fashion to that illustrated in Figure 8.2 for pedestrian operated signals.
Notes:
Where the refuge connects significant shared use paths the minimum width of refuge of 2.0 m is likely to be inadequate and a greater width should be provided, and warning signs should include a bicycle. (Figure 9.2).
Street lighting should be provided in accordance with AS/NZS1158.1.
Pedestrian assist handrails may be provided where space is available in the island. If provided, they should be frangible.
Source: Based on AS 1742.10.

Figure 8.1: An example of a pedestrian refuge
Notes relating to the numbered circles in Figure 8.1 are:

1. Island kerbs may be painted white.
2. If the refuge is used in conjunction with a marked crossing, the spacing between the islands should be increased accordingly.
3. Length of painted median should be increased or other delineation devices considered if visibility to the island is reduced by vertical or horizontal alignment. Uni-directional raised retro-reflective pavement markers are provided.
4. Painted median is preceded by barrier line.
5. Where refuges are used on arterial or high speed roads, pedestrians or children warning signs W6-1 or W6-3 (minimum size B), as appropriate, are erected together with supplementary plate Refuge Island (W8-25) in advance of the refuge.
6. Kerb ramps should be constructed within the refuge island if practicable.
7. When used at intersections, the length of the raised part of the island closest to the intersection may be reduced to accommodate turning traffic.
8. A suitable hazard marker from the D4 Series (AS1742.2) may be used under the Keep Left (R2-3) sign. Mounting heights need to be selected so as to avoid obscuring visibility of child pedestrians.

In addition, it should be noted that:
- where permanent parking is present a footpath kerb extension may be provided to enable parking to occur closer to the crossing
- if the road is on a bicycle route with bicycle lanes the lanes should continue through the treatment but at a width that would not unduly increase the pedestrian crossing length
- if the treatment serves an off-road bicycle path or shared path a wider refuge should be provided.

The width of refuges should be:
- desirably at least 2.0 m wide so that they provide adequate separation from traffic flows particularly where traffic speeds are high
- a minimum of 1.8 m to allow for the standing of a person wheeling a pram, a person in a wheelchair or walking with a bicycle
- at least 2.4 m wide where practical at an unsignalised pedestrian crossing so that consideration may be given to staggering the pedestrian movement to force pedestrians to face traffic approaching on the carriageway they are about to cross.

More information on the use and design of refuges is provided in Commentary 5.

Staged crossing of a median
Where a median is less than 2.4 m in width it is usually desirable that pedestrians are not staged in the median but are allowed to cross the road without delay. Where the median width is greater than 3.5 m it may be desirable to stage pedestrians in the median so that excessive delay is not caused to motor traffic.
Figure 8.2 shows an example of practice whereby the pedestrian crossings are staggered and pedestrians are required to pass through a chicane (2.4 to 3.5 m wide median) or deviate at an angle (median width > 3.5 m). In each case the stagger is oriented so that pedestrians face the oncoming traffic when approaching the crossing point.

Notes:
1. Wide carriageways may require primary signals mounted on mast arms to improve visibility.
2. Stagger distance $S$ may depend on the number of pedestrians to be stored in the median. Suggested minimum distance for low pedestrian volumes is 6 m.


Figure 8.2: An example of a median crossing for pedestrian operated signals
Footpath kerb extension

Pedestrian safety and traffic management can be improved with the introduction of footpath extensions (also known as kerb extensions or pedestrian nibs). These consist of a local widening of the footpath into the carriageway within an adjacent shoulder or kerbside parking lane (Figure 8.3).

The kerb should be extended to the car parking lane line and be wide enough to ensure that parking is not possible too close to the crossing and approaching drivers are therefore provided with approach sight distance to pedestrians about to step onto the crossing.

The width of the extension will be dependent on the overall road width, but is usually 2.0 m to 2.3 m wide and 6 m to 10 m long.

![Diagram of footpath kerb extension](image)

Notes:
Warning signs in advance of footpath extensions are not generally essential unless the signs are required for a regulated pedestrian crossing.
Any signing provided should be in accordance with the requirements of AS 1742.13 for similar road narrowing treatments.
Provide suitable delineation for these treatments (e.g. painting of the kerbs, pavement marking, retro-reflective pavement markers).
Drainage of the roadway adjacent to the nibs needs to be considered and the kerb line shape should be compatible with the turning characteristics of street sweeping equipment.
Source: Austroads 1995.

Figure 8.3: An example of a footpath kerb extension

Further information on the use of footpath kerb extensions is provided in Commentary 6.

Road narrowing indented parking

On some less important arterial roads and collector type roads, footpath (kerb) extensions are constructed at regular intervals along the road together with the relevant road markings to create an indented (protected) parking arrangement and a narrower roadway to meet local traffic management objectives.
8.2.3 **Time Separated (Controlled Traffic) Facilities**

‘Time separated’ facilities are the most commonly requested form of facility to assist pedestrians in crossing roadways. They offer a higher degree of safety by requiring (through road rules) that vehicular traffic stop and/or give way while pedestrians are crossing. When used in conjunction with similar and other devices along a section of road, as part of an overall traffic management treatment, they provide considerable benefits to local communities.

Time separated facilities should only be provided if conditions at a site meet the warrants and guides given in AS 1742.10 or jurisdictional guides.

To ensure that it is utilised it is important that the crossing facility be placed on, or as close as practicable to the pedestrian desire line.

Commentary 7 provides some additional information on the need for these facilities.

**Pedestrian zebra crossing**

A typical pedestrian (zebra) crossing application is illustrated in Figure 8.4. At these facilities traffic regulations require a motorist to give way to pedestrians on the crossing. This facility relies on the motorist seeing the pedestrian on the carriageway, and then slowing or stopping if necessary to allow the pedestrian to proceed across the roadway. The driver’s obligation is to give way, but having done so, may proceed without waiting for the pedestrian to clear the roadway.

Minimum numerical warrants are given in AS 1742.10 but some traffic or road authorities have adopted different or additional warrants. Generally zebra crossings are not favoured on arterial roads where traffic speeds and volumes are relatively high. However, they are often used to provide a formal crossing of left-turn slip lanes at signalised intersections of arterial roads.

Zebra crossings are usually suited only to low-speed environments (≤ 50 km/h) on local residential streets, collector roads where speeds are constrained, in shopping centre car parks and multi-level car parks.

Zebra crossings may be used in conjunction with kerb extensions or refuges. Where crossing movements are spread out along a road, a narrow raised or painted median, or in some cases pedestrian refuge islands connected by painted medians, can provide more effective traffic safety, especially in strip commercial developments. This approach is discussed in Commentary 8 along with suggested measures to enhance the safety of pedestrian crossings.
Note: Where there is significant night-time use, street lighting should be provided.
Source: Based on AS 1742.10.

Figure 8.4: An example of a pedestrian (zebra) crossing

Notes relating to the numbered circles in Figure 8.4:

1. See AS 1742.10, Clause 11.2 for zebra pavement marking detail.
2. Sign W6-2 (minimum size B) is used in advance of pedestrian crossings where visibility of R3-1 sign is obstructed due to road curvature or other local conditions. The sign may be supplemented with advance pavement messages.
3. Sign R3-1 may be supplemented by twin alternating continuously operating yellow signals.
4. Where stationary vehicles near a crossing seriously limit visibility between drivers and pedestrians, an increase in the no stopping length may be required.

**Pedestrian operated signals**

Pedestrian actuated traffic signals may be the best solution at mid-block locations where pedestrian crossing activity is concentrated along a short section of road, carrying high traffic volumes. However, the high cost of implementation normally restricts the use of these facilities to roads that have relatively high volumes of traffic and pedestrians.

Numerical warrants and other guidelines are provided in AS 1742.10 – but designers should refer to local guides where they have been developed by the relevant road authorities.

AS 1742.10 also includes the following guideline:

If the guidelines for the provision of a pedestrian crossing (zebra) are met and the site is either, adjacent to a railway level crossing, on a public transport route, close to a signalised intersection on an arterial road, or within a coordinated traffic signal system, consideration should be given to the use of pedestrian actuated signals, instead of the pedestrian (zebra) crossing.

A typical layout for a mid-block signalised pedestrian crossing is illustrated in Figure 8.5. In considering the provision of a mid-block signalised pedestrian crossing, the possibility of signalising a nearby unsignalised intersection and incorporating pedestrian facilities should be considered as an alternative as this can provide better overall pedestrian safety and traffic management.

As emphasised in the Australian Standard, mid-block pedestrian operated signals require special attention to the standard of signalling provided to mitigate the absence of usual intersection cues. Mast-arm or median island signals may need to be installed on carriageways with more than three lanes in one direction. Details of these requirements as well as pedestrian detection, phasings, timings and signal hardware requirements are given in the *Guide to Traffic Management – Part 9: Traffic Operations* (Austroads 2009k).

**Pelican crossings**

The ‘pelican’ crossing is a normal pedestrian operated signal crossing with a more sophisticated form of signal control which allows a more flexible time sharing between motorists and pedestrians. The device is characterised by the inclusion of a flashing yellow period for the motorist while a flashing red man for the pedestrian movement is displayed. Drivers having stopped at the red traffic signal display may proceed with caution through the crossing during the flashing yellow period but they are obliged to give way to pedestrians still on the crossing. The advantage of this operation is the reduced delay to vehicles due to a reduced red phase. Studies have shown that vehicle delays at pelican crossings are approximately half those at conventional pedestrian actuated crossings.

The warrants and requirements for the installation of pelican crossings are the same as for pedestrian actuated signals, but with the additional criteria that the 85th percentile speed at the proposed location is less than 80 km/h.

Pelican crossings are considered to be an advantage at a site where there is concern about excessive vehicle delays due to the need to have a long pedestrian phase.
Source: Based on AS 1742.10.

Figure 8.5: An example of pedestrian – actuated traffic signals (mid-block)

Notes relating to the numbered circles in Figure 8.5:

1. Sign W3-3 is required if the crossing is in an isolated location or if the crossing is not visible at a distance greater than 200 m. Where used, at least a Size B sign should be used.
2. No stopping distance as required by the relevant jurisdiction.
**Puffin crossings**

The name ‘puffin’ is derived from ‘pedestrian user friendly intelligent’ signals. The crossing is a normal pedestrian operated signal crossing that is modified to overcome deficiencies in existing facilities. Infra-red devices detect the presence of people crossing the carriageway and enable extra time to be allocated to the pedestrian phase if needed. This can eliminate the need to extend every pedestrian phase time to account for slower moving pedestrians such as the elderly and people with disabilities.

As a result, the overall efficiency and acceptability of the crossing is improved. The installation provides a more flexible operation to pedestrians who need it and gives pedestrians a greater share of the total cycle time when volumes demand it. The cancellation of unwanted pedestrian phases can be a significant benefit to through vehicular traffic.

**8.2.4 Kerb Ramps for Pedestrians**

The difference in level between a roadway and an adjacent footpath is a common on-street situation which poses difficulties for pedestrians, particularly those with mobility and vision disabilities. While the level difference is relatively small, its treatment needs careful attention to properly cater for all users.

A drop kerb (commonly referred to as a pram crossing) or kerb ramp provides a smooth change in the level between the footpath and road pavement. It allows pedestrians to gain access to the roadway, with minimum impediment and is essential where people in wheelchairs and those with mobility impairment need to be catered for. It is important that kerb ramps be aligned in the direction of travel to guide vision-impaired pedestrians directly across the road and not out into the intersection.

The general form of kerb ramps is illustrated in Figure 8.6. A minimum footway width of 1330 mm should be provided beyond the top of the ramp, to ensure that users of the footway along the street are not inconvenienced by the ramp. AS 1428.1 provides guidance regarding the design of kerb ramps. As wheelchairs may tip backwards when being wheeled up steep ramps, a gradient of 1:10 should not be exceeded if possible. Note that this gradient is less than the maximum of 1:8 quoted in AS 1428.1, which should be considered as an absolute maximum ramp gradient.

It is important to avoid the construction of a lip at the drainage channel or line of kerb to allow the free movement of wheel chairs as illustrated in Figure 8.6. However, tactile tiles or grooving should be provided to indicate the edge of the roadway to vision-impaired pedestrians. Surface grading for drainage at intersections should be designed to avoid having low points and the accumulation of water where pedestrian crosswalks and kerb ramps are to be located.
Notes:
The ramp and sloping sides should be slip resistant and of a colour that contrasts with the adjoining surfaces. Tactile ground surface indicators should be provided in accordance with AS 1428.4 and jurisdictional guidelines. The kerb ramp should be aligned in the direction of travel. For guidance on installation of tactile ground surface indicators, refer to AS 1428.4. Source: Based on AS 1428.1.

Figure 8.6: An example of a kerb ramp design
9 CYCLIST CROSSINGS

9.1 Introduction

The traffic management considerations for the use of pedestrian and cyclist crossings are provided in the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007). From a road safety perspective it is critical that the correct devices are provided and that they are designed in a uniform and consistent manner.

Cyclist crossings of roads at mid-block locations generally involve the intersection of paths with roads. The types of crossings may include grade separation, traffic signals or unsignalised crossings that may have refuges within islands or medians. Guidelines for grade separation are covered in the Guide to Road Design – Part 4C: Interchanges (Austroads 2009d) while signalised and unsignalised crossings are discussed below.

9.2 Unsignalised Crossings

9.2.2 Low Volume Streets

Unsignalised crossings of two-lane two-way local streets or collector roads may require cyclists to give way to road traffic, and in low volume streets (≤ 3000 vpd) need not provide a refuge for cyclists in the middle of the road. In such situations the treatment provides for a straight crossing of the road using kerb ramps on both sides of the road with a suitable terminal treatment.

If the intersection is designed in accordance with the criteria described above then the intersection and priority will be easily identified and give-way or stop signs for cyclists should not be necessary. However, care is required for give way requirements where a path for cycling intersects with a footpath located adjacent and parallel to a road.

Space is often not available to provide separated paths for pedestrians and cyclists within the verge of a road. However, where this arrangement is possible it is particularly important to clearly define the priority that applies in order to reduce the likelihood of conflict between cyclists and pedestrians. Where space is available the treatment shown in Figure 9.1 may be suitable.
Warning signs 50-80 m in advance of intersection

This treatment diagram shows an exclusive two-way bicycle path. This design can also apply to a two-way shared path.

R=30 m

R=3 m

2 m min

10 m from path intersection

Optional median refuge to assist bicycle crossing where road has more than two traffic lanes or traffic volumes are high.

Area between bicycle path and the roadway must be kept clear of any obstacles which hamper visibility

Warning signs 50-80 m in advance of intersection

Source: Adapted from RTA (2005).

Figure 9.1: Bicycle path crossing of a two-way two-lane road and separated paths
9.2.3 Refuges away from Intersections

Where an off-road path crosses a busy local street or an arterial road away from an intersection it may be necessary to provide facilities to aid the cyclists to make a safe crossing. These facilities may be in the form of controlled crossings as discussed previously, or physical refuges. Physical refuges in the centre of the road are recommended to enable a staged crossing where volumes are greater than 3000 vpd. A typical refuge is shown in Figure 9.2 for a shared path crossing a two-way, four-lane road. Separate areas may be provided within the refuge for cyclists and pedestrians if sufficient space can be made available.

Note: Where required tactile ground surface indicators should be provided on paths and ramps in accordance with AS 1428.4 and jurisdictional guidelines.

Source: Based on AS 1742.10.

Figure 9.2: Example of a cyclist and pedestrian refuge at a mid-block location
In order to accommodate a bicycle which is typically 1.75 m long, it is desirable that a refuge be at least 2.0 m wide. However, 1.8 m may suffice in tight situations. Where there are concentrated cyclist demands at certain periods of the day (e.g. secondary schools) a greater width and length may be required to provide additional storage and separate areas provided for cyclists and pedestrians.

Some further information on the use of refuges is provided in Commentary 9.

Refuges should be furnished with a holding rail to allow a stationary cyclist to remain mounted within the refuge area. Rails should be located clear of the gap although where the gap is wide (i.e. greater than 2.0 m) the rails can be located within the gap, on the left hand side. Refuges should also be provided with adequate street lighting to enhance visibility of the island and cyclists using it at night.

### 9.2.4 Refuges within Unsignalised Intersections

A refuge may be placed within an intersection to accommodate the crossing movements of both pedestrians from footpaths and cyclists from bicycle lanes in the side roads while restricting motorists to a ‘left-turn in/left-turn out’ arrangement. Such a treatment is shown in Figure 9.3.
9.2.5 Cyclist Priority Treatment at Path Crossings of Low Volume Streets

The occurrence of low-volume local streets frequently intersecting with paths that have a significant network role can result in a poor level of service for commuter cyclists, or an inferior riding experience for recreational cyclists.

Many local authorities invest considerable resources into local area traffic management schemes and into bicycle and pedestrian path networks. An opportunity often exists to improve the continuity of paths for cyclists and pedestrians while simultaneously providing a ‘device’ to control speeds in local streets. The preferred treatment is a path crossing that is raised with appropriate give-way sign controls erected to regulate road traffic. A suggested treatment is shown in Figure 9.4.

Source: Based on RTA (2005).

Figure 9.3: Refuge within an intersection for pedestrians and cyclists in bicycle lanes

Note
If the road being crossed by the bicycle route (horizontal road) is narrow and carries light traffic, the central refuge is not required. When a refuge is not used, straight-through movements are permissible for all vehicles.
Figure 9.4: Cyclist priority treatment for use at low-volume street crossings

There are legislative constraints to the use of the treatment under several jurisdictions and therefore some care needs to be taken before implementation to ensure any proposed treatment would conform to relevant requirements.

This treatment is generally appropriate where:

- it conforms to the details in Figure 9.4
- the speed environment is below the general urban speed limit, or where a local area traffic management scheme is proposed that would achieve suitable crossing conditions
- it is located in urban areas
- good visibility at the crossing point exists for both road and path users
- it is located away from intersections of roads
- the priority that would be assigned to the road is consistent with that elsewhere along the road, in the vicinity of the crossing
- not more than two lanes of traffic exist (both directions)
- the proportion of commercial traffic is low
- a warrant for a higher form of road crossing is not satisfied, such as a pedestrian actuated signal crossing, which should then be used as an alternative (AS 1742.10 or relevant state regulations).

9.2.6 Paths Adjacent to Roads

Paths which run parallel to busy roads often have to cross side roads which may be minor or important traffic routes and the intersection may be signalised or unsignalised. These treatments are discussed in Section 9.6.
9.3 Signalised Mid-block Crossings

Road crossings for cyclists can be coordinated with signalised or unsignalised pedestrian crossings and school crossings. Cyclists are usually required by law to dismount at formal pedestrian crossings including school crossings. Where a bicycle route crosses a road at a signalised crossing care should be taken to ensure that activation buttons are located to avoid the need for cyclists to cross in front of oncoming path users and are within easy reach for a mounted cyclist. Induction loops can also be installed to facilitate detection.

Traffic lanterns displaying bicycle symbols should be provided where the crossing serves both pedestrians and cyclists provided jurisdictional traffic regulations permit this treatment. Where road rules permit, a green bicycle signal allows cyclists to ride across the crossing. Where pedestrian and cyclist demands are both heavy there is a tendency for pedestrians to move to the front and block the progress of cyclists using the crossing. In such cases consideration should be given to segregating cyclists and pedestrians as shown in Figure 9.5 (i.e. separate and well delineated crosswalks for pedestrians and cyclists).

The appropriate type of crossing should be determined with reference to normal warrants for pedestrian crossings using the combined cyclist and pedestrian demand.

![Figure 9.5: Signalised crossing with separate pedestrian and cyclist areas](image)
9.4 Cyclist Crossings at Signalised Intersections

9.4.1 General

It is often necessary to integrate off-road bicycle facilities with other road user requirements at signalised intersections. The design should ensure that the movements of cyclists are managed and regulated to ensure the safe interaction of cyclists with pedestrians and motor vehicles.

The facility to be integrated may be a shared path, an exclusive bicycle path, or a separated path. Where a shared path passes through an intersection cyclists are expected to share the marked foot crossing with pedestrians. Where a bicycle path or a separated path is to be accommodated the cyclists and pedestrians will usually be separated on the crossing.

9.4.2 Separated Path Crossing

Figure 9.6 shows an example of a multi-lane road intersection with off-road bicycle paths on one road and a shared path on the other road in a constrained road reservation. In this case the various paths adjoin and cross parallel to the intersecting roads. This example shows two-way bicycle paths on both sides of one road and shared paths on both sides of the intersecting road. For this type of treatment it is desirable to have separate detection and lanterns for cyclists and pedestrians (Guide to Traffic Management – Part 9: Traffic Operations (Austroads 2009k)).
Notes:
Only the additional bicycle signal lamps are shown, not the complete traffic signal layout.
In-path or other remote detection is recommended for bicycle paths.
The width of the marked crossing for separated paths should match the width of the paths on the approach.
At intersections where the volume of cyclists and pedestrians is high it is advisable to provide contrasting surfaces to delineate the use and priority of movement.
Source: Adapted from RTA (2005).

Figure 9.6: Shared path and one-way bicycle path at a signalised intersection

Where off-road bicycle routes are required to pass through major intersections, signal control should be considered for left-turn slip lanes. The designer should aim to provide a similar level of service through the intersection for cyclists as for motor vehicles. Desirably the signal phasing and timing should enable cyclists to pass through the intersection in one stage. Where practicable pedestrian and cyclist crossings should be separated; however, where this is not possible cyclists will have to share the crossing with pedestrians.

It is important that:
- the design and markings are designed to minimise conflict between cyclist and pedestrians
- where appropriate bicycle detection loops are provided
- where provided, bicycle activation buttons (similar to pedestrian buttons) are located in a convenient position close to the crossing approach or holding line
- adequate queuing and storage space is provided for cyclists
- additional width is allowed for cyclists starting up at the signals.

9.4.3 Right turns from Off-road Bicycle Paths

The treatment shown in Figure 9.7 is similar to that used at large signalised intersections to assist bicycle hook turns. Up to four bicycles can be accommodated in this area while waiting for a green right-turn arrow. If the cyclist volume is high, green pavement surfacing should be considered on both the holding area and the bicycle crossing.

Source: Adapted from RTA (2005).

Figure 9.7: Right turn from an off-road bicycle path to an on-road bicycle lane
9.5 Kerb Ramps for Cycling

Although bicycle paths can be provided for the exclusive use of cyclists the paths are generally shared with pedestrians and as cyclists also require a smooth and relatively flat transition between the road and path, the kerb ramps should comply with AS 1428.1 as illustrated in Figure 8.6.

The provision of a gently graded and smooth invert at the gutter is a vital design feature for the safety and comfort of all path users, including cyclists. However, where cyclists and pedestrians share paths it is also important to have a sharp transition to provide a cue for vision-impaired pedestrians (Figure 8.6). However, kerb ramps on bicycle facilities require other features to ensure that they are safe and convenient for use by cyclists, for example:

- the width of the ramp should match the width of the path
- as cyclists need to turn left from the road onto the ramp, or from the ramp onto the road, a satisfactory turning radius should be provided, in which case the three-plane style kerb ramps (shown in AS 1428.1 and Figure 8.5) may not be appropriate
- flatter kerb ramps of 1 (vertical) in 15 (horizontal) should be considered to provide more efficient and comfortable movement for cyclists between the road and the ramp.

These features are illustrated in Figure 9.8.

Three-plane kerb ramps are preferred where a path for cyclists exists in the verge area of a road, and which is parallel and in close proximity to the road. This style of ramp is generally appropriate where pedestrians are present, and to avoid the existence of a vertical step in the verge area. Where a step cannot be avoided a suitable barrier with a minimum height of 900 mm should be provided (e.g. holding rails).

Where there are short (less than 5 m wide) sections of path across traffic islands it may be preferable to construct the path at road level rather than back-to-back kerb ramps with only a few metres of raised path in between. Maintenance practices need to ensure the resultant channel is kept clear of debris.
9.6 Path Crossings of Side Roads

9.6.1 General

Where a bicycle path or shared path is provided in the verge of a road, cyclists using the path will often have to cross intersecting side streets. These side street crossings should be designed:

- to ensure that motorists are aware of the existence of the crossing and the priority that applies
- so that the location and design of the crossing, and the priority adopted, does not put motorists at risk when turning from the major road
- to encourage safe and correct use by cyclists.

Where the path is located on one side of a road, kerb ramps should be provided opposite every side street to enable access for local users.

9.6.2 Path Approach Design Criteria

The key requirements for the intersection between a path in a road reservation and a side road are:

- approach sight distance should be provided for drivers approaching the intersection from the side road (Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b))
- drivers turning from the major road into the side street should have clear sight lines to cyclists using the path in both directions
- the speeds of cyclists using the path should be controlled on the path approaches to the intersection.

Sharp downgrades on path approaches to road crossings should be avoided where possible. Where the path alignment is straight on the approach to a road then the path should be as flat as possible. It is desirable that the longitudinal downgrade should be limited to 3% and should not exceed 5%.

Paths for cycling should be aligned to intersect roads at approximately 90°. Where the approach sight distance for cyclists is restricted, appropriate warning signs should be provided or measures taken to reduce the approach speed of cyclists.

9.6.3 Types of Crossings of Side Roads

There are three types of treatment available for the design of path crossings of side streets, a design where the path approach is bent-out (i.e. is deviated away from the major road), a design where the approach is straight, and a treatment where a one-way bicycle path is deviated to become an on-road bicycle lane. The first two types of treatment may be applied to bicycle paths or separated paths.

For cases involving two-way paths the priority can be allocated to the path or to drivers on the side road (e.g. refer to Figure 9.1). Give-way signs and holding lines should be used to clearly define priority and regulate the movement of cyclists and motorists.

Bent-out treatment

Where there is sufficient space in the road reservation exclusive bicycle paths or separated paths can be bent away from the parallel road at its intersection with the side road. The principal reason for bending out is to allow storage space for vehicles turning into the side road. Therefore, bending out is only necessary where it is desired to give path users priority.

Figure 9.9 shows a bent-out treatment on a bicycle path which allows storage space for vehicles entering and leaving the side road. The minimum distance between the path and the parallel road is 7 m to allow for a car length and clearance. The desirable minimum distance is 15 m which allows for a single unit bus/truck and clearance. It is essential that the area between the bicycle path and parallel road be kept clear of obstructions to visibility as motorists will otherwise lose sight of cyclists and cyclists may perceive the bending-out as a major detour and look for short cuts.

The treatment may be suitable where:

- few large heavy vehicles (e.g. semi trailers) use the side road
- volumes on the side road are low
- speed on the major road and side road is ≤ 60 km/h.
It is also desirable that:

- an auxiliary left-turn lane is provided on the major road to minimise the likelihood of turning vehicles queuing onto the major road
- the bicycle path or the bicycle section of a separated path is delineated by a contrasting surface across the side road
- where the treatment is applied to a separated path the pedestrian priority across the side road should be achieved by installing a pedestrian crossing that complies with jurisdictional road rules and guidelines.

A bent-out treatment is not suitable for shared paths as there is currently no legal facility that would provide priority for an unsignalised shared crossing of a road (i.e. cyclists are not permitted to ride on pedestrian crossings under current road rules).

Bending-out should be achieved with smooth curves (e.g. 30 m) as the use of tight curves can introduce manoeuvres that require the cyclist’s attention at a point where their attention should be focused on the crossing and approaching vehicles.

In the past there has been a common misconception among practitioners that the purpose of bending-out is to reduce the speeds of approaching cyclists. The use of tight curves, rails and bollards should not be used as speed reduction devices at these locations and normal traffic management devices such as warning signs and regulatory signs should be used to control approach speeds and crossing priority.
Figure 9.9: Bicycle path crossing bent-out at side road

Straight crossings (not bent-out)

Figure 9.10 shows an option for a straight crossing on a separated two-way bicycle path. The treatment provides for both cyclists and pedestrians to have formal crossings of the side street controlled by pedestrian crossing signs and give way signs respectively. To maintain better route continuity and rider comfort this treatment may be placed on a platform as shown in the figure.
The treatment is suitable where traffic volumes in side streets are low (e.g. residential streets). Where side streets have higher volumes a bent-in treatment may be appropriate. In instances where pedestrian and cyclists volumes are relatively low priority will often be given to motor vehicles.

The main benefit of a straight crossing relatively close to the major road is that the path has a higher visibility for road users where space for a bent-out crossing is not available. It is important therefore that the path is placed close enough to the edge of the major road to maintain visibility although at least 6 m should be provided between the treatment and the major road in order to store a car clear of the crossing. This separation also enables a left-turn auxiliary lane to be provided.

Source: Based on RTA (2005).

Figure 9.10: Bicycle path crossing not bent-out at side road
**Bent-in treatment**

This treatment provides for a one-way bicycle path to transition into an on-road bicycle lane, thereby enabling cyclists to have priority across the side street. It should not be used for two-way paths because of the head-on conflict that would arise between cyclists and motor vehicles. This treatment is shown in Figure 9.11.

The bent-in treatment has the advantage of providing greater visibility of cyclists for drivers at the intersection and should enable drivers to better anticipate the movement of cyclists. It also easily provides for cyclist priority at the intersection and for the transition from path to on-road lane to be physically protected. These treatments are suitable only for experienced cyclists who have the skill and maturity to safely enter and ride in traffic. They are not suitable for paths used by children en route to schools.

If a pedestrian crossing is provided in the side street it should be located at least a vehicle storage length form the side street holding line.
Source: Based on RTA (2005).

Figure 9.11: One-way bicycle path crossing bent-in at side road
9.7 Path Terminals
Path terminal devices are generally erected where a bicycle path or shared use path ends at an intersecting road, whether or not a crossing is provided to link to a continuation of the path on the opposite side of the road. Their purpose is to restrict drivers of cars from illegally gaining access to paths and reserves and also to warn cyclists that they are approaching a road.

As path terminals are an integral part of the path guidance on their use and design is provided in the *Guide to Road Design – Part 6A: Pedestrian and Cyclist Paths* (Austroads 2009f).

9.8 Intersections Between Off-road Shared Use Paths
Guidelines for intersections between two off-road paths are provided in the *Guide to Road Design – Part 6A: Pedestrian and Cyclists Paths* (Austroads 2009f).
10 RAIL CROSSINGS

10.1 General

An overview of traffic management considerations for railway crossings is provided in Section 7 of the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007). The primary references for treatments and traffic control at railway level crossings are the Australian Standard AS 1742.7 and in New Zealand MOTSAM Part 1: Traffic Signs (Transit NZ 2007); MOTSAM Part 2: Markings (Transit NZ 2008).

The Australian level crossing assessment model (ALCAM) is a safety risk assessment tool that provides a rigorous, defensible process for decision making for road and pedestrian level crossings as well as a method to help determine the optimum safety improvements for individual sites. It is currently applied across all Australian states and territories (Section 7.8 of the Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings (Austroads 2007)).

At-grade railway level crossings present a potential for severe crashes. Designers should aim to eliminate, improve, or grade separate existing crossings and to avoid the introduction of any new at-grade crossings where possible.

This section outlines geometric guidelines for typical situations that arise for at-grade railway/road level crossings. The guidelines are intended to aid but not replace sound engineering judgement based on particular local conditions.

10.2 Sight Distance

The sight distance requirements for a railway level crossing depend on the form of control. The forms of control are:

- passive control by give-way signs
- passive control by stop signs
- active control (flashing lights, boom barriers, etc.).

For passive control by give-way signs sufficient sight distance should be available for a road vehicle driver:

- approaching the crossing at the 85th percentile speed to see an approaching train in time to stop if necessary before reaching the crossing (a sight triangle)
- at the railway crossing give-way line to be able to start off and clear the crossing before the arrival of a previously unseen train.

For passive control by stop sign sufficient sight distance should be available for a road vehicle driver at the railway crossing stop line to be able to start off and clear the crossing before the arrival of a previously unseen train. Where this sight distance cannot be achieved either the sight distance must be increased to the required value by undertaking works (e.g. sight benching in cuttings, general earthworks, clearing or geometric changes to the road approaches and crossing) or active control devices must be installed.

These requirements do not apply where other factors such as the level of train and vehicle exposure may require that active control (e.g. flashing lights) is installed at the crossing. For crossings controlled by lights, the sight distance requirements relate to the ability of a driver to see the signals, in which case the approach sight distance requirements described in Section 3 of the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b) should be achieved.
AS 1742.7 specifies the use of railway crossing warning signs which prompt drivers to look for trains when approaching a crossing that has passive control and to look for a flashing light assembly when approaching a crossing that has active control. The use of such signs does not diminish the need for adequate sight distance.

The derivation of sight distance requirements at railway level crossings is discussed in Appendix B.

10.2.1 **Sight Triangles**

Sight triangles are required at railway level crossings that have passive control. The relationship between the sight distance triangles for the give-way sign and the stop sign is shown in Figure 10.1.

Triangle A represents the sight distance required for a road vehicle approaching and potentially passing through the level crossing at speed (i.e. give-way sign control can be used). Triangle B represents the sight distance required for safe start up and clearance from the crossing for a stopped vehicle (i.e. the triangle needed for both stop and give-way sign control).

![Figure 10.1: Sight triangles for give way and stop sign control](source: AS 1742.7)

10.2.2 **Angle of Approach**

The most desirable angle of crossing is a right angle as this will usually produce the best sight distance for both road and rail vehicles and enable designers to achieve the most satisfactory grading of the road where it crosses the rails. However, where a skewed crossing cannot be avoided the angles shown in Figure 10.3 should not be exceeded (i.e. not greater than $110^\circ$ to the left or $140^\circ$ to the right).

A skewed crossing may be required where the crossing is the result of a road parallel to the railway changing from one side to the other using reverse horizontal curves to effect the change. In addition to limiting the angle of skew:

- it is necessary to ensure that the curve radii are suitable for the speed environment of the crossing
it may be essential to change the approach geometry of the road
it is important to introduce speed reducing devices at the crossing to avoid crashes resulting from loss of control of vehicles on curves comprising a large decrease in speed. Refer to Section 4.5.3 of the Guide to Road Design – Part 4B: Roundabouts (Austroads 2009c) for the various types of speed-reducing treatments.

Designers should be aware that it is unknown whether any safety benefit would result from the provision of sharp horizontal curves on the approaches to railway level crossings. Where the road traffic volume is high but there is little rail traffic, the sharp curves may lead to single vehicle out-of-control crashes and a higher total crash rate than would be the case with a higher speed road alignment. Some further discussion on this issue is provided in Commentary 10.

10.3 Horizontal Alignment

Approach and crossing visibility is the primary feature affecting safety of the at-grade railway level crossings. The approach visibility is deemed to be adequate when an area of unrestricted visibility exists for each approach as shown in Figure 10.2.

Approach visibility is adequate when the following conditions are met:

The driver of an approaching vehicle, travelling at the 85th percentile speed ($V_a$) can see a train travelling at maximum operating speed ($V_t$), when the vehicle and the train are at distances $S_1$ and $S_2$ respectively from the crossing, such that the vehicle can either safely stop short of the crossing, or clear the crossing before the train reaches it. Appropriate values of $V_t$ should be obtained from the rail authority.

Distance $S_1$ must not be less than truck stopping sight distance. For a given vehicle, the approach visibility must be adequate for trains approaching from either direction.

The approach visibility angle must not exceed 95° to the left of the crossing and 110° to the right of the crossing as shown in Figure 10.2. Occasional obstructions such as posts, small trees and sparse vegetation can be considered acceptable if their size and spacing would not obscure the driver’s vision of a train.

Crossing visibility is deemed to be adequate when an area of unrestricted visibility exists for each approach and the driver of a stationary vehicle, positioned at a stop line, has a clear view of approaching trains to a distance along the tracks such that a train appearing in the driver’s field of view (at the point where the vehicle begins to move) would reach the crossing after the vehicle has cleared the crossing.

For the purpose of calculating the visibility triangle, the following figures should be used:

- distance from the driver’s eye to the rail, while at a standstill, is 5.0 m
- height of the driver’s eye above the road is 1.1 m
- height of train above the rails is 2.3 m.
Figure 10.2: Approach visibility angles

Figure 10.3: Crossing visibility angle for drivers looking left and right
For a given vehicle, the crossing visibility must be adequate for trains approaching from either direction. The crossing visibility angle must not exceed $110^\circ$ to the left of the crossing (Figure 10.3 (a)) and $140^\circ$ to the right of the crossing (Figure 10.3 (b)). If there is a choice of crossing angle, $90^\circ$ is preferred.

Many railways run parallel to adjacent roads and motorists on such roads may be unaware of a train travelling just behind the vehicle in the same direction. In these cases where the road crosses the rail or a side road crosses the rail, distances $S_1$ and $S_2$ must be checked (unless there is a stop control on the crossing with advance warning signs) at the design speed of the main road. It is essential that the visibility angles for $S_1$ and $S_2$ fall within the prescribed limits (Figure 10.4).

Note: $X_{DP}$ is the driver viewing angle measured from distance $S_1$ on the road centreline (from the stop line) where a driver must first see a train approaching on the right at a distance $S_2$ from the crossing.

Source: Austroads 2003.
10.4 Vertical Alignment

10.4.1 Road Grading

General

At level crossings it is essential for smooth travel at the operating speed that the levels of the road pavement coincide with the levels of the rails. Where the road is straight at the crossing, vehicles can be provided with a smooth crossing at speed provided that the:

- road grade matches the level difference of the rails, and any variation of the pavement crossfalls to match the rail grade presenting no difficulty
- change of crossfalls length, or rate of rotation, is adequate.

The railway grading is usually a control on the road. As a general guide, for rural roads the road surface should not be more than 75 mm above, nor more than 150 mm below, the projection of the top of the rail pair at a distance of 10 m from the nearest rail (Figure 10.5).

![Figure 10.5: General guide to grading limitations](image)

The maximum level difference between road and rail when the track is below the road level is 10 mm. On rural roads, the rail level should not protrude above the surface, although this may not always be achievable. The maximum permissible protrusion above the road surface is 10 mm.

The protrusion of the rail level above the road level is more of a problem when the angle between the road and the rail is acute, particularly for cyclists and motorcyclists.

Where a road crosses multiple railway lines at a level crossing, a smoother crossing can be achieved by adjusting the relative grade of the railway lines to more closely match the longitudinal grade of the road.

Curved road at crossing

When the road is curved it is desirable that the curve is designed in accordance with Part 3 of the Guide to Road Design. However, it is rare for the grade of the rails to match the superelevation on the curve in which case the superelevation of the curve at the railway has to be modified to suit the superelevation of the rails with a suitable transition within the curve. If the difference between the design superelevation of the curve and the superelevation of the rails is too great the curve becomes hazardous.

On road curves the:

- difference between the design superelevation of the curve and the superelevation of the rails must not be greater than the maximum values given in Table 10.1
value of the coefficient of side friction for the reduced superelevation on the curve, calculated at the rails for the design speed must not be greater than the maximum allowed value (Guide to Road Design – Part 3: Geometric Design (Austroads 2009a)).

- general superelevation on the curve should desirably not be nil.

It should be noted that a greater variation is permitted at lower design speeds. The design speed should be realistic for the site and if there is any doubt about the safety of the crossing, the test described in (b) above should be made for a design speed 15 km/h greater than the design speed.

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Maximum variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>5</td>
</tr>
<tr>
<td>60</td>
<td>4</td>
</tr>
<tr>
<td>70</td>
<td>3.5</td>
</tr>
<tr>
<td>80</td>
<td>3</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>120</td>
<td>0.5</td>
</tr>
</tbody>
</table>

Table 10.1: Variation in superelevation at railway level crossings

Note: As the value of (e+f) for the curve is constant, the above figures, when expressed as a decimal, also represent the permitted variation in f.

Source: QDMR 2002.

Minimum treatment for minor roads

Where the normal road grade does not match the crossing it becomes necessary to vary the road grade to provide at least for uniformity in levels at the crossing. The minimum standards of vertical curvature must be the absolute minimum provided in the Guide to Road Design: Part 3 – Geometric Design (Austroads 2009a), or the grading normally applied to floodways in the case of minor roads.

In grading to the rails it is always desirable that the grade line coincides with the tops of the rails but cases arise where this is not possible and a variation in grade must be provided through the crossing as shown in Figure 10.6. Maximum variations in grade are provided in Table 10.2.
Table 10.2: Permitted variations in grade between road and rails at level crossings

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>Maximum variation (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 80</td>
<td>4</td>
</tr>
<tr>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>110</td>
<td>1</td>
</tr>
<tr>
<td>120</td>
<td>0</td>
</tr>
</tbody>
</table>

Source: QDMR 2002.

Where there are two (or more) tracks at such levels that it is not possible to provide even a minimum standard grade line the tracks should be regraded to permit the provision of a satisfactory road grading. Adequate warning signs should be provided where a minimum grading standard is used.

In cases where the rails are both curved and superelevated, skewed road approaches will often allow a satisfactory crossing design.

10.5 Cross-section

10.5.1 Width

The minimum clear width provided through level crossings should be equal to the width of all the traffic lanes plus 1.5 m each side; that is, the carriageway width plus 3 m.

On duplicated roads, the 1.5 m clearances are added to the outer edge of each carriageway.

10.5.2 Crossfall

At the level crossing, the pavement slope should match the grade line of the railway. This could present a potential hazard where the road is on a curved alignment. The road curvature and superelevation should be selected with superelevation matching the rail grading, so that crossfall does not reduce in the direction of travel along the curve.

10.6 Pedestrians and Cyclists

Traffic management aspects and layout arrangements for pedestrian and bicycle crossings of railways are covered in Section 7.6 of the *Guide to Traffic Management – Part 6: Intersections, Interchanges and Crossings* (Austroads 2007) and in AS 1742.7. Key requirements are that the crossing should have a smooth and straight alignment, preferably at right angles to the rails, with a well-maintained interface between the path and rails, and the appropriate traffic control devices to warn, regulate, advise and control pedestrians (including people who have impairments) and cyclists.
REFERENCES

Arndt OK 2004, ‘Relationship between unsignalised intersection geometry and accident rates’, PhD Thesis, Queensland University of Technology

AASHTO 2001, A policy on geometric design of highways and streets, American Association of State Highway and Transportation Officials, Washington, DC, USA.


Austroads 2000, A framework for arterial road access management, by R Brindle, AP-R163/00, Austroads, Sydney, NSW.

Austroads 2003, Rural road design: a guide to the geometric design of rural roads, AP-G1/03, Austroads, Sydney, NSW.

Austroads 2005, Guide to traffic engineering practice: part 5: intersections at grade, AP-G11.5/05, Austroads, Sydney, NSW.

Austroads 2006a, Design vehicle and turning path templates, by R George, AP-G34/06, Austroads, Sydney, NSW

Austroads 2006b, Guide to road design: part 1: introduction to road design, by G Veith & D Bennett, AGRD01/06, Austroads, Sydney, NSW.

Austroads 2006c, Guide to road design: part 2: design considerations, by G Veith, D Bennett & A Armistead, AGRD02/06, Austroads, Sydney, NSW.

Austroads 2006 – 2009, Guide to road safety, parts 1-9, Austroads, Sydney, NSW

Austroads 2007, Guide to traffic management: part 6: intersections, interchanges and crossings, AGTM06/07, Austroads, Sydney, NSW.

Austroads 2008a, Guide to traffic management: part 5: road management, AGTM05/08, Austroads, Sydney, NSW.

Austroads 2008b, Guide to traffic management part 11: parking, AGTM11/08, Austroads, Sydney, NSW.

Austroads 2009a, Guide to road design: part 3: geometric design, Austroads, Sydney, NSW.

Austroads 2009b, Guide to road design: part 4a: unsignalised and signalised Intersections, Austroads, Sydney, NSW.

Austroads 2009c, Guide to road design: part 4b: roundabouts, Austroads, Sydney, NSW.

Austroads 2009d, Guide to road design: part 4c: interchanges, Austroads, Sydney, NSW.

Austroads 2009e, Guide to road design: part 6: roadside design, safety and barriers, Austroads, Sydney, NSW.

Austroads 2009g, *Guide to road design: part 6b: roadside environment*, Austroads, Sydney, NSW.


Land Transport New Zealand 2007a, *Pedestrian planning and design guide*, Land Transport NZ, Wellington, NZ.


Main Roads Western Australia (MRWA) 1989, *Safety for seniors: final report on pedestrian safety*, Western Australia, Working Group on Safety for Seniors, Main Roads Western Australia, Perth, WA.


Queensland Department of Main Roads 1975, *Urban road design manual*, Queensland Department of Main Roads, Brisbane, Qld.


Roads and Traffic Authority (RTA) 2002, *How to prepare a pedestrian and mobility plan: an easy three stage guide*, Roads and Traffic Authority of New South Wales, Sydney, NSW.

Transit New Zealand 2007, MOTSAM: manual of traffic signs and markings: part 1: traffic signs, Transit New Zealand, Wellington, NZ.

Transit New Zealand 2007, Planning policy manual – for integrated planning and development of state highways. Transit New Zealand, Wellington, NZ.


Australian and New Zealand Standards


AS 1158.4-1987, The lighting of urban roads and other public thoroughfares part 4: supplementary lighting at pedestrian crossings.

AS 1348-2002, Road and traffic engineering - glossary of terms.

AS 1428.1-2001, Design for access and mobility part 1: general requirements for access - new building work.


AS 1742.7-2007, Manual of uniform traffic control devices part 7: railway crossings


APPENDIX A  ACCESS SPACING

A.1  Introduction

This Appendix expands on information provided in Section 7. The information is intended to be informative and discusses methods for considering the spacing of unsignalised minor intersections and driveways on various bases which may be used by road authorities to specify a suitable outcome in any given situation. Much of the information is sourced from TRB (2003), modified where necessary to reflect Australian conditions.

Ideally arterial roads should have no intersecting driveways and minor streets and sub-arterial roads should have this level of access limited. Furthermore, major intersections on these roads should be spaced to support traffic signal coordination which will identify windows in the time-distance profile that allow suitable access at other locations along the road.

Each major intersection has a functional area (Figure A 1) on approaches and departures within which the provision of any driveway or minor intersection is undesirable and should not be permitted. In effect, the space available between the functional areas is what is available for minor accesses. Driveways and unsignalised minor street connections have similar traffic characteristics and should be treated in a similar way.

As mentioned in Section 7 the spacing of unsignalised access (streets and driveways) can be assessed by considering:

- safety
- stopping sight distance
- intersection sight distance
- functional area
- left-turn conflict overlap
- influence distance
- egress capacity.

A.2  Safety

Separating conflicts and minimising conflicts is the usual way to improve safety. TRB (2003) gives relative crash rates as shown in Table A 1 where the base for comparison is 10 access connections per mile (6 per km). Even this base rate could be up to 80% greater than a road with zero access points per km (Austroads 2000).
Table A 1: Relative crash rates for unsignalised access spacing

<table>
<thead>
<tr>
<th>Unsignalised access points per km¹</th>
<th>Average spacing (m)</th>
<th>Relative crash rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>330</td>
<td>1.0</td>
</tr>
<tr>
<td>12</td>
<td>165</td>
<td>1.4</td>
</tr>
<tr>
<td>18</td>
<td>110</td>
<td>1.8</td>
</tr>
<tr>
<td>24</td>
<td>80</td>
<td>2.1</td>
</tr>
<tr>
<td>30</td>
<td>66</td>
<td>2.4</td>
</tr>
<tr>
<td>36</td>
<td>55</td>
<td>3.0</td>
</tr>
<tr>
<td>42</td>
<td>48</td>
<td>3.5</td>
</tr>
</tbody>
</table>

1. Total access connections on both sides of the roadway.
2. Average spacing between access connections on the same side of the roadway.

Notes:
Values converted from the original imperial units with minor rounding.
This table is not inconsistent with the findings of Austroads (2000).

It should be noted that:
- an increase from 0 to 10 commercial access points per kilometre on two-lane urban roads can add about 80% to the accident rate
- an increase from zero to 20 access points per kilometre can double or treble the rate
- providing sufficient spacing between connections to allow turn lanes to be developed in the median will improve the level of safety.
  This would indicate a minimum spacing of 120 m to allow development of adjacent right-turn lanes in the median, assuming no storage is required and the approach speeds are low (<60 km/h).

A.3 Stopping Sight Distance

Desirably, a driver can clear the intersection or access connection and have at least stopping sight distance available to react to a potential conflict and come to a stop. Thus a downstream access connection should not be less than the stopping sight distance from the downstream side of the previous connection or intersection. Details of stopping sight distance are available in the Guide to Road Design – Part 3: Geometric Design (Austroads 2009a). It is numerically equal to approach sight distance that is described in Section 3 of the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b).

A.4 Intersection Sight Distance

This sight distance is required to allow a driver to enter or cross a major roadway. Section 3 of the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b) provides details of the derivation of intersection sight distance and gives tables of appropriate values.

Providing intersection sight distance will result in greater spacing than providing stopping sight distance but a lesser spacing than using the functional area approach (Section A.5).
A.5 Functional Area

The functional area of an intersection is the area beyond the physical intersection of two facilities that comprises decision and manoeuvre distance, plus any required vehicle storage length, and can be protected through corner clearance standards and connection spacing standards.

The upstream functional area is that length over which vehicles on the through road are manoeuvring to execute a right or left-turn at the intersecting road. This length is the greater of the distance required for the right or left-hand turn, including storage or the queue length. The downstream distance is that required for a driver to avoid a collision with a vehicle entering the road from an access connection.

**Upstream dimensions (Figure A 1)**

- $d_1$ – distance travelled during perception-reaction time of driver.

- $d_2$ – distance travelled while driver manoeuvres laterally and decelerates to a stop (lateral movement of 1.2 m/sec in urban areas; 0.9 m/sec in rural areas).

- $d_3$ – length required to store turning vehicles.

[Diagram showing $d_1$, $d_2$, and $d_3$ with labels]

**Source:** Queensland Department and Main Roads (Queensland DTMR).

**Figure A 1:** Upstream functional intersection area (based on right-turning vehicles)

**Downstream dimensions**

Stopping distance is a method of assessing the required downstream distance. This allows a driver to pass through the intersection before having to decide that it is necessary to stop because of a conflict at a downstream access connection (TRB 2003).

If this overlaps with the upstream functional area of the next intersection, then there is no access window. In urban areas, it may not be possible to prevent any accesses in this situation and conditions will have to be applied to any approvals to grant an access in this zone.

The distance required to avoid access connections in the functional area of an intersection is described above. Ideally, no access connection will be located in the functional area of an intersection. Table A 2 sets out the appropriate values for this distance with provision for storage as stated. Actual storage distances should be calculated using the methods provided in the *Guide to Traffic Management – Part 3: Traffic Studies and Analysis* (Austroads 2009i).
Table A 2: Examples of upstream functional intersection distances

<table>
<thead>
<tr>
<th>Location</th>
<th>Speed (km/h)</th>
<th>(d_1 + d_2) (m)</th>
<th>Storage: (d_3) (m)</th>
<th>Upstream functional distance (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural</td>
<td>80</td>
<td>185</td>
<td>25(^1)</td>
<td>210</td>
</tr>
<tr>
<td></td>
<td>100</td>
<td>250</td>
<td>25(^1)</td>
<td>275</td>
</tr>
<tr>
<td></td>
<td>110</td>
<td>310</td>
<td>25(^1)</td>
<td>335</td>
</tr>
<tr>
<td>Sub-urban</td>
<td>50</td>
<td>80</td>
<td>30(^2)</td>
<td>110</td>
</tr>
<tr>
<td></td>
<td>60</td>
<td>125</td>
<td>30(^2)</td>
<td>155</td>
</tr>
<tr>
<td>Urban</td>
<td>35</td>
<td>35</td>
<td>60(^3)</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>50</td>
<td>70</td>
<td>60(^3)</td>
<td>130</td>
</tr>
</tbody>
</table>

1. Storage based on one B-double.
2. Storage based on five cars.
3. Storage based on 10 cars.

Notes:
- Actual storage must be calculated for the specific circumstances.
- This table has been modified from TRB (2003) by using metric units and rounding the values.
- Source: Modified from TRB (2003).

A.6 Left-turn Conflict Overlap

An overlap occurs when the through driver must monitor more than one access at a time. Providing at least the stopping sight distance between access points will allow a through vehicle to avoid a collision with an entering vehicle. However, this is too conservative as the entering vehicle will be accelerating away. Table A 3 provides the minimum distance to avoid the overlap according to the method used by TRB (2003). The acceleration and deceleration rates used in this method are conservative.

Austroads uses deceleration rates from 2.5 m/sec\(^2\) (comfortable) to 3.5 m/sec\(^2\) (maximum) and implied acceleration rates for developing acceleration lanes from about 1.0 m/sec\(^2\) to 1.4 m/sec\(^2\) (Section 3 of the Guide to Road Design – Part 4A: Unsignalised and Signalised Intersections (Austroads 2009b)).

Table A 3: Minimum distance to reduce collision potential due to overlapping left turns

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>Minimum spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>60</td>
</tr>
<tr>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>70</td>
<td>105</td>
</tr>
</tbody>
</table>

Notes:
- The minimum spacing is measured centre to centre of the access connections.
- A vehicle entering the traffic stream from a driveway completes a 90° left-turn and accelerates from a stop at 0.6 m/sec\(^2\). The vehicle in the through lane does not change lanes and decelerates at 1.8 m/sec\(^2\) after a perception reaction time of 2.0 secs. No clearance is provided between the through vehicle and the vehicle entering from the driveway. This results in a significant speed differential between the two vehicles depending on the operating speed of the through road (30 to 50 km/h).
- Source: Queensland Department of Transport and Main Roads (Queensland DTMR).
If it is assumed that an entering vehicle starts from zero and accelerates away from the connection at the same time as the approaching through vehicle brakes to avoid a collision, the two vehicles coming together at the same time (with no clearance), then the resulting distance will be the minimum spacing of driveways. Figure A 2 illustrates the concept where vehicle A enters the roadway and accelerates while vehicle B brakes, the two vehicles reaching the same speed before collision.

By applying the standard equations of motion and assuming constant acceleration and deceleration rates, the values for ‘d’ and ‘a’ can be calculated, the value of ‘d’ being the minimum spacing to avoid the collision (Table A 4).

Table A 4: Minimum spacing of driveways based on left-turn collision avoidance

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>d + a (m)</th>
<th>a (m)</th>
<th>Spacing (desirable) A – C (m)</th>
<th>Spacing (minimum) B – D (m)</th>
<th>SSD (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A Decel. rate 2.5m/s²</td>
<td>B Decel. rate 3.5m/s²</td>
<td>C Accel. rate 1.0m/s²</td>
<td>D Accel. rate 1.5m/s²</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>31</td>
<td>26</td>
<td>5</td>
<td>7</td>
<td>30(26) 20(19) 45</td>
</tr>
<tr>
<td>60</td>
<td>45</td>
<td>38</td>
<td>7</td>
<td>10</td>
<td>40(38) 30(28) 65</td>
</tr>
<tr>
<td>70</td>
<td>61</td>
<td>51</td>
<td>9</td>
<td>14</td>
<td>55(52) 40(37) 85</td>
</tr>
<tr>
<td>80</td>
<td>79</td>
<td>67</td>
<td>12</td>
<td>18</td>
<td>70(67) 50(49) 105</td>
</tr>
<tr>
<td>90</td>
<td>100</td>
<td>85</td>
<td>15</td>
<td>23</td>
<td>85(85) 65(62) 130</td>
</tr>
<tr>
<td>100</td>
<td>124</td>
<td>105</td>
<td>19</td>
<td>29</td>
<td>105(105) 80(76) 170</td>
</tr>
</tbody>
</table>

Notes:
Figures in brackets are the calculated value – rounded to nearest 5 m above.
These values for spacing appear to be more reasonable than those in Table A 3.
Source: Queensland Department of Transport and Main Roads (Queensland DTMR).
A.7 Influence Distance

The influence distance of a driveway (or minor access street) is defined as the sum of the impact distance (comparable to the manoeuvre distance in section A.5) plus the perception/reaction distance:

\[ d_1 – \text{distance travelled during perception-reaction time of driver}. \]

\[ d_2 – \text{impact distance is the distance upstream where the brake lights of a following through vehicle are activated and is comparable to the distance travelled while the driver manoeuvres laterally and decelerates to a stop (lateral movement of 1.2 m/sec in urban areas; 0.9 m/sec in rural areas) at an intersection (TRB 2003)}. \]

Three conditions can occur:

- a through vehicle is not influenced by a turning vehicle
- a through vehicle is influenced by a turning vehicle
- a through vehicle is influenced by a turning vehicle at or upstream of two or more driveways.

When a vehicle is influenced by a left-turning vehicle at an access, it is referred to as ‘spill back’, and the ‘spill back rate’ is the percentage of vehicles that experience this influence. The higher the road classification, the lower the spill back rate should be. TRB (2003) suggests that for a major roadway, a spill back rate of less than 2% may be appropriate but 15% may be acceptable on major collectors in residential areas. Table A 5 provides appropriate distances for a range of spill back percentages.

These distances can be used as a guide to suitable spacing of access connections but it is only one of the possible methods for deciding this.

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>Spill-back rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2%</td>
</tr>
<tr>
<td>50</td>
<td>115</td>
</tr>
<tr>
<td>55</td>
<td>120</td>
</tr>
<tr>
<td>60</td>
<td>130</td>
</tr>
<tr>
<td>70</td>
<td>155</td>
</tr>
<tr>
<td>80</td>
<td>190</td>
</tr>
<tr>
<td>90</td>
<td>225</td>
</tr>
</tbody>
</table>

Notes:
- All distances in metres.
- Values rounded to nearest 5 m.
- Source: Modified from TRB (2003).

A.8 Egress Capacity

Egress capacity refers to the ability of vehicles to exit from an access into the traffic stream. TRB (2003) quotes research from Australia (Major and Buckley 1962) to derive a spacing based on the capacity to exit from an access. This research showed that the capacity increases with increasing spacing of the access points until the spacing is 1.5 times the distance to accelerate from a stop to the average speed of the through traffic. This criterion results in the values in Table A 6.
Table A 6: Distances to maximise the ability of cars to re-enter the through traffic stream from an unsignalised driveway

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>Minimum access spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>30</td>
<td>45</td>
</tr>
<tr>
<td>40</td>
<td>75</td>
</tr>
<tr>
<td>50</td>
<td>115</td>
</tr>
<tr>
<td>60</td>
<td>170</td>
</tr>
<tr>
<td>70</td>
<td>240</td>
</tr>
</tbody>
</table>


A.9 Consideration of Other Methods

Other methods of assessing appropriate driveway spacing and intersection clearances were provided in Queensland Department of Main Roads (1975) – *Urban Road Design Manual*. These methods are based on queuing theory, acceleration rates, appropriate headways, and logical analysis of vehicular movements in several situations.

Three situations are considered:

1. Blockage of an intersection due to vehicles queued to enter an adjoining driveway.
2. Diagonal movement of a vehicle leaving the access and proceeding diagonally across the through lanes to turn at the next intersection.
3. Simultaneous entry to the through road from two adjoining points.

Intersection blockage from an adjoining driveway can be analysed in accordance with the principles in the *Guide to Traffic Management – Part 3: Traffic Studies and Analysis* (Austroads 2009i) by assuming that the driveway is an intersection. This is not dissimilar to the ‘functional area’ of an intersection concept or the factors considered in assessing the required corner clearance.

The diagonal movement is addressed by assuming a lateral rate of movement of a vehicle once it has entered the major road. The minimum distance is when the movement can be accomplished as a straight diagonal movement. The traffic volumes would have to be low to allow this to happen but it could also be possible if a sufficient gap occurred after the platoon of vehicles cleared the intersection.

The minimum distance to cross three 3.5 m lanes is 30 m, and two 3.5 m lanes, 20 m. If the manoeuvre had to be performed in the presence of approaching traffic, a significantly greater distance would be required because of the slower lane change rate. These minimum distances would place the access within the functional area of the intersection and would not be allowed.

The simultaneous entry approach assumes that the spacing of the driveways must be such that a vehicle entering the roadway from a stop and accelerating to a terminal speed of 50 km/h will not need to adjust the speed because of the vehicle entering from the next driveway. Both vehicles start from the same speed and have a common acceleration rate. In analysing the possible combinations, the approximate spacing required is 25 m between successive driveways (on the same side or on opposite sides).
To assess the required distance downstream of an intersection to avoid any interruption from an entering vehicle from a downstream driveway, the assumption is that the vehicle turning from the intersection starts at 25 km/h while the vehicle starts from a stop at the driveway (i.e. 0 km/h). The required headway for the vehicles is 1.75 seconds. Using appropriate acceleration graphs, the distance required can be calculated. For the conditions specified, typical distances amount to about 110 m (left turn to a downstream driveway) and 75 m (right turn to a downstream driveway). Once again, the functional area of the intersection must be considered.

**A.10 Summary of Access Spacing Methods**

The methods described above could be used to develop general guidelines to access spacing that may be suitable for roads of different types. The specific requirements for a particular road where the operating speed and traffic volumes are known can be assessed for those conditions and appropriate conclusions drawn and access conditions specified.

For the general cases in a table of values to be used as guidelines, the typical conditions expected on the road types specified must be acknowledged. The following factors should be considered:

- Longer spacing is generally required on roads of higher classification.
- Higher classification roads will generally have higher operating speeds than lower classification roads, although this will not be true of any lower classification rural roads where the topography and geometry encourage high operating speed.
- Higher classification roads tend to carry higher volumes of traffic than other roads.
- Vehicles entering or leaving an access cause interference to the through traffic stream, the degree of interference increasing as the traffic volume increases.
- Roads with speeds greater than 70 km/h are usually more critical than roads with speeds less than 70 km/h.
Table A 7: Summary of spacing assessments

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>Left-turn overlap (TRB)</th>
<th>Left-turn overlap (Les Louis)</th>
<th>Influence distance</th>
<th>Egress capacity</th>
<th>Criteria used to assess driveway spacing</th>
<th>Urban Road Design Manual (1975) methods QDMR (1975)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Intersect. blockage</td>
<td>Diagonal movement a</td>
</tr>
<tr>
<td>50</td>
<td>60</td>
<td>30</td>
<td>75</td>
<td>115</td>
<td>#</td>
<td>20</td>
</tr>
<tr>
<td>60</td>
<td>80</td>
<td>40</td>
<td>90</td>
<td>170</td>
<td>#</td>
<td>20</td>
</tr>
<tr>
<td>70</td>
<td>105</td>
<td>55</td>
<td>100</td>
<td>240</td>
<td>#</td>
<td>20</td>
</tr>
<tr>
<td>80</td>
<td>70</td>
<td>160</td>
<td>300</td>
<td></td>
<td>#</td>
<td>*</td>
</tr>
<tr>
<td>90</td>
<td>85</td>
<td>185</td>
<td>375</td>
<td></td>
<td>#</td>
<td>*</td>
</tr>
</tbody>
</table>

Notes:
1. 20% spill-back rate.
2. 15% spill-back rate.
3. 5% spill-back rate.
4. # denotes – ‘depends on the traffic volumes’.
5. Based on crossing a two-lane roadway.
6. 75 m – right turn to downtown driveway; 110 m – left turn to a downstream driveway; 25 m – adjacent driveways.
7. * denotes – ‘not an appropriate situation’.
Source: Queensland Department of Transport and Main Roads (Queensland DTMR).

For roads operating above 90 km/h, access points should be treated as intersections and spacing should be at least the safe intersection sight distance (SISD). Suitable spacing could also be assessed as being the sum of the distance required to fully develop acceleration from the first driveway to the design speed of the road and the distance to achieve deceleration from the design speed to zero for the next driveway; however, this condition may seem excessive in some situations.

Table A 8: Alternative spacing assessments for high-speed roads

<table>
<thead>
<tr>
<th>Design speed (km/h)</th>
<th>SISD (m)</th>
<th>Acceleration distance (m) A</th>
<th>Deceleration distance (m) B</th>
<th>A + B (m) (rounded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>90</td>
<td>215</td>
<td>330</td>
<td>125</td>
<td>450</td>
</tr>
<tr>
<td>100</td>
<td>250</td>
<td>450</td>
<td>155</td>
<td>600</td>
</tr>
<tr>
<td>110</td>
<td>300</td>
<td>610</td>
<td>185</td>
<td>800</td>
</tr>
</tbody>
</table>

Source: Queensland Department of Transport and Main Roads (Queensland DTMR).

For roads with these speeds, the SISD criterion could be regarded as the minimum and the (A+B) condition as providing the desirable spacing.

A.11 Corner Clearance

Corner clearance is the distance from the intersection to the nearest driveway. The distance required depends on the type of road and the traffic volumes on that road, as well as available sight distance to the driveway. If the distance is not sufficient, then the access connection can be blocked by vehicles queuing from the intersection; and/or the vehicles entering or exiting from the access can cause traffic to block back into the intersection itself.
One way of determining a suitable corner clearance to a driveway is to decide what proportion of the signal cycles that will block the driveway is acceptable. This will depend on the volumes of traffic on the road. At a stop controlled intersection, the probability of the driveway being blocked can be determined. These measures can give a guide to the required corner clearance.

The required corner clearance can also be assessed using the same methods as described in Sections A.2 to A.9. That is, the functional area of the intersection, the influence distance, egress capacity and visibility can be used to assess appropriate distances. The methods described in Section A.4 could have application in some road classifications.

While it is possible to adopt the same standard spacing requirements for the corner clearances as for other access connections, this does not take account of the differences between intersections. It is preferable to analyse the requirements for each intersection, but in the absence of detailed information, the standard access connection spacing could be adopted in the first instance.

Figure A 3 and Figure A 4 illustrate the dimensions that should be determined.

![Figure A 3: Corner clearances](image)

Notes:
Upstream on major roadway – equals or exceeds the functional distance of the intersection (Section A.5)
Downstream on the major roadway – equals or exceeds the downstream functional distance; or the influence distance; or the left-turn conflict overlap; but is not less than the stopping distance.
Approach side on minor roadway – assess by queuing analysis.
Departure side on the minor roadway – 40 m (unchannelised – as shown).
Source: Modified from TRB (2003).
Figure A 4: Corner clearance – channelised intersection

Source: Queensland Department and Main Roads (Queensland DTMR).
APPENDIX B DERIVATION OF SIGHT DISTANCE REQUIREMENTS AT RAILWAY LEVEL CROSSINGS

B.1 General

Before detailing the procedures used in the derivation of the formulae used in this Guide, it is important that users note that sight distance requirements at railway level crossings have historically varied from State to State.

It is necessary to consider two scenarios in the evaluation of sight distance requirements at railway level crossings. Case 1 addresses the sight distances required for an approaching vehicle considering two critical situations (necessary to establish whether the give way control is adequate); and case 2 addresses the sight distance along the railway for a vehicle stopped at a stop sign (necessary to establish the adequacy of stop sign control). The geometry and associated notation for cases 1 and 2 are depicted on Figure B 2 and Figure B 3 respectively.

B.2 Case 1: Sight Distance Required for Give Way Control

Case 1 allows a motorist approaching the crossing at distance \( S_1 \) to sight a train at distance \( S_2 \) from the crossing and either:

Case 1(i) Decelerate and safely stop at the stop or holding line, or

Case 1(ii) Proceed and clear the crossing with an adequate safety margin.

When motorists reach a crossing and see a train approaching, they must decide whether to decelerate and stop, or proceed and clear the crossing. There is a finite distance required between the vehicle and the rail in order to reach a decision and act in safety. This distance, assuming a level grade crossing site, comprises four components:

- The distance travelled during the perception/reaction time is given by Equation 1:
  \[ R_I V_f = \frac{R_I V_f}{3.6} \text{ metres} \]

- Braking distance is given by Equation 2:
  \[ \frac{V_f^2}{2a} = \left( \frac{V_u}{3.6} \right)^2 = \frac{V_f^2}{254F} \text{ metres} \]

  where

  \[ g = \text{acceleration due to gravity} = 9.81 \text{m/sec}^2. \]

- Distance of the driver from the front of the vehicle (\( L_d \) metres), and

- Clearance from the vehicle stop or holding line to the nearest rail (\( C_v \) metres).

Thus, to stop on level ground, require \( S_1 \) as given by:

\[ S_1 \geq \frac{R_I V_f}{3.6} + \frac{V_f^2}{254F} + L_d + C_v \]
The influence of slope on the stopping distance component of this equation can be derived using simple physics as shown in Figure B 1.

![Figure B 1: Influence of slope on stopping distance](image)

Source: Austroads (2003).

The influence of grade on vehicle deceleration can be derived as follows:

- **Braking distance**
  \[
  \frac{V_y^2}{2a} = \frac{\left(\frac{V_y}{3.6}\right)^2}{2gF} = \frac{V_y^2}{254F} \text{ metres}
  \]

- Component of vehicle mass acting down the slope = \(mgsin\theta\)
- \((g = \text{acceleration due to gravity} = 9.81\text{m/sec}^2)\)
- For small angles \(sin\theta = tan\theta = x/y = G \text{ (m/m)}\)
- (grade is expressed as ratio, negative for downhill)
- Force acting down the slope . \(mgsin\theta\) . \(mgtan\theta = mgG\)
- Effective deceleration = \(gF + gG = g(F + G)\) and
- Therefore effective deceleration = \(g(F + G)\).
In order to stop on sloped ground, Equation 3 subsequently becomes that given in Equation 4:

\[
S_1 \geq \frac{R_T V_v}{3.6} + \frac{V_v^2}{254(F + G)} + L_d + C_v
\]

where

- \( S_1 \) = minimum distance of an approaching road vehicle from the nearest rail when the driver of the vehicle can see an approaching train (m)
- \( R_T \) = perception/reaction time (general case assumption = 2.5 sec)
- \( V_v \) = the 85th percentile road vehicle speed in the vicinity of the crossing. The road speed limit plus 10% is a reasonable approximation where the 85th percentile speed is not known (km/h)
- \( F \) = coefficient of longitudinal friction (Guide to Road Design – Part 3: Geometric Design (Austroads 2009a))
- \( L_d \) = distance from the driver to the front of the vehicle (general case assumption = 1.5 m)
- \( C_v \) = clearance from the vehicle stop or holding line to the nearest rail (general case assumption = 3.5 m)
- \( G \) = grade, negative for downhill, positive for uphill (m/m).
- \( S_1 \) = minimum distance of an approaching road vehicle from the nearest rail when the driver of the vehicle can see an approaching train (m)
- \( R_T \) = perception/reaction time (general case assumption = 2.5 sec).

### B.3 Case 1(i): Decelerate and Safety Stop at the Stop or Holding Line

The time required for a motorist (at a distance \( S_1 \) from the nearest rail) to stop at the stop or holding line, comprises:

- perception/reaction time (RT)
- braking time in seconds.

\[
\frac{V_v}{a} = \frac{V_v}{3.6} = \frac{V_v}{gF} = \frac{V_v}{35.3F}
\]

where

- \( g \) = acceleration due to gravity = 9.81 m/sec\(^2\).
Therefore, for the motorist to safely stop, the train would have to be sighted at a minimum distance, $S_2$ from the crossing as given by Equation 6:

$$S_2 = \frac{V_T}{3.6} \left[ R_T + \frac{V_T}{35.3F} \right] \text{metres}$$

where

- $S_2$ = minimum distance of an approaching train from the point of impact with a road vehicle, when the driver of the road vehicle first sees a train approaching in order to safely stop at the stop or holding line (m);
- $V_T$ = the speed of the train approaching the crossing (the allowed operating speed of trains, as advised by the rail authority) (km/h);
- $R_T$ = perception/reaction time (general case assumption = 2.5 sec);
- $V_V$ = the 85th percentile road vehicle speed in the vicinity of the crossing. The road speed limit plus 10% is a reasonable approximation where the 85th percentile speed is not known (km/h);
- $F$ = coefficient of longitudinal friction (Guide to Road Design – Part 3: Geometric Design (Austroads 2009a))

Note that the distance $S_2$ is measured from alternate datum points which are contingent upon whether a train approaches from the left or right. For a train approaching from the left, the point of impact is at the road edge line, while, for a train approaching from the right, it is at the road centre line. For a field survey, distances $S_{2L}$ and $S_{2R}$ are required to be calculated separately as a common datum point is referenced.

**Sight distance S2L adjustment**

For the case of a train approaching the crossing from the left, the sight distance $S_2$ is calculated from the left edge line of the road (or the road pavement if there is no edge line). In order to measure distance $S_{2L}$ from the referenced datum point, an adjustment needs to be incorporated in the $S_2$ equation.

The datum point referenced in the field survey is the intersection of the centre line of the road and the mid-point of the rail tracks at the crossing.

$$\text{Adjustment for S2L equation } = \frac{0.5W}{\sin Z}$$

In the case of a train approaching the crossing from the right, the sight distance $S_{2R}$ is equal to that adopted for $S_2$, as the potential point of impact is at the datum point.

The minimum distances, $S_{2L}$ and $S_{2R}$, where an approaching train is first sighted in order for a driver of an approaching vehicle to safely stop at the stop or holding line, are calculated from relationships Equations 8 and 9 respectively. Equation 8 is the sum of Equation 6 and the adjustment given in Equation 7.
The minimum distance for a train approaching from the left of the crossing, to enable the driver of a road vehicle to decelerate and safely stop at the stop or holding line is given in Equation 8:

\[
S_{2L(i)} \geq \frac{0.5W_R}{\sin Z} + \frac{V_T}{3.6} \left[ R_T + \frac{V_F}{35.3F} \right] \tag{8}
\]

The minimum distance for a train approaching from the right of the crossing, to enable the driver of a road vehicle to decelerate and safely stop at the stop or holding line is given in Equation 9:

\[
S_{2R(i)} = \frac{V_F}{3.6} \left[ R_T + \frac{V_F}{35.3F} \right] \tag{9}
\]

The calculated distances \(S_{2L}\) and \(S_{2R}\) are then compared to the distances obtained in the case of a driver of a road vehicle safely proceeding and clearing the crossing, Case 1(ii) described in B.4. The larger value (i.e. the distance required to stop compared with the distance required to proceed safely through the crossing) is adopted as the critical case.

**B.4 Case 1(ii): Proceed and Clear the Crossing with an Adequate Safety Margin**

It is also important to consider the case in which a motorist at distance \(S_1\) from the crossing decides to proceed (even though he/she could safely stop) and attempt to clear the crossing prior to the arrival of the train.

Referring to Figure B 3, the distance a motorist has to travel to clear the crossing is given by the Equation 10:

\[
S_1 + \frac{W_F}{\tan Z} + \frac{W_F}{\sin Z} + C_T + C_T + L - L_d \tag{10}
\]

Substituting \(S_1\) from Equation 4 into Equation 10 results in Equation 11:

\[
\frac{R_FV_F}{3.6} + \frac{V_F^2}{254(F + G)} + \frac{W_R}{\tan Z} + \frac{W_F}{\sin Z} + 2C_T + C_T + L \tag{11}
\]
Therefore, the distance travelled by the train for the motorist to precede and clear the crossing is given by Equation 12:

\[
S_2 = \frac{V_T}{V_V} \left[ \frac{R_T V_V}{3.6} + \frac{V_V^2}{254(F+G)} + \frac{W_R}{\tan Z} + \frac{W_T}{\sin Z} + 2C_V + C_T + L \right]
\]

where

- \(S_2\) = minimum distance of an approaching train from the point of impact with a road vehicle, when the driver of the road vehicle can first see the train approaching the crossing in order to proceed and safely clear the crossing (m).
- \(V_T\) = the speed of the train approaching the crossing (the allowed operating speed of trains, as advised by the rail authority) (km/h).
- \(R_T\) = perception/reaction time (general case assumption = 2.5 sec).
- \(V_V\) = the 85th percentile road vehicle speed in the vicinity of the crossing. The road speed limit plus 10% is a reasonable approximation where the 85th percentile speed is not known (km/h).
- \(F\) = coefficient of longitudinal friction (Guide to Road Design – Part 3: Geometric Design (Austroads 2009a)).
- \(C_V\) = clearance from the vehicle stop or holding line to the nearest rail (general case assumption = 3.5 m).
- \(C_T\) = clearance or safety margin from stop or holding line on departure side of the crossing (general case assumption = 5 m);
- \(L\) = length of road vehicle (i.e. design vehicle for road: refer to Table B 1 for examples).
- \(W_R\) = width of the travelled way (portion of the roadway allocated for the movement of the vehicles) at the crossing (m).
- \(W_T\) = width, outer rail to outer rail, of the rail tracks at the crossing (1.1 m for single track, 5.1 m for double track).
- \(Z\) = angle between the road and the railway at the crossing (degrees).
Table B 1: Examples of vehicle lengths

<table>
<thead>
<tr>
<th>Vehicle route</th>
<th>Vehicle type and length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roads not on nominated route</td>
<td>Medium car – 5 m</td>
</tr>
<tr>
<td>B-double route</td>
<td>Prime mover and semi-trailer – 19 m</td>
</tr>
<tr>
<td>Road train route – Type 1</td>
<td>B-double – 25 m</td>
</tr>
<tr>
<td>Road train route – Type 2</td>
<td>Type 1 road train – 33 m</td>
</tr>
<tr>
<td></td>
<td>Type 2 road train – 50 m</td>
</tr>
</tbody>
</table>

Note: Length used should be for appropriate design vehicle for the road concerned.

Source: Austroads (2003).

As discussed in Case 1(i), distance $S_2$ is measured from alternate datum points to correspond with the potential point of impact for the left and right train approaches. In order to carry out a detailed survey of a crossing, distances $S_{2L}$ and $S_{2R}$ are required to be calculated separately, as a common datum point is utilised.

The minimum distance ($S_{2L}$) of an approaching train from the intersection of the centre line and the mid-point of the rail tracks, when the driver of the road vehicle first sees a train approaching from the left, in order to safely proceed and clear the crossing (considering the sight distance $S_{2L}$ adjustment indicated in Case 1(i)) is given in Equation 13:

$$S_{2L} = \frac{0.5W_R}{\sin Z} + \frac{V_T}{V_V} \left[ \frac{R_T V_T}{3.6} + \frac{V_V^2}{254(F + G)} + \frac{W_R}{\tan Z} + \frac{W_T}{\sin Z} + 2C_V + C_T + L \right]$$

The minimum distance ($S_{2R}$) of an approaching train from the intersection of the centre line of the road and the mid-point of the rail tracks, when the driver of the road vehicle first sees a train approaching from the right, in order to proceed and clear the crossing is given in Equation 14:

$$S_{2R} = \frac{V_T}{V_V} \left[ \frac{R_T V_T}{3.6} + \frac{V_V^2}{254(F + G)} + \frac{W_R}{\tan Z} + \frac{W_T}{\sin Z} + 2C_V + C_T + L \right]$$

In order to obtain the critical sight distances, $S_{2L}$ and $S_{2R}$, the larger distances from Cases 1(i) and (ii) should be adopted.
Notes:
1. Case 1(i) Motorist approaching crossing sights train, decelerates and stops at the holding line.
2. Case 1(ii) Motorist approaching crossing sights train, proceeds and safely clears the crossing.
Source: Austroads (2003).

Figure B 2: Approach visibility at railway level crossings – Case 1(i) and Case 1(ii)
The Notation for Figure B 2 (units and/or general case assumptions) are:

- $S_1$: Minimum distance of an approaching road vehicle from the nearest rail when the driver of the vehicle can see an approaching train (m).
- $S_2$: Minimum distance of an approaching train from the point of impact with a road vehicle, when the driver of the road vehicle first sees a train approaching (m).
- $S_{2L}$: Minimum distance of an approaching train from the intersection of the road centre line and the mid-point of the rail tracks, when the driver of the road vehicle first sees a train approaching from the left (m).
- $S_{2R}$: Minimum distance of an approaching train from the intersection of the road centre line and the mid-point of the rail tracks, when the driver of the road vehicle first sees a train approaching from the right (m).
- $V_T$: The speed of the train approaching the crossing (the allowed operating speed of trains, as advised by the rail authority (km/h)).
- $V_V$: The 85th percentile road vehicle speed in the vicinity of the crossing. The road speed limit plus 10% is a reasonable approximation where the 85th percentile speed is not known.
- $C_V$: Clearance from the vehicle stop or holding line to the nearest rail (general case assumption = 3.5 m).
- $C_T$: Clearance or safety margin from the vehicle stop or holding line on the departure side of the crossing (general case assumption = 5 m).
- $L$: Length of road vehicle (m).
- $L_d$: Distance from the driver to the front of the vehicle (general case assumption = 1.5 m).
- $W_R$: Width of the travelled way (portion of the roadway allocated for the movement of the vehicles) at the crossing (m).
- $W_T$: Width, outer rail to outer rail, of the rail tracks at the crossing (1.1 m for single track, 5.1 m for double track).
- $X_{1L}$: Vehicle driver viewing angle measured from distance $S_1$ on the road centre line, where a driver must first see a train approaching from the left at distance $S_2$ from the crossing.
- $X_{1R}$: Vehicle driver viewing angle measured from distance $S_1$ on the road centre line, where a driver must first see a train approaching from the right at distance $S_2$ from the crossing.
- $Z$: Angle between the road and the railway at the crossing (degrees).

### B.5 Case 2: Sight Distance Required for STOP Sign Control

When motorists are stationary at a crossing controlled by a STOP sign, they require adequate sight distance to determine whether or not it is safe to cross the tracks before the train arrives. Referring to Figure B 3, it presents a method by which the time taken to complete this manoeuvre can be ascertained. The time comprises:

- perception time and time required to depress clutch ($J$)
- time to clear the crossing by a safe distance given by:

$$
X = \left[ \frac{2}{\tan Z} \frac{W_R + W_T + 2C_V + C_T + L}{\sin Z} \right]^{1/2}
$$

The distance travelled by the train during this time:

$$
S_3 = \frac{V_T}{3.6} \left\{ J + \left[ \frac{2}{\tan Z} \frac{W_R + W_T + 2C_V + C_T + L}{\sin Z} \right]^{1/2} \right\}
$$
Field testing has confirmed that the influence of grade on vehicles accelerating from a stationary position is not accurately modelled by the application of simple physics principles (Lay 1990:571). American literature (AASHTO Policy on Geometric Design of Highways quoted in MRD (WA) 1991:16) provides the grade correction factors in Table B 2.

Equation 16 subsequently becomes:

\[
S_3 = \frac{V_T}{3.6} \left[ \frac{1}{2} \left( \frac{W_R}{\tan Z} + \frac{W_T}{\sin Z} + 2C_V + C_T + L \right)^{1/2} \right]
\]

where

- \( S_3 \) = minimum distance of an approaching train from the point of impact with a road vehicle, when the driver of the road vehicle must first see an approaching train in order to safely cross the tracks (m).
- \( V_T \) = the speed of the train approaching the crossing (the allowed operating speed of trains, as advised by the rail authority) (km/h).
- \( J \) = sum of the perception time and time required to depress clutch (general case assumption = 2 sec).
- \( G_s \) = grade correction factor, refer to Table B 2.
- \( L \) = length of road vehicle, refer to Table B 1 (m).
- \( C_v \) = clearance from the vehicle stop or holding line to the nearest rail (general case assumption = 3.5 m).
- \( C_T \) = clearance or safety margin from stop or holding line on departure side of the crossing (general case assumption = 5 m).
- \( W_R \) = width of the travelled way (portion of the roadway allocated for the movement of the vehicles) at the crossing (m).
- \( W_T \) = width, outer rail to outer rail, of the rail tracks at the crossing (1.1 m for single track, 5.1 m for double track).
- \( Z \) = angle between the road and the railway at the crossing (degrees).
- \( a \) = average acceleration of the vehicle in starting gear (general case assumption = 0.5 m/sec\(^2\), refer to Table B 3.)
Table B 2: Grade correction factors

<table>
<thead>
<tr>
<th>Percentage grade %</th>
<th>Grade correction factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>-4</td>
<td>0.8</td>
</tr>
<tr>
<td>-2</td>
<td>0.9</td>
</tr>
<tr>
<td>+2</td>
<td>1.2</td>
</tr>
<tr>
<td>+4</td>
<td>1.7</td>
</tr>
</tbody>
</table>


Sight distance $S_{3L}$ adjustment

A sight distance adjustment is necessary to calculate $S_{3L}$ for the common datum point used in the field survey. The datum point referenced in the field survey is the intersection of the centre line of the road and the mid-point of the railway tracks at the crossing.

\[
\text{Adjustment for } S_{3L} \text{ equation } = \frac{0.5W_R}{\sin Z}
\]

Therefore, the minimum distance of an approaching train from the intersection of the road centre line and the mid-point of the rail tracks, when the driver of a road vehicle must first see a train approaching from the left in order to safely cross the track from a stopped position is:

\[
S_{3L} = \frac{0.5W_R}{\sin Z} + \frac{V_T}{3.6} \left[ J + G_S \left\{ \frac{\left( \frac{W_R}{\tan Z} + \frac{W_T}{\sin Z} + 2C_V + C_T + L \right)^{1/2}}{a} \right\} \right]
\]

The minimum distance of an approaching train from the intersection of the road centre line and the mid-point of the rail tracks, when the driver of a road vehicle must first see a train approaching from the right in order to safely cross the track from a stopped position is:

\[
S_{3R} = \frac{V_T}{3.6} \left[ J + G_S \left\{ \frac{\left( \frac{W_R}{\tan Z} + \frac{W_T}{\sin Z} + 2C_V + C_T + L \right)^{1/2}}{a} \right\} \right]
\]
Table B 3: Heavy vehicle speed/acceleration performance (RTA 1990 and QT 1993)

<table>
<thead>
<tr>
<th>Type of vehicle</th>
<th>Distance travelled (m)</th>
<th>Time (sec)</th>
<th>Average speed (m/sec)</th>
<th>Average acceleration (m/sec²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laden rigid truck (RTA 1990)</td>
<td>22.4</td>
<td>9.3</td>
<td>2.4</td>
<td>0.50</td>
</tr>
<tr>
<td>Laden semi-trailer (RTA 1990)</td>
<td>28.9</td>
<td>12.6</td>
<td>2.3</td>
<td>0.36</td>
</tr>
<tr>
<td>Laden B-double (RTA 1990)</td>
<td>34.4</td>
<td>13.6</td>
<td>2.5</td>
<td>0.37</td>
</tr>
<tr>
<td>Laden road train (RTA 1990)</td>
<td>46.4</td>
<td>21.3</td>
<td>2.2</td>
<td>0.29</td>
</tr>
<tr>
<td>Laden 19 m semi-trailer (QT Mt Cotton Facility 1993)</td>
<td>27.5</td>
<td>11.3</td>
<td>2.4</td>
<td>0.43</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8.7</td>
<td>3.2</td>
<td>0.73</td>
</tr>
<tr>
<td>Laden 19 m semi-trailer (QT Mt Cotton Facility 1993)</td>
<td>34.5</td>
<td>13.8</td>
<td>2.5</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10.8</td>
<td>3.2</td>
<td>0.59</td>
</tr>
</tbody>
</table>

Note: The information in Table B 3 has been taken directly from Austroads (2003) which stated that: In addition to the data provided in Table B 3, limited data collected by ARRB (Barton 1990:6) suggests the average speed of a heavy vehicle commencing from a stopped position equals 3.3 m/sec over a typical crossing distance. The Main Roads Department (Western Australia) (1991:13) quotes values of acceleration obtained from American literature ranging from “45 m/sec2 for the acceleration of trucks in first gear, to 0.54 m/sec2 over a distance of around 12 m, then gradually back down to a value of 0.5 m/sec2 for a distance of around 50 m”. For the required crossing visibility at the critical case, they subsequently recommend the adoption of a heavy vehicle acceleration value of 0.5 m/sec2 to “be on the conservative side”, and indicate that this value has been shown “to be acceptable by measuring the acceleration rates of a number of fully laden trucks, which resulted in values between 0.55 m/sec2 and 0.90 m/sec2”. Source: Austroads (2003).
Note: Case 2   Motorist stopped at crossing requires adequate time to accelerate and safely clear the crossing.
Source: Austroads (2003).

**Figure B 3: Approach visibility at railway level crossings – Case 2**

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$S_3$</td>
<td>Minimum distance of an approaching train from the point of impact with a road vehicle, when the driver of the road vehicle must first see an approaching train in order to safely cross the tracks.</td>
</tr>
<tr>
<td>$S_{3L}$</td>
<td>Minimum distance of an approaching train from the intersection of the road centre line and the mid-point of the rail tracks, when the driver of a road vehicle must first see a train approaching from the left in order to safely cross the track from a stopped position at the stop or holding line (m).</td>
</tr>
<tr>
<td>$S_{3R}$</td>
<td>Minimum distance of an approaching train from the intersection of the road centre line and the mid-point of the rail tracks, when the driver of a road vehicle must first see a train approaching from the right in order to safely cross the track from a stopped position at the stop or holding line (m).</td>
</tr>
<tr>
<td>$V_t$</td>
<td>The speed of the train approaching the crossing (the allowed operating speed of trains, as advised by the rail authority) (km/h).</td>
</tr>
<tr>
<td>$L$</td>
<td>Length of road vehicle (m).</td>
</tr>
<tr>
<td>$L_d$</td>
<td>Distance from the driver to the front of the vehicle (general case assumption = 1.5 m).</td>
</tr>
<tr>
<td>$C_v$</td>
<td>Clearance from the vehicle stop or holding line to the nearest rail (general case assumption = 3.5 m).</td>
</tr>
<tr>
<td>$C_t$</td>
<td>Clearance or safety margin from the vehicle stop or holding line on the departure side of the crossing (general case assumption = 5 m).</td>
</tr>
<tr>
<td>$W_k$</td>
<td>Width of the travelled way (portion of the roadway allocated for the movement of the vehicles) at the crossing (m).</td>
</tr>
<tr>
<td>$W_t$</td>
<td>Width, outer rail to outer rail, of the rail tracks at the crossing (1.1 m for single track, 5.1 m for double track).</td>
</tr>
<tr>
<td>$X_{3L}$</td>
<td>Vehicle driver viewing angle measured from at the stop line to a train approaching from the left at distance $S_3$ from the crossing.</td>
</tr>
<tr>
<td>$X_{3R}$</td>
<td>Vehicle driver viewing angle measured from at the stop line to the road centre line to a train approaching from the right at distance $S_3$ from the crossing.</td>
</tr>
<tr>
<td>$Z$</td>
<td>Angle between the road and the railway at the crossing (degrees).</td>
</tr>
</tbody>
</table>
COMMENTARY 1

C1.1 Intersection Function

A road network provides for the movement of people and goods. Its relationship to land use is fundamental. Traffic is a function of land use and land use is a function of access. A road network is an integral part of land use and cannot be considered independently.

Traditionally, roads have had two basic functions. A typical road provides for both through traffic movement (movement function) and the movements necessary to support the adjoining land use (access function). This can lead to a reduction in the service provided for both functions, particularly delays for arterial road traffic and crashes involving vehicles entering and leaving the road.

When traffic volumes are low, the dual function can be accepted. However, as traffic volumes increase, the problems associated with this duality of operation become very important. Effective traffic management requires an appropriate balance to be achieved between the movement and access functions for the particular road or route. It is not always necessary for a road to provide both a movement function and an access function. Current practice is to allocate functions to roads, based on a road hierarchy, as listed in Table C1 1.

<table>
<thead>
<tr>
<th>Type</th>
<th>Movement function</th>
<th>Access function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial (fwy)</td>
<td>Sole function</td>
<td>Nil</td>
</tr>
<tr>
<td>Arterial (n/fw)</td>
<td>Major</td>
<td>Minimal</td>
</tr>
<tr>
<td>Sub-arterial</td>
<td>Significant</td>
<td>Minor</td>
</tr>
<tr>
<td>Collector</td>
<td>Minor</td>
<td>Significant</td>
</tr>
<tr>
<td>Local</td>
<td>Minimal</td>
<td>Major</td>
</tr>
</tbody>
</table>

(fwy) = freeway – full access control.
(n/fw) = non freeway – partial or no access control.
Source: Austroads (2005).
Intersections are a fundamental part of a road hierarchy. They are the nodes of the system, and determine how effectively the network operates. They govern how effectively each road can perform its allocated function in the hierarchy. Because of this, each intersection has a profound influence on land use and development options.

An intersection is not an entity in itself. It must have a purpose defined by the network. In turn, the road network is an integral part of community land use, and cannot be developed independently.

Figure C1 2 shows that there are intersections which connect facilities of the same rank, i.e. arterial to arterial, sub-arterial to sub-arterial. These are shown by the open circles. As well, there are intersections which connect facilities at different levels in the hierarchy, such as arterial to sub-arterial, sub-arterial to collector, collector to local road. These are shown by shaded circles. Other intersections within the hierarchy may be inappropriate. These are shown by the dashed lines.

It should also be recognised that pedestrian movements and bicycle networks intersect with each other and motor vehicle movements, and must be identified and managed.

Source: Austroads (2005).

Figure C1 1: Road hierarchy showing functions, characteristics and major sources of funds

Figure C1 1 plots the road hierarchy in terms of the relationships between access and movement functions, characteristics and the major sources of funding. The structure of a road hierarchy is more fully discussed in AS 1348.2.
Figure C1 2: Appropriate and inappropriate intersections as determined by the hierarchy

Note 1: For rural networks it may be difficult to differentiate between sub arterial/arterial roads, and collector/local roads.

Note 2: Unfortunately, the administrative classification of a road may not reflect its function in the network.

Note 3: 'Intersections' on freeway type facilities require grade separation and connecting ramps (i.e. interchanges).
COMMENTARY 2

C2.1 Intersection and Access Spacing

The example in Table C2.1 (provided by Queensland DTMR) illustrates how a balance can be achieved between the traffic movement and access functions of various classifications of roads. Access management and the concept of access categories are discussed in the *Guide to Traffic Management – Part 5: Road Management* (Austroads 2008a). However, the access categories shown in Table C2.1 relate only to Queensland DTMR and are used to denote the access limitations and characteristics required for the various types of roads described in the table.
## Table C2.1: Example of access categories and performance criteria

<table>
<thead>
<tr>
<th>Road class</th>
<th>Design categories</th>
<th>Access categories</th>
<th>Performance criteria</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>National highway (NH)</td>
<td>Motorway</td>
<td>1</td>
<td>See SSR</td>
<td>Same as for state strategic roads</td>
</tr>
<tr>
<td></td>
<td>Urban divided</td>
<td>2, 3</td>
<td>See SSR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rural divided</td>
<td>4, 5</td>
<td>See SSR</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rural two-lane</td>
<td>6</td>
<td>No property access</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersections with major roads only</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersection spacing not less than 5 km (RPDM Ch. 4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≥100 km/h</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>No driveway connections other than for service centres</td>
<td></td>
</tr>
<tr>
<td>State strategic road (SSR)</td>
<td>Motorway</td>
<td>1</td>
<td>No property access</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interchanges only</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interchange spacing 2 km (min)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Urban divided</td>
<td>2</td>
<td>No property access</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interchanges with motorways</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersections with other SSR and RRs only</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Signalised intersections – spacing 1.6 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3</td>
<td>Limited property access</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interchanges with motorways</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersections with other SSRs and RRs only</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Signalised and unsignalised intersections – spacing 400 m or more</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total access frequency1 not greater than 10/km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Driveway connections not closer than 240 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>4</td>
<td>No property access</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interchanges with motorways</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersections with other SSRs and RRs only</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersection spacing not less than 5 km (desirable 10 km) – (RPDM Ch. 4)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>≥100 km/h</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>5</td>
<td>Limited property access</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interchanges with major streets only – spacing not less than 2 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total access frequency1 not greater than 6/km.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Driveway connections not closer than 300 m</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6</td>
<td>Limited property access</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Interchanges with major roads only</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersection spacing not less than 5 km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total access frequency1 not greater than 2/km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Driveway connections not closer than 800 m</td>
<td></td>
</tr>
</tbody>
</table>
### Table C2 1: Example of access categories and performance criteria (continued)

<table>
<thead>
<tr>
<th>Road class</th>
<th>Design categories</th>
<th>Access categories</th>
<th>Performance criteria</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional road (RR)</td>
<td>Urban divided</td>
<td>7</td>
<td>Limited property access&lt;br&gt;Intersections with SSR, other RRs, DRs&lt;br&gt;Intersection spacing not less than 500 m&lt;br&gt;Total access frequency(^1) not greater than 6/km&lt;br&gt;Driveway connections not closer than 300 m</td>
<td>≥ 80 km/h&lt;br&gt;No driveway connections within the functional and influence areas of intersections and other driveways</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8</td>
<td>Property access allowed&lt;br&gt;Intersections with SSR, other RRs, DRs&lt;br&gt;Intersection spacing not less than 250 m&lt;br&gt;Total access frequency(^1) not greater than 20/km&lt;br&gt;Driveway connections not closer than 170 m</td>
<td>60 km/h&lt;br&gt;No driveway connections within the functional and influence areas of intersections and other driveways</td>
</tr>
<tr>
<td>Urban two lane</td>
<td>9</td>
<td>Property access allowed&lt;br&gt;Intersections with SSR, other RRs, DRs&lt;br&gt;Intersection spacing not less than 250 m&lt;br&gt;Total access frequency(^1) not greater than 20/km&lt;br&gt;Driveway connections not closer than 170 m</td>
<td>60 km/h&lt;br&gt;No driveway connections within the functional and influence areas of intersections and other driveways</td>
<td></td>
</tr>
<tr>
<td>Rural divided</td>
<td>10</td>
<td>Property access allowed&lt;br&gt;Intersections with SSRs, other RRs and DRs&lt;br&gt;Intersection spacing not less than 2 km (desirable 5 km)&lt;br&gt;Total access frequency(^1) not greater than 6/km&lt;br&gt;Driveway connections not closer than 300 m (800 m desirable)</td>
<td>≥ 100 km/h&lt;br&gt;No driveway connections within the functional and influence areas of intersections and other driveways</td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>Property access allowed&lt;br&gt;Intersections with SSRs, other RRs and DRs&lt;br&gt;Intersection spacing not less than 1 km&lt;br&gt;Total access frequency(^1) not greater than 12/km&lt;br&gt;Driveway connections not closer than 240 m</td>
<td>70–80 km/h; 60 km/h (transition rural to urban)&lt;br&gt;No driveway connections within the functional and influence areas of intersections and other driveways</td>
<td></td>
</tr>
</tbody>
</table>
### Table C2 1: Example of access categories and performance criteria (continued)

<table>
<thead>
<tr>
<th>Road class</th>
<th>Design categories</th>
<th>Access categories</th>
<th>Performance criteria</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regional road (RR)</td>
<td>Rural two lane</td>
<td>12</td>
<td>Property access allowed</td>
<td>≥ 100 km/h No driveway connections within the functional and influence areas of intersections and other driveways</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersections with SSRs, other RRs and DRs</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Intersection spacing not less than 2km (desirable 5 km)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total access frequency(^1) not greater than 6km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Driveway connections not closer than 300 m (800 m desirable)</td>
<td></td>
</tr>
<tr>
<td>District road (DR)</td>
<td>Arterial</td>
<td>7–12</td>
<td>No driveway connections within the functional and influence areas of intersections and other driveways</td>
<td>As per regional road</td>
</tr>
<tr>
<td></td>
<td>Collector</td>
<td>13</td>
<td>Rural (≥ 80 km/h); Urban (≥ 60 km/h)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total access frequency(^1) not greater than 20/km</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Driveway connections not closer than 250 m (rural); 100 m (urban)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Local</td>
<td>14</td>
<td>Rural (&lt; 80 km/h); Urban (≤ 60 km/h)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Access allowed at minimum spacing – 55 m (rural); 25 m (urban)</td>
<td></td>
</tr>
</tbody>
</table>

1. Frequency per kilometre is for both sides of the road, i.e. for 12 per kilometre, there would be six on each side of the road in a kilometre.


Notes:

Total access frequency is the maximum allowable at any point of the road. Lower frequencies are desirable.

The spacing of driveway connections represents the closest spacing allowed within the overall access frequency.

While all accesses for roads over 90 km/h should be treated as intersections, consideration of the traffic volumes using them must also be considered. Usually, the volumes using an access will be low and a closer spacing may be tolerable than for a full intersection. Planners and designers will need to assess the individual accesses in this light.

The values of spacing given in this table are generalised values. For specific cases, planners and designers should examine the situation and make an assessment based on the prevailing conditions for the site. The main text examines a range of conditions and the distances required for them.
COMMENTARY 3

Austroads (2006a) defines and provides dimensions for 12 design and restricted access vehicles. Four are general access vehicles that may use any road, unless prohibited by regulatory signs, and six are restricted access vehicles (Table 5.1 in this guide).

Land Transport NZ (2007) has also defined six standard design vehicles. These are listed in Table 5.2 of this guide and should be used for the design of intersections in New Zealand.

In some cases, however, a different design vehicle may be adopted for different traffic movements depending on the demand, the practicality of providing for a larger vehicle, or the traffic management strategy adopted for the area.

On some arterial roads, provision for vehicles 8.0 m or more in length or restricted access vehicles such as B-doubles or road trains (up to 53.5 m) may be required, although the largest vehicles may sometimes be accommodated by allowing encroachment into adjacent lanes that operate in the same direction. This is sometimes necessary as the provision of sufficient space to enable very large vehicles to turn from the ‘correct’ lane, generally results in large expanses of pavement that may cause safety issues for smaller vehicles and other road users. This treatment may be applied at signalised intersections as given in Part 4A of the Guide to Road Design, or at roundabouts as given in Part 4B of the Guide to Road Design.

Examples of turning templates are shown in Figure C3 1 and Figure C3 2.
Figure C3 1: Typical Austroads design vehicle turning template

Figure C3 2: Typical Land Transport New Zealand design vehicle turning template
COMMENTARY 4

Crossing a road is a potentially dangerous activity for a pedestrian and it is essential that both pedestrians and drivers approach any crossing with caution. Any device which may potentially give a pedestrian an illusory sense of safety when crossing the road should not be used. Crossing roads is particularly difficult for people with disabilities and this seriously inhibits them from moving about on the street system. People with limited or no vision have difficulty identifying where to cross, and people in wheelchairs and those with limited mobility sometimes have trouble moving on and off crossings or completing a crossing in the time available.
COMMENTARY 5

Pedestrian refuges:

- are generally used where it is difficult for pedestrians to cross the full width of a roadway in one stage
- are particularly suited to locations where pedestrian movements across a carriageway are spread over a length of heavily trafficked road, such as in shopping streets
- enable the pedestrian to stand safely in the middle of the roadway and cross one direction of traffic at a time
- are usually located centrally in the roadway, or may utilise traffic islands or medians where these are provided for other reasons
- are often used in conjunction with one or more other devices including ‘time separated’ facilities
- should be constructed as kerbed islands
- should have pedestrian walk and standing areas within them that are flush with the roadway to allow wheelchair users, people with prams, cyclists, etc., to easily get out of the traffic stream. Where this cannot be done, properly designed kerb ramps will be needed
- should have a length sufficient to accommodate the expected number of pedestrians waiting and with a total area sufficient to allow the installation of the necessary traffic signs and ensure that the island is adequately prominent and visible to approaching traffic. An island length of at least 10 m is desirable to achieve these requirements.
- should have pavement markings to ensure that vehicles are safely guided past the island and that the roadway is not unexpectedly constrained. The number of traffic lanes on the approach should be maintained past the island, if necessary by modifying the linemarking to reduce the lane widths and by imposing parking controls. If pedestrian refuges are needed at successive closely spaced intervals along a street, consideration should be given to providing a continuous raised median or a flush (pavement marked) treatment linking the separate islands
- should be made of a noticeably different surface material from that of the road pavement. This will assist vision-impaired people to locate the refuge. In addition, the refuge boundaries need to be clearly distinguished by both vehicle drivers and pedestrians. The contrast between a dark (asphalt) road surface and light concrete kerb and island surface is initially adequate, but as this effect deteriorates with time and road grime it may be lost entirely in wet conditions (when most needed)
- should desirably have raised retro-reflective pavement markers to enhance the delineation of the refuge, particularly where the level of street lighting is low
- should in all cases be adequately illuminated in accordance with AS/NZS 1158 – 2007 and where necessary by the careful positioning of street lights by supplementary flood lighting in accordance with AS 1158.4: 2007.

The following aspects should also be considered in the provision of refuges:

- As many people feel unsafe standing on a refuge in the middle of the road, wherever possible, alternative approaches, such as using kerb extensions to reduce the width of road to be crossed, should be considered.
- A staggered arrangement may also be used at signalised pedestrian crossings if it is intended to ‘stage’ the pedestrians on the refuge island (or median), requiring them to cross each directional roadway in separate signal phases.
• Appropriate barriers and fencing may be installed to protect pedestrians from vehicular traffic, provided they do not hide the pedestrians from the view of drivers. A free standing post or handrail is useful, as a support for elderly, infirm or fatigued pedestrians. If fences are used to control pedestrian movements, care must be taken to ensure that they are not a hazard to pedestrians or vehicles (Underwood 1990). A weld-mesh type fence is very suitable; however, horizontal metal pipe or timber railing should be avoided as these pose serious hazards to motorists in the event of an impact with the railing. Chains should not be used in this situation as they do not provide handrail support and cannot be detected adequately by vision-impaired pedestrians.

Refuges can be used in conjunction with footpath (kerb) extensions to further reduce the road width where this is necessary. It is important to provide openings or pram crossings on the refuge and also on the footpaths approaching the refuge from either side of the road.

It is essential that the height and location of signs and other road furniture be selected to maintain clear sight lines for both pedestrians and drivers. In particular, the height of signs in the path of pedestrians should be at a minimum of 2.0 m above the top of the kerb to avoid obstructing pedestrian movement. Care also needs to be taken to ensure that the line of sight between drivers and pedestrians is not obscured and that pedestrians, particularly small children are not hidden behind traffic signs at critical locations. This often occurs due to the mounting of Keep Left signs on narrow median and pedestrian refuge islands. These signs should be mounted either high or very low to avoid these problems.

A limitation to the application of island treatments is that they can restrict vehicular access to abutting properties. The provision of a combination of concrete refuge islands and a painted median treatment allows for a pedestrian facility where people cross over a significant length of road. In those states which permit turns across painted medians this method allows right-turn access into properties having frontage onto the road and access to parking on both sides of the road. It may therefore be applicable to some commercial areas, depending on overall traffic management objectives.
COMMENTARY 6

Extended footpaths involve the widening of footpaths to the edge of the traffic lane and consequently providing indented parking bays. This form of treatment reinforces the existence and prominence of a pedestrian crossing (where provided) and the presence of pedestrians to other road users. It reduces the width of the road pedestrians have to cross, improves the inter-visibility between pedestrians and motorists and discourages illegal parking. Extended footpaths:

- are the most appropriate locations for use on collector roads and local streets and in strip shopping centres, where pedestrian traffic is high and the restriction on vehicular traffic can be accepted
- may be used at minor intersections and at mid-block locations where there is kerbside parking, particularly angle parking
- are commonly used at mid-block sites where a pedestrian crossing facility exists and are becoming more common in local area traffic management schemes in conjunction with a road hump or slow point
- can also be appropriate where primary arterial roads pass through rural towns and along which there is unlikely to be a requirement for parking bans and clearways
- are not appropriate where the kerbside lane is used for moving traffic during peak periods, when parking is prohibited or clearways are utilised (e.g. on many urban arterial roads).

Other factors to consider include:

- Pedestrians are able to stand within the widened zone which also accommodates the kerb ramp.
- A footpath extension treatment is often formed in combination with the embayment of parking, typically retrofitted in older commercial areas but is now becoming common practice in new street design.
- The provision of footpath extensions in combination with a central pedestrian refuge island offers a less expensive alternative to a signalised crossing, although without the other benefits offered by traffic signals.
- The design of these treatments in conjunction with special paving for traffic management or aesthetic purposes can cause uncertainty for pedestrians as to who has the right-of-way. This type of treatment should be avoided, but if used, special attention needs to be given to defining the roadway. An advisory sign such as pedestrians give way to traffic can be used in such locations, to emphasise the need for pedestrians to give way to vehicular traffic.
COMMENTARY 7

The warrants and guides given in AS 1742.10 are not necessarily applied rigidly by all road and traffic authorities. They are accepted as a guide and are applied with flexibility depending on the value judgements and other relevant circumstances in individual state practices. For example, in Western Australia, the warrant for installation of a pelican crossing uses a pedestrian volume of 150 pedestrians per hour rather than the value of 350 as quoted in AS 1742.10.

It is desirable to ensure that such control devices are only provided where sufficient pedestrian demand exists, as drivers who use the route regularly will tend to ignore the presence of a device if they never see it used. Similarly, pedestrians tend to ignore or misuse a device if vehicle volumes are so low as to make its use unnecessary on most occasions. However, frequent random interruptions to a dense traffic stream may create congestion and increase the likelihood of vehicle accidents. These factors highlight the need for care in the setting and observance of pedestrian volume guidelines for each type of crossing facility.
COMMENTARY 8

This has been demonstrated in Western Australia where experience indicated that where the warrants were met and traffic islands and pedestrian refuges were used instead of zebra crossings, there has been a dramatic reduction in accident rates at 25 sites examined (MRWA, 1989). This study showed that pedestrian accidents had reduced to one fifth of their original level and vehicular accidents had reduced to one sixth of their original level as had overall accidents, while before and after pedestrian volumes were not significantly changed. The replacement of zebra crossings with refuge islands was initiated on the premise that many pedestrians assume right-of-way at zebra crossings while crossing at pedestrian refuge islands with more caution. This is supported by US evidence which shows that a person using the marked crossing was twice as likely to have an accident as those not using the crossing. Notwithstanding these findings, there is a perception amongst the elderly and people with disabilities, that the removal of the zebra crossings reduces their ability to cross the road.

As the safe operation of these facilities is dependent on drivers having good visibility of pedestrians, street lighting is critical. As with other types of pedestrian crossings, it is important to provide and maintain high skid resistance on the approach to crossings. Safety can be further improved by the provision of footpath extensions (as discussed in Commentary 6), to improve sight distance and reduce the carriageway width at the crossing point. There may be a need to provide significantly improved identification of the crossings by more effective traffic signs. Where a zebra crossing is installed on an arterial road or where there is poor visibility the provision of flashing yellow lights should be considered.

Provision of a zebra type of crossing should be considered at arterial road roundabouts with high pedestrian usage.
COMMENTARY 9

Refuges may also be provided at shared path or bicycle path crossings to provide for pedestrians and cyclists to wait in the centre of roads. They are generally beneficial because they:

- allow pedestrians and cyclists to cross the road in two stages
- provide physical protection for cyclists and pedestrians
- increase motorists’ awareness of the crossing
- can be installed at relatively low cost.

Refuges are appropriate where:

- motor traffic volumes and speeds make it difficult for cyclists and pedestrians to cross two-way motor traffic flow
- the combined pedestrian and cyclist demand justifies special treatment
- sufficient road width exists or can be readily achieved to enable the installation of the refuge treatment (such that the resultant road width does not create squeeze points for on-road cyclists).
COMMENTARY 10

A railway line with large volumes of rail traffic increases the chances of a rail level crossing crash. Under these conditions it is possible that sharp horizontal curves on the roadway, which slow motorists approaching the crossing, will decrease the potential for rail level crossing crashes. Whether or not the savings in rail level crossing crashes outweighs the increase in single vehicle crashes likely to be associated with the sharp curves is unknown. A literature review and research would be required to determine the optimum arrangement for various levels of exposure. However, provision of a substantial clear zone around the outside of the sharp horizontal curves would help to minimise any negative effects of errant vehicle crashes.

In situations where the roadway has significant vehicle volumes, but the railway line has little volume, it is likely that sharp horizontal curves would lead to single vehicle out-of-control type crashes. Under these conditions it is extremely unlikely that a rail level crossing crash would occur because of the low exposure of rail traffic. In this case, it is likely that the provision of sharp horizontal curves on the roadway would result in a higher total crash rate than if a straight approach were used.