

Guide to Road Design Part 4C

Interchanges



Guide to Road Design Part 4C: Interchanges



Austroads

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Guide to Road Design Part 4C: Interchanges

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This second edition contains minor editorial and technical changes to Sections 1.3, 1.4, 1.8, 3.2, 4.9 (new), 9.2, 10.1, 11 and 17.3. Updates have been made throughout this edition to include new and updated reference material and cross-references to other Guides, including:

- Section 1 Introduction: updates to road safety including the Safe System principles; and additional information on design objectives and staged development.
- Section 3 Forms of Interchange: additional information on factors that may influence the type of interchange.
- Section 4 Structures: additional section providing information on safety screens.
- Section 9 Vertical Alignment: additional information on criteria to be considered for grading at a cross-road.
- Section 10 Ramp Terminals at Major Roads: amending the longitudinal grade of a minor road to not exceed 2%.
- Section 11 Ramp Terminals at the Major Road: additional information to expand the range of speeds shown in Table 11.2 and Table 11.3.
- Section 17 Other Considerations: additional section on oversized and high wide load corridors.

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Abstract

The *Guide to Road Design Part 4C: Interchanges* provides guidance on the geometric design of interchanges on freeways/motorways and on major arterial roads. The Guide covers the design of interchanges between: freeways and arterial roads; two freeways; and two major arterial roads. It covers the geometric design of all the elements of an interchange including the: alignment and cross-section of the freeway in the vicinity of the interchange, the intersecting road and the ramps; merge and diverge ramp terminals at the freeway; and ramp terminals at the intersecting road.

Keywords

Design considerations, design process, pedestrian, cyclist, public transport, cross-section, design speed, horizontal alignment, vertical alignment, sight distance, ramp terminals, ramp terminal locations, ramp alignment, entry ramp nose, exit ramp nose.

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- promote improved practice and capability by road agencies.
- promote consistency in road and road agency operations.

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

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1. Introduction

1.1 Purpose

The Austroads *Guide to Road Design* seeks to capture the contemporary road design practice of member organisations (*Guide to Road Design Part 1: Introduction to Road Design*, Austroads 2015a). In doing so, it provides valuable guidance to designers in the production of safe, economical and efficient road designs.

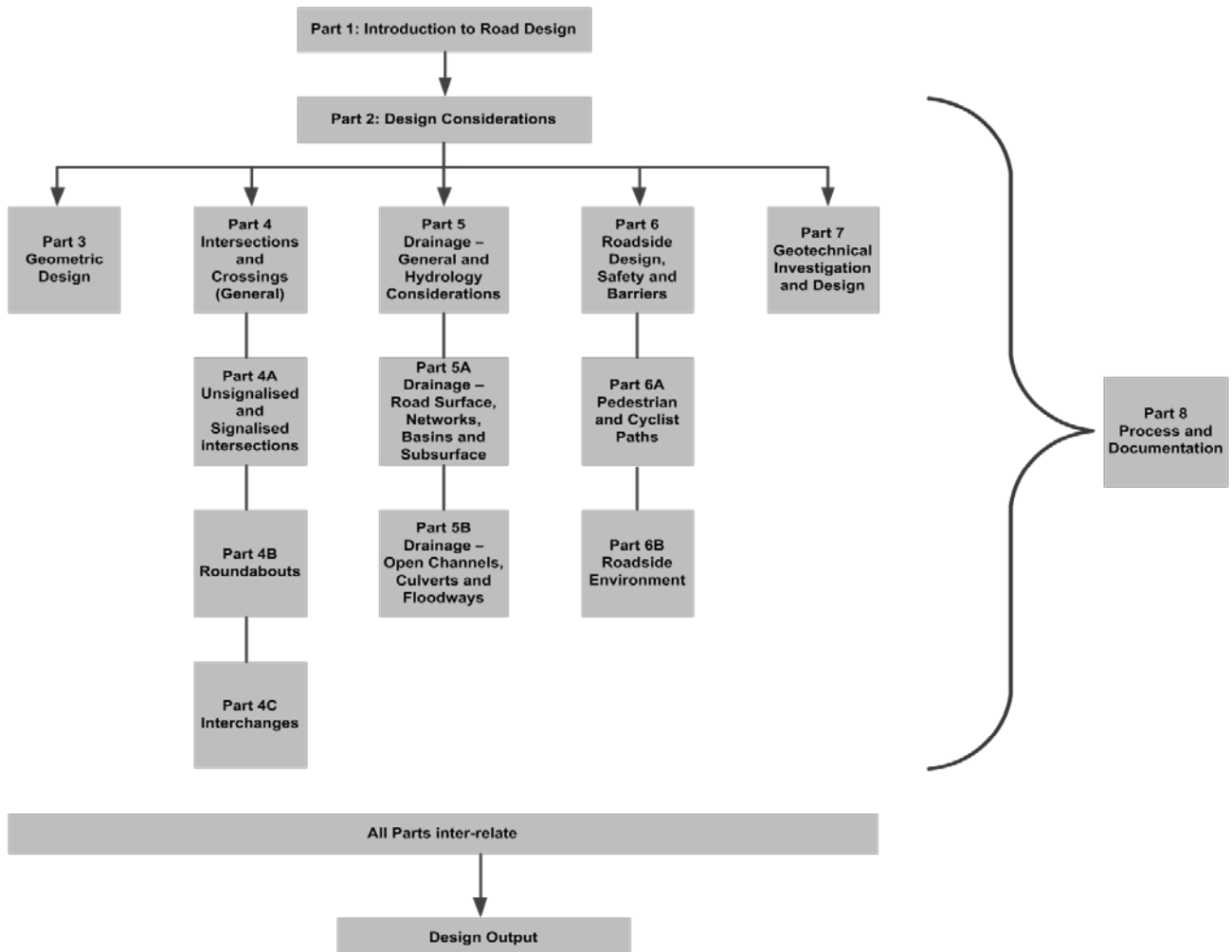
The *Guide to Road Design Part 4C: Interchanges (AGRD Part 4C)* provides guidance on the geometric design of interchanges, and together with three other sub-parts:

- Part 4: Intersections and Crossings – General (AGRD Part 4) (Austroads 2009a)
- Part 4A: Unsignalised and Signalised Intersections (AGRD Part 4A) (Austroads 2010a)
- *Part 4B: Roundabouts* (AGRD Part 4B) (Austroads 2015c)

provide guidance on the geometric design of intersections and crossings.

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

Figure 1.1: Flow chart of the Guide to Road Design



1.2 Scope of this Part

This Guide covers the geometric design of interchanges on freeways/motorways and on major arterial roads. While the term freeway is used throughout the Guide it should be interpreted to include motorway.

The Guide does not cover the planning and traffic considerations associated with interchange design. A prerequisite to the application of the Guide is that planning and traffic engineering investigations have been undertaken to determine the appropriate form of interchange and to establish the number of lanes required throughout the interchange. However, the Guide should be used in conjunction with the planning process to ensure that proposals are able to be designed sensibly in accordance with the required standards.

The Guide covers the design of interchanges between:

- freeways and major/minor arterial roads
- two freeways
- two major arterial roads.

It provides guidance that should enable practitioners to produce a satisfactory design for an interchange for a range of traffic and physical conditions that may apply at a site. It covers the geometric design of all the elements of an interchange including the:

- alignment and cross-section of the freeway in the vicinity of the interchange, the intersecting road and the ramps
- merge and diverge ramp terminals at the freeway
- ramp terminals at the intersecting road.

The *Guide to Road Design Part 1: Introduction to Road Design* (Austroads 2015a) outlines the general content of each of the eight parts of the *Guide to Road Design* illustrated in Figure 1.1, all of which will influence the design of roads, intersections and interchanges. Throughout this Part cross-reference is therefore made to other parts of the *Guide to Road Design* in dealing with design issues and practice relating to interchanges. There are nine other subject areas spanning the range of Austroads publications that may also be relevant to the design of interchanges (www.austroads.com.au).

AGRD Part 4 (Austroads 2009a), 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, interchanges and crossings.

1.3 Road Safety

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

The Safe System approach requires, in part (Australian Transport Council 2011):

- Roads and roadsides designed and maintained to reduce the risk of crashes occurring and to lessen the severity of injury if a crash does occur. Safe roads prevent unintended use through design and encourage safe behaviour by users.
- Forgiving road environments that prevent serious injury or death when crashes occur.
- Align speed limits with the risk and function of the road and roadside environment (Australian Transport Council 2011).

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

Road designers should be aware of, and through the design process, actively support the philosophy and road safety objectives covered in the *Guide to Road Safety*. Further information on the Safe System principles can be found in the *Guide to Road Design Part 2: Design Considerations* (Austroads 2015b).

1.4 Road Design Objectives

Road design objectives are discussed in the *Guide to Road Design Part 2: Design Considerations* (Austroads 2015b) and these objectives also apply to the design of intersections and crossings, including interchanges.

The design of grade-separated interchanges has the primary design objectives to:

- obtain better safety outcomes
- minimise costs associated with construction and maintenance
- reduce the travel costs along the road
- minimise adverse environmental impacts
- provide an enhanced road appearance
- consider the future expansion requirements.

Absolute minimum standards should be avoided except where absolutely essential to achieving the most suitable outcome. Generally, a minimum value for any particular design element should not be used in conjunction with a minimum for any other element on that particular section of road. This is necessary to allow an appropriate factor of safety to road users.

1.5 Traffic Management at Interchanges

As interchange design is based on the need to provide for traffic and manage it, road designers should be familiar with traffic management considerations associated with interchanges that are covered in the *Austroads Guide to Traffic Management Part 6: Intersections, Interchanges and Crossings (AGTM Part 6)* (Austroads 2013a). *AGTM Part 6* provides information on planning and route considerations, road space allocation, lane management, forms of interchange and ramp layouts.

An interchange and its associated intersections should not be designed without considering existing and proposed traffic management requirements on the approaches. Designers should therefore also refer to the *Guide to Traffic Management Part 5: Road Management* (Austroads 2014) which covers mid-block traffic management considerations and provides guidance on access management, road space allocation, lane management and speed limits.

Designers should consider the whole layout early in the design process and identify situations where difficulties may arise if the design proceeds on the basis of that particular layout. Issues such as exit ramps on right-hand curves and entry ramps on left-hand curves may be avoided if appropriate adjustments are made in the early planning stages of the project.

1.6 Safety Performance of Interchanges

An interchange improves traffic operation and safety at a site by removing conflict between major traffic movements and controlling conflict associated with minor traffic movements. All drivers travelling through an interchange on the major road only face conflict with traffic that is diverging or merging (apart from that resulting from congestion within the traffic stream). The main traffic conflicts at interchanges are usually associated with the at-grade intersections at the ramp terminals with the minor road.

1.7 Traffic Capacity of Interchanges

The performance of interchanges is covered in the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013d). Techniques for performance assessment and capacity analysis of interchanges include software packages.

Traffic analysis (including level of service analysis) is an important aspect of the design of interchanges as it determines the number and arrangement of lanes that are required on the major road (e.g. freeway), the minor road (e.g. arterial road), and the ramps to ensure an appropriate level of service for motorists.

Care should be taken in assessing the future traffic volumes and their patterns (refer to the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013d), Transport Research Board (TRB) (2010) and the *Guide to Traffic Management Part 4: Network Management* (Austroads 2015e)). An interchange layout should generally be designed for a future design year although this concept may be impracticable in some inner urban situations where the road attracts so much traffic that it reaches capacity in a relatively short period of time.

There are six levels of service, designated A to F, that are used to define the range of traffic conditions that can occur, with each level representing a range of conditions. Level of service may apply to the main freeway carriageways, diverging areas, merging areas, weaving sections and traffic movements at ramp terminal intersections with the minor road. Levels of service (LOS) are further discussed in the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013d), *AGTM Part 6* (Austroads 2013a).

It is desirable that interchanges should be designed to achieve LOS B and LOS C in the design year for interchanges as a whole in rural and urban areas respectively. Where economic or physical constraints apply to a site, LOS C and LOS D may be adopted as a minimum for the design of rural and urban interchanges respectively. In some cases it may be necessary to adopt a lower LOS for particular movements within an interchange (e.g. LOS D).

The design year adopted for calculation of level of service may vary depending on the interchange location (e.g. inner urban, outer urban, rural) but 15 to 20 years after opening will often be adopted depending on physical conditions and predicted traffic conditions at the site.

Where an interchange will not reach capacity until some distant design year it may be appropriate to use the 'ultimate' design as the basis for an initial or interim design. In such cases provision should be made in the design for the initial interchange to be readily expanded when traffic demands reach a specified level. This approach usually results from the investment strategy of the relevant agency and is discussed further in Section 1.8.

1.8 Staged Development of Interchanges

1.8.1 Staging Interchange Development

The design of an interchange can be based on projected traffic volumes estimated for 20 or more years into the future, and it is sometimes possible to provide for the development of the interchange in a staged manner to minimise the initial cost. If this course is to be pursued, careful attention to the way the future works are to be undertaken will be required, ensuring that it is not at the expense of flexibility in determining road alignments.

Most complex interchanges are 'staged' with some pavements being constructed initially, and the complete interchange may be developed in a series of steps, which may extend over a period of many years. Therefore, when developing layouts, designers should be familiar with the proposed development program and attempt to minimise early stage construction costs if this can be done without compromising flexibility.

Minimising first-stage costs may be an economic advantage if the net present value of the total cost of the final interchange is not increased. In some cases, designing to minimise early expenditure may be justified where the net present value increases (e.g. because of funding limitations, additional disruption).

Stages should as far as possible be completely self-contained and functional. Caution should be exercised in constructing any element before it is functionally required. While future planned upgrading of the facility must not be precluded, excessive provision for long-range development should be avoided. What one sees initially as the probable future development is very often modified considerably because of the actual pattern of development. The aim should be to provide flexibility without incurring excessive costs during the initial stages of development.

The factors to consider in staging include:

- providing flexibility for future and ultimate stages
- geometry of the initial and final interchange elements
- traffic growth over the life of the staged development and traffic operations and management at each stage of the development
- land use planning
- overall road network development in the vicinity
- land acquisition requirements, costs and other constraints
- structures needed at each stage of the development and their design life
- earthworks at each stage
- drainage requirements at each stage
- signing requirements at each stage
- location of utilities
- landscaping and planting needs at each stage and in the final stage.

1.8.2 Flexibility and Constructability

Interchanges are one of the most costly parts of the road system, being expensive to construct initially and exceptionally expensive to reconstruct under traffic when expansion to a new configuration is necessary to meet future needs. For these reasons it is most desirable that initial interchange designs should provide flexibility well beyond the target design life. For example, this flexibility could be provided (e.g. built-in) by ensuring that overpass bridges will be long enough for the 'ultimate stage' of the interchange and motorway, or that another level could be economically added without requiring significant changes.

Designers should always consider the potential to build flexibility into the design to accommodate possible future changes, particularly when future land use changes and traffic patterns are uncertain. Whilst flexibility is usually more important for system and other major interchanges, designers should take account of the long-term (say 50 years into the future) layouts and configurations that may be required for all interchanges. For example, where sufficient space is available and a satisfactory alignment of the minor road through the initial at-grade intersection with the major road can be achieved, the minor road should be constructed clear of any future bridgeworks. In determining a suitable alignment, consideration should also be given to providing sufficient clearance to likely worksites e.g. allowance for deep excavation for any future bridge construction and clearance for machinery such as pile driving.

Traffic operations during construction must also be considered in the planning and design process. Construction of interchanges may result in long periods of disruption and delay (and hence cost) to road users, particularly if an existing interchange is to be reconstructed. It is desirable that future works can be constructed without interrupting the existing traffic as far as possible so the first stage will generally include the outside elements of the facility.

For staged treatments in rural areas, an intersection treatment may be provided on a duplicated road with the intention of providing an interchange at some future time. The first-stage of an at-grade intersection should be located to allow the future overpass structure to be constructed on the ultimate alignment without affecting the first-stage construction. In urban areas, considerable thought should be given to the traffic management when converting existing intersections to interchanges. Each step should be documented by a drawing with a description of the construction in progress, and the locations and management of the traffic movements.

It may be possible to provide minimum widths of carriageways to suit initial traffic volumes, and to widen or duplicate as necessary in the future. In some cases, ramps with very low predicted volumes may be omitted. However, if any movement is provided, the ramp for the return movement at the same site also should be provided.

It is desirable that future works are able to be constructed with minimal interruption to traffic, and therefore the first stage will generally include the outside elements of the facility. For example:

- If an interchange with one or more loops is needed in the future, it may be possible to omit the loops in the first stage and use the outer connection ramps as legs of a diamond interchange in the interim. These ramps would be positioned in their final locations allowing the loops to be constructed inside these ramps at a later date.
- Provision could be made in the first-stage development of an interchange for a third level to be 'easily' added to the interchange when traffic reached a predetermined volume.
- If a freeway is terminated initially at a proposed cross-road interchange, it is desirable to use the ultimate ramp alignments for the interim intersection treatment to facilitate the later construction of the interchange.

2. Design Considerations Process and Principles

2.1 General

The need for interchanges, their locations, spacing and general form will be established during a planning investigation that will also involve the prediction of future traffic volumes and traffic analysis to determine the number and arrangement of traffic lanes on each of the interchange elements. The planning investigation will also consider the road safety implications of the location, spacing and form of the interchanges and the design should carry the resulting requirements forward into the details required for implementation.

The form and detail of the interchange including whether it is a service or system interchange will be dependent on the planning objectives and overall strategy for the roads and the area in general. The controls, criteria and expectations identified in the planning process provide basic input to the design of interchanges.

2.2 Design Considerations

2.2.1 Design Information

The *Guide to Road Design Part 2: Design Considerations* (Austroads 2015b) provides information that needs to be considered in the design of a road that is also relevant to interchanges and Table 3.1 of that Guide summarises the factors for consideration, and the type, nature and likely sources of the information required.

Key aspects that require consideration for interchange design include:

- safety performance of possible treatments
- topographic details
- land use details
- environmental conditions and constraints
- cultural heritage values
- property details and values
- structural clearances
- location and nature of utility plant and equipment
- geotechnical data
- access requirements in the area
- drainage and flooding issues
- landscape requirements
- accommodation of public transport facilities
- pedestrian and cyclist facilities
- location, standard and function of the intersecting roadways that the interchange will be serving.

The style, economy and layout of an interchange will be heavily dependent on the topography and other physical constraints existing at the site. Rolling and hilly topography presents opportunities to mould the design of the interchange into the landscape and take advantage of level differences to reduce cost. In flat terrain, the design will have to create the level differences occurring naturally in undulating country and detailed attention to the relative grades will be required to achieve the most economical and visually pleasing result.

Interchanges require a significant area of land and the availability of right of way can influence the type of interchange adopted. The detailed location of the facility may also have to be tailored to the available land with appropriate adjustments to the local road system to ensure that the facility is properly used.

2.2.2 Design Controls and Criteria

The planning process (including public consultation) and the data gathering phases of the design process will identify the various factors that will control the approach to and the details of the interchange. In this process, it is essential that it is clear which criteria are discretionary and those that are mandatory. As the design unfolds, conflicts with the established criteria may emerge and it is necessary to determine where compromises can be accommodated.

2.2.3 Stormwater Drainage

Guidance on the estimation of runoff and design of drainage systems is provided in the *Guide to Road Design Part 5: Drainage – General and Hydrology Considerations* (Austroads 2013b). Road designers should refer to *Part 5* in the preparation of drainage designs for interchanges. Reference should also be made to the *Guide to Road Design Part 3: Geometric Design (AGRD Part 3)* (Austroads 2010b).

Road drainage systems associated with interchanges are designed to prevent the accumulation and retention of runoff within the limits of the interchange roadway elements in order to ensure that they are safe and to avoid interference to traffic operations. The consequences arising from excessive water on the road and the possible closure of ramps are generally unacceptable.

The basic requirements for an interchange drainage design, taking into account economics, benefit to traffic and effect on adjacent property, are to:

- discharge water efficiently from the road surface so as to avoid flooding and aquaplaning and enhance road safety
- protect the roadways, ramps and structures against damage from surface and subsurface waters
- cater for the estimated discharge, levels and velocities of flooding for each individual element as part of the total drainage system
- prevent the prolonged ponding of water between the interchange roadways and within the road reservation
- provide for the ultimate interchange development and abutting lane use to minimise maintenance costs.

Design criteria

Typical design recurrence intervals are provided in the *Guide to Road Design Part 5: Drainage – General and Hydrology Considerations* (Austroads 2013b). However, the design storm for drainage systems for other authorities may be different and this should be considered when:

- such systems cross the interchange roadways
- the interchange drainage system is connected to such systems
- such systems control the hydraulic performance of the interchange drainage system.

Ramp entrances and exits

The wide pavement areas often combined with relatively flat grades and cross slopes at ramp entrances and exits present difficulties for drainage design. The length, width and depth of surface flow at these areas should be lessened to facilitate traffic safety and operations. It is essential to ensure that the relative ramp and through carriageway grades and cross slopes, including transition sections, do not result in undesirable two-directional flow conditions.

In designing ramp entrances and exits designers should consider the possible location of:

- side-entry pits on the ramps or ramp tapers to prevent by-passing drainage flows into or from the gore area of ramp tapers
- side-entry pits at gore areas
- narrow grated pits longitudinally along gore areas (where grades are flat). It is preferable to avoid these pits in this location but if unavoidable, the covers should be skid resistant.

Pits and drainage lines

The location of drainage pipes and pits should be based on the proper consideration of the following factors:

- Location of pits should allow for safe access and ease of access for maintenance under traffic conditions.
- Drainage lines should be laid, for all stages of the interchange development, at such a line and level as to be clear of, or not obstruct:
 - bridge piers and footings
 - future pavement and structure widening
 - sign and pole foundations
 - safety barriers
 - proposed underground services.
- Small drainage lines should generally have straight alignments between access points to minimise the possibility of blockage at inaccessible locations.

2.2.4 Landscape Development

All interchanges are to be designed with a view to aesthetic requirements. To this end, the services of a landscape architect and urban designer would be beneficial at an early stage so that the layout and grading can be designed to meet both the functional and aesthetic requirements. A better result at a lower cost can be achieved if these factors are incorporated as part of the design, rather than as an 'add-on' at a later stage.

2.2.5 Public Transport Facilities

General

To support the provision of public transport and address the competing demands for road space, an integrated approach to the improvement of all aspects of the public transport system is required. Road based public transport has a significant role to play and may require the provision of specific facilities and priority measures for buses and trams in order to provide an appropriate level of service to on-road public transport.

Depending on the strategic significance to public transport of a particular road, intersection or interchange it may be advantageous to incorporate a range of facilities and priority measures to assist public transport services on the freeway or the intersecting road at an interchange such as:

- bus lanes on the freeway, ramps or intersecting road
- tram lanes on the intersecting road
- a busway or tram reservation
- high occupancy vehicle lanes on the freeway, ramps or intersecting road, defined as transit lanes in Australia under the *Australian Road Rules*

- traffic signal priority measures (refer to *Guide to Traffic Management Part 9: Traffic Operations* (Austroads 2009c))
- queue-jump lanes (refer to *Guide to Road Design Part 4: Intersections and Crossings – General* (Austroads 2009a))
- bus or tram stops within the interchange (refer to *AGTM Part 6* (Austroads 2013a)).
- a modal interchange within or adjacent to the interchange to serve bus or rail services (refer to *Guide to Traffic Management Part 11: Parking* (Austroads 2008b))
- ramp metering with or without bypass lanes.

Freeway access ramps for buses

It is not always feasible, nor beneficial, to allocate an extended bus-only lane on a major highway or freeway, especially where bus flows are not large or where the freeway flows are relatively uncongested. However, bus access to the freeway itself may be significantly delayed by traffic congestion on mixed-traffic freeway entry ramps, regardless of whether ramp-metering devices are in operation to regulate entry flows to the freeway. This may be overcome through the construction of a bus-only ramp, or a bus lane on the freeway access ramp, allowing buses to bypass traffic queues.

Linking city centre bus lanes to freeway entry/exit ramps can also provide significant bus travel time improvements.

Where a busway is provided within a freeway median or adjacent to a freeway it will often be necessary to integrate separate busway ramp terminals into or adjacent to interchanges (Figure 2.1).

Heavy rail

In appropriate circumstances it may be strategically desirable to accommodate a heavy rail service within the median of a freeway. This will result in the need for railway stations and modal interchanges some of which may be located within an interchange. Patrons of the modal interchange are likely to arrive as pedestrians from adjacent development or interchange from buses, for example. The safe and efficient movement of pedestrians, including people who have disabilities, is paramount in such cases.

Figure 2.1: Dedicated freeway entry/exit ramps for the Kwinana Freeway busway (Canning Highway Interchange)



Source: Western Australia Public Transport Authority (2004).

2.3 Design Process

The design of an interchange involves the steps outlined in Section 2.3.1 to Section 2.3.4.

2.3.1 Review Planning Reports

The location of the interchange, the appropriate form of interchange, and the number of lanes on various elements of the interchange will have been determined during the planning investigation for the new road or freeway. This information may be presented in a planning report that examines options for the location of the route and recommends a preferred option. The recommended interchanges are based on a preliminary traffic analysis.

In this part of the design process the design team reviews planning reports, supporting information and plans to develop a sound understanding of the basis for the choice of alignment and conceptual interchange layout. Of particular interest are design controls and criteria that may be related to any of the aspects listed in Section 2.2.1 (e.g. topography, geology, watercourses and environment).

In some cases the planning investigations may precede the design of the road by many years and in this part of the process the traffic prediction and analysis should be revisited to confirm that the conceptual layout is still appropriate and socially and environmentally acceptable.

2.3.2 Design Brief

Prior to commencing a design it is recommended that a design brief is prepared to record all the important factors relating to the design including the geometric design standards to be adopted for all elements of the interchange (speed parameters, cross-section, etc.).

2.3.3 Preliminary Design

This stage of the process involves:

- selection of the type of interchange
- designing horizontal and vertical alignments of the major road and intersecting road through the interchange area
- locating ramp terminals
- locating bridge abutments
- design of the connecting ramps
- design of any collector-distributor roads
- preparing a strategic drainage scheme to identify any drainage-related grading controls
- comparing options for combinations of ramps under or over each roadway
- selecting the optimum combination of ramps to meet the design objectives
- completing ramp terminal details (diverge and merge) at the major road or major forks/branch connections in the case of freeway interchanges
- completing intersection ramp terminals at the intersecting road considering all road users
- checking all relevant sight distance requirements at ramp terminals and intersections to ensure that they are achieved
- confirming that normal standards can be achieved, and if not, identifying the appropriate risk management measures to address non-conformances to standards
- developing a services relocation strategy
- developing the fencing and noise wall strategies
- identifying provisions for pedestrians and cyclists through the interchange area
- determining the requirements for providing current or future intelligent transport systems infrastructure
- reviewing the layout to confirm the safety outcome objectives are met.

If an interchange is part of a staged development, a preliminary design of the ultimate interchange layout will be important to facilitate ultimate construction.

2.3.4 Detailed Design Stage

The detailed design stage of the process involves the preparation of all detailed drawings and specifications required for construction of the project, including those relating to:

- alignment (horizontal and vertical)
- cross-section
- drainage
- pavement

- barriers
- landscaping
- signs and markings
- road lighting
- traffic signals
- incident management
- cyclist and pedestrian facilities
- noise walls
- emergency stopping bays
- utility plant and equipment.

In some cases designs may be required for special features such as run-off treatment, geotechnical treatments and service centres within the interchange.

2.4 Principles

2.4.1 Interchange Elements

The elements that form an interchange are the:

- carriageway/s of the major road
- carriageway/s of the minor road
- ramps
- diverge and merge areas associated with the major road
- ramp terminals at the minor road (e.g. unsignalised or signalised intersections or roundabouts)
- shared paths (pedestrians and cyclists).

There will be many instances where two roads of similar importance intersect in which case the terms major and minor will be arbitrary. For example, interchanges between two freeways will have direct or semi-direct ramp connections and at-grade intersections will not be an element in the design.

Each movement through an interchange should be provided with an appropriate and consistent level of service and particular attention should be paid to:

- acceleration and deceleration lanes
- merge and diverge areas
- weaving sections between ramps.

The most critical points for analysis and hence design are usually just upstream of a diverge or just downstream of a ramp merge. Traffic using these interchange elements should be able to operate at a satisfactory level of service without reducing the design level of service on the freeway. The design should be based on a thorough traffic analysis (refer to the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013d)).

Target levels of service, including the safety objectives, in the design year will be influenced by economic and political criteria, and the designer should aim to achieve the highest practicable levels.

2.4.2 Interchange Uniformity and Spacing

Uniformity

Route considerations are discussed in Section 6.3 of *AGTM Part 6* (Austroads 2013a). Important aspects from a route perspective are the spacing of interchanges, route continuity and consistency in the form of interchanges along a route.

With respect to route continuity it is necessary to provide a design that favours major movements as the designated through route/s and the route and interchanges should have a form of design and signage to reflect this driver expectation.

Drivers can become confused if the form of interchange and exit conditions change repeatedly along a route. Driver perception of ease of negotiating interchanges from both the major and minor roads is an important factor in efficiency of operation and the safety of the network. While interchanges should be custom-designed to suit the specific conditions of the site, consistency can be achieved along a link through the use of a consistent form of interchange, but it is also achieved by a consistent approach to the pattern of the exits and entrances and their signing.

For example, drivers expect to exit to the left and they expect the ramp to start in advance of the separation structure. If this feature is incorporated regardless of the form of the interchange beyond the exit, consistency will have been achieved. A similar approach to entrance ramps should be taken.

This is particularly so in rural areas where drivers may generally expect diamond interchanges, although semi-directional (free-flow) interchanges are often used for access to towns that are being bypassed. Where these interchanges are used designers should not produce a design that accommodates high-speed ramps and local crossing and access movements within the one interchange as this invariably leads to driver confusion and road safety issues.

Where a system interchange is being implemented, local access connections should be avoided. Mixing the local access arrangements and the requirements for free flow in the system interchange leads to inconsistency of form and a lower level of road safety in the interchange. Local access arrangements should be accomplished at an appropriate service interchange.

Spacing

The location of interchanges is usually determined by the road network requirements for accessibility and route interconnectivity. However, there are limits to the number of interchanges that can be accommodated and to the spacing of the ramp terminals without compromising the capacity and safety of the road.

Every ramp, whether an entry or exit ramp, creates conflict and causes some disturbance to the traffic flow on the freeway. The effects of this disturbance are felt for some distance on each side of the ramp/carriageway terminal. Examination of these effects gives a clear indication of the minimum spacing that can be tolerated (refer to *AGTM Part 6* (Austroads 2013a), Section 6.6.6 and Table 6.3).

The spacing of interchanges is important because it can result in issues associated with the overlapping or insufficient separation of entry ramps and exit ramps. This in turn can lead to the use of an inconsistent form of interchange or difficulties in locating major direction signs in a satisfactory location. More importantly, it may result in problems associated with traffic weaving between interchanges. However, this does not take account of other factors that influence interchange spacing such as:

- Signing requirements (refer to AS 1742.15; *MOTSAM Part 3*, (NZ Transport Agency (NZTA) 2010b) and jurisdictional guides).

- The distance required for a driver to change lanes to position the vehicle sufficiently in advance of an exit to safely undertake the manoeuvre. Buses and heavy vehicles require 200 m per lane change, while cars desirably require 150 m per lane change¹.
- The extent of weaving caused by the placement of successive entry and exit ramps. Weaving introduces an additional element of conflict and has a negative effect on both levels of service and safety. TRB (2010) provides details of the methodology required to address the weaving issue from a level of service point of view (refer to *AGTM Part 6* (Austroads 2013a), Section 6.6.6 and Table 6.3).

The general conclusion that can be drawn from these requirements is that the minimum spacing of interchanges is:

- in urban areas about:
 - 2 km on four-lane freeways (i.e. two lanes in each direction)
 - 3 km on six-lane freeways
 - 4 km on eight-lane freeways
- in rural areas between 5 km and 8 km.

It is emphasised that these minimum spacing for urban areas are not necessarily desirable and should be checked to ensure that the main carriageways will operate satisfactorily. Traffic analysis may indicate that the desirable spacing is greater than these values. It follows that the ultimate number of lanes should be considered when the location of interchanges is initially planned.

Where other factors dictate the need to have the interchanges at closer spacing than these, the required spacing can be effectively achieved through the form of the interchange. For example, the ramps can be grade separated ('braided' ramps) to create a bigger spacing of the ramp terminals or collector-distributor roads can be used with the added advantage of keeping local traffic clear of the main through traffic. Different forms of interchange and their relative advantages and disadvantages are provided in *AGTM Part 6* (Austroads 2013a).

Maximum spacing is less easily determined and will depend on the needs for accessibility and service to the local road network. In urban areas, spacing above about 4 km would not be expected. In rural areas a spacing greater than about 12 km should be carefully examined for adequacy of service and where spacing above this is proposed, the overall level of service provided by the road system should be reviewed.

Where long lengths of rural freeway do not need interchanges for access and service reasons, the need for rest areas and/or service centres has to be assessed to ensure that drivers have adequate facilities for rest, refreshment and refuelling. The need for U-turn facilities should also be considered.

¹ The merge distances are based on a rate of lateral movement of 0.6 m/s for cars and a lower rate of 0.5 m/s adopted for buses and heavy vehicles. Note: distances have been rounded.

3. Forms of Interchange

3.1 Traffic Considerations

Forms of interchange and their relative advantages and disadvantages are discussed in Section 6.5 of *AGTM Part 6* (Austroads 2013a). The appropriate form of interchange is generally that which maintains the operational capacity under the predicted demand conditions while retaining the principles of consistency and route continuity.

From an operational perspective, the form of interchange adopted at a particular site will depend on the:

- functional classification of the roads and the importance of the intersection in the road network
- volume and characteristics of traffic to be accommodated
- need for ramp metering either now or in the future
- desired level of service generally or for a particular movement.

Interchanges broadly fall into two categories:

- Service interchanges – a service interchange is an interchange between a major and a minor road (Figure 3.1). A minor road typically refers to a highway, arterial or sub-arterial that contains at-grade intersections. Major road/minor road interchanges consist of a major road carrying high traffic volumes crossing a minor road carrying low to moderate traffic volumes.
- System interchanges – a system interchange is an interchange between two major roads (Figure 3.2). A major road typically refers to a freeway, major arterial or a major highway that does not contain at-grade intersections. At interchanges of major roads, high traffic volumes usually exist on both roadways. System interchanges aim to provide free flow for both major movements and for the interconnecting ramps.

There is an extensive range of types and forms of interchange, the more common of which are discussed in *AGTM Part 6* (Austroads 2013a). Figure 3.3 and Figure 3.4 respectively show examples of service and system interchanges including the key geometric elements that affect the interchange design.

Interchange types are characterised by the basic shapes of ramps. The types of ramps are usually known as:

- Diagonal ramps that are provided at service interchanges and generally cater for all turning movements (Figure 3.3). They can be either exit ramps or entrance ramps.
- Directional ramps that are used at system interchanges exclusively for one right-turn movement and provide the most direct right-turn connection between two roadways (Figure 3.5). They must only be used as part of a major fork or branch connection (refer to Figure 11.4 and Figure 11.8).
- Semi-directional ramps are exclusively for one right-turn movement. They can be a separate ramp as shown in Figure 3.4 or, in the case of a four-legged interchange, share an exit ramp terminal with an outer connector and subsequently branch off from the outer connector.
- Loop ramps are used where traffic changes direction by 90° by means of a 270° turn as shown in Figure 3.4(a). At system interchanges, loop ramps are exclusively for one movement which can be a left or right turn. At service interchanges, loop ramps can be either exit ramps or entrance ramps and generally cater for all turning movements.
- Outer connector ramps are exclusively for one left-turn movement and provide the most direct left-turn connection between two roadways.

Figure 3.1: A service interchange



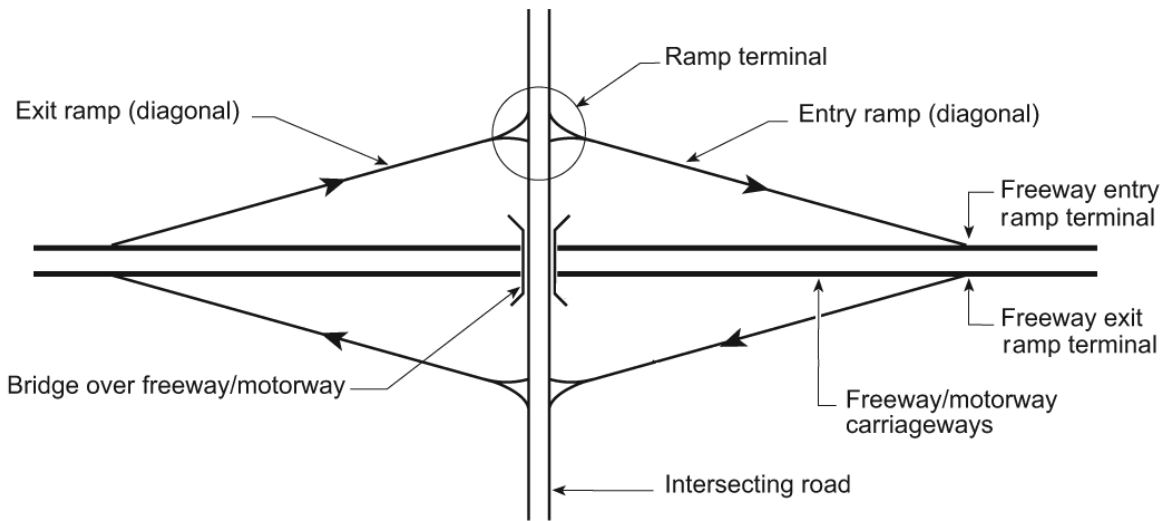
Source: VicRoads.

Figure 3.2: A system interchange

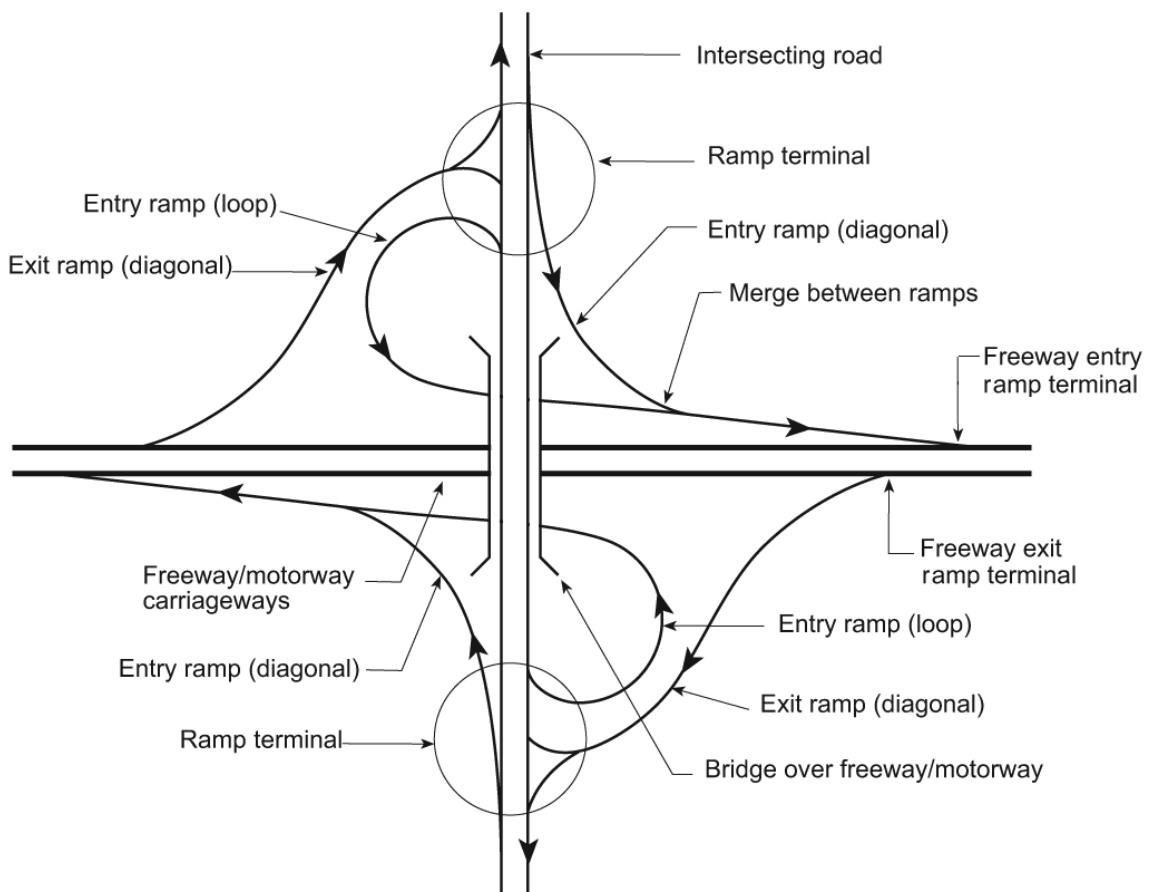


Source: VicRoads.

Figure 3.3: Examples of service interchanges and elements



(a) Example of a diamond interchange with diagonal ramps



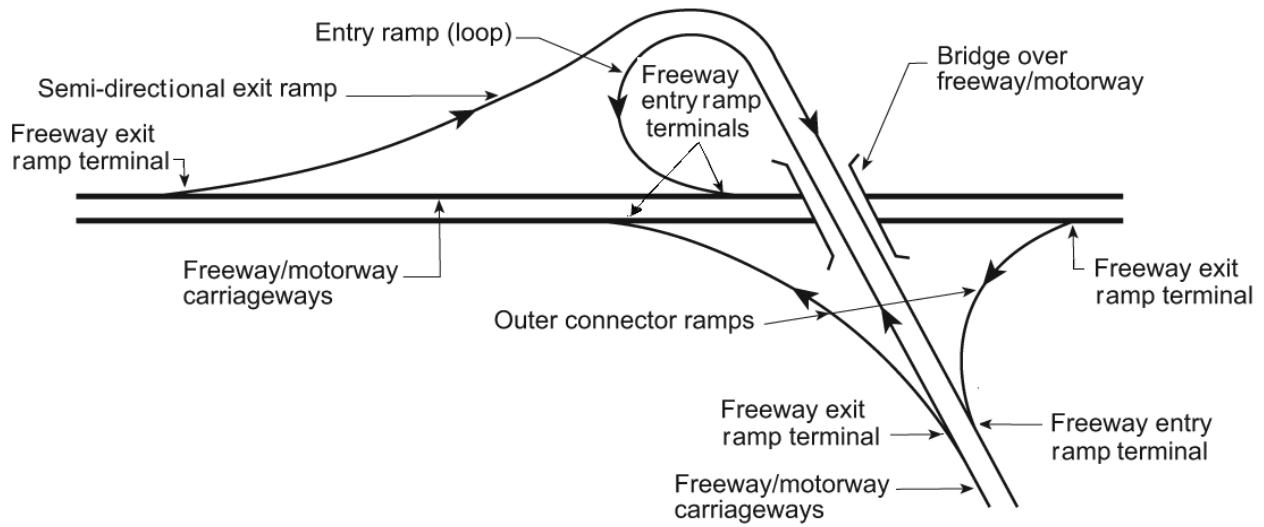
(b) Example of an interchange with loop ramps

Notes:

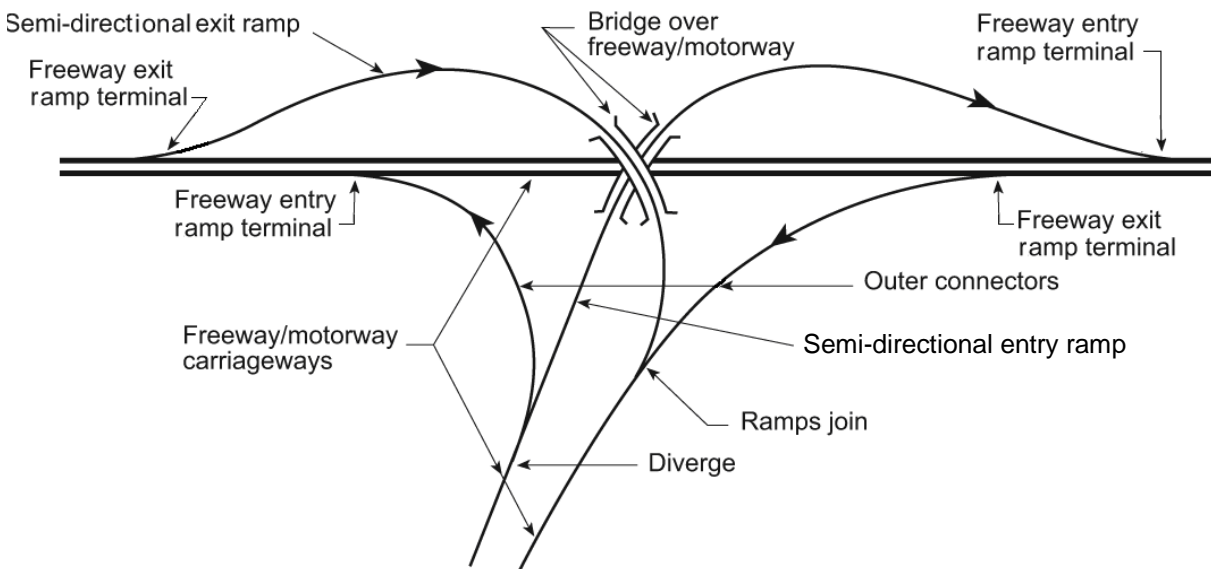
Underpass may be used instead of bridge.

Ramp terminal may be an unsignalised or a signalised intersection, or a roundabout.

Figure 3.4: Examples of system interchanges and elements



(a) Example – trumpet interchange



(b) Example – T interchange

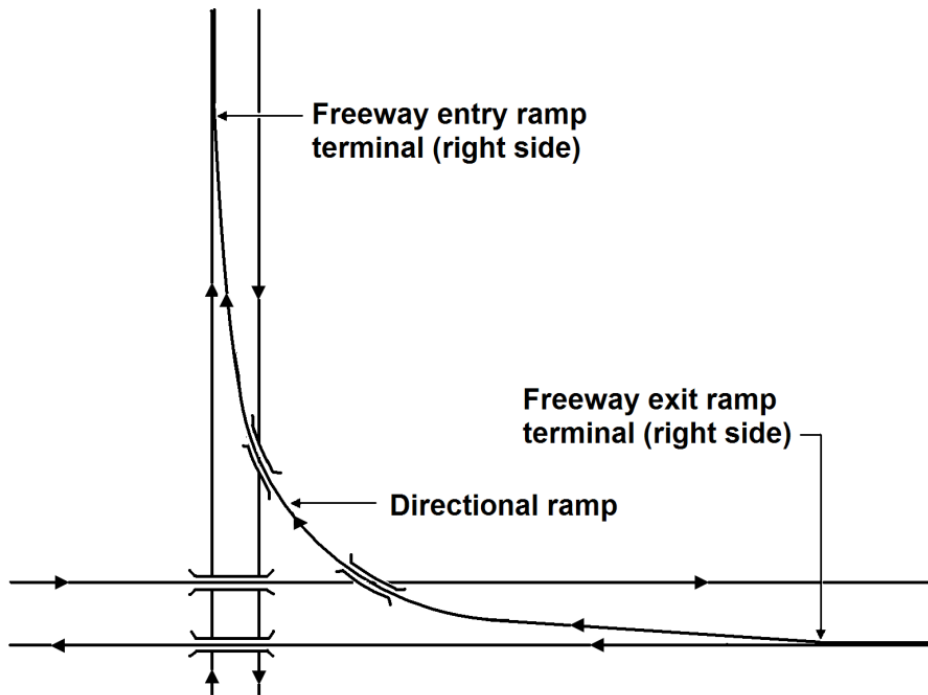
Notes:

Ramps may pass under freeway.

Ramp types can also be applied to a four-legged interchange.

Ramp types can be configured in numerous ways to provide the most appropriate layout for the circumstances.

Figure 3.5: Illustration of a directional ramp



3.2 Other Considerations

3.2.1 General

Whilst traffic performance and safety are key factors, many other considerations may affect the type of interchange that is adopted. Such factors include, for example, topography, practicality of acquiring particular areas of land, and the presence of watercourses (Section 2.2.1). Whilst land acquisition can sometimes be an issue in rural areas, this difficulty is more likely to occur in urban areas where the cost and disruption associated with land acquisition is high.

In many cases, the topography and the relative grading of the roads will dictate the most appropriate form of interchange. Generally, one of three conditions can arise:

- the influence of topography dominates and the design is fitted to it
- the topography does not favour either of the roads
- the alignment and grade-line controls of one road are sufficiently important to subordinate those of the other.

In general, the design that fits the topography will be the most pleasing and the most economical. If this situation does not prevail, the factors discussed in Section 3.2.2 are to be considered in making the decision on the relative grades of the roads.

Other factors which can influence the type of interchange include:

- Requirement for oversize vehicle manoeuvres
- staging of construction
- environmental factors (including noise and visual impacts)
- requirements for proposed or future mass transit systems.

Further information on the types of interchanges can be found in *AGTM Part 6* (Austroads 2013a).

3.2.2 Underpass or Overpass

Whether the major road passes over or under the minor road can be a significant decision that affects the general form of an interchange. Aspects to consider are:

- Overall strategy – the grade of the major road may be determined by an overall requirement to have the facility completely depressed or completely elevated.
- Economy – the alternative arrangements (including the need for earthworks balance) should be investigated to assess whether to go over or under. In general it is more economical to have the major road constructed at the existing ground level and to place the minor road over. This usually results in fewer and smaller bridges, with the additional advantage of a smoother surface on the major route (especially at bridge abutments and other joints) and fewer interruptions during periods of maintenance.
- Visual amenity – the through road may be given preference by making it the overpass to take advantage of a vista or to create a feeling of minimum restriction.
- Operations – at interchanges, the operations on the ramps are assisted by having the major road on the lower level. This provides for the exiting traffic to slow down on the upgrade and the entering traffic to accelerate on the downgrade, an advantage particularly where a significant number of trucks use the ramps.
- Sight distance – in rolling topography, if there is no pronounced advantage in using either an overpass or an underpass, the type that produces the best sight distance for the major road should be selected.
- Stage construction – an overpass solution offers the best approach to stage construction since the first stage can be built part-width as a complete entity. The second stage can be built separate from this structure without significant loss in use of the first stage. The length of span should allow for the future widening of the road or railway under the structure.
- Drainage – in some situations the choice of an underpass may create difficult drainage problems that would not arise if the major road was carried over the minor road with no changes to the grade line of the minor road.
- Ease of construction – if the new road is to be carried across a heavily trafficked road, an overpass will create the least disruption during construction.
- High loads – on high load routes an overpass has no limits on vertical clearance and may be the best solution. If the minor road passes over the major road, high loads may be accommodated on the ramps of the interchange if appropriately designed.
- Noise reduction – the road depressed below the surrounding area will have a lower noise impact. The road with the highest traffic will be better placed in this situation in general.

4. Structures

4.1 General

Structures may be used for grade separation of traffic movements or as stand-alone structures over watercourses or railways. In addition to the need to have structures at interchanges to carry the intersecting road across the major road, it is often necessary for access and network continuity to carry other roads across the major road. As discussed in Section 3.2.2, the structures will carry either the major road over the intersecting road or the minor road over the major road.

This discussion is confined to the geometric features of structures although many aspects of structural design should be considered – refer to the *Guide to Bridge Technology* (Austroads 2009-2012), the New Zealand *Bridge Manual* (NZ Transport Agency 2013a), and the New Zealand *State Highway Control Manual* (NZ Transport Agency 2013b).

A grade separation should conform in alignment (both horizontal and vertical) and cross-section to the natural lines of the approaches. The structure should be designed to fit the road, not the road to fit the structure. However, road designers should align roadways to minimise skews, optimise span lengths, provide consistent widths and avoid tapers on bridges, and avoid curves and superelevation on bridges, and thereby reducing the cost and complexity of structures.

4.1.1 Types of Structure

Structures provided within interchanges include bridges, pedestrian bridges, culverts, retaining walls, wildlife crossings, sign structures and safety barriers. The types of structures required and the constraints imposed by them should be considered during preparation of interchange layouts and during detailed design.

The type of structure best suited to grade separation is one that gives drivers little sense of restriction. Where drivers take practically no notice of the structure they are passing over, their behaviour is the same or nearly the same as at other points on the highway, and sudden, erratic changes in speed and direction are unlikely (AASHTO 2011). The driving experience should be consistent.

In the case of structures passing over the road, it is impossible to be unaware of their presence. These structures should be designed to fit into the environment in a pleasing way that is not distracting. The best result will be achieved through collaboration with the bridge designer and a landscape architect/urban designer to ensure that the structure meets all requirements.

Two general types of bridges are built – solid abutment types and open-end span types. The solid abutments are also referred to as vertical or semi-retained abutments (Figure 4.1) whilst open-end spans are also referred to as spill-through abutments (Figure 4.2). The abutment may also be a combination of both types as shown in Figure 4.3. Open-end spans are preferred and are to be used unless good reasons can be advanced for the construction of solid abutments (e.g. solid abutments are generally more economical for bridges on large skews, and the presence of retaining walls for other purposes in an arterial road interchange may dictate the use of solid abutments). When designing the abutment, consideration should also be given to the slope of the abutment. Preferably the slope would be traversable and if this is not achievable, a safety barrier may be needed.

Structures that pass over a divided road may or may not have central piers in the median. Although it is preferable from a visual amenity and safety point of view to have the median free of such obstructions, economic and practical considerations may prevent this being achieved. When the median requires the installation of a continuous safety barrier, there is little point in attempting to dispense with a pier in the median.

Figure 4.1: Solid-end (or vertical) bridge abutment



Figure 4.2: Open-end or spill-through bridge abutment



Figure 4.3: Combination of solid-end and spill-through bridge abutment



4.2 Form of Structure

The factors for which advice should be sought and should be considered when selecting the forms of structures include:

- geometry of the interchange elements
- limitations on grade line and span lengths
- foundation conditions
- environmental and aesthetic requirements
- facilitation of stage construction
- maintenance
- services
- constructability
- traffic management
- economy of structure.

The parapet must be designed to an appropriate performance level and have the ability to redirect errant vehicles (refer to relevant bridge design codes). Similarly, where a road or pedestrian bridge passes over a freeway it is important that the integrity of the structure is protected in the event of a vehicle crashing into piers. This is particularly the case where an existing freeway is to be widened and slender columns of an existing structure will remain relatively close to the road. In these cases it is suggested that a barrier capable of containing heavy vehicles should be provided (refer to the *Guide to Road Design Part 6: Roadside Design, Safety and Barriers* (Austroads 2010c)).

The conventional type of structure over divided roads is a two-span deck-beam type bridge, which may be continuous for economy. The bridge pier on the median may need protection by safety barriers, which will need to be sufficiently strong to prevent trucks from crashing into the pier. The form of structure adopted will depend on the circumstances at the particular site and the particular road conditions being serviced. This is a matter for determination by bridge designers for the site being designed.

Significant savings in cost can be made by standardising bridge types and spans as much as possible. However, in some cases the bridge form will need to be selected for architectural reasons, to enhance the historical character of the area or to identify a location.

4.3 Cross-sections on Bridges

Factors affecting the cross-section on bridges are covered in *AGRD Part 3* (Austroads 2010b) and in Part 1 of AS 5100 and for New Zealand, the NZ Transport Agency *Bridge Manual* (NZ Transport Agency 2013a).

4.4 Pedestrian/Cyclist Grade Separations

4.4.1 General

Pedestrian (and cyclist) grade separations should be considered where there is sufficient current and/or future crossing demand, particularly by children, people with disabilities and the elderly. Pedestrian access and mobility planning as part of project planning will assist to identify demand. Overpasses may be poorly patronised where pedestrians have difficulty with the change in level, commonly about 6.5 m. Although the change in level is less for underpasses, commonly about 3.5 m, consideration should be given to the ability to see along the structure to assure personal security, taking into consideration the high cost of lighting and the cost of repairing damage from vandalism.

Dimensions for pedestrian bridges are set out in AS 5100. Grades and landings suitable to provide access for the disabled are covered by AS 1428.1 and stairways are covered by AS 1657. NZS 4121 sets out requirements for handrails, slopes and disability rest areas for New Zealand practitioners.

4.4.2 Safety Barriers at Pedestrian Bridges

Pedestrian bridges may collapse if a pier were to be impacted by an errant truck. For this reason it is preferred to have a single span across the freeway and some jurisdictions may have a policy to avoid the provision of central piers for pedestrian overpasses. A decision to provide a central pier should be based on a risk assessment and supports/piers should be designed to resist the likely traffic impact load. High-containment safety barriers appropriate for the level of risk should be placed on the approaches to pedestrian bridges over freeways.

4.5 Culverts

Culverts may be required within or close to interchanges. Culverts should be designed for hydraulic and structural adequacy in accordance with the *Guide to Road Design Part 5: Drainage – Open Channels, Culverts and Floodways* (Austroads 2013c) and other special requirements of the relevant drainage authority. Culvert end walls should be driveable, or protected by a safety barrier system (refer to the *Guide to Road Design Part 6: Roadside Design, Safety and Barriers* (Austroads 2010c)).

Culverts used as service tunnels should be designed for the forces and flows which may occur in the event of failure of the service pipeline within the tunnel. Access for emergency vehicles and equipment should be from outside the freeway boundary.

4.6 Retaining Walls

Retaining walls associated with interchanges may be gravity walls, reinforced concrete and reinforced soil types. Where large areas are exposed, the advice of a landscape architect on visual amenity should be sought. Consideration should be given in the design to means of preventing or removing graffiti from the surfaces of exposed walls.

The base of retaining walls should be protected by a safety barrier to provide protection from damage especially by trucks, or the wall should have a suitable concrete barrier profile constructed into its base. The wall should be located to provide for the 'working width' of trucks, an additional width to account for the tilting of trucks passing close to the wall (refer to *AGRD Part 3* (Austroads 2010b)).

4.7 Wildlife Crossings

If the location of the interchange is in conflict with a wildlife corridor, then consideration should be given to means of providing appropriate connectivity for wildlife movement. Planning for the interchange location should have taken this issue into account and located the facility to compensate for the environmental requirements. These issues are discussed in the *Guide to Road Design Part 6B: Roadside Environment* (Austroads 2015d).

4.8 Services on Structure

In general, utility plant and equipment should not be installed along freeway reserves, and crossings should be installed in service tunnels where possible. Service tunnels under embankments are easier to drain. This approach would avoid the need for such services on freeway structures.

Where services are required to be installed on bridges crossing the freeway, the following conditions should apply:

- pipes carrying fluids should not be placed within the cells of box girders
- services which are mutually hazardous should be carried on opposite sides of the structure
- maintenance should not need to be carried out from the freeway or from ramps.

4.9 Safety Screens

Consideration must be given to the risk imposed on motorists by objects accidentally falling or being illegally thrown from overhead bridge structures at interchanges. A risk assessment should be undertaken to determine the need to place safety screening on bridges. An example of a risk assessment can be found in *Roads and Maritime Services (2012)* which includes a risk assessment matrix for this purpose and additional information including:

- the impacted vehicle is a significant factor, therefore high-speed roads are accorded a high priority
- new interchanges are expected to incorporate facilities that may be required during the life of the structure
- all overbridges over motorways, restricted access roads or major public roads, which are within 2 km of a school, club, hotel, or similar facilities would invariably warrant protection.

Safety screens may impact on the visibility at intersections and the sight distance should be assessed at these locations.

5. Cross-Section

5.1 Major Road and Minor Road

The cross-section of the major road (e.g. freeway or divided arterial road) and for the minor road will be determined from planning requirements and traffic analysis. Detailed guidance and design widths for various elements in a road cross-section are covered in *AGRD Part 3* (Austroads 2010b).

5.2 Ramp Cross-section

5.2.1 Number of Lanes on Ramps

Ramps should have the number of lanes required to provide a satisfactory level of service on the design element and to avoid traffic queues from adversely affecting adjacent elements. This requirement applies to the approaches to ramp terminals and generally throughout the length of the ramp. Direct or semi-direct ramps may have one lane but are often designed for two-lane operation with provision for emergency parking, unless the expected volume exceeds the capacity of two through lanes. In this case, three-lane operation on the ramp should be considered.

Exit and entry ramps may be one lane or two lanes at the nose depending on traffic volumes. Where two lanes are required at the nose to meet the traffic demand, the cross-section should allow for a stalled vehicle to be passed in addition to the full traffic lanes.

Exit ramps

Where the ramp caters for a relatively low volume of traffic a single lane at the exit nose and along the ramp will suffice as shown in Figure 11.1. The shoulder of the freeway is carried past the nose and onto the ramp to provide for emergency stopping or vehicle breakdown.

Single-lane (at the nose) exit ramps should be widened to two lanes on the ramp as shown in Figure 11.2 when:

- a truck will exit at less than 50 km/h at the nose, and a significant number of trucks use the ramp
- the ramp is longer than 600 m.

The transition from two lanes to one lane at the nose should be implemented as shown in Figure 11.2.

Additional lanes are often required at exit ramp terminals with the minor road to provide adequate intersection capacity. Relatively short exit ramps may be widened over their entire length to cater for storage requirements at the minor road intersection (e.g. in urban situations).

Two-lane exit ramps with a single lane at the nose are effectively one-lane ramps with provision for overtaking. It is therefore not necessary to have full shoulder widths on these ramps. A 1.0 m shoulder on each side to support the pavement is sufficient.

High volume exits require two lanes at the nose as shown in Figure 11.3 or a high-speed bifurcation into two roadways as shown in Figure 11.4.

Entry ramps

Where an entry ramp caters for a relatively low volume of traffic a single lane at the nose and a single lane along the ramp are often adequate, a shoulder being provided past the nose and on the ramp (Figure 11.6 and Figure 11.7(a)).

For an entry ramp with a single lane at the nose, and with a design speed of the through roadway of 80 km/h or more, a second entry ramp lane should be provided when:

- the length of a single-lane ramp exceeds 300 m on a level grade and a truck accelerating from rest at the ramp terminus would not be expected to reach 50 km/h at the nose, and a significant number of trucks use the ramp
- a very long (i.e. length > 600 m) entry ramp is provided.

If the design year traffic volumes require two lanes on an entry ramp, two alternative approaches may be taken, namely provide a:

- single lane at the nose, using the restricted capacity of this lane to control the volume of traffic entering the freeway (Figure 11.7(c))
- full two-lane entry with an added lane on the freeway. These ramps require the capacity of the two lanes and should therefore be provided with sufficient shoulder width to allow a stalled vehicle to be passed (Figure 11.7(b)).

5.2.2 Ramp Lane Widths

Pavement and shoulder widths for ramps are given in Table 5.1. Shoulders should be paved full depth and sealed. Where it is practicable, shoulders with colour and/or texture differing from the pavement provide a useful contrast and help to prevent traffic usage of the shoulder. Audible edge lines may have a similar effect.

Table 5.1: Ramps – lane and shoulder widths for service and system interchanges

Number of lanes on the ramp	Lane width ⁽¹⁾ (m)	Shoulder width ⁽²⁾ (m)	
		Left	Right
One (at the nose)	4.0	2.0	1.0
Two (at the nose)	3.5	2.0	1.0
Two for length of ramp (one at the nose)	3.5	1.0	1.0
Three	3.5	2.0	1.0

¹ Plus curve widening where applicable on turning roadways.

² Allows for a stalled vehicle to be passed using the total width of the ramp pavement. On high-speed turning roadways, consideration may be given to adopting a left-hand shoulder width of 3.0 m to allow stalled vehicles to stand clear of the through lanes.

Where ramps intersect with the minor road, the number of lanes may be increased to cater for storage requirements at the minor road intersection. The length and number of these lanes will be determined from traffic analysis and intersection design principles.

On loops designed for one lane of traffic, curve widening may be required to allow for the tracking of the design vehicle. For two-lane loops, the lane widths should allow for a semi-trailer and a car to travel side by side as a minimum. Where the composition of the traffic includes a significant percentage of heavy vehicles, then the width should accommodate the largest design vehicle in the left lane travelling side by side with a single unit truck. In any case, the lane width on loops should be determined using appropriate turning path software.

Kerbs

Kerbs are generally not used on ramps in rural areas except at the intersection with the minor road. In urban areas, semi-mountable kerbs may be provided on low-speed ramps (e.g. diagonal ramps) and should be located at the back of the shoulders. In these situations kerbs may provide an advantage as they:

- delineate edges
- control pavement drainage
- restrain undesirable traffic movement
- improve the roadway appearance.

However, kerbs should only be used where street lighting is provided in accordance with AS/NZS 1158.

Generally kerbs should not be used on:

- diverge or exit noses on interchanges where the operating speed of the major road is 80 km/h or greater as the kerb presents an obstacle to errant vehicles which may be relatively common in these areas
- either side of loops as any impact of the tyres with the kerb can destabilise and roll a heavy vehicle (e.g. semi-trailer or B-double). In this situation, a safety barrier is usually necessary and the kerb should not be placed in front of a barrier.

Designers should have a good reason for providing a kerb in any particular situation. Barrier kerbs should not be used within interchanges.

5.3 Clearances on Major Road

Vertical and horizontal clearance on the major or minor road, or ramps where they pass under structures, is covered in *AGRD Part 3* (Austroads 2010b) and in New Zealand, the NZ Transport Agency *Bridge Manual* (NZ Transport Agency 2013a).

6. Design Speed

6.1 General

The speed adopted for design of the elements of the interchange is to be the operating speed on that element.

The speed adopted by a driver within an interchange depends upon the combined effects of a number of factors including:

- types of roads intersecting and consequent geometric limitations on speed
- numbers and spacing of driver decision points
- characteristics of ramps and ramp terminals
- the presence of manoeuvring vehicles
- the proportion of trucks in the traffic
- the approach speed when entering the interchange
- traffic volumes and levels of service.

The design speeds for the intersecting roads on the approaches to an interchange will be the operating speed of the through traffic movements within the interchange. The determination of design speed for these major movements is covered in *AGRD Part 3* (Austroads 2010b).

6.2 Major Road

Intersecting roads may have the same or different functions and speed environments. In either case the design of elements within the interchange should:

- allow for drivers to diverge from the major road at the operating speed of the major road (i.e. without interfering with the traffic flow)
- progressively and safely reduce speed (Section 6.4.2) to a magnitude that is consistent with the ramp alignment and the ramp terminal conditions (i.e. intersection at a minor road or merge into another major road).

It is desirable that the decrease in design speed between successive elements (e.g. curves) does not exceed 20 km/h and that traffic moving onto the major road can merge at the operating speed of that road. The minimum speed to be attained by merging traffic may be 10 km/h less than the operating speed of the through road where the desirable condition cannot be obtained or in constrained circumstances.

6.3 Minor Road

Where a minor road passes over a major road on a crest vertical curve at a spread diamond (generally rural) interchange it may be difficult to achieve appropriate sight distances to the intersections if the operating speed of the minor road is greater than 80 km/h. In these circumstances, action may be required to reduce the operating speed through the interchange on the minor road. This will generally require an appropriate reduction of the posted speed to ensure that the operating speed matches the design (use the relationship $\text{operating speed} = \text{posted speed} + 10 \text{ km/h}$). The *Guide to Road Safety Part 3: Speed Limits and Speed Management* (Austroads 2008a) provides guidance on the setting of posted speed limits.

The proposed speed adopted for design should be practicable for the circumstances. For example, in a rural area it might be expected that drivers will accept a reduction in speed through the interchange from 100 to 80 km/h which may result in a satisfactory level of compliance. However, a reduction from 100 to 60 km/h is not likely to receive that same level of acceptance.

In urban areas where a number of severe constraints apply at the interchange site and it is impractical to match the design speed of the approach road, it will be necessary to reduce the posted speed limit to allow the design speed to be reduced to the posted speed plus 10 km/h on the minor road through the interchange.

Where roundabouts are considered to be a suitable treatment at both ramp terminals on the minor road (i.e. at the exit ramp and the entry ramp) and the treatment is expected to have an adequate capacity and design such that no alternative type of layout will be required in future, it may be appropriate to adopt a relatively low design speed for the alignment between the terminals. This is possible because the roundabouts will control the approach speeds on the inner legs of the interchange (i.e. on the overpass). However, a higher design speed will be necessary for sight distance on the external approaches to the interchange.

Where a ramp terminates at the minor urban road it will often be inappropriate to provide a large radius (i.e. relatively high-speed) free flow left-turn treatment. This is particularly the case where another intersection exists just downstream of the treatment and drivers have to select a gap in the traffic that has emerged from the ramp. If on the other hand the minor road has no such intersection, no pedestrian movement across the road, or a need for the ramp traffic to weave across the major road, then a free-flow treatment may be appropriate. However, the needs of cyclists should be considered and an appropriate treatment provided where necessary (refer to *AGRD Part 4A* (Austroads 2010a)).

6.4 Ramps

6.4.1 Ramp Design Speed

The design speed adopted for ramps depends on the form of the interchange. For system interchanges between freeways the design speeds for ramps are generally higher than other forms and may be the same as the main carriageways.

There are two distinct types of ramps to consider when determining the operating speed on the ramp:

- The first type is where both terminals of the ramps are either diverges or merges, e.g. direct, semi-direct, outer connectors and some loops.
- The second type is where the ramp connects a major road to a minor road with one terminal being an intersection, e.g. diagonal ramp.

The design speed on both types of ramps at any point should be equal to the operating speed (85th percentile speed) on the ramp. However, the methods of determining the operating speed on these types of ramps are quite different.

For ramps of the first type, the operating speed is the lower value of the following:

- that predicted by using the operating speed model in *AGRD Part 3* (Austroads 2010b)
- 10 km/h over the ramp posted speed limit.

For ramps of the second type, the design speed at any point is based on the deceleration or acceleration likely to be used, which can be estimated from Table 11.1 or Table 11.2.

The suggested minimum design speeds for these ramp types as a function of the desired operating speeds on the major road are shown in Table 6.1. It is most important to provide sufficient deceleration distance for drivers approaching at the major road operating speed to slow to the ramp speeds shown in Table 6.1 (e.g. to negotiate a loop in a parclo² layout).

Table 6.1: Suggested minimum design speeds for interchange elements

Form of interchange	Ramp type	Design speed of through road							
		70 km/h		90 km/h		110 km/h		120 km/h	
		Ramp design speed ⁽¹⁾ (km/h)	Minimum ramp radius ⁽²⁾ (m)	Ramp design speed ⁽¹⁾ (km/h)	Minimum ramp radius ⁽²⁾ (m)	Ramp design speed ⁽¹⁾ (km/h)	Minimum ramp radius ⁽²⁾ (m)	Ramp design speed ⁽¹⁾ (km/h)	Minimum ramp radius ⁽²⁾ (m)
System interchange	Direct	Not applicable		70–85	130–250	85–100	250–440	90–110	330–580
	Semi-direct	Not applicable		70–85	135–250	85–100	250–440	90–110	330–580
	Outer	Not applicable		60–85	90–250	80–100	200–440	85–100	250–440
	Loop	Not applicable		50–55	55–80	50–55	55–80	50–55	55–80
Service interchange	Direct	60–70	90–130	70–85	130–250	80–90	250–330	85–100	250–440
	Semi-direct	50–70	55–130	60–80	90–200	80–90	200–330	85–90	250–330
	Outer	50–70	55–130	60–80	90–200	70–90	130–250	80–90	200–330
	Loop	30–50	35–55	50–55	55–80	50–55	55–80	50–55	55–80

¹ Ramp design speed ranges derived from operating speed model relative to minimum ramp radius.

² Minimum ramp radius derived from AASHTO (1994).

6.4.2 Other Considerations

The following influences and requirements with respect to operating speeds on ramps should be noted:

- All ramps and connections are designed with a straight section between the nose and the curve of the ramp (if applicable) to provide a transition to or from the speed of the major road.
- The potential relative speed between vehicles at the merge and diverge areas of the major road (i.e. the major road-ramp terminal interface) should not exceed 10 km/h which can be readily achieved for cars, but is more difficult where trucks are in the traffic stream.
- For ramps in the configuration of a loop, a design speed above 50 km/h requires large areas of land to accommodate the ramps with little gain in the travel time required to achieve the turning manoeuvre. However, adequate speed change arrangements should be incorporated to provide for the transition from the highway speed to the ramp speed.
- Loop ramps may not offer a satisfactory level of service and stability for heavy vehicles. Interactive warning signs may be required.
- Higher-range speeds are required for direct connections (Table 6.1) and appropriate transitions will be required for drivers to move from the highway speed to the speed value for the ramp connection.

² A parclo interchange layout is in the form of a partial cloverleaf.

- The difference in the geometry used for the through carriageways compared to ramps results in the possibility of high relative speeds between vehicles when moving from one element to another.
- Horizontal compound curves should be avoided along exit ramps.
- Along exit ramps, large decreases in speed are often required to meet the needs of the intersection at the terminal. It is desirable that these decreases do not exceed 20 km/h between reverse curves. An example in Appendix A shows how to achieve these limits using successive reverse curves. The form and available space for the ramps will often preclude this approach. If space is not available, one or more of the following possible alternative approaches can be used:
 - large advance warning signs
 - appropriate speed limit signs
 - appropriate pavement markings
 - lighting, especially at the intersection
 - run-out areas (refer to Figure 8.2).
- Creating a lower speed environment 'feel' by the use of treatments producing the impression of restriction to the driver (e.g. dense planting close to the edges of the ramp without inhibiting sight lines; narrower total cross-section).

7. Sight Distance

7.1 General

The sight distances required through a freeway interchange include:

- stopping sight distance on the major road, minor road and all ramps
- sight distance from a driver on the major road to the exit nose and the ramp pavement beyond the exit nose
- sight distance from a driver on the major road to the nose and the merge terminal at entry ramps
- mutual visibility between a driver on the major road and a driver on the entry ramp
- approach sight distance (ASD) to at-grade intersections at ramp terminals
- minimum gap sight distance (MGSD) for intersections at ramp terminals (criteria 2 and 3 sight distance for roundabouts – refer to *AGRD Part 4B: Roundabouts* (Austroads 2015c))
- safe intersection sight distance (SISD) between a driver approaching on the minor road and a vehicle waiting on the off-ramp approach.

Sight distances at exit and entry ramps should be longer than stopping sight distance in order to allow for navigational decisions as well as operational decisions. Although not necessarily hazardous, if decision time is insufficient, drivers on freeways may inadvertently leave the freeway or miss the desired exit.

Designers should also be aware of the potential sight distance problems on grade-separated roundabout interchanges where the tendency to provide higher bridge parapets may interrupt the sight line for drivers. Computer aids can assist in reviewing sight distance requirements.

7.2 Stopping Sight Distance on the Major Road and Minor Road

Stopping sight distance along each lane of the major road, the minor road and the ramps should be at least equal to the stopping sight distances given in *AGRD 3* (Austroads 2010b) for the appropriate speed. The combined vertical and horizontal alignment and the clearance of lateral obstructions such as walls, bridge piers, noise barriers, landscaping features and safety barrier should be checked to ensure that adequate sight distance is provided and will be maintained.

If minimum stopping sight distance occurs only over a short distance while the remainder of the facility has a higher standard, modifications to achieve a uniformly higher than minimum standard should be considered.

Where the major road (e.g. freeway) passes over a minor road, stopping sight distance along the minor road would usually be adequate unless it is on a curve or stopping sight distance is restricted by a physical object. Wide verges and additional bridge span length may be required to achieve sight distance across the inside of curves.

Adequate sight distance should be provided on the minor road and ramp approaches to at-grade intersections at the ramp terminals. For at-grade intersections the sight distances should comply with the guidelines provided in *AGRD Part 4A* (Austroads 2010a) and *AGRD Part 4B* (Austroads 2015c).

7.3 Exit Ramp Nose

At exit ramps it is essential that adequate sight distance is provided so that drivers have sufficient time to comprehend the location of the exit and diverge in a controlled manner. This is particularly important in rural areas where drivers are generally less alert than in urban situations, and in weather conditions that may adversely affect the driver's ability to see the road ahead.

Figure 7.1 illustrates the sight distance required at freeway exit ramps. Initially drivers will search for the start of the exit treatment (defined by the start of the taper) and thereafter the alignment of the exit lane and the position of the exit nose. Consequently, the figure shows that it is essential for drivers to be provided with adequate sight distance to the start of the taper and to the pavement in the lane adjacent to the physical exit nose. Desirably, sight distance should also be provided to a point 60 m beyond the physical nose to ensure that a greater length of the physical nose and exit lane is visible to drivers approaching within the exit treatment.

In the case of a tapered exit treatment (Figure 7.1(b)) the sight distance provided should be equivalent to ten seconds of travel time at the operating speed of the major road. Where an auxiliary lane is provided (Figure 7.1(c)) the exit is generally more conspicuous and therefore the sight distance is based on seven seconds of travel time at the operating speed of the major road. The sight distance should be maintained continuously throughout the length of the auxiliary lane. The minimum length of auxiliary lane in this case is given in Figure 11.1(a).

The sight distances that should be provided for various major road operating speeds for both tapered and auxiliary lane treatments are provided Table 7.1. The sight distances are measured from a driver eye height of 1.1 m to pavement level (an object height of 0.0 m). The distance is measured from the centre of the outside lane on the freeway to the centre of the ramp lane closest to the taper. The object height is 0.0 m to reflect the need to see the pavement markings at the start of the ramp taper and at the nose.

Table 7.1: Major road sight distance required at exits (diverges and nose)

Design speed of major road (km/h)	Dimension 'x', sight distance required ⁽¹⁾ (m)	
	Exit with taper only ⁽²⁾	Exit with auxiliary lane ⁽³⁾
60	170	120
80	230	155
100	280	195
110	310	215
120	330	235
130	360	255

1 Measured from 1.1 m to 0.0 m.

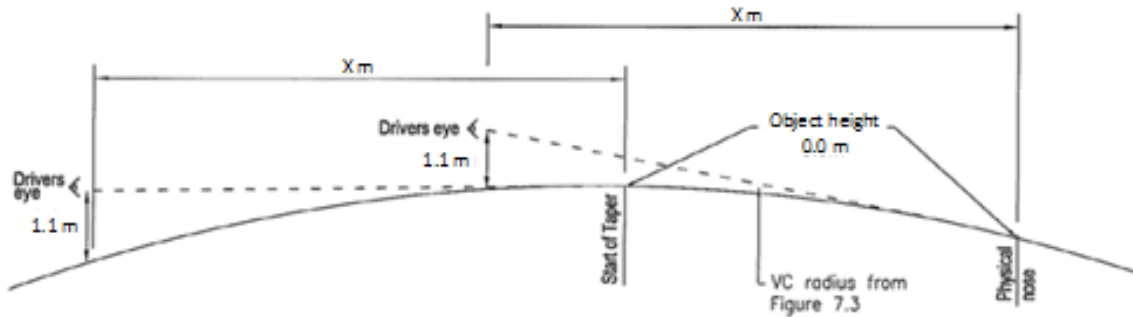
2 Refer to Figure 7.1(b).

3 Refer to Figure 7.1(c).

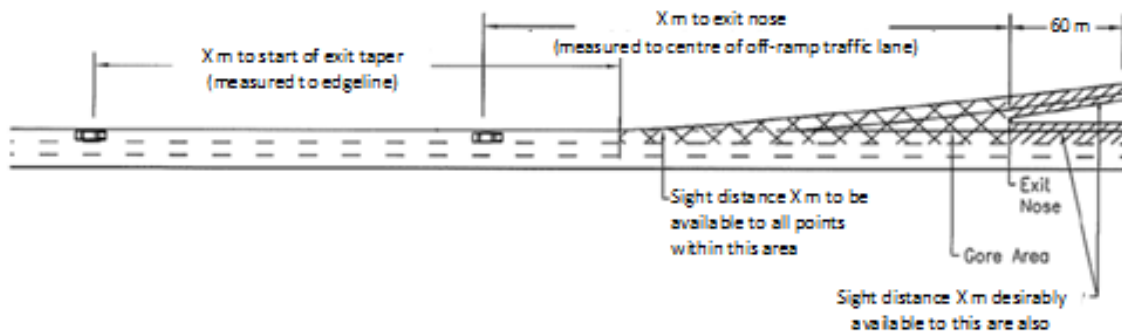
Source: Department of Main Roads (2005)³.

³ Department of Main Roads (2005) has been superseded and Table 7.1 has not been carried forward into Department of Transport and Main Roads (2014).

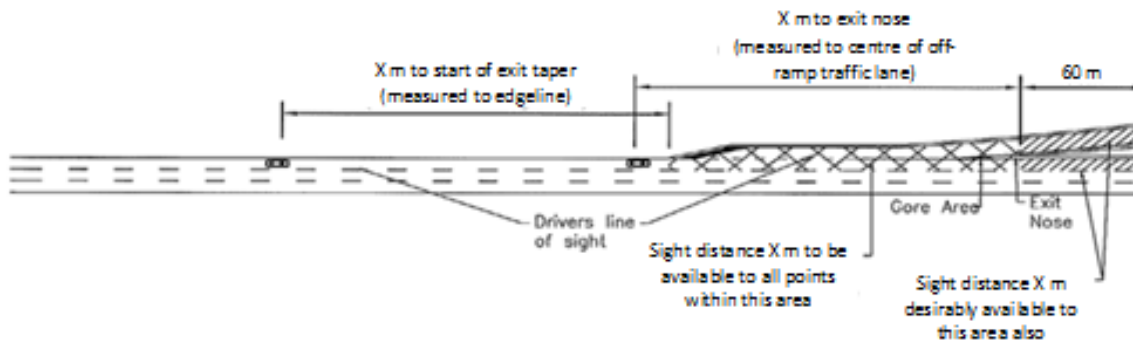
Figure 7.1: Sight distance requirements at exit ramps



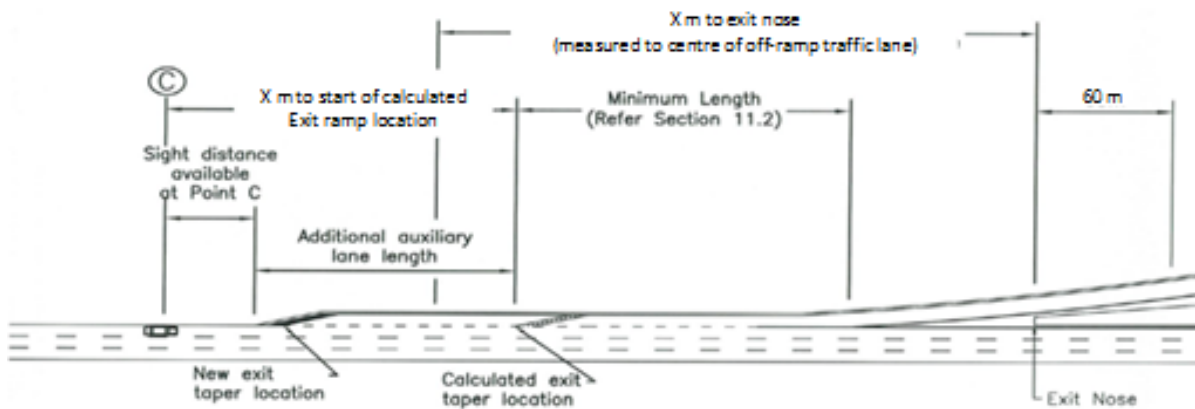
(a) Elevation – exit taper



(b) Plan – exit taper



(c) Plan – auxiliary lane

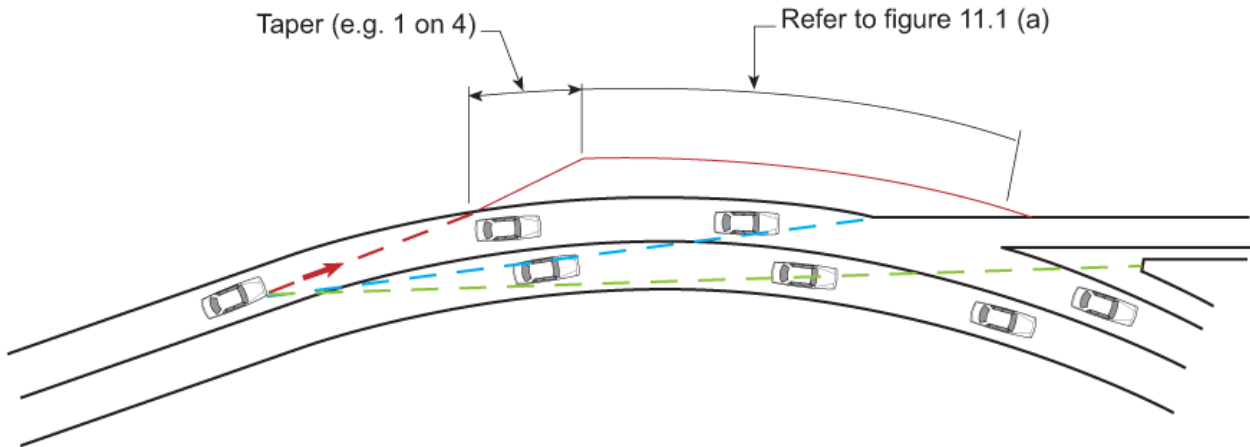


(d) Plan – auxiliary lane extension where sight distance is constrained

Source: Department of Transport and Main Roads (2014), Department of Transport and Main Roads (2015).

An exit ramp on the outside of a relatively tight right-hand curve on rural freeways should be avoided as this situation can confuse drivers into thinking the ramp is the through lane. It is therefore recommended that the radius of the major road curve, where the operating speed is ≥ 100 km/h, should preferably be at least 1500 m. If this alignment standard cannot be achieved a parallel exit lane should be used, particularly on all curves of radius less than 900 m in rural areas. Where this geometry is adopted, the parallel lane should be designed as shown in Figure 7.2.

Figure 7.2: Parallel lane at exit on right-hand curve



Source: Department of Main Roads (2005)⁴.

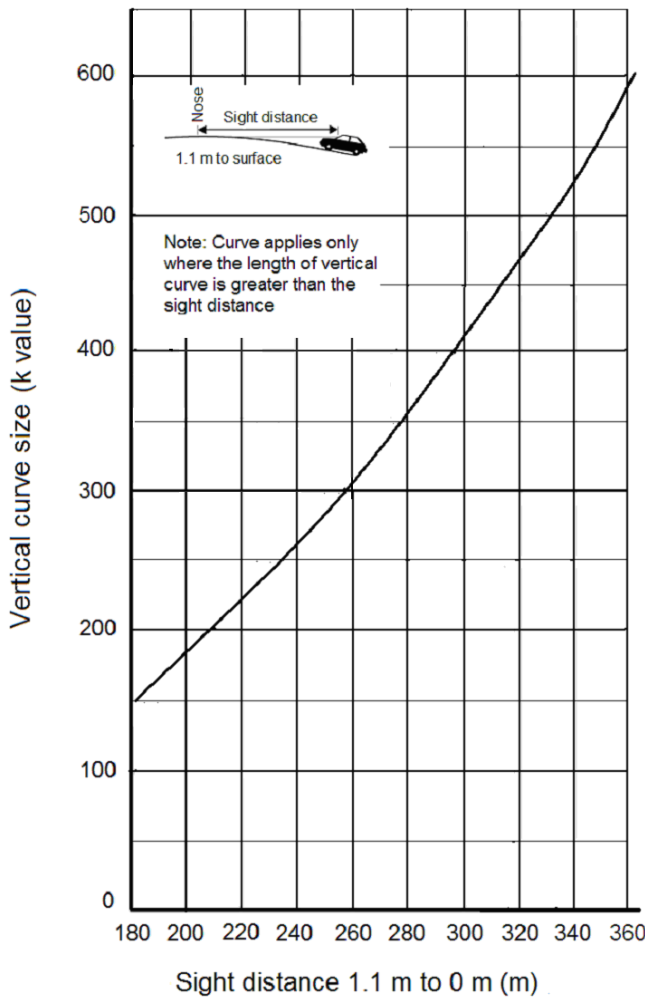
It should be noted that the sight distances given in Table 7.1 are greater than the sight distances tabulated in *AGRD Part 3* (Austroads 2010b) as they allow extra decision time to account for the higher driver workload at freeway exits.

Figure 7.3 gives vertical crest curve radii required at exits in order to achieve the sight distances given in Table 7.1. Further information is provided in Commentary 1.

[\[see Commentary 1\]](#)

⁴ Department of Main Roads (2005) has been superseded and Figure 7.2 has not been carried forward into Department of Transport and Main Roads (2014).

Figure 7.3: Vertical curve radius required for sight distance (from 1.1 m to 0 m)



7.4 Entry Ramp Nose

At entry ramp merges, it is necessary for drivers on each carriageway to be able to see the pending merge followed by the need to have mutual visibility between vehicles on the ramp and vehicles on the through lanes and the need to be able to see the far end (or terminal) of the merge.

With respect to sight distance on the approach, drivers on the ramp need to see in advance where they will have to start looking for vehicles on the through road. The 'approach to nose' criteria in Table 7.2 provides sufficient sight distance to meet these requirements. This sight distance is measured from the centre of the outside freeway lane at an eye height of 1.1 m to an object height of 0.1 m at the nose.

Drivers in the through lanes initially need to be able to see that there is likely to be traffic entering from the ramp and not just rely on signs to warn them of this possibility. This gives drivers in the left lane the chance to decide to change lanes to avoid possible impedence from entering traffic, particularly for taper-only entries. Drivers in the adjacent through lanes need to be aware of possible lane changes by vehicles in the left lane and possible impedence from the entering vehicles and vehicles changing from the left lane. The 'mutual visibility between carriageways' criteria in Table 7.2 provides sufficient sight distance for this to occur.

Closer to the merge, but still prior to where any merging or lane changing may occur, mutual visibility allows drivers on the ramp to detect gaps in the traffic in the left through lane and judge vehicle speeds. Drivers in the left through lane are able to see entering vehicles and may have to adjust speed accordingly.

Before the end of any merge, drivers need to be able see the end of the merge and take appropriate action. This is achieved by provision of the ‘terminal visibility’ criteria in Table 7.2.

The implications of these sight distance controls are:

- Where the minor road passes over the major road (e.g. freeway) or the major road (e.g. freeway) passes under the minor road, the major road alignment should be relatively straight to avoid having to lengthen the bridge. If a minimum radius curve were used, the bridge abutment would have to be set back to provide the sight distance, thus increasing the structural cost.
- Where the major road crosses over the minor road, or the minor road passes under the major road, the entry ramp nose should be moved further downstream in preference to widening the structure unnecessarily.
- The last 60 m of entry ramp prior to the entry nose should be graded so that the right edge of the ramp lane is within 0.6 m of the level of the edge of the left traffic lane of the major road (e.g. freeway).

These requirements are based on drivers travelling on the entry ramp being able to clearly see the ramp terminal, the merge area and also have adequate inter-visibility with a driver of a vehicle in the left lane of the major road. Note that no differentiation is made between ramps and merges of major roads. The higher volumes associated with the latter are assumed to be compensated by the fact that the right-hand lane from the left approach leg does not have to merge with the left lane from the right approach leg. Further information is provided in Commentary 2.

[\[see Commentary 2\]](#)

Table 7.2: Visibility requirements at entry ramp merges and merges of major roads

Parameter limit	Visibility requirement		
	Approach to nose	Mutual visibility between carriageways	Terminal visibility
Desirable minimum	6 sec of travel at respective operating speeds on each carriageway prior to nose (1.1 m eye height to 0.1 m object height)	4 sec of travel at respective operating speeds on each carriageway prior to point where merging lanes are separated by 2 m (1.1 m eye height to 1.1 m eye height)	6 sec of travel at operating speed to any point on merge taper ⁽²⁾ (1.1 m eye height to 0.0 m object height)
Absolute minimum	4 sec of travel at respective operating speeds on each carriageway prior to nose (1.1 m eye height to 0.1 m object height)	4 sec of travel at respective operating speeds on each carriageway prior to point where merging lanes are separated by 1 m ⁽¹⁾ (1.1 m eye height to 1.1 m eye height)	6 sec of travel at operating speed to any point on merge taper ⁽²⁾ (1.1 m eye height to 0.0 m object height)

¹ Only for tunnels and low-speed non-freeway interchanges.

² In practice, this means that all of a taper type merge has to be seen prior to the nose and most of the parallel lane of a parallel type merge will be seen from the nose.

Where an entry ramp coincides with a left-hand curve, designers should be aware that:

- curves requiring greater than the maximum desirable ' f ' value must not be used as they can inhibit vehicle control (true for both right-hand and left-hand curves)
- it is difficult for an entering driver on the ramp to see approaching vehicles on the freeway because of the observation angle
- it is difficult for the entering driver to judge the length of approaching multi-combination vehicles
- vehicles approaching on the freeway can be in the blind spot of entering trucks.

A possible solution is to provide a parallel auxiliary lane to give drivers of entering vehicles more time to view vehicles in the adjacent lane, select a gap and merge safely. This should be applied to situations where the curve radius is less than 900 m and is a desirable requirement on all entry ramps where the operating speed on the major road is greater than 80 km/h.

7.5 Safe Intersection Sight Distance

For rural situations, sight distances relating to the external approaches to interchange ramp terminals should be based on a 2.5 seconds reaction time. However, because drivers travelling within the interchange should be alert, sight distance, based on a reaction time of 2.0 seconds may be used on the minor road intersection approaches between the ramp terminals. The sight distance on external approaches to urban interchanges may be based on a reaction time of 2.0 seconds and in constrained situations 1.5 seconds may be acceptable. Refer also to *AGRD Part 3* (Austroads 2010b) for information on reaction times.

Approach sight distance

Desirably, approach sight distance (ASD) should be applied to all approaches of at-grade intersections. As a minimum, ASD should be provided on the ramp approaches to at-grade intersections. ASD should comply with the guidelines provided in *AGRD Part 4A* (Austroads 2010a). At roundabouts, ASD should be provided on all approaches in accordance with criteria 1 contained in *AGRD Part 4B* (Austroads 2015c).

Minimum gap sight distance

Minimum gap sight distance (MGSD) should be provided on all terminating legs at unsignalised intersections in accordance with Section 3 of *AGRD Part 4A* (Austroads 2010a). Desirably, MGSD should be provided at all signalised intersection approaches in the event of signal failure.

For roundabouts, criteria 2 sight distance (similar to MGSD for unsignalised intersections) and criteria 3 sight distance should be provided in accordance with *AGRD Part 4B* (2015c).

Safe intersection sight distance

Safe intersection sight distance (SISD) should be provided on all terminating legs at unsignalised intersections in accordance with *AGRD Part 4A* (Austroads 2010a). Desirably, SISD should be provided at all signalised intersection approaches in the event of signal failure.

Spread diamond interchanges are impracticable in urban areas because they require a large area of land. Consequently urban service interchanges are usually closed diamond interchanges because they consume less land than spread diamonds. A characteristic of closed diamond interchanges is that the ramp terminals are relatively close to the bridge abutments and hence the SISD may be restricted by bridge barriers (minor road over) or the abutments (minor road under).

8. Horizontal Alignment

Detailed guidelines for the design of horizontal alignment are covered in *AGRD Part 3* (Austroads 2010b). This section discusses aspects that have specific relevance to interchange design.

8.1 Major Road

The major road (e.g. freeway) horizontal alignment near an interchange should desirably be either straight or a large radius curve in order to ensure that sight distance requirements in the vicinity of exit and entry ramp terminals can be met.

At urban interchanges, constraints on land acquisition may lead to the major road alignment through the interchange being on a smaller than desirable curve. In such cases it is most desirable to ensure that sight lines to exit and entry ramps are adequate and that exit signage is prominent and located in the appropriate position.

8.2 Minor Road

8.2.1 Curvature

Where the minor road (i.e. relatively less important) overpasses the major road (e.g. freeway), the crossing should be nearly square and the alignment through the interchange should be as straight as possible. If the minor road must be on a curve, the radius should be as large as practicable. Reasons for this include:

- curved structures cost more than straight structures
- curved box girder bridges are difficult to be widened
- the curvature restricts sight distance from the exit ramp across the structure on the inside of the curve, and it is sometimes necessary to widen the bridge or provide a splay to meet sight distance requirements, and this is costly
- superelevation on a curved bridge
 - can adversely affect sight distance on one of the ramps
 - adds significantly to the difficulty and cost of construction
 - may cause instability of trucks turning from exit ramps or onto entry ramps in some cases.

8.2.2 Spread Diamond Interchanges

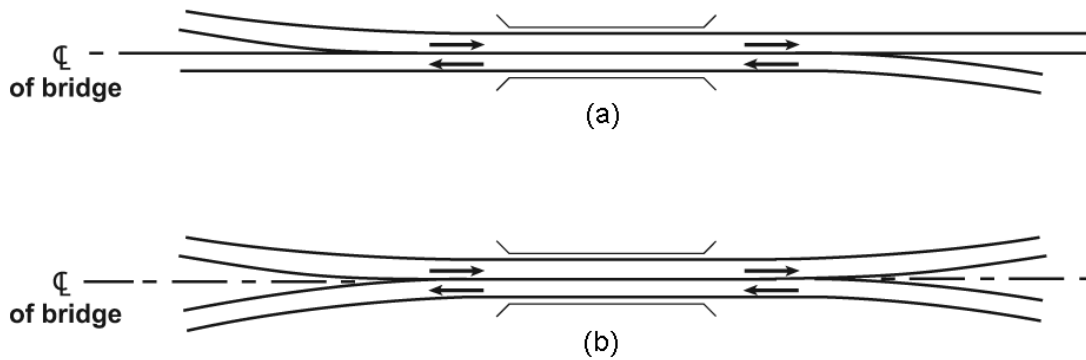
On spread diamond interchanges where the minor road is a two-lane two-way road and passes over the major road (e.g. freeway), painted or raised medians are developed on each approach to the structure to allow for protected right-turn lanes at the ramp terminals. Deviation of traffic lane alignments is required to accommodate these medians.

There are two acceptable ways of developing the shift in alignment:

- deviate the road alignment on the approach side of the structure where it is clearly visible to drivers (Figure 8.1(a))
- spread the deviation so that approximately half is developed on each side of the structure (Figure 8.1(b)).

It is not acceptable to provide a straight alignment on the approaches to and across the structure and deviate the alignment by a full lane width on departures from the bridge as drivers travelling across the overpass on a crest curve may not expect such an abrupt change in alignment.

Figure 8.1: Alignment of minor road traffic lanes – spread diamond



Source: Department of Main Roads (2005)⁵.

For option (a), the radii should be as large as practicable and there should be good delineation on the approaches to the bridge. This layout has the advantage that the deviation is clearly presented to approaching drivers on a rising grade to the overpass and that vehicles travelling on a crest curve leave the overpass on a straight alignment. A minor disadvantage is that all the necessary deviation takes place on the immediate approach to the end of the rigid bridge safety barrier.

For option (b), where vehicles must deviate on leaving the overpass, curves on the far side of the structure with adverse crossfall should have a radius of at least 3000 m, with 4000 m being desirable. On the approach side, radii should suit the operating speed.

An advantage of option (b) is that it enables the required separation between carriageways to be developed in minimum distance. It should not be used as a means of reducing the distance between the structure and the ramp terminal. The position of the ramp terminals should satisfy SISD requirements and longitudinal grade requirements with respect to the stability of heavy vehicles turning left or right.

On balance, option (a), is preferred from a safety perspective as some drivers may not expect an alignment shift on the departure from the bridge, over a crest curve. As the minor road usually passes over the major road on fill embankments safety barriers are necessary on the bridge approaches for both options (a) and (b).

Alignment shifts should be developed using curves with radii which are consistent with the operating speed of the road (refer to *AGRD Part 3* (Austroads 2010b)). Adverse crossfall on the curves should be avoided. Where adverse crossfall cannot be avoided it should be limited to 2.5% and used only with a suitably large radius that is consistent with the crossfall and operating speed.

⁵ Department of Main Roads (2005) has been superseded and Figure 7.2 has not been carried forward into Department of Transport and Main Roads (2014).

8.3 Ramps

8.3.1 General

When the form of the interchange has been determined, the ramps should be designed on alignments and to standards that suit the particular location. The design of the ramp should be determined by the physical limitations of the site, the traffic pattern, traffic volume, design speeds, topography, intersection angle, type of ramp terminal and the necessity or otherwise of reducing the amount of land required. Whatever the shape of the ramp, the requirements with respect to design speed, sight distance and terminal intersection design should be achieved.

Ideally, the alignment should have the exit ramp on an up-grade and the entry ramp on a down grade to assist drivers to decelerate and accelerate, particularly the drivers of heavy vehicles.

8.3.2 Geometric Requirements

Table 8.1 provides a guide to the geometric requirements of ramps for various design speeds.

Table 8.1: Geometric requirements for ramps

Design control characteristic	Value when design speed of element ⁽¹⁾ (km/h) is:								
	40	50	60	70	80	90	100	110	120
Desirable maximum superelevation (%) ⁽²⁾	6	6	6	6	6	6	6	6	6
Desirable minimum radius of horizontal curvature (m) – desirable min. <i>f</i> values ⁽³⁾	35	55	95	155	230	340	440	530	670
Maximum superelevation (%)	7	7	7	7	6	6	6	6	6
Minimum radius of curvature (m) – using maximum <i>f</i> values ⁽³⁾	30	50	75	105	160	245	360	530	670

1 Values given exclusive of intersection roadways at ramp terminals.

2 Higher values may be used in constrained circumstances with an absolute maximum of 10%.

3 Refer to AGRD Part 3 (Austroads 2010b).

8.3.3 System Interchanges

System interchanges are normally provided only between two freeways or significant rural divided highways. The ramps within these interchanges are semi-direct or direct (refer to Section 3.1) and are designed for a high speed (≥ 80 km/h). However, where physical or economic constraints exist it may be necessary to provide loop type ramps that are designed to a lower operating speed (e.g. 50–70 km/h). The alignment design of direct and semi-direct ramps is based on the principles and guidance provided in *AGRD Part 3* (Austroads 2010b) and typically consists of a series of curves and tangents.

Terminals on these ramps are designed as diverges and merges, both between the ramp and the major through roads and between ramps (i.e. two ramps may join before merging onto the major road).

Loop ramps are sometimes provided within system interchanges (e.g. cloverleaf interchanges) in which case a collector-distributor road should be used to control driver speeds and behaviour, particularly on the approach to the exit loops. Without collector-distributor roads, weaving movements are introduced on the major road, signing becomes difficult and inconsistency of exit from and entry to the freeway is created.

Direct ramps

Direct ramps are exclusively for one right-turn movement (refer to Figure 3.5). These ramps provide the most direct right-turn connection between two roadways. They should only be used as part of a major fork or branch connection (refer to Section 11.2.3 and Section 11.3.6 respectively).

The operating speed on a directional ramp should desirably be no less than the operating speed of the approach on the through road minus 10 km/h. Speed drops above 20 km/h should only be provided where dictated by economic constraints, and should be accompanied by treatments to reduce speed (as given in Section 6.4.2 and Appendix A).

8.3.4 Service Interchanges

Service interchanges is a term given to an interchange between a major road (e.g. freeway) and a (relatively) minor road of lesser importance where traffic entering and leaving the minor road does so through at-grade intersections at the ramp terminal with the minor road. In many cases, the form of intersection at the minor road terminal will most appropriately be a roundabout but the individual circumstances at each location will dictate the final form of the intersection. In urban areas, the intersection will usually be signalised if a roundabout is unsuitable.

Service interchanges may have diagonal ramps or loop ramps (refer to *AGTM Part 6* (Austroads 2013a)). The most common form of interchange is the diamond interchange, which may be a spread diamond or a closed diamond.

Diagonal ramps

Spread diamond interchanges are usually associated with rural areas as land is relatively inexpensive and hence the terminals are located a significant distance from the centreline of the major road (e.g. 250 m). That is, the terminals are 'spread' apart by up to 500 m, depending on whether the major road is depressed below the natural surface. This approach is taken to minimise the earthworks and hence cost of constructing fill embankments whilst meeting other design requirements.

Spread diamond interchanges, therefore, typically have ramps with a horizontal curve beyond the exit nose from the major road to encourage drivers leaving the major road to reduce speed by about 20 km/h and may have a second curve to further reduce speed. It is important, however, that the immediate approach to the ramp terminal is straight with adequate sight lines above the formation.

Closed diamond interchanges are usually associated with urban sites where land is at a premium and expensive. The terminals are located relatively close to the overpass or underpass, hence the name. The ramp alignment is usually relatively straight.

The ramp length is a function of the relative levels of the major road, the natural ground and the terminals at the minor road, as well as the distance a terminal is from the major road centreline. It is also dependent on acceleration distance for entry ramps and deceleration distance and vehicle storage requirements for exit ramps.

Typical exit ramp length is 300 to 450 m with a minimum of 200 m past the exit nose. However, the length is a function of the type of interchange and Table 8.2 can be used as a starting point for preliminary design purposes.

Table 8.2: Trial exit ramp length for diamond interchanges

Trial exit ramp lengths ⁽¹⁾ (m)		
	Minor road over major road	Major road over minor road
Closed diamond	200–300 (270) ⁽²⁾	350–450
Spread diamond	250–400 (300) ⁽²⁾	

1 The length of the ramp is measured from the nose to the intersection with the minor road – the values in the table are rounded approximate values.

2 The figures in brackets are suggested lengths as a first estimate of the nose location. These lengths should be increased by 30 m if the ramp is located on the outside of a superelevated curve.

On a flat entry ramp that is 300 m long an average truck can accelerate from a stop to about 50 km/h to 60 km/h and the speed decrement at the merge is excessive. It is often impractical to provide very long entry ramps and hence they should generally be in the range of 300 m to 450 m. As a general principle it is preferable to provide an auxiliary lane on the freeway at the entry rather than a longer ramp in order to provide a satisfactory distance for acceleration to occur and vehicles to merge with traffic on the major road (refer to *AGRD Part 4A* (Austroads 2010a) for acceleration distances for cars and guidance on treatment of trucks).

For ramps where there is a significant number of trucks and an uphill grade (e.g. in excess of 3%) the provision of two lanes on the ramp may be considered to allow light vehicles to overtake trucks (refer to Section 5.2).

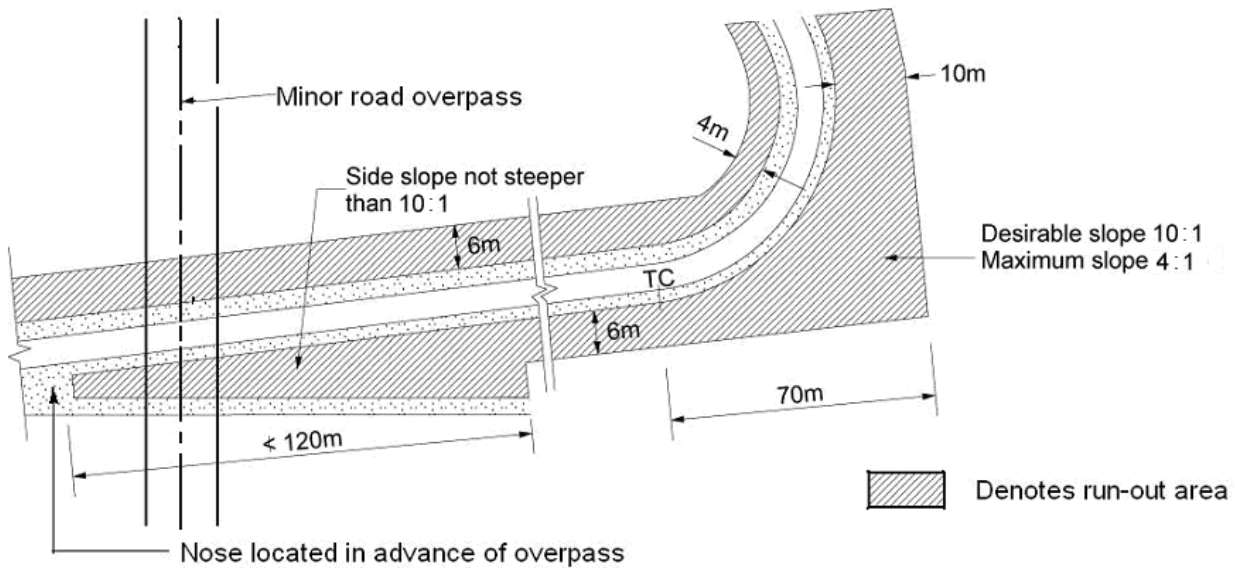
Exit loop ramps

Where exit loops are used at service interchanges and the minor road passes over the major road, the exit ramp from the major road is located under the overpass at the abutment. In such cases:

- The ramp nose should be located in advance of the overpass structure so that it is not obscured by the bridge abutment (Figure 8.2). For cloverleaf interchanges, a collector-distributor road should be used to provide for this.
- The ramp alignment should be straight for a distance past the nose and under the abutment to allow drivers to see an adequate length of curve on the loop (about 5° of field of view).
- The length of ramp between the nose and loop should be adequate to enable drivers to comfortably decelerate to the operating speed of the loop (refer to *AGRD Part 4* (Austroads 2009a) for deceleration distances).
- An alternative treatment using a series of speed reduction curves to progressively reduce vehicle speeds should be considered (Appendix A).
- Spiral transition curves should not be used on the approaches to loop ramps as drivers approaching the loop tend to overestimate the safe speed of the curve because the spiral changes the driver’s perception of the approaching curve radius.

The general minimum radius for an exit ramp loop is 55 m, with an absolute minimum radius of 35 m, the larger value being preferred where it is necessary to use a minimum value for high-speed freeway interchanges (refer to Table 6.1 for appropriate usage). Loops of radius greater than 80 m are not generally used since the faster speed around the loop is negated by the extra distance travelled, and the greater area of land that is required.

Figure 8.2: Exit loop and run-out area



Source: Department of Main Roads (2005)⁶.

Because of the significant difference in speed of the through road and the loop, drivers may approach the curve of the loop at too great a speed. Loss of control can occur and is most likely in the first 80 m of the loop. A run-out area should be provided around the outside of the loop as shown in Figure 8.2 and should be free of obstructions and hazards. If a driveable area cannot be provided as shown, a road safety barrier should be installed around the outside of the curve.

Where the major road passes over the minor road the exit loop may be on a downhill gradient and measures to slow the approach speed of vehicles are even more important. In this case the nose is likely to be a short distance beyond the abutment of the overpass with the ramp disappearing down to the driver's left. Other cues and measures such as high fencing will be required to delineate the shape and location of the loop.

Entry loop ramps

For entry loops, the minimum radius should be 55 m but in urban areas in confined conditions, radii as low as 30 m can be used provided the maximum grade criteria in Table 9.3 are met. If the exit speed from the minor road exceeds 60 km/h, the layout of the approach to the loop should be similar to that in Figure 8.2 but adapted to the minor road.

⁶ Department of Main Roads (2005) has been superseded and Figure 8.2 has not been carried forward into Department of Transport and Main Roads (2014).

9. Vertical Alignment

Detailed guidelines for the design of vertical alignment are covered in *AGRD Part 3* (Austroads 2010b). This section discusses aspects that have specific relevance to interchange design.

9.1 Major Road

9.1.1 Grading Options

There are basically two grading options: the major road (e.g. freeway) over the minor road or the reverse, including the situation where either the freeway or the secondary road is depressed into the natural surface (fully or partially). Factors affecting the choice of options are summarised in Table 9.1.

Table 9.1: Factors affecting configuration of interchange

Factor	Comment
Topography	Desirably, the major road (freeway) should be designed to match the terrain and minimise visual intrusion. As the geometric standards used on the minor road are lower than on the major road, it is commonly easier and less visually intrusive to grade the minor road over the major road on flat terrain than the reverse.
Adjacent development	In developed urban areas, the major road (freeway) usually has to be graded to minimise disruption to local development. Overpass structures may be acceptable in industrial areas but in residential areas they may be considered by residents as visually intrusive and an invasion of privacy. A fully depressed major road avoids visual intrusion and provides some noise attenuation.
Trucks	The major road (freeway) depressed under minor road arrangement is advantageous where the number of trucks is significant because the downhill entry ramps shorten the distance required by the trucks to achieve freeway speeds. Also, uphill exit ramps assist truck braking.
Noise	In urban areas, a major road (freeway) located below the adjacent land and under a minor road may be preferable because major road noise is minimised. For the alternative arrangement, noise attenuation walls may be installed.
Construction staging at an interchange	An elevated major road (freeway) minimises disruption to traffic on the minor road during construction. Where the minor road passes over the major road the disruption may be minimised by building the overpass on a new alignment.
Economy	The relative economy of the two options depends on the topography, the number of lanes on the major road and the minor road and the effect on services.

The minor road over major road option is generally cheaper for interchanges with roads that are not arterial roads. Assuming that the reservation width is based on the ultimate major road (e.g. freeway) cross-section, future additional major road lanes can be constructed without affecting the bridge.

Where the minor road (relatively) is a major arterial road, the freeway-over option could be cheaper because the cross-sections are comparable and it is less disruptive to existing traffic. In this case, allowance should be made in the initial structural design for the bridge widening required in the future.

9.1.2 Grading Controls

The method of determining the critical grading controls is described in *AGRD Part 3* (Austroads 2010b). Once the controls have been determined, the grading of the surface road can be determined.

If a crest vertical curve is used on a straight approach to a ramp nose, the minimum permissible radius of the crest curve must meet the required sight distance requirement for the design speed being used.

The lowest level of the interchange is usually controlled by gravity drainage outlets or flood levels. Pumped drainage should be avoided except in extremely constrained locations.

If the minor road passes over the major road (e.g. freeway), local earthworks would be balanced when the major road is cut to a depth of approximately one third of the height of the interchange. Conversely, with the major road (freeway) over the minor road, the major road grade line should be located at approximately one third of the height of the interchange above the natural surface. Designers should aim for a slight surplus of about 8 to 10% of the earthworks, rather than a strict balance to accommodate possible unsuitable materials, which can be disposed of on-site relatively easily. It is recognised, however, that the need to balance earthworks and work within other controls over a long length of major road (freeway) also affects the levels of interchanges.

9.2 Minor Road

9.2.1 Closed Diamond

Figure 9.1(a) and (b) show two grading arrangements that are often used for closed diamond interchanges; the major road partially depressed below the natural surface and the major road fully depressed. Other arrangements may be adopted depending on the surrounding topography.

An essential feature of the closed diamond interchange is location of the ramp terminals on the crest vertical curve. ASD should be provided on the approaches to the terminals, which are also on the crest vertical curve. SISD will be achieved if ASD is provided on a crest vertical curve. As SISD should also be provided on each approach, the crest vertical curve should be extended for a distance equal to SISD on each approach.

Any terminal located within the minimum vertical curve will provide the required sight distance across the structure. If SISD is not available from the exit ramp terminal across the structure, then the options available include widening the structure, designing a splay on the structure or its approach, or moving the ramp terminals further away from the structure.

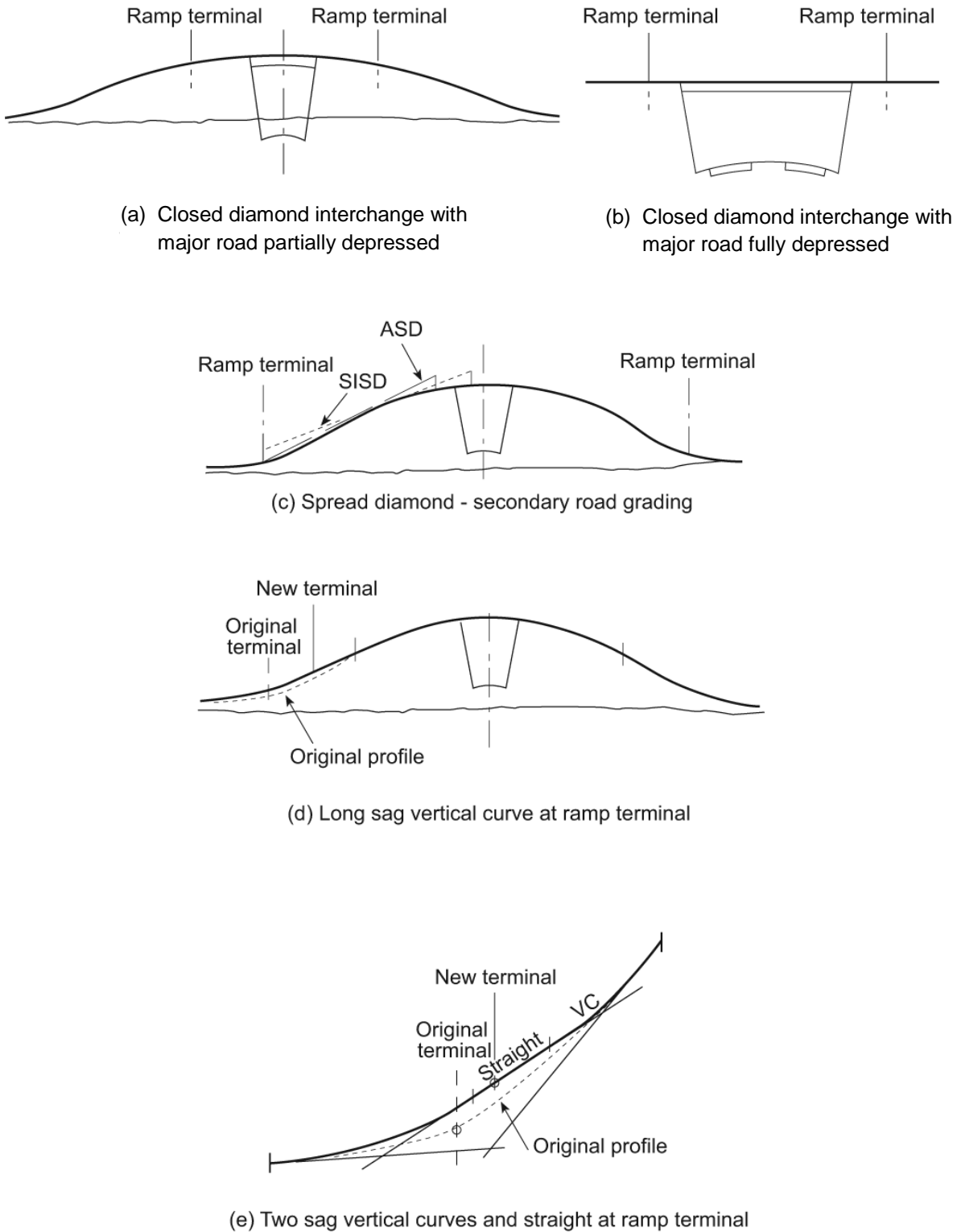
The minimum length of the vertical curve is controlled by ASD (and SISD will therefore be provided). Shorter vertical curves are not acceptable.

Where a closed diamond is adopted and the major road passes over the minor road it is important to ensure that appropriate sight distance along the minor road from the exit ramp is not obscured by bridge abutments, piers or safety fences. These sight distance requirements should be provided even if the ramp terminals are signalised.

9.2.2 Spread Diamond

A typical spread diamond where the minor road passes over the major road and ramp terminals are located on sag curves is shown in Figure 9.1(c) and (d). The geometric standards of the vertical curves are defined in terms of 'K' values (refer to *AGRD Part 3* (Austroads 2010b) for explanations of 'K' values).

Figure 9.1: Typical grading at diamond interchanges



Source: Department of Main Roads (2005)⁷.

⁷ Department of Main Roads (2005) has been superseded and Figure 9.1 has not been carried forward into Department of Transport and Main Roads (2014).

Interchanges should desirably be designed to meet all sight distance requirements for the operating speed of the road. In the case of spread diamond interchanges where the minor road passes over the major road it may be appropriate to consider values for some of the parameters of the stopping sight distance model that are towards the lower end of the normal design domain. Parameters that may be considered include the reaction time (e.g. 1.5 or 2.0 seconds, depending on the environment around the interchange and the likelihood that drivers will be more alert) and the coefficient of deceleration (e.g. 0.46 for specific road types and situations). Alternatively, it may be appropriate to reduce the speed limit through the interchange on the minor road to an acceptable value, depending on the approach speed on the minor road. The reduction in posted speed should not be more than 20 km/h. In such cases, the operating speed will tend to be about 10 km/h above the speed limit.

Selecting a crest vertical curve based on such values enables the interchange design to be more compact with the result that:

- ramp terminals have a closer spacing and less land acquisition is required
- earthworks and other construction costs are less
- SISD is more easily achieved.

Under normal circumstances use of the vertical geometry described above and shown in Figure 9.1 will ensure that the (SISD) standards at the ramp terminals are met (refer to *AGRD Part 4* (Austroads 2009a)).

Designers should check that SISD is not restricted by guard fence, bridge railing, or the likely locations of signs or sign posts.

When the minor road is curved, sight distance in the vertical plane is slightly increased on the inside of the curve (low side) and is more likely to be reduced on the outside of the curve (high side). In view of the curvature effect, the minimum *K* value should be used only for the initial concept design of curved overpasses. The sight distance should be checked from the preliminary design plans and, if necessary, appropriate corrections should be made to the vertical geometry to meet the sight distance requirements.

The grading of the minor road shown in Figure 9.1(a) and the ramp grading controls effectively fix the location of the ramp terminals. In some cases the ramp locations obtained conflict with other controls, for example, the road reservation. In these cases suitable alternative terminal locations can be obtained using either flatter sag vertical curves as shown on Figure 9.1(d) or two sag vertical curves with a straight in between as shown on Figure 9.1(e). In specific cases, it may be advantageous to have the vertical curve asymmetrically placed around the structure.

For both types of interchanges, the following additional criteria need to be considered:

- The crossfall on the minor road may be reduced to a minimum of 2% at ramp terminals to reduce the impact of adverse crossfall on the turning movements. The crossfall on the minor road bridge structure may be reduced to match that at the ramp terminal where a suitable profile on the minor road cannot be achieved. The impact on drainage spread widths should be considered before reducing crossfall on the bridge. In general a higher crossfall on the bridge will result in less drainage facilities being required.
- The minimum vertical design speed on a ramp at the intersection with the minor road is 40 km/h.
- The maximum upgrade for at least the last 30 m from the intersecting edge of pavement for an exit ramp should be limited to 3%.

9.3 Ramps

9.3.1 Ramp Gradients for System Interchanges

The ramps on system interchanges are either direct ramps or semi-direct ramps and provide for relatively high-speed movements (≥ 80 km/h) between major arterial roads (e.g. freeways). Therefore the vertical geometry should be chosen to enable ramp traffic to move between the major roads efficiently and safely. For this reason the gradients used should accord with those used for rural arterial roads (refer to *AGRD Part 3* (Austroads 2010b)). It is recommended that the preferred maximum gradient is 3% with an absolute maximum of 5%.

The choice of gradient on these ramps should take account of the high number of trucks that use such facilities and ensure that an appropriate level of service is provided (refer to the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013d)). However, system interchanges often occur in urban areas where sites are constrained and minimum gradients may not be feasible, and as these ramps are relatively long, two-lane ramps are usually provided to enable slower vehicles to be overtaken on rising gradients.

9.3.2 Ramp Gradients on Service Interchanges

The vertical alignment of an entry ramp (i.e. sag and crest curves) should be designed for the operating speed at the point being considered. In the case of a crest vertical curve at an entry ramp, the acceleration distances in Table 11.2 can be used as a guide to determine an appropriate operating speed for the crest.

For exit ramps, the vertical alignment should be based on the likely operating speed. This can be estimated using the deceleration rates in Table 11.1 based on the mean free speed of the through road (about numerically equal to the speed limit) at the nose decelerating down to the posted speed on the diagonal exit ramp. It is preferable that entry ramps are located on a downgrade and exit ramps on an upgrade.

Diamond-type ramps

The maximum gradients for diamond ramps are shown in Table 9.2.

Table 9.2: Maximum ramp grades for diamond ramps

Ramp type	Grade orientation	Desirable	Maximum
Exit ramp	Downhill	-4%	-6%
	Uphill	+6%	+8%
Entry ramp	Downhill	-6%	-8%
	Uphill	+3%	+5%

Loop ramps

The maximum gradients for loop ramps are shown in Table 9.3.

Table 9.3: Maximum ramp grades for loop ramps

Ramp type	Grade orientation	Desirable	Maximum
Exit ramp	Downhill	-3%	-4%
	Uphill	+5%	+7%
Entry ramp	Downhill	-6%	-8%
	Uphill	+3%	+5%

10. Ramp Terminals at Major Roads

10.1 Ramp Terminal Locations

There are four requirements for ramp terminal locations:

- The longitudinal gradient of the minor road at the terminal should not exceed 2% to ensure that turning trucks remain stable.
- ASD, MGSD and SISD should be provided. MGSD and SISD should be available to ensure that vehicles turning right from an exit ramp can cross the intersection safely. Although traffic signals are usually provided at urban ramp terminals, it is considered equally as important to provide MGSD and SISD at signalised terminals for safety when signals are not operational. The provision of adequate sight distance will also improve driver confidence and hence operational efficiency of the signalised intersection.
- The spacing between ramp terminals of a closed diamond in an urban area should provide for the necessary deceleration length and storage between the ramps. This may require a wider structure to provide for overlapping right turns or double right-turn lanes. If additional right-turn storage cannot be achieved within the interchange it may be necessary to extend the storage lanes onto the external approaches. This often applies in urban situations and may adversely affect traffic signal phasing and efficiency.
- For a spread diamond interchange in a rural area the minimum terminal spacing is approximately equal to the length of the bridge plus the lengths of two right-turn deceleration lanes including the lengths required for tapers and alignment shifts.

Other factors which influence the final ramp location include:

- Capacity controls – placing ramp terminals too close to each other may result in the need for additional right-turn lanes for storage.
- Road reservation – close ramp spacing may be necessitated by tight right-of-way controls.

At closed diamond interchanges, the ramp terminals should be located to ensure that the SISD triangle is not obstructed by the bridge railing especially on curved bridges. Occasionally bridges may have to be widened or a splay provided to ensure that a clear sight distance triangle is available, but bridge widening should be avoided wherever possible because of the high cost.

The amount of bridge widening required on straight roads can be determined from the graph in Appendix B. Alternatively, this graph can be used to determine the ramp terminal location when the bridge railing location is fixed.

On curved roads ramp locations are usually determined iteratively from scale drawings.

10.2 Ramp Alignment at Minor Road Terminals

10.2.1 Exit Ramp Alignment at Minor Road Terminals

Although the main alignment of the diamond-type ramp can follow the right-turn lane or the left-turn lane, the preferred practice is that it follows the right-turn lane and the left-turn lane diverges. The location of the ramp terminal and hence right-turn lane from the minor road is covered in Section 10.1.

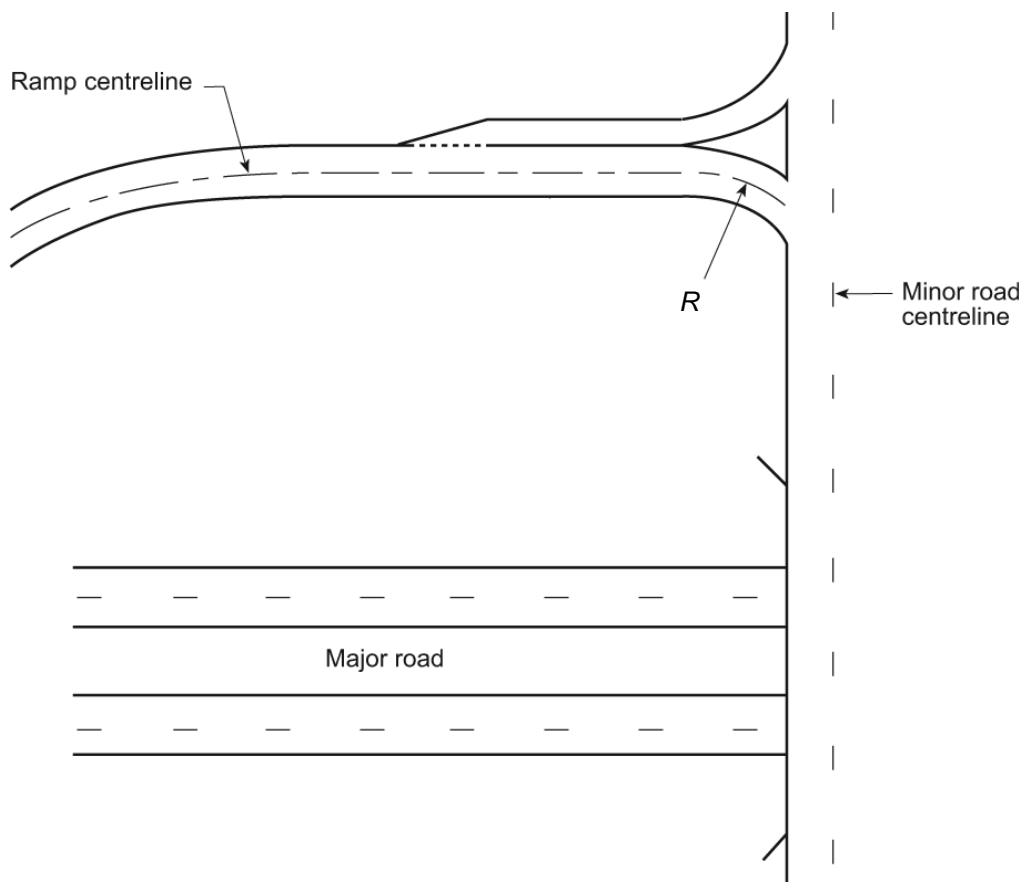
Intersection angle and curve radius

The last tangent on the ramp at a spread diamond interchange should intersect at an angle of 70° to 90° with the minor road at the terminal.

The principle to be applied is that the tangent on the approach to the terminal provides the appropriate ASD to the intersection whilst the relatively small radius for right-turners at the intersection sets up the intersection turning radius for heavy vehicles on the immediate approach.

The radius R shown in Figure 10.1 depends on the swept path of the design vehicle. In determining an appropriate radius, designers should ensure that the requirements for MGSD are achieved (refer to Section 3 of *AGRD Part 4A* (Austroads 2010a)).

Figure 10.1: Example of an exit ramp terminal



Exit ramp splitter island

The splitter island nose should be visible to approaching traffic for at least the ASD for the operating speed at that location. The island should be extended back over a crest vertical curve if applicable, to warn motorists of the approaching intersection.

The left-turn slip lane should be designed in accordance with the *Guide to Road Design Part 4: Intersections and Crossings – General* (Austroads 2009a) to ensure, in particular, that the driver observation angle is satisfactory. The right-turn and left-turn lanes should be clearly delineated to avoid any driver confusion.

On urban interchanges where two ramp lanes are required for the right turn, a relatively sharp taper (Equation 1) may be used to develop the left-turn lane, and where necessary a parallel lane that is long enough to clear the 95th percentile queue created by right-turning traffic is added.

$$T = \frac{0.33VW_T}{3.6}$$

1

where

V = design speed of the major road approach (km/h)

W_T = width of the turn lane (m)

T = length of taper to the deceleration lane (m)

Similarly more than one lane may be required for the left-turn movement in an urban area. The layout should be developed based on traffic demand (refer to the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013d)).

Design to prevent wrong-way movements

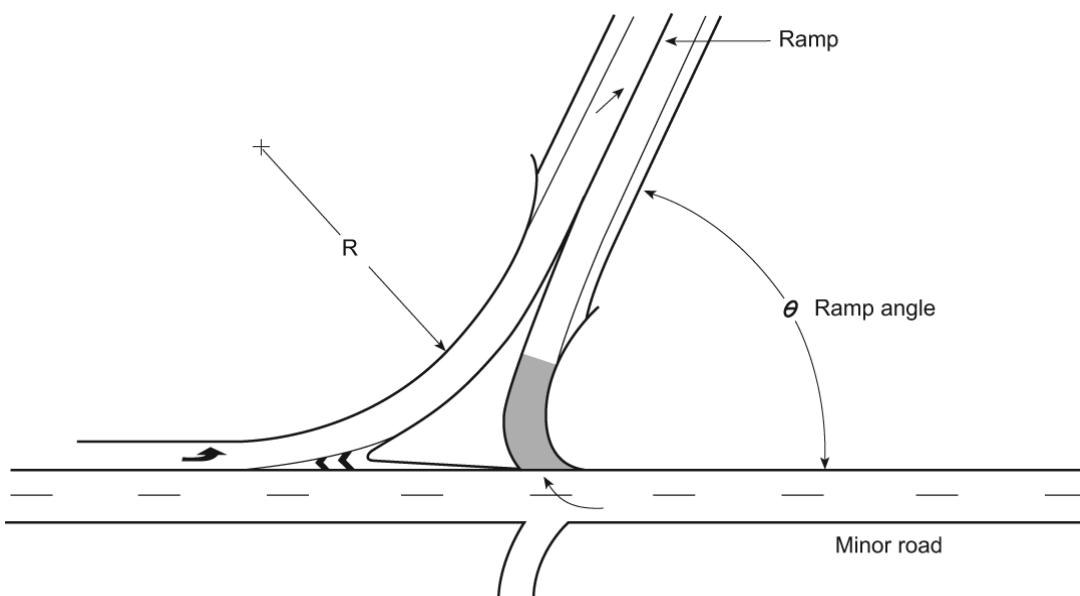
Where a diagonal ramp meets the minor road, an intersection providing for right and left turns into the minor road is required. The design of the islands and the median at the intersection should be such that wrong-way movements on to the exit ramp are positively discouraged, (refer to Figure 10.3).

10.2.2 Entry Ramp Alignment at Minor Road Terminals

The right-turn roadway

An example of an entry ramp terminal is shown in Figure 10.2. The location of the turning roadway is fixed by the vertical alignment of the minor road, the horizontal alignment of the ramp and the design vehicle turning template (external radius typically in the range of 20 to 30 m). The swept path of the template should clear the kerbs by 0.5 m on both sides.

Figure 10.2: Example of an entry ramp terminal



To facilitate recognition of the entry ramp on spread diamonds, the width of the throat based on turning templates should be increased by a splay of 1.5 m on the inside of the curve and 1 m on the outside of the curve. On closed diamonds, the offset on the inside may have to be reduced to 1 m or 0.5 m depending on the space available (Figure 10.4).

Left-turn into entry ramp

Desirably a left-turn lane into an entry ramp should be formed from a single left-hand curve or a curve followed by a straight, assisted by positive superelevation. Reverse curves should only be used where approach speeds are low. The radius of the left turn is related to the angle of the ramp to the minor road θ (refer to Figure 10.2). In rural areas it may be desirable to allow a relatively high-speed left turn onto the ramp. However, in urban areas where pedestrians cross at the terminal the operating speed of the left turn should be relatively low (e.g. 20 to 30 km/h).

10.3 Ramp Terminal at Minor Road

At diamond interchanges, provision should be made for straight through movements at ramp intersections where the ramps may be used to accommodate oversize loads (including high wide-load routes) that cannot go under interchange bridges. Making provision for straight through movements at diamond interchanges also enables the use of the ramps as a detour in the case of an emergency or for maintenance/construction on the through carriageway.

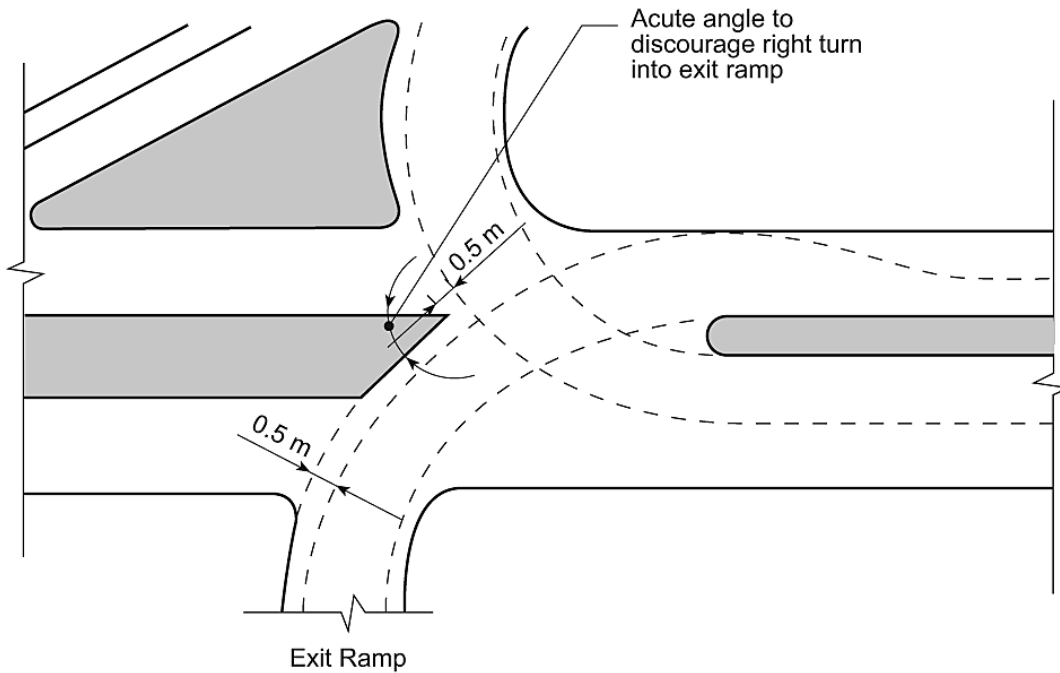
At urban interchanges the major road may be used as a bus route with a passenger interchange at the minor road terminal. In these cases bus stops should be accommodated in the design (e.g. within traffic islands) and the design and signal phasing should enable a bus to conveniently move from the exit ramp to the entry ramp so that it can re-enter the major road.

Figure 10.3 shows an illustration of a minor road ramp terminal and involves both the exit ramp and entry ramp. The shape of the terminal is defined by the design vehicle for the particular location. On freeway interchanges the design vehicle may be a semi-trailer or B-double. A checking vehicle at least one size larger than the design vehicle should also be applied to the design.

Minor road ramp terminals provide for left-turn and right-turn movements from the exit ramp and into the entry ramp. They should be designed in accordance with the general principles of intersection design contained in *AGRD Part 4A* (Austroads 2010a) and, in the case of roundabouts, *AGRD Part 4B* (Austroads 2015c).

A critical aspect of the design is the median nose in the minor road, which should be shaped to discourage wrong-way right-turn movements into the exit ramp. However, the design for the right turn from the exit ramp should clearly direct this movement into the correct carriageway of the minor road.

Figure 10.3: Minor road terminal treatment to prevent wrong-way movement



Source: Adapted from Department of Main Roads (2005)⁸.

The right turn into the entry ramp is generally a more restricted turn than the left turn into the ramp. It is important to ensure that the turning roadway at the throat of the entry ramp is wide enough to accommodate the design vehicle, and that the checking vehicle can traverse the intersection (refer to *AGRD Part 4A* (Austroads 2010a)).

The left-turn radius can be made much larger than the right-turn, particularly in rural locations, since the orientation of the ramp will favour this movement. In urban situations it is usually not desirable to provide a large radius for left-turning movements because of the increased crash risk in general and particularly with respect to pedestrians and cyclists.

As described in *AGRD Part 4A* (Austroads 2010a), the design of any unsignalised left turn should be either a high entry angle design or a design with a full acceleration lane. Treatments with a simple merge taper should not be used.

In urban situations, higher-speed left turns should not be used unless a signalised crossing is provided for pedestrians. Where pedestrians are required to cross left-turn roadways, a smaller radius should be used to control the speed of potentially conflicting vehicles.

Also, at unsignalised terminals on spread diamonds where the ramp slopes down with the normal crossfall of the minor road, strips of concrete paving 1.5 m wide should be provided behind the kerb on both sides of the approach curve leading into the entry ramp. Only a short section of kerb is required on the right-hand side. A 1.5 m wide sealed shoulder should be provided beyond the section with kerbing (Figure 10.4).

⁸ Department of Main Roads (2005) has been superseded and Figure 10.3 has not been carried forward into Department of Transport and Main Roads (2014).

The shoulder and concrete apron on the right-hand side of the curve allows for surface drainage and ensures that sight distance to the turning roadway is not obscured by grass. The concrete paving on the left side of the roadway provides improved delineation and should be graded upwards at 10% or steeper to ensure that the paving is visible for a car driver on the minor road 100 m from the turn lane (Figure 10.5). Concrete strips are not required where traffic signals are provided.

Figure 10.4: Details of paved aprons

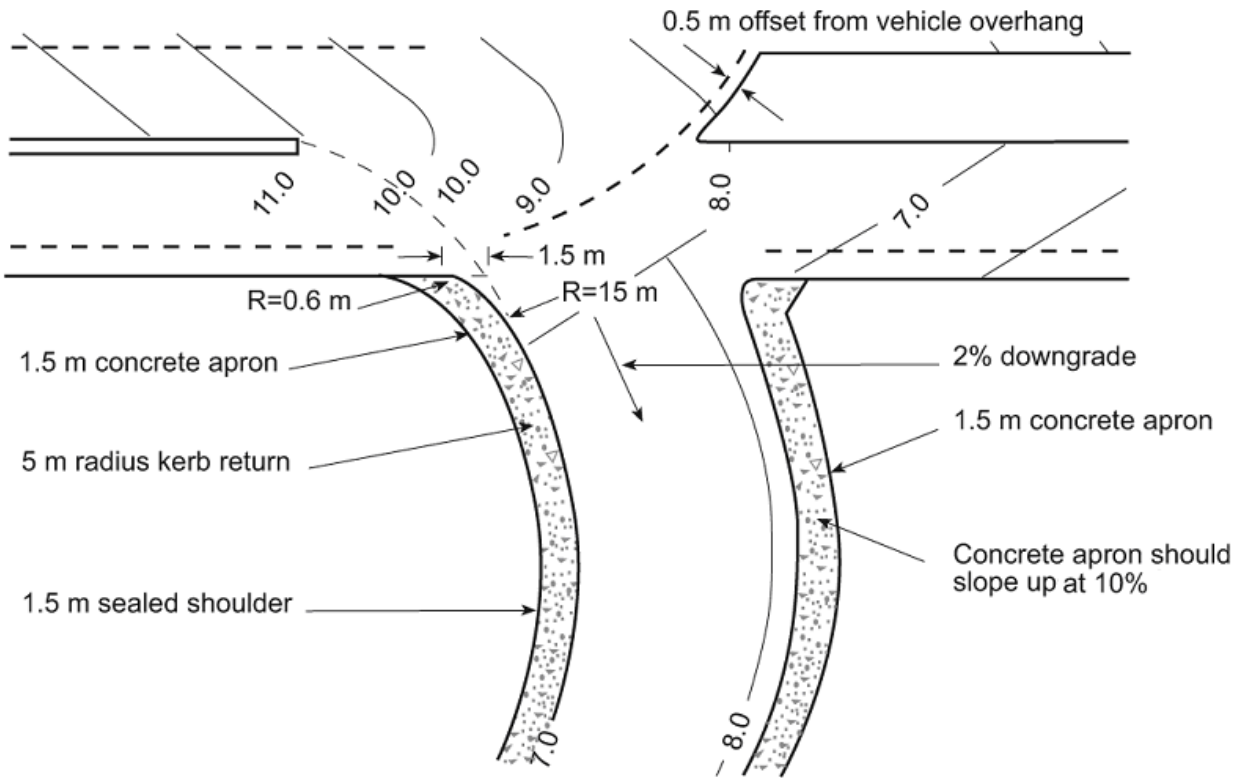
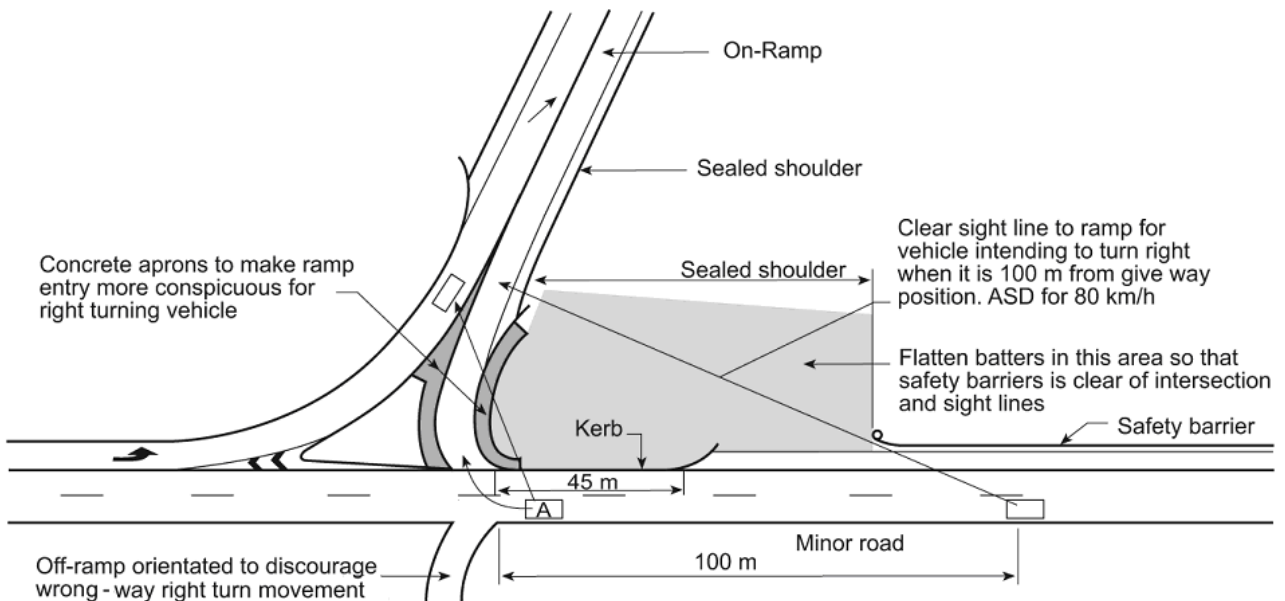


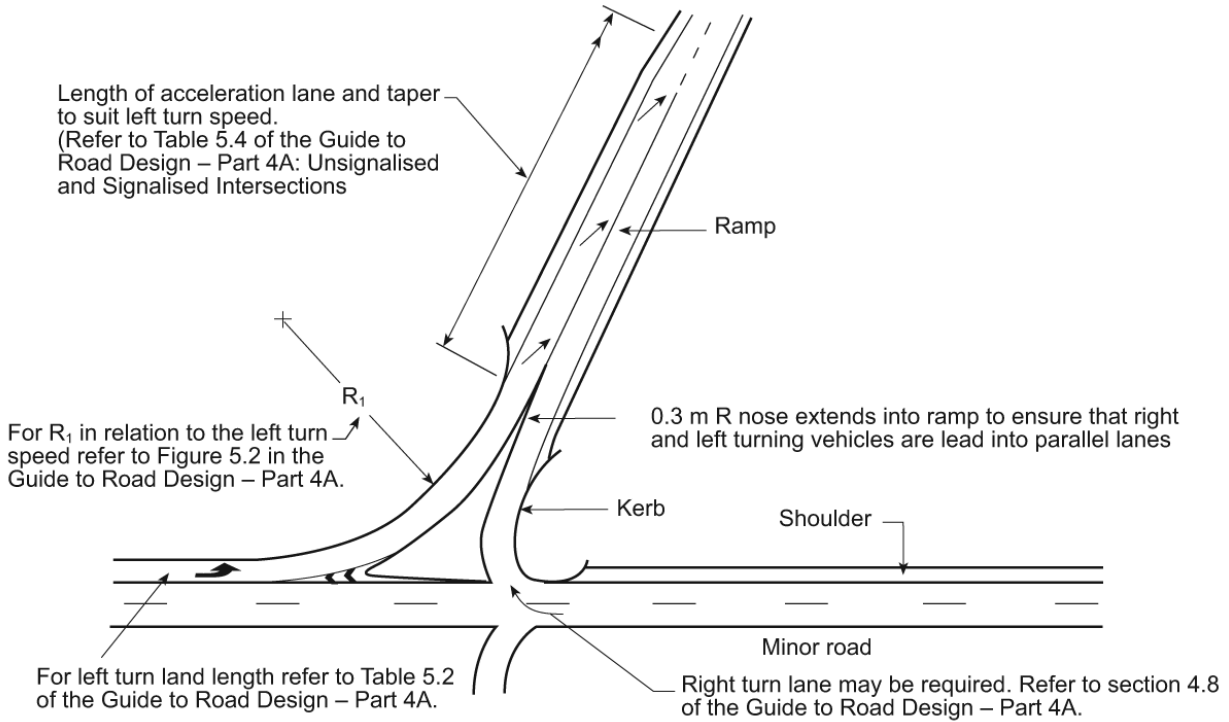
Figure 10.5: Sight lines on entry ramps for spread diamond interchanges



- Notes:
1. Vehicles on left turn road way must be visible to driver of Car A
 2. Kerb opposite off-ramp extends for 45 m to discourage right turning heavy vehicles from off-ramp encroaching onto verge.

The entry ramp island departure nose should be long and narrow to ensure that right-turning traffic is directed into a lane that is separate from and parallel to the left-turn lane (and hence does not cut across the path of traffic from the left-turn slip lane, refer to Figure 10.6). Alternatively the left-turn slip lane should be designed with a high entry angle.

Figure 10.6: Left-turn island for diamond interchange



A safety barrier should not be used within 70 m of the entry ramp in order to ensure that the right-turning roadway into the entry ramp is not obscured. Flatter batters should be used in this area to avoid the need for safety barrier. Desirably the full length of the right-turn roadway and merge area on the entry ramp should be visible from the departure end of the right-turn lane on the minor road. Also, sight distance should be available from the end of the right-turn lane on the minor road to traffic approaching in the left-turning roadway on the approach to the merge area (i.e. short crest vertical curves that restrict sight distance should be avoided).

11. Ramp Terminals at the Major Road

11.1 General

The ease with which vehicles can enter or leave the major road determines the traffic flow characteristics in the interchange area, and the efficiency of the major road operation and the capacity of the ramps depend largely on the ramp terminal designs at the major road. While the design principles applied to ramp terminals are consistent, design details may vary between jurisdictions.

A good terminal design ensures that vehicles can decelerate and accelerate without impeding through traffic. In addition, the ramp length and number of lanes on the ramp should be adequate to ensure that vehicles queued on exit ramps will not impede through traffic.

The exit ramp and entry ramp terminals at the major road (usually a freeway) are designed:

- for exit ramps as a simple diverge (but marked with a relatively sharp exit taper for recognition) where volumes are low or as a longer auxiliary lane where volumes are high
- for entry ramps as a simple merge where volumes are low, or as an auxiliary lane followed by a merge, or as an added lane which may continue to the next interchange and beyond, where volumes are high.

A simple merge is usually only suitable for rural roads where volumes are relatively low and gaps are generally available in the left lane. Where volumes are higher and speeds high an auxiliary lane should be provided. This will normally be the case on urban freeways.

The entrance to a freeway for high-speed conditions is based on providing drivers with an opportunity to merge after reaching the freeway road speed. A parallel lane adjacent to the through lanes should generally be used to assist the merge operation, both from a capacity and a safety point of view, especially at high traffic volumes.

11.2 Exit Ramps

11.2.1 Single-lane Exits

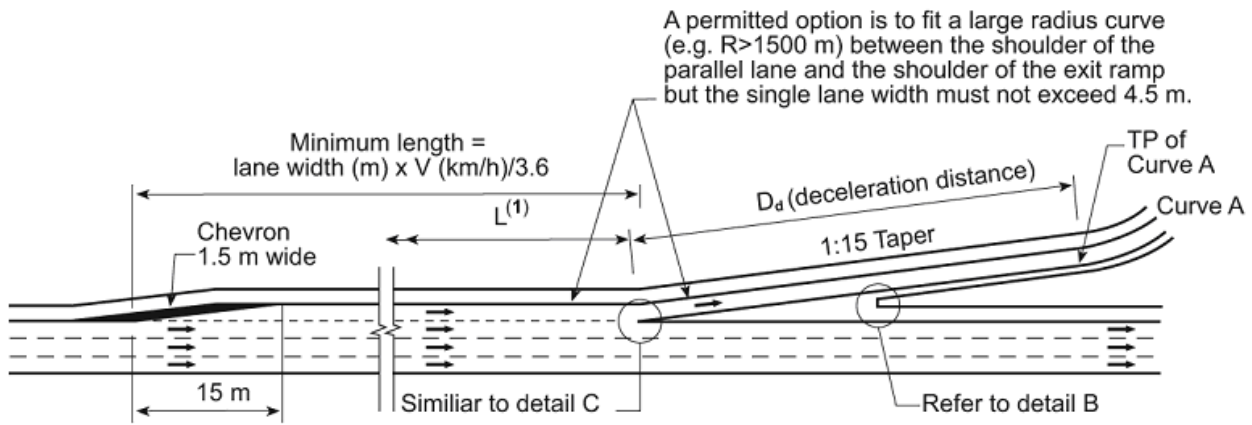
Figure 11.1 shows typical single-lane exits for interchanges for use on freeways and major divided roads. The auxiliary lane design is based on exit to the left of the through lane with deceleration occurring after the vehicle has left the through lane (Figure 11.1(a)). Figure 11.1(b) shows the minimum exit treatment that has been used for low-volume exits which comprises a simple diverge.

An auxiliary lane also emphasises the presence of the exit and this is highly desirable, particularly where the exit occurs on a right-hand curve and drivers may inadvertently enter the ramp. For the same reason exits based on a simple diverge have been marked to appear as a short parallel lane. An example of this marking is shown in Commentary 3.

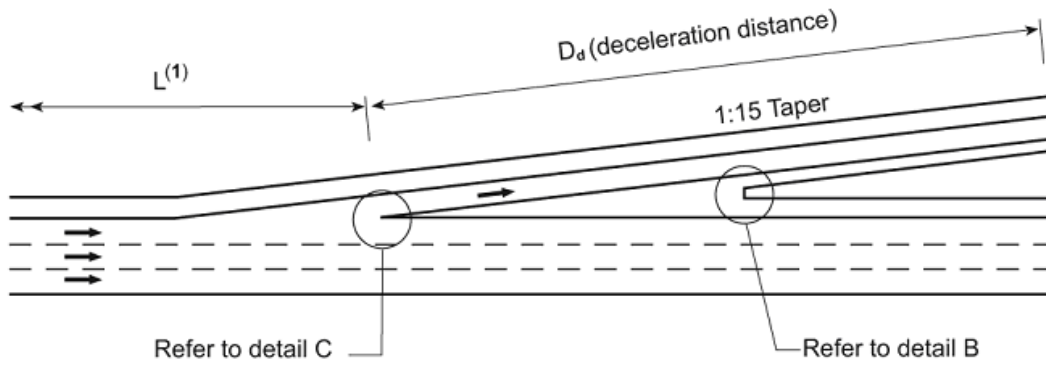
[\[see Commentary 3\]](#)

A parallel lane is the desirable minimum layout for a high-volume road or where a high level of service is required for a ramp on a freeway.

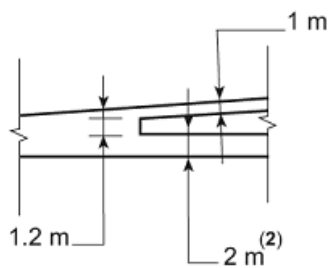
Figure 11.1: An example of single-lane exits and ramps for freeways and major divided roads



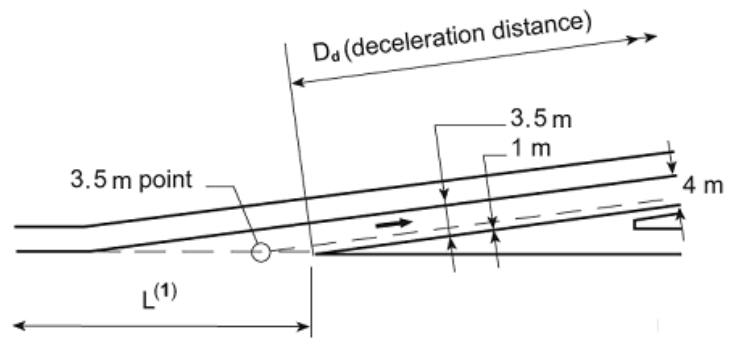
(a) Single lane exit ramp – preferred treatment



(b) Single lane exit ramp – minimum treatment



(c) Nose detail B



(d) Detail C

¹ L = distance between exit ramp and preceding entry ramp. Refer to Section 6.6.6 and Table 6.3 of AGTM Part 6 (Austroads 2013a).

² Indicative only. Refer to AGRD Part 3 (Austroads 2010b).

Source: Department of Main Roads (2005)⁹.

⁹ Department of Main Roads (2005) has been superseded and Figure 11.1 has not been carried forward into Department of Transport and Main Roads (2014).

The gore area of diverges and exits from high-speed roads should be traversable by vehicles for at least 120 m past the nose (i.e. where the pavements separate) (desirable maximum slope of 10:1 (H:V), absolute maximum slope 4:1). It is desirable to keep this area free from fixed objects but where this is not possible supports must be provided with breakaway bases. When these requirements cannot be met, appropriate protection should be provided to shield the driver of an errant vehicle. Energy absorbing barriers are the most effective devices where a rigid object is located in this area (refer to the *Guide to Road Design Part 6: Roadside Design, Safety and Barriers* (Austroads 2010c)). The deceleration distance (D_d) is shown in Figure 11.1 whilst the values of D_d are provided in Table 11.1¹⁰ together with adjustments for gradient.

Table 11.1: Deceleration distance D_d for cars and adjustment for grade

Design speed of curve A (km/h)	D_d (m)					Adjustment for grade ⁽²⁾		
	Design speed of through road ⁽¹⁾					Grade (%)	Ratio of length on grade to length on level	
	80	90	100	110	120		Upgrade	Downgrade
30	85	110	140	175	210			
40	75	100	130	160	200	0 to 2	1.0	1.0
50	60	85	115	150	185	3 to 4	0.9	1.2
60	45	70	100	130	170	5 to 6	0.8	1.35
70	25	50	80	110	150			
80	0 ⁽³⁾	25	55	90	125			

¹ The design speed of the through road must at least equal the mean free speed (about numerically equal to the posted speed).

² D_d values shown in the table are for level grade. Adjust for grade.

³ As the design speed of the curve and through road are the same, a deceleration distance is not required.

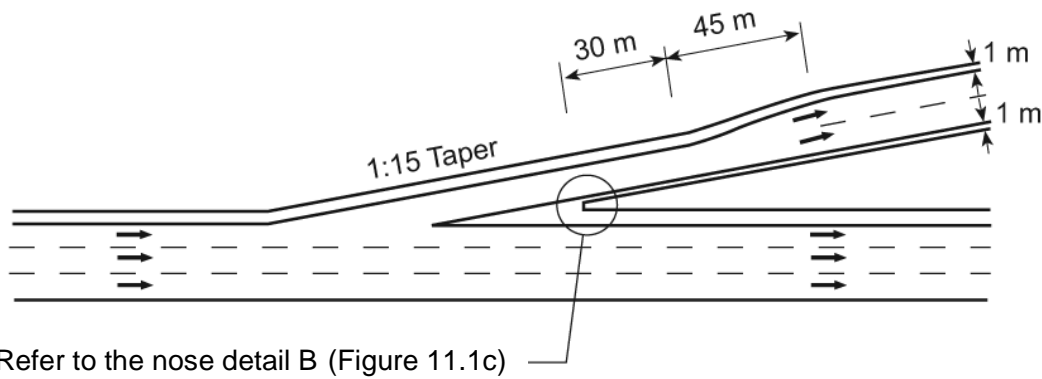
Source: Adapted from Roads and Traffic Authority (2000)¹¹.

Figure 11.2 illustrates two options for a two-lane ramp beyond a single-lane exit. It is preferred that the diverge treatment is developed on the left side of the ramp, however a diverge from the right is acceptable.

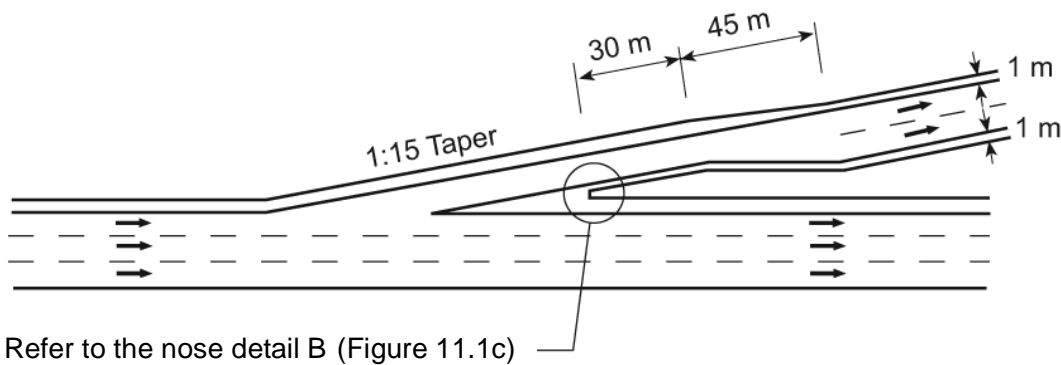
¹⁰ Roads and Traffic Authority (2000) has been superseded and not all information was carried forward into Roads and Maritime Services (2015).

¹¹ Roads and Traffic Authority (2000) has been superseded and not all information was carried forward into Roads and Maritime Services (2015).

Figure 11.2: Single-lane exit with two-lane ramps treatments



(a) Preferred treatment – single-lane exit with two-lane ramp and left diverge



(b) Acceptable treatment – single-lane exit with two-lane ramp and right diverge

Source: Adapted from Department of Main Roads (2005)¹².

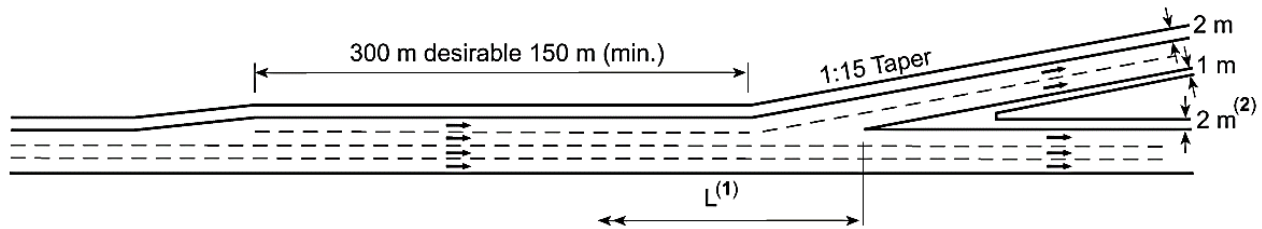
11.2.2 Two-lane Exits

Two-lane ramps with two lanes at the nose are required when warrants are met (refer to Table 6.3 of *AGTM Part 6* (Austroads 2013a)) or when traffic analysis indicates that two lanes are required to provide the necessary level of service in the design year for the interchange (refer to the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013d)).

Figure 11.3 shows a typical two-lane exit ramp with two lanes at the nose. Whilst the auxiliary lane length shown in the figure is 150–300 m on major urban freeways or freeways that carry very heavy traffic volumes these lanes may be up to 800 m long or extend to the preceding interchange.

¹² Department of Main Roads (2005) has been superseded and Figure 11.2 has not been carried forward into Department of Transport and Main Roads (2014).

Figure 11.3: An example of two-lane exit for a freeway, freeway or major divided road



1 L = distance between exit ramp and preceding entry ramp. Refer to Section 6.6.6 and Table 6.3 of AGTM Part 6 (Austroads 2013a).

2 Indicative only. Refer to AGRD Part 3 (Austroads 2010b).

Note: For nose detail, refer to Figure 11.1(c) – Nose detail B.

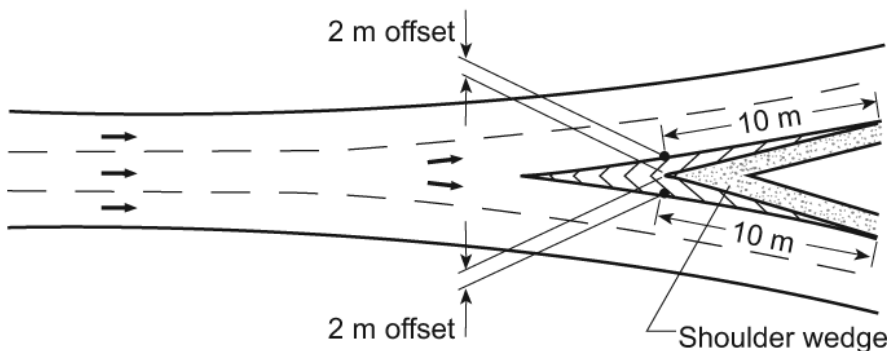
Source: Adapted from Department of Main Roads (2005)¹³.

11.2.3 Exits to Two High-speed Roadways

A different type of operation applies where it is necessary for traffic to diverge to two high-speed roads that are of similar importance. In this case, both roadways diverge tangentially instead of one diverging at an angle as with a normal ramp – commonly referred to as a ‘major fork’. This type of arrangement is usually adopted only when the right-turning traffic is greater than 50% of the total traffic.

Figure 11.4 illustrates the principle of diverging two major roadways, where the layout is based on achieving a high standard of alignment for both high-speed movements. This arrangement may be applied at a system interchange.

Figure 11.4: Major fork (or diverge)



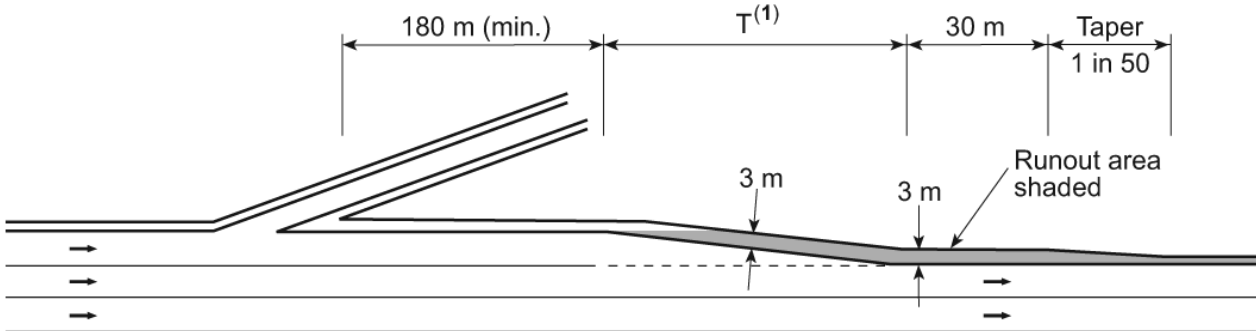
Source: Department of Main Roads (2005)¹³.

¹³ Department of Main Roads (2005) has been superseded and Figure 11.3 and Figure 11.4 have not been carried forward into Department of Transport and Main Roads (2014).

11.2.4 Lane Drop at an Exit

Where traffic analysis shows that a lane should be dropped beyond an exit, it should be accomplished as shown in Figure 11.5. The lane drop taper should be designed for a lateral rate of movement of 0.6 m/s and the run-out area designed in accordance with the details shown in *AGRD Part 3* (Austroads 2010b).

Figure 11.5: Lane drop at an exit



¹ Note: T = taper length based on a rate of lateral shift of 0.6 m/s.

Source: Adapted from Department of Main Roads (2005)¹⁴.

11.3 Entry Ramps

11.3.1 General

Entry ramps may have one or two lanes on the ramp and one or two lanes at the entry nose to the major road.

At all interchanges on high-speed roads (operating speed > 80 km/h) it is good practice to provide an auxiliary lane to enable entering traffic to travel parallel to and at the same operating speed as the through carriageway whilst searching for a gap in the adjacent lane. At interchanges on low-speed freeways that have relatively low traffic volumes, gaps are readily available for entering traffic and a simple merge may be provided beyond the nose.

11.3.2 Single-lane Entry

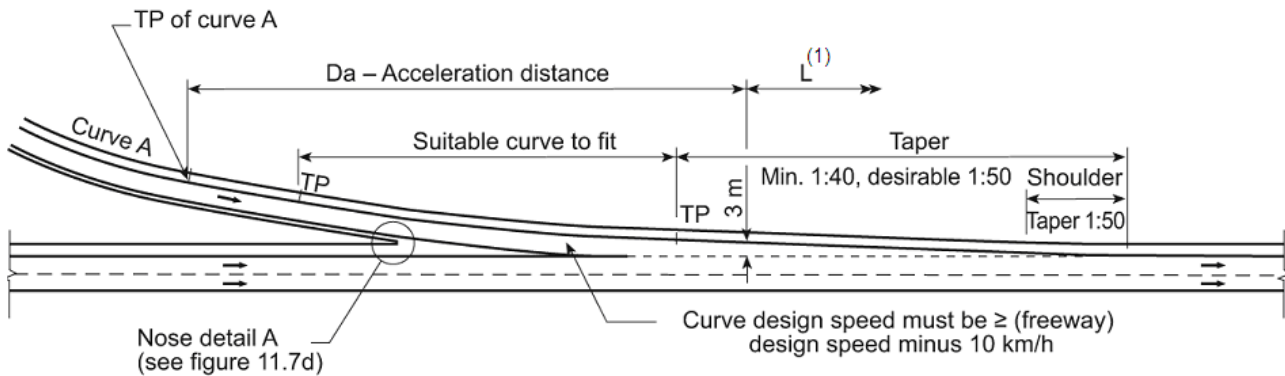
Simple merge

Figure 11.6 shows a single-lane entry with a simple merge taper, suitable for some low-speed situations.

The continuity line along the length of the merge indicates that merging vehicles are changing lanes and do not, therefore, have priority over vehicles in the left lane of the major road. Some jurisdictions prefer not to provide this line which means that drivers in both streams are required to 'zip merge' as provided for in road rules (i.e. the driver whose vehicle is in ahead of the other vehicle has right of way).

¹⁴ Department of Main Roads (2005) has been superseded and Figure 11.5 has not been carried forward into Department of Transport and Main Roads (2014).

Figure 11.6: An example of single lane with a simple merge



1 L = distance between the entry ramp and the following exit ramp. Refer to Section 6.6.6 and Table 6.3 of AGTM Part 6 (Austroads 2013a).

Source: Department of Main Roads (2005)¹⁵.

Interchanges are sometimes provided on major non-freeway roads and some freeway standard roads are designed for low-speed (≤ 80 km/h) operation. The arrangement illustrated in Figure 11.6 can be used in very constrained situations (i.e. where space is not available for a parallel lane). A suitable run-out area should be provided at the end of the merge taper (e.g. a sealed shoulder wide enough to provide shelter for a vehicle until a gap appears in the left lane).

11.3.3 Entry with Auxiliary Lane

Figure 11.7(a) shows a single-lane entry ramp with an auxiliary lane to allow entering drivers to travel parallel to and at the operating speed of the major road whilst selecting a gap. It should be appreciated that Figure 11.7 applies to situations where a curve that has a design speed less than the design speed of the through road is provided just in advance of the nose. While these situations arise in practice, it is preferable that the alignment and length of the on-ramp is sufficient to enable cars to be travelling at the design speed of the through road when they are at the nose, and that an entry treatment that complies with the relevant road agency guidelines is provided in *AGRD Part 4A* (Austroads 2010a) should be used to assess the length of ramp required for acceleration to the design speed of the through road.

Where a curve exists just prior to the nose of an on-ramp it is important that adequate acceleration distance is provided (Table 11.2) and that a run-out area is provided at the end of the merge taper where shoulders are less than 2.5 m wide. The merge taper should provide for vehicles to merge at a lateral rate of movement of 1.0 m/s.

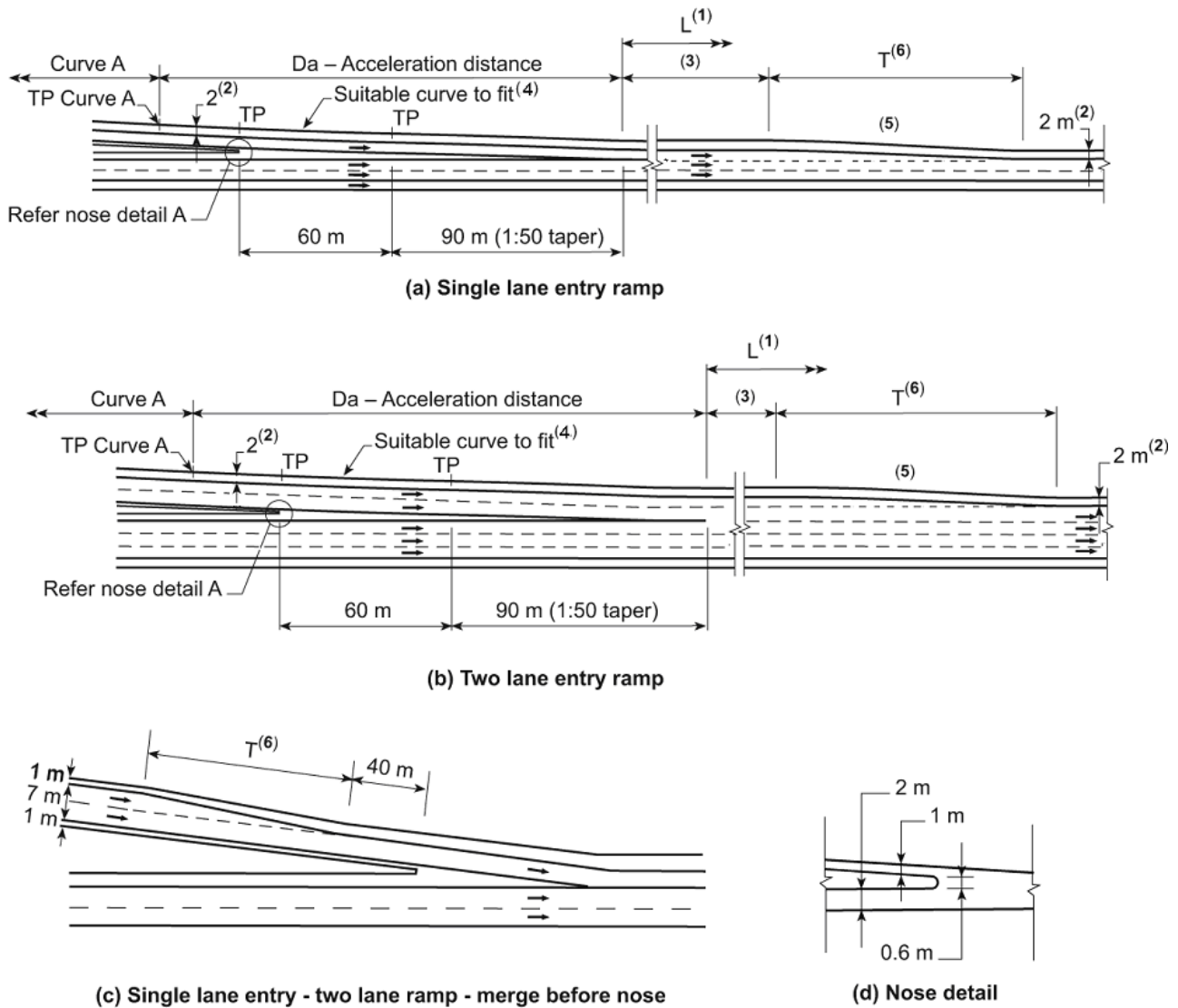
The length of parallel lane is also an important consideration. Table 11.4 shows the recommended distance based on four seconds of travel by the merging driver. The length of parallel lane should be extended if:

- a traffic analysis (i.e. based on Transportation Research Board 2010) and/or operating experience shows the need for a longer lane
- the lane has to go over a crest and suitable sight distance to the end of the lane has to be achieved (at least ASD should be provided to the end of the lane).

Figure 11.7(c) shows details of a lane termination where a two-lane ramp narrows to a single lane at the nose whilst Figure 11.7(d) illustrates nose details.

¹⁵ Department of Main Roads (2005) has been superseded and Figure 11.6 has not been carried forward into Department of Transport and Main Roads (2014).

Figure 11.7: An example of single-lane entry and two-lane entry



- 1 L = distance between the entry ramp and the following exit ramp. Refer to Section 6.6.6 and Table 6.3 of AGTM Part 6 (Austroads 2013a).
- 2 Indicative only. Refer to AGRD Part 3 (Austroads 2010b).
- 3 See Table 11.4. However, length should be extended to achieve improved level of service where determined by appropriate traffic analysis.
- 4 Curve design speed should at least equal to the mean free speed of the through road (about numerically equal to the speed limit).
- 5 Run-out area required.
- 6 Taper length T based on a lateral movement at 1.0 m/s.

Source: Department of Main Roads (2005)¹⁶.

¹⁶ Department of Main Roads (2005) has been superseded and Figure 11.7 has not been carried forward into Department of Transport and Main Roads (2014).

Table 11.2: Acceleration distance D_a

Design speed of curve A (km/h)	D_a (m)					
	Design speed of through road (km/h)					
	70	80	90	100	110	120
0	165	235	330	450	610	795
20	150	220	315	435	595	780
30	140	210	305	425	585	770
40	125	195	290	410	570	755
50	95	165	260	380	540	730
60	55	125	220	340	500	700
70	–	75	170	290	450	660
80	–	–	95	220	380	600

Notes:

This table applies to situations where a curve having a design speed less than the design speed of the through road is provided prior to the ramp nose (refer to Section 11.3.3).

Where ramp traffic signals (refer to Section 11.4) are provided near the nose, the acceleration distance required (from a stopped condition) should be based on Table 5.4 in AGRD Part 4A (Austroads 2010a).

The design speed of the through road must at least equal the mean free speed (about numerically equal to the posted speed).

D_a values shown in table are for level grade. Adjust for grade using Table 11.3.

Source: Adapted from Roads and Maritime Services (2015).

Table 11.3: Correction of acceleration distances as a result of grade

Design speed of road entered (km/h)	Ratio of length on grade to length on level for: Design speed of turning roadway curve (km/h)													
	3 to 4% upgrade								5 to 6% upgrade					
	0	20	30	40	50	60	70	80	30	40	50	60	70	80
70			1.30	1.30	1.35	1.35	–	–	1.50	1.55	1.60	1.75	–	–
80			1.30	1.35	1.40	1.40	1.45	–	1.50	1.60	1.70	1.90	2.15	–
90			1.35	1.40	1.45	1.45	1.50	1.55	1.60	1.70	1.80	2.05	2.30	2.50
100			1.40	1.45	1.50	1.50	1.55	1.60	1.70	1.80	2.00	2.20	2.45	2.70
110			1.50	1.55	1.60	1.65	1.70	1.80	2.00	2.10	2.30	2.60	2.80	3.00
120			1.60	1.65	1.70	1.75	1.85	2.00	2.30	2.50	2.70	3.00	3.25	3.50
			3 to 4% downgrade						5 to 6% downgrade					
			All speeds						All speeds					
80			0.65						0.55					
100			0.6						0.5					
110			0.6						0.5					
120			0.6						0.5					

Source: Adapted from Roads and Maritime Services (2015).

Table 11.4: Length of parallel lane at entry ramps

Road type	Length of parallel lane (m)	
	Desirable ⁽¹⁾	Absolute minimum
High-speed freeways (operating speed > 80 km/h)	Length based on 4 sec of travel time (maximum is generally 200 m)	Length based on 4 sec of travel time
Low-speed freeways (operating speed ≤ 80 km/h) and non-freeway roads	Length based on 4 sec of travel time	0 ⁽²⁾

1 The desirable length is also the typical upper bound of the design domain. The upper bound is limited by the likelihood of drivers mistaking the parallel lane for an added lane. This can occur for drivers of both entering and through-lane vehicles at heavy vehicle flows. The length should only be extended if:

- traffic analysis and/or operating experience shows the need for a longer lane
- the lane has to go over a crest and suitable sight distance to the end of the lane has to be achieved.

2 Use only in very constrained circumstances.

11.3.4 Two-lane Entry

Figure 11.7(b) shows a two-lane entry ramp with two lanes at the nose. It should be appreciated that Figure 11.7 and Table 11.2 apply to situations where a curve that has a design speed less than the design speed of the through road is provided just in advance of the nose. Whilst these situations arise in practice, it is preferable that the alignment and length of the on-ramp is sufficient to enable cars to be travelling at the design speed of the through road when they are at the nose, and that an entry treatment that complies with the relevant road agency guidelines is provided. *AGRD Part 4A* (Austroads 2010a) should be used to assess the length of ramp required for acceleration to the design speed of the through road.

The key feature of this arrangement is that the right lane of the entry ramp is directed into an added lane on the freeway downstream of the interchange. This added lane should continue for a considerable distance downstream to enable the combined ramp flow to stabilise prior to merging with the through traffic on the major road.

The left lane of the two-lane ramp is treated in the same way as a single-lane entry but in this case traffic from this lane merges with traffic from the right-hand lane of the ramp.

11.3.5 Loop Ramps

The diverge and merge arrangements described in this section should also be applied to ramps which have a loop type alignment.

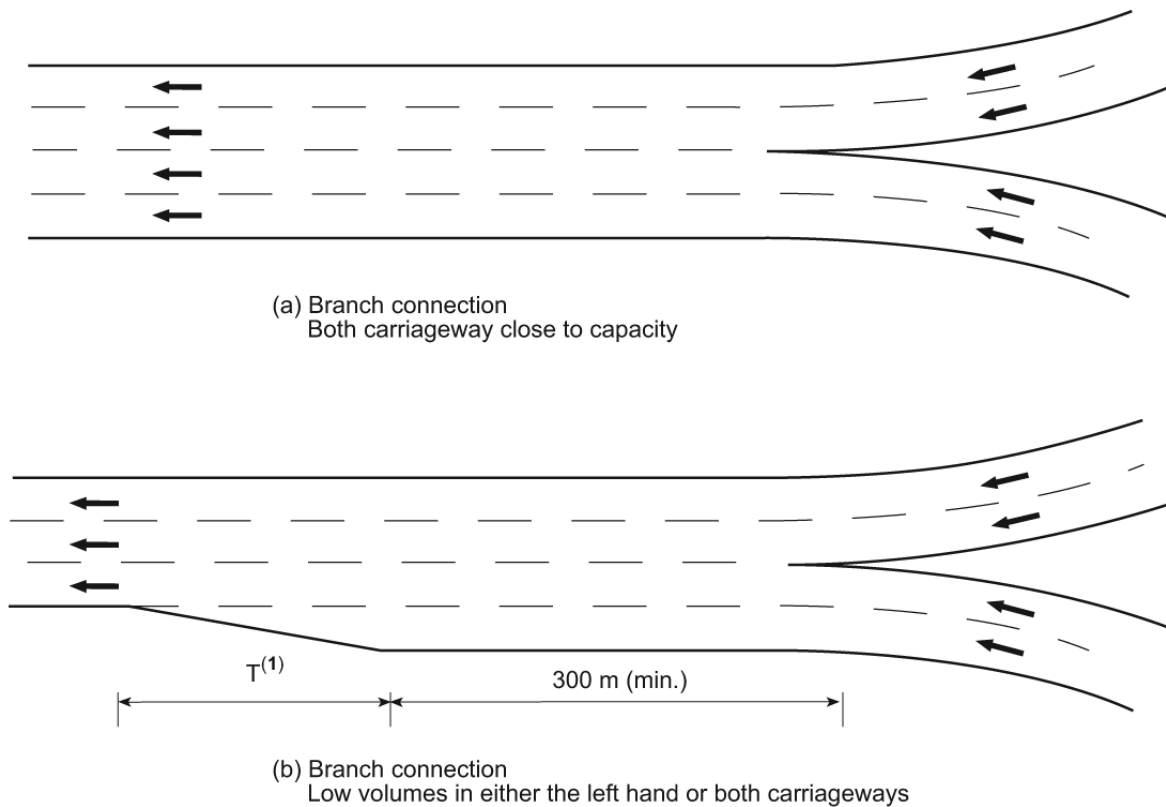
11.3.6 Merging of High-speed Major Roads

A different type of operation applies where it is necessary to merge two high-speed roads that are of similar importance – referred to as a branch connection. In this case, the two roadways meet tangentially instead of at a slight angle as with a ramp (1:50). The angle associated with a normal ramp is intended to provide a cue for an impending lane change which is not the case in a treatment for two high-speed roads.

Figure 11.8 illustrates the principle of merging two major roadways, where the layout is based on achieving a high standard of alignment for both high-speed movements. This arrangement may be used at a system interchange.

It is very important that right-hand merges are avoided in greenfield projects (preferably re-designed at other sites) because of the safety and operational problems they cause. This means that the merging streams should have their own lanes after the merge and any reduction in the total number of lanes beyond the merge should be achieved in a manner similar to that shown in Figure 11.8(b), using a left-hand merge on the outermost left-hand lane. If the right-hand branch carries significantly lower volumes than the left-hand roadway, then an acceptable arrangement is to bring the right-hand roadway over the left-hand roadway and create a normal left-hand merge (refer to *AGTM Part 6* (Austroads 2013a)).

Figure 11.8: Major branch connection



¹ T = taper length based on a rate of lateral shift of 0.6 m/s.

Source: Based on *VicRoads* (2011).

11.4 Ramp Traffic Signals

11.4.1 General

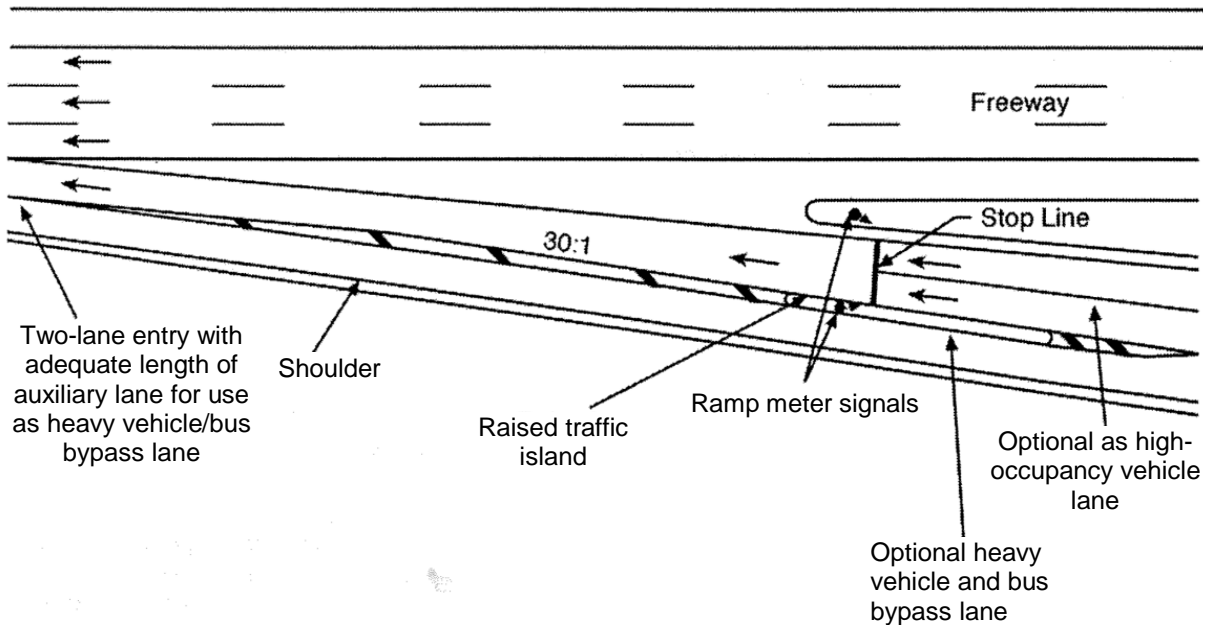
Traffic signals installed on the on-ramp of the freeway are used to control the rate at which traffic enters the freeway. They are installed to improve the operation of the mainline freeway and improve the merging movement onto the freeway. Reference should also be made to *AGTM Part 6* (Austroads 2013a).

The objective of the system is to use the signals to release vehicles at a prescribed rate that is based on the mainline traffic flow conditions. For this reason the system is also known as 'ramp metering' in some jurisdictions. This metering enables traffic flow along the mainline to be maintained at or just below capacity at key congested periods. This reduces the probability of flow breakdown occurring and enables smoother merging of vehicles at the on-ramp. The control of vehicles entering the mainline reduces turbulence as fewer drivers upstream of the merge change lanes to avoid platoons of traffic that would otherwise attempt to enter the freeway, and this assists in maintaining a flow near capacity.

Although ramp signals can be applied in isolated cases to address a particular bottleneck, ramp signals are most effective when applied system-wide along a freeway corridor. Effective system-wide ramp signals are set up in a stratified approach that balances the needs of maximising the freeway throughput over a considerable length in addition to effective queue management of the on-ramps.

Figure 11.9 illustrates the features of ramp traffic signals including the provision of a high-occupancy vehicle lane and/or a bypass lane for heavy vehicles where they are required as part of the traffic management strategy for the interchange.

Figure 11.9: Ramp traffic signal arrangement including optional high-occupancy vehicle and bypass lanes



Freeway ramp signals can potentially impact on the design principles of freeways in the vicinity of on-ramps. The key factors for consideration include:

- Ramp capacity: this is based on the release rate needed at the ramp signals to avoid flow breakdown on the mainline of the freeway and to avoid queues extending back to the arterial road ramp intersection and adversely impacting on the operation of the arterial road.
- Geometric design and design layout: this will need to take into consideration the number and length of lanes (i.e. storage) required, stop line location, distance required for acceleration and merging, the location of the controls (i.e. signals, stop holding lines) and location of any detectors.

11.4.2 Capacity Analysis

Capacity analysis of the freeway should be undertaken to determine the need for ramp signals and where they are needed, either initially or in future, the likely location of critical bottlenecks and the maximum inflow permissible to prevent flow breakdown. The analysis will assist in assessing the general impact of the ramp signals on the on-ramp, the required location and operation of the signals, and hence the geometry of the on-ramp to facilitate the ramp signals.

The analysis will essentially determine the number of lanes required and the length of storage which will define the design of the approach to the signals.

11.4.3 Geometric and Layout Design

The key features of the freeway geometry that are impacted by the installation of ramp signals are generally limited to the ramp length, ramp width and merging of ramp traffic beyond the stop line.

Ramp length

The ramp length is important for the storage of vehicles at the ramp signal. The length of the ramp and the number of lanes on the ramp determine the amount of storage and hence the capacity at the stop line and the configuration at the merge. In addition the width of the ramp may include the provision of bypass lanes for priority vehicles such as freight vehicles.

Ramp width

The width at the ramp signals is determined by the number of lanes required to meter general ramp traffic onto the freeway at the required rate plus a bypass lane for use by special classes of traffic where a need has been established (e.g. keep heavy vehicles moving where the approach to signals is on an upgrade). Traffic analysis techniques should be used to establish the required release rate and the need for a bypass lane.

In some cases it may be necessary to provide three or four lanes at the stop line which will lead to a significant width that will affect the way in which the merging of ramp traffic is managed (discussed below).

Shoulders should be provided on the on-ramp where there is only one general traffic lane as this will ensure that traffic flow can be maintained if a vehicle breaks down. Where more than one lane on the on-ramp merges into one lane prior to merging with the mainline freeway, the shoulder should be developed over the merge length (i.e. a tapered approach) and should be no less than 2 m in width.

Because of the effect heavy vehicles may have on the operation of ramp signals when accelerating from a stationary position, particularly on an upgrade, an additional lane may be necessary so that these vehicles can bypass the ramp queue at speed. This will also improve the operation of the ramp merge. Bypass lanes should be separated from the general traffic lanes at the ramp signals so that the operation of each type of lane is clearly defined by signs and/or signals.

Merge geometry

Freeway nose geometry involves either a single-lane entry ramp or a two-lane entry ramp (Figure 11.7). Where the number of lanes at the stop line of the ramp signal exceeds the number of lanes at the nose (i.e. just prior to the merge into the main carriageways) any merging of the stand-up lanes at the ramp signals should be completed prior to the ramp nose, except where an uncontrolled (i.e. non-metered) bypass lane is used which should operate as an auxiliary lane adjacent to the merge treatment.

When determining the acceleration length and location of the stop line, consideration should be given to the following:

- The type of vehicle which needs to accelerate from a stopped position. Where heavy commercial vehicles utilise the on-ramp and no bypass facility is in place for their use, the impact of these vehicles on the operation of the signals and merge should be considered.
- Any merging that may need to be undertaken on the ramp itself (i.e. where more than one lane of traffic on the ramp needs to merge prior to merging with the main freeway carriageway and after the location of the ramp signals).
- Sight distance to the merge location on the ramp, particularly where the merge is located on a curved ramp.
- Visibility to the signals, particularly where alterations are made to the vertical or horizontal alignment of an existing ramp.

Where an on-ramp (existing or proposed) has ramp signals, the position of the stop line should be such that a vehicle is able to accelerate and merge into the mainline of the freeway. The length required for acceleration and to undertake the merge at the on-ramp should be based on the operating speed of the left lane of the freeway when the ramp signals would be in operation. In most cases, for a managed freeway system operating near capacity, the acceleration length required from the stop holding line (i.e. when ramp signals are in operation) would generally be based on a speed no greater than 80 km/h.

The length of merge is a critical parameter related to the number of lanes involved. Where there is a difference of two or more in the number of lanes at the ramp signals compared to at the ramp nose, the merge should be designed so that:

- from three lanes to one lane the merge should occur in sequential steps with a transition provided between each subsequent merge.
- from four lanes to two lanes, two pairs of merges should occur simultaneously. An extended merge length of more than 80 m is recommended to overcome any issues arising from potential driver confusion due to an increased number of vehicles being released per signal cycle. A suggested minimum distance is 120 m.

Once the vehicles at the stand-up lanes of the ramp signals have merged into the lanes provided at the ramp nose a standard length of auxiliary lane and merge taper should be provided to enable the entering vehicles to merge with the mainline freeway (Figure 11.7).

The ramp geometry and merging distance need to be satisfactory to enable the on-ramp to function both when the signals are operating and also when they are not operating. When ramp signals are not operating drivers approaching in platoons from the arterial road/on-ramp intersection should be able to approach and enter the freeway as they would at a ramp that has no signals (i.e. a standard freeway entry ramp layout).

Example designs

Appendix C provides two examples of ramp and merge layouts for ramp signals based on various situations, namely:

- two lanes at the ramp signals and one lane at the merge with the main freeway carriageway
- two lanes at the ramp signals plus a free-flow bypass lane for use by heavy vehicles and high-occupancy vehicles with a merge to the main freeway carriageway.

These examples show the geometric layout and the basic signals and fixed signage required. They do not show the extensive traffic management infrastructure including electronic signs that may be required within a jurisdiction.

The examples are only two in a possible extensive range where permitted use and the number of lanes at the signals may vary. Possible variations may include:

- a two-lane on-ramp with three lanes at the ramp signal, a fourth lane designated as a free-flow bypass lane and a multi-lane merge with the main freeway carriageway
- a two-lane on-ramp with four lanes at the ramp signals and a multi-lane merge with the main freeway carriageway
- a two-lane on-ramp with three metered lanes at the ramp signals and one lane at the merge with the main freeway carriageway
- use of the bypass lane by heavy vehicles, buses and taxis only.

12. Ramps on Two-Lane Two-Way Freeways

Two-lane two-way freeways sometimes occur as a stage in the construction of a standard divided freeway, and it is necessary to provide ramps between the minor road and the two-lane two-way major road. In these cases, the major road design within the interchange is to either:

- include sufficient length of median to prevent wrong-way and other inappropriate movements at the terminals
- provide full interchange design with all roadway elements in their final positions.

Where the staged interchange is to be used, a median with a safety barrier should be installed over the full extent of the interchange geometry (including tapers) plus 100 m beyond the final entry ramp taper. The median width required will depend on the type of barrier (refer to *AGRD Part 3* (Austroads 2010b) and the *Guide to Road Design Part 6: Roadside Design, Safety and Barriers* (Austroads 2010c)). This extent of median is necessary to ensure that the drivers of entering traffic are prevented from crossing to the on-coming lane in the mistaken belief that they are entering a one-way carriageway. Two-way carriageway signs must be used to reinforce this.

Where the interchange is spread sufficiently to allow the necessary transitions between cross-sections, and these requirements would require undue widening of the overpass structure, the extent of the median may be reduced by starting it 50 m upstream of the nose of the entry ramp. This layout should only be adopted where significant cost savings can be made.

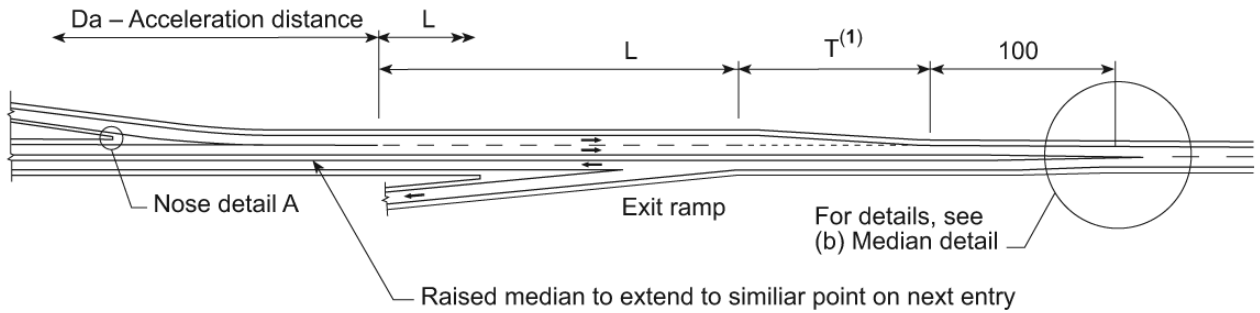
Widening of the two-lane pavement approaching the median should be accomplished with tapers at least 60 m long (1.1 m lateral movement for each lane in each direction). Figure 12.1 shows the extent of the median and the required dimensions.

The design of the ramps is to be in accordance with Sections 11.2 and 11.3 (only ramps with one lane at the nose will be applicable). The ramps should be located in their final position, suitable for the ultimate interchange design with appropriate temporary connections to the initial through pavement.

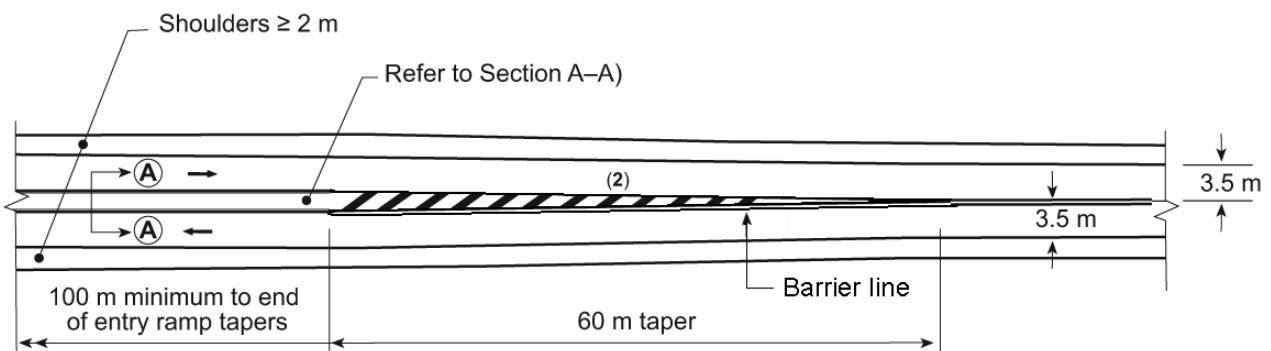
Appropriate signing and pavement markings in accordance with AS 1742 in Australia or *MOTSAM Part 3* (NZTA 2010b) in New Zealand should be included in the design. Drivers of entering traffic should be made fully aware of the fact that the roadway they are entering is a two-way carriageway.

A better solution may be to provide the full interchange design with all roadway elements located in their final positions. The major road would be divided throughout the extent of the interchange. This is probably more expensive than the staged construction, but the life of the staged works, their relative safety and efficiency and the extent of wasted construction (which affects both options) should be considered before adopting the two-lane two-way option.

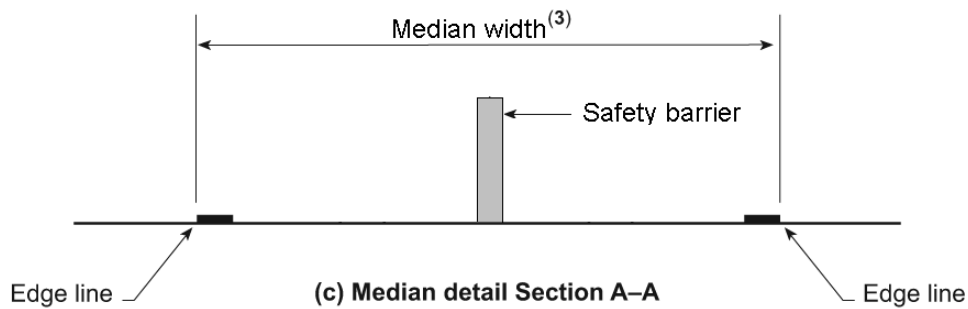
Figure 12.1: Special cases of ramp design – two-lane two-way freeways (staged construction)



(a) Layout



(b) Median detail



(c) Median detail Section A-A

- 1 Taper length T based on a lateral movement at 1.0 m/s.
- 2 Diagonal markings in accordance with AS 1742.2 or NZTA (2010a).
- 3 Median width varies depending on type of barrier and the required shoulder width or clearance required for barrier deflection. Refer to AGRD Part 3 (Austroads 2010b) and the Guide to Road Design Part 6: Roadside Design, Safety and Barriers (Austroads 2010c).

Source: Department of Main Roads (2005)¹⁷.

¹⁷ Department of Main Roads (2005) has been superseded and Figure 12.1 has not been carried forward into Department of Transport and Main Roads (2014).

13. Pedestrians

13.1 General

Pedestrians should be prohibited from entering urban freeways by the erection of standard signs at the ramp terminals with the minor road. However, provision should be made for drivers of broken-down vehicles to reach the help-telephones safely along the shoulders of freeways. In providing the help-telephone, consideration should also be given to the travel path available along the roadside area for these drivers to reach the help-telephones with some clearance from the passing traffic.

Pedestrian circulation should be provided along frontage roads, along the minor roads through interchanges and by grade separated crossings of the freeway.

Pedestrian facilities should be provided at the minor road ramp terminals in accordance with *AGRD Part 4* (Austroads 2009a) and *AGRD Part 4A* (Austroads 2010a). It may also be necessary to place a fence at the terminal to control movement of pedestrians in the vicinity. The fence should be of a type such that the components cannot spear an errant vehicle.

On bridges, a minimum width of 1.8 m to the face of the kerb is required wherever specific provision is made for pedestrians.

Where the freeway passes along a valley or through recreational land, provision of a separate pedestrian trail or a shared bicycle/pedestrian path may be considered.

13.2 Bus Passengers

In urban areas, provision may be made for express buses to leave and re-enter the freeway at interchanges. Where this is the case it is preferable that the buses use the left lane or the left shoulder. At diamond interchanges, bus stops should be located near the ramp terminals either in an indented bay on the entry ramp or within the left-turn islands at the exit and entry ramp terminals. It is important that the:

- island is large enough to accommodate the number of pedestrians waiting for the express service
- local feeder bus stops are located in close proximity to the express stops
- buses waiting at stops, and furniture associated with the stops do not impede sight distance for other road users.

At other interchange types, provision for bus movements will be more complex. At certain interchanges the bus route may leave the freeway and continue by way of the arterial road system.

Where a major bus stop is provided at freeway level to serve a busway within the median, the design should enable passengers from feeder services to disembark directly in the local road and access the freeway service via escalators, lifts, ramps or stairs, although stairs are not preferred and should not be the sole means of access. Careful pedestrian access planning is required to ensure that passengers can access the stations from both sides of the carriageway.

Specific pedestrian access arrangements will also be required to ensure appropriate access to rail stations adjacent to a freeway or its interchanges when a rail line is constructed adjacent to, or in the median of the freeway.

14. Cyclists

14.1 General

The main issue that should be addressed in deciding whether cyclists may use freeways is road safety. The policy with respect to cyclists using freeways varies between jurisdictions. Where cyclists are permitted to use a freeway it is important that they are provided with information, guidance and road conditions which enable them to use it safely. It is inappropriate for cyclists to use the normal traffic lanes of freeways and so the safe use of these facilities by cyclists is predicated on providing:

- an efficient and safe route within the corridor, e.g. a high-speed exclusive bicycle path, a shared path or an alternative road route
- smooth, debris-free shoulders of adequate width if cyclists are permitted to use the freeway
- safe treatments at interchanges.

Because rural freeways usually have relatively low volumes of traffic leaving and entering at interchange ramps and gradients are normally less than non-freeway arterials, cyclists are often able to use them with a high level of safety and convenience. Cyclists should normally be allowed to use rural freeways, particularly those having sealed shoulders, provided that information and guidance is given to guide them safely across exit and entry ramps.

The use of urban freeways by cyclists is a matter to be determined by the relevant jurisdiction which may decide to deny cyclists' access to specific freeways because of the difficulties and hazards which would confront them in high-volume, high-speed traffic environments. A number of factors should be considered when assessing the suitability of a freeway and its interchanges for use by cyclists. Commentary 4 provides further considerations with respect to cycling on freeways.

[\[see Commentary 4\]](#)

14.2 Treatment at Interchanges

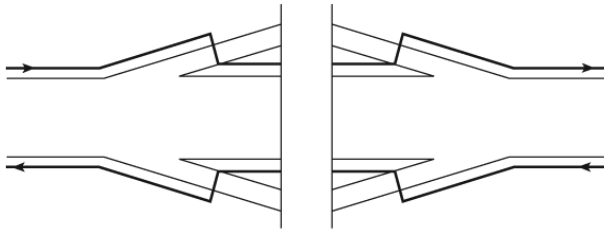
At interchanges, the route to be provided for cyclists should be established and signed on the following basis:

- Where it can be established that sufficient gaps will occur in the traffic flow along ramps to enable cyclists to cross safely, the route shown in Figure 14.1(a) should be encouraged at one-lane ramps only whereas the method shown in Figure 14.1(b) should be used where the ramp has more than one lane. This method requires a cyclist to turn from the shoulder/breakdown lane and cross the ramp at right angles. The traffic analysis associated with this manoeuvre is described in Commentary 5.

[\[see Commentary 5\]](#)

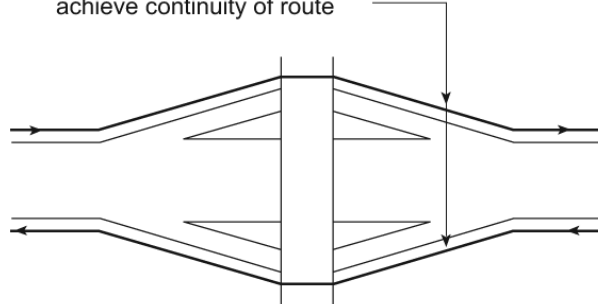
- If calculations or site observations confirm that insufficient gaps will exist in the flow of motor vehicles using the ramp then cyclists should be directed to use the route shown in Figure 14.1(b); grade separation should be considered, or an alternative route to the freeway should be developed.
- At freeway ramps where a significant number of cyclists have to cross through a large volume of motor vehicles, delays to cyclists may be excessive causing them to either take unreasonable risks or use an alternative route. In these instances consideration may be given to providing cyclists with a grade separation. High ramp volumes on an existing freeway may, in the absence of feasible alternative routes through or around the interchange, indicate that the freeway itself or that segment of it is unsuitable for cycling. An alternative route off the freeway may be required.

Figure 14.1: Bicycle routes through interchanges



(a) Cyclists' path through interchange when crossing ramps

Note: At half diamond interchanges provide bicycle paths to achieve continuity of route



(b) Cyclists' path through interchange avoiding need to cross ramps

Figure 14.2 provides a pictorial representation of the bicycle route shown in Figure 14.1(a).

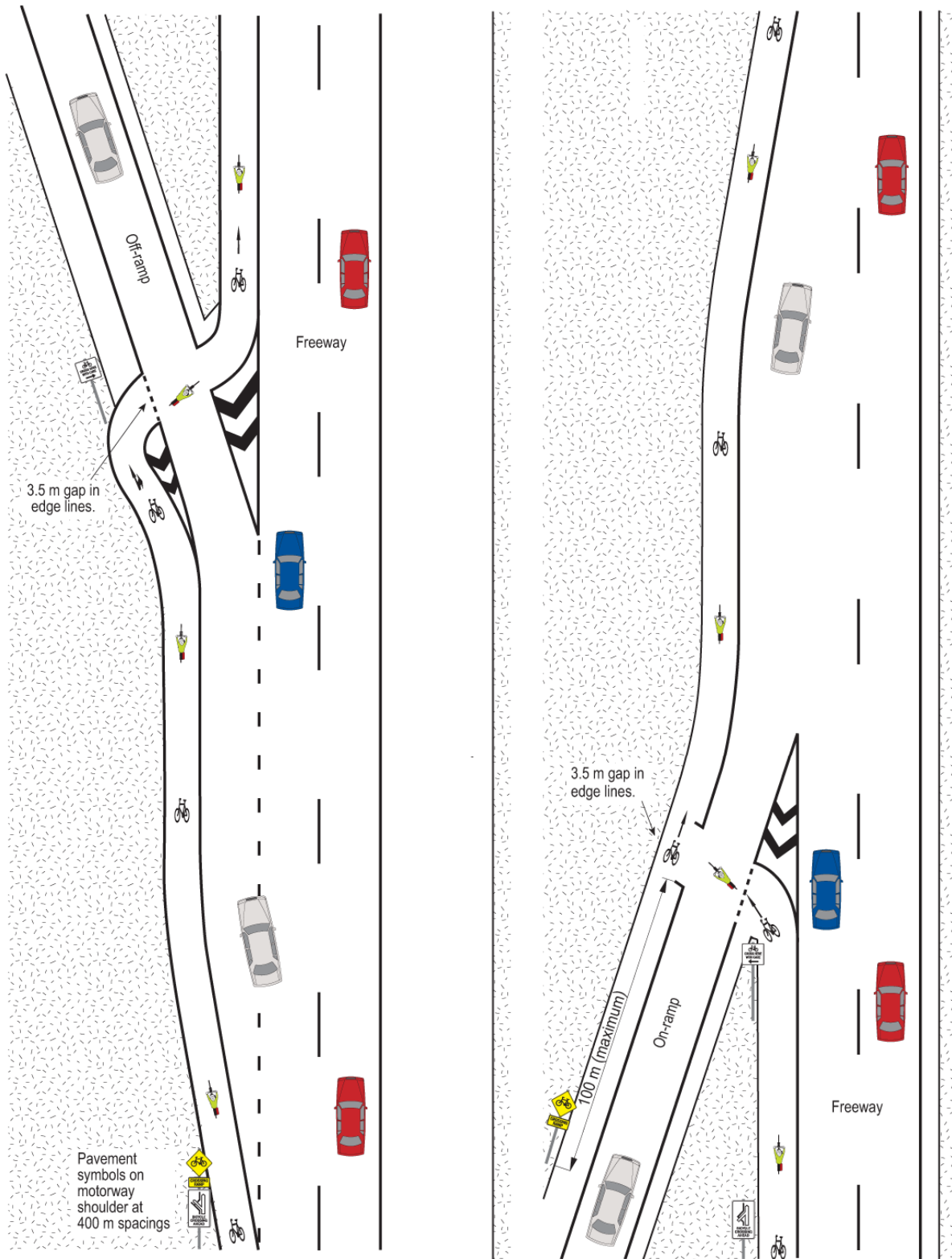
14.2.1 Cyclists Required to Exit and Re-enter Freeway

Where cyclists are required to follow the route shown in Figure 14.1(b) the treatment should include:

- regulatory signs to direct cyclists to leave the freeway
- sealed shoulders of adequate width on the exit and entry ramps (e.g. 2.0 m)
- crossing facilities at the ramp terminal at the minor road
- a crossing of the left-turning roadway into the entry ramp.

For guidance on cyclist facilities at unsignalised and signalised intersections and crossings, refer to *AGRD Part 4* (Austroads 2009a) or *AGRD Part 4A* (Austroads 2010a).

Figure 14.2: Typical at-grade treatment for cyclists at exit and entry ramps



(a) Exit ramp

(b) Entry ramp

Source: Roads and Traffic Authority (2005).

14.2.2 Grade Separation of Ramps for Cyclists

Grade separation of cyclist movements across exit and entry ramps would only be contemplated for very large flows of commuter cyclists. At such levels of flow it may be more appropriate to provide a high-speed exclusive bicycle path within the freeway reservation with grade separations at the minor roads. Even if cyclists continued to use the freeway shoulders it may be more viable and practical to require them to use the freeway ramps, and provide an underpass of the minor road for example.

14.2.3 Alternative Routes

Where it is deemed to be unsafe for cyclists to use a freeway, alternative routes providing a similar level of service should be defined and developed off the freeway. These routes may comprise:

- routes on the surface arterial road network or local street network
- a bicycle path or shared path within the freeway reservation with either at-grade crossings of the minor road at ramp terminals, or grade separation of the minor road (refer to the *Guide to Road Design Part 6A: Pedestrian and Cyclist Paths* (Austroads 2009b)).
- routes through adjacent reservations associated with parkland or watercourses.

15. Pavement Markings, Signs and Lighting

15.1 General

It is critical that the pavement markings and signs (including electronic signs) used at interchanges and their associated at-grade intersections are:

- consistent with the intended operation of the interchange and intersections
- support the effectiveness of other traffic control devices
- provide adequate warning and guidance to all road users.

The signs and markings required at or in the vicinity of freeway interchanges will involve regulatory, warning, guide (direction and advance direction) and information signs, some of which will relate to particular road users or road user activities. On the freeway itself, the key traffic control devices are the guide signs and associated pavement markings that should provide adequate advance information to drivers to enable them to take up a position early enough to ensure a safe and efficient departure from the facility. Similarly signage and other traffic control devices (e.g. ramp metering signals) on the entry ramps should ensure safe and efficient traffic movement onto the freeway.

Urban freeway to freeway interchanges can be problematic with respect to the satisfactory design and location of advance exit signs and exit signs because of the number of entries and exits and the relatively close spacing of some interchanges. The sign face design and the placement of these signs are critical and should be undertaken by a practitioner who is experienced in the discipline. This is particularly important for system interchanges, and service interchanges that are closely spaced. As a general rule urban freeway to freeway interchanges, because of the high traffic volumes and large numbers of heavy vehicles, should be provided with overhead mounted guide signs. Signs mounted at the side of urban freeways are too often obscured by large high vehicles.

Freeway ramp terminals at the minor road should have all the necessary signs and markings required under local jurisdictional standards and guidelines. These signs may relate to general traffic, parking, pedestrians, cyclists, public transport, or heavy vehicles.

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

- Australian Standard AS 1742 – Manual of Uniform Traffic Control Devices
- NZ Transport Agency Manual of Traffic Signs and Markings (MOTSAM): Part 3 (NZTA 2010b)
- NZ Transport Agency *Traffic Control Devices Manual* (NZ Transport Agency 2015)
- Guide to Road Design Part 4: Intersections and Crossings – General (Austroads 2009a) or the Guide to Road Design Part 4A: Unsignalised and Signalised Intersections (Austroads 2010a)
- Guide to Traffic Management Part 10: Traffic Control and Communication Devices (Austroads 2009d)
- Specific jurisdictional guides.

15.2 Key Considerations

Signing and marking through interchanges is essential to their efficient operation. A major criteria for acceptability of a layout for an interchange is the ability to properly and effectively sign that layout to make it work. Significant issues to be considered include the following:

- location of signs to ensure adequate decision times
- positioning of the signs with respect to the major road lanes (either overhead on gantries or mounted to the side)
- location and type of support legs for the signs – non-frangible sign supports must not be placed in the gore areas at ramps or in run-out areas
- gantry signs are essential for major forks to avoid driver confusion because the gore is long and narrow to accommodate the large radius curves involved
- gantry signs are far more effective for carriageways with three or more lanes (refer to AS 1742.15)
- frangible sign supports and lighting poles must be used if the sign supports and lighting poles are not protected by safety barrier
- non-frangible sign posts and lighting poles must be located behind safety barriers or protected with appropriate devices.
- signs should be clearly visible in all conditions and the sign face material should be chosen to provide the required properties (e.g. Class 1 retro-reflective material). Individual lighting of signs should be considered if the ambient or general lighting is not adequate.

15.3 Lighting of Interchanges

The lighting of freeways, major roads and interchanges on those roads is a matter for jurisdictional policy and guidelines. Some guidance is provided in the *Guide to Road Design Part 6B: Roadside Environment* (Austroads 2015d). Where it is decided to light an interchange, lighting should be provided in accordance with AS/NZS 1158.

Where there is lighting at closely spaced interchanges (e.g. < 1 km between the ramp taper ends) consideration should be given to providing continuous lighting along the main carriageway between the interchanges as drivers' eyes may not fully adjust to the change in lighting conditions.

16. Landscaping and Street Furniture

16.1 General

Landscaping and street furniture should be designed and installed with the objective of providing a safe and forgiving roadside environment for all network users. Within this context, interchanges should be landscaped as part of a general landscaping plan for the major road (refer to the *Guide to Road Design Part 6B: Roadside Environment* (Austroads 2015d)). While the overall visual continuity along the major road is an important consideration, the landscape design at interchanges may also provide navigation and way-finding functions for drivers travelling along the major road.

Drivers sometimes lose their sense of where they are in relation to their required freeway exit. Signs are available to indicate destinations and hence location for drivers. However, readily identifiable and individual landscaping themes at each interchange can assist drivers by providing a visual signal/cue in the landscape that confirms their location. In some instances the landscaping may be supplemented by sculpture or other forms of art including colours and patterns on the faces of retaining walls, bridge abutments and piers.

16.2 Landscape Development

All interchanges should be designed so that the landscaping complements the road design objectives and the overall visual amenity is pleasing to drivers and passengers. Landscaping should be designed to assist drivers by providing visual cues and directional guidance within the interchange area (for example by screening distractions), and to help focus the driver field of view on the roadway area. The landscaping may include public art in the form of sculptures or feature decorative treatments of structures, such as abutments to enhance the sense of arrival and local visual amenity.

Significant cut/fill batters and drainage basins are often associated with interchanges. Landscaping should be appropriate to the landform and contribute to the operational and environmental functions. Surface treatments should complement the functional use zones within the interchange (e.g. drainage basins) and minimise the ongoing landscape maintenance requirements.

Planting buffers and selective screening of the interchange area from adjoining land uses such as residential areas may be required to minimise visual impacts and contribute to the overall visual amenity experienced by landholders adjoining the interchange. In some cases additional built screens or walls may be required to address visual intrusion or the loss of visual privacy (e.g. views into private living areas from ramps), and to meet community expectations.

16.3 Road Safety

All landscaping in the vicinity of freeway interchanges should provide the appropriate sight lines with due consideration given to the likely operating speeds and curvature of ramps and turning roadways. No fixed objects such as rocks, trees or walls should be allowed within the roadside area and all surfaces should be graded smoothly to provide a consistent surface that will not destabilise an errant vehicle. In addition, the surface should be maintained in a condition that will not 'snag' the undercarriage of an errant vehicle and cause it to roll. Landscaping should be designed to minimise the potential for visual distractions or visual information overload that may detract from safe driving.

17. Other Considerations

17.1 Access in the Vicinity of Interchanges

17.1.1 Access to the Freeway

Legal and physical limitation of access along freeways to interchange locations eliminates deceleration, crossing, turning, parking and driveway conflicts between high-speed and low-speed vehicles, and between pedestrians, animals and vehicles, and thus makes a significant contribution to safe operation of a freeway. The same is true with respect to interchanges.

Access from private properties may be restricted or restored by providing frontage roads on both sides outside the boundary of the freeway. Where new subdivisions are proposed beside a freeway reservation, the developer should provide properties abutting the freeway with access from roads internal to the subdivision. No private access should be allowed to the main carriageways or ramps of a freeway. The only exception is privately owned traffic generators such as service centres (Section 17.2). Access control on freeways provides the greatest single benefit to road safety on these high-speed facilities.

17.1.2 Access to the Minor Road

Access control on the minor road in the vicinity of interchanges may be necessary to improve safety and traffic operational efficiency of the interchange and its approaches. Factors to be considered in determining the limits of such access control include:

- existing and possible future development in the vicinity of the ramp terminals (parking and driveways)
- separation of intersections between frontage roads or local streets from the minor road ramp terminal so that they do not fall within the deceleration lanes
- costs of prohibiting abutting access
- channelisation of the crossroad and ramp terminals
- provision for pedestrians
- legally declared status of the road.

An expressway with partial control of access facilitates the flow of through traffic and has characteristics similar to a freeway, but includes some at-grade intersections and some carefully selected and predetermined service facilities.

Control of driveways and roadside development is an integral part of access control strategies for roads (refer to the *Guide to Traffic Management Part 5: Road Management* (Austroads 2014)).

Usually utility services are not permitted along freeways, so eliminating the hazards of poles and excavation of the road or road reserve, and slow moving or stationary maintenance vehicles.

17.2 Service Centres

Service centres and rest areas are costly, and should be installed on rural or urban freeways only after preparation of a strategic plan to identify suitable locations. The layout design should be developed in consultation with landscape architects and other relevant specialists. Consultation with the service centre operators is also essential.

Service centres may be located on the freeway carriageway in the vicinity of an interchange only if the separation is large enough to ensure that no operational problems will result from associated weaving manoeuvres (refer to *AGTM Part 6* (Austroads 2013a)), Section 6.6.6 and in particular, Table 6.3). Analysis should be undertaken in accordance with the *Guide to Traffic Management Part 3: Traffic Studies and Analysis* (Austroads 2013d). The investigation should take account of future traffic flows and (as a general rule) it will be difficult to achieve a satisfactory outcome for service centres on urban freeways.

Where necessary, service centres may be placed in the quadrants of rural spread diamond interchanges (i.e. in the area bounded by the ramp, the major road and the minor road). However, where this occurs:

- the entry from the freeway into the service centre should be via a deceleration lane on the right-hand side of the exit ramp situated at least 100 m past the physical exit nose
- re-entry to the freeway should desirably be via a ramp that passes under the abutment of the bridge over the freeway and merges with the freeway entry ramp (for spacing of ramps and noses, refer to *AGTM Part 6* (Austroads 2013a))
- under no circumstances should an exit from the service centre be allowed directly onto the freeway exit ramp as this will not be expected by drivers on the ramp and will lead to safety problems
- convenient and safe access should be provided for local traffic, either through an additional leg at the ramp terminal with the minor road or a separate intersection (entry/exit) on the minor road
- safe, convenient and secure pedestrian routes and facilities should be provided for local residents from abutting land so that they are not tempted to seek alternative routes across freeway carriageways or ramps.

Service centres may offer the only 24-hour service available to a local area. Local people may often use the facility for take away food and drinks late at night so it is important that interchanges and the centre have a high standard of lighting to provide for their protection and to deter crime.

The facilities offered by service centres and other aspects relating to the road design and traffic management of service centres is covered in the *Guide to Road Design Part 6B: Roadside Environment* (Austroads 2015d).

17.3 Oversized Loads and High Wide Load Corridors

Where roads are to be grade separated any oversized load or high wide load (HWL) route (known as over-dimension routes in New Zealand) should desirably pass over crossroads to reduce clearance requirements and costs.

Where the oversized load/HWL corridor route passes under the crossroad and the crossroad links to the oversized load/HWL route with an interchange, a diamond shape interchange parallel to the route should be installed to minimise clearance requirements at the interchange. If there is no connection between the oversized load/HWL route and the crossroad, or if there is an existing non-diamond interchange, an alternative route with appropriate clearances should be considered. Options that may be considered include a detour only for the use of oversized load/HWL, or a crossover to the opposite carriageway.

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Appendix A Example of Ramp Speed Analysis

The upper diagram of Figure A 1 shows an exit ramp of a partial cloverleaf interchange. The diverge speed from the major road is 100 km/h and the vehicle path radius on the R30 m curve is 32 m. A decrease in speed of 56 km/h exists at the start of the R30 m curve. This decrease in speed combined with the long length of curve (typical for a 270° exit ramp) results in a potentially high single-vehicle accident rate at this location.

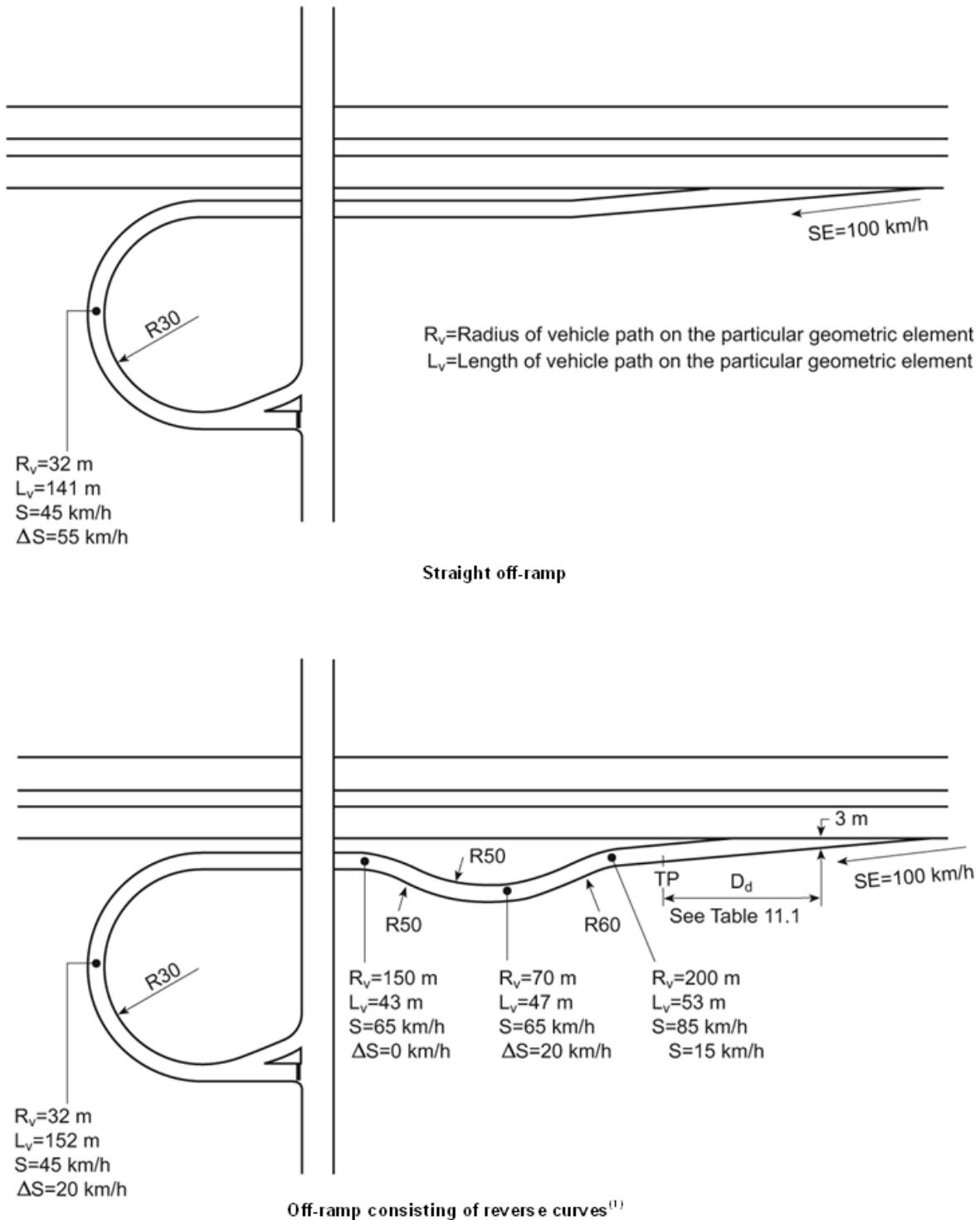
The lower diagram of Figure A 1 shows the same exit ramp with an additional two reverse curves before the R30 m curve. The maximum decrease in speeds between successive elements for this layout is 20 km/h as recommended. Fewer single-vehicle accidents would be expected on this geometry when compared with the geometry shown in the upper diagram.

The reverse curves shown need to be of minimal length, as single-vehicle accident rates are proportional to the lengths of the curves. The length of these curves needs to be just long enough to achieve the required vehicle path radii. If the ramp consists of multiple lanes, the curves are also required to be long enough to discourage drivers from cutting across lanes.

The driver path radius on the last reverse curve is 150 m. This value is significantly greater than the driver path radius on the preceding reverse curve of 70 m, and this produces no decrease in vehicle speed on the last curve.

In order to produce a decrease in speed on the last reverse curve, the curve would need to be reduced to an extremely small radius or would need to be lengthened considerably. The first option would not produce a practical result and the latter would produce unnecessarily long reverse curves that would have a negative impact on safety. Therefore, appropriate design practice in this particular application is to provide no reduction in vehicle speed on the last reverse curve.

Figure A 1: Example of exit ramp speed analysis for a partial cloverleaf interchange



1 Single lane off-ramp shown. This treatment may not be suitable for off-ramps comprising greater than one lane because of the potential for drivers to cut across lanes.

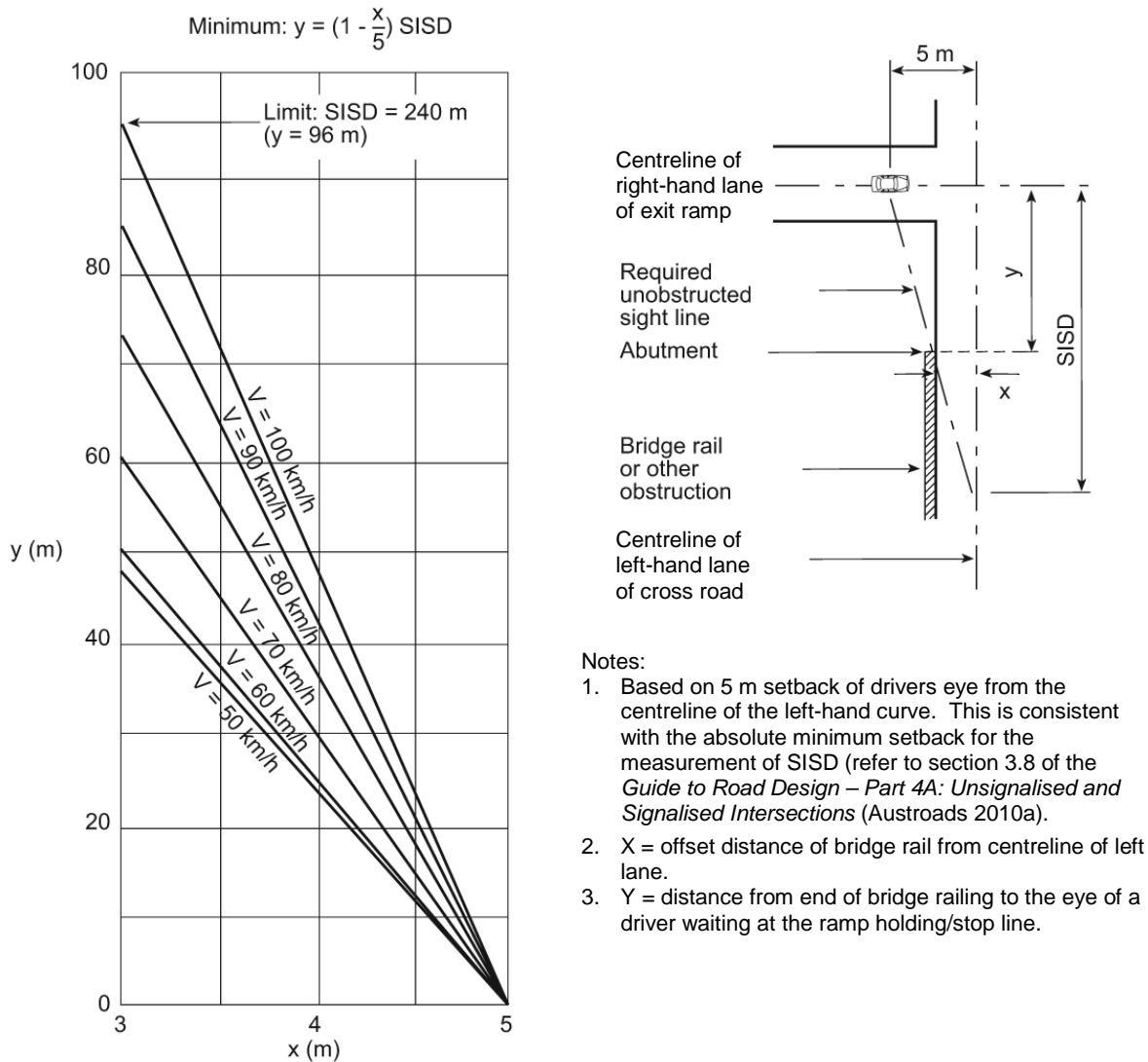
Source: Department of Main Roads (2005)¹⁸.

¹⁸ Department of Main Roads (2005) has been superseded and Figure A 1 has not been carried forward into Department of Transport and Main Roads (2014).

Appendix B Ramp Terminal Location

The amount of bridge widening can be determined using Figure B 1.

Figure B 1: Ramp terminal location compared to bridge rail offset



Example

A bridge over which the operating speed of traffic is 80 km/h is to have 3.5 m lanes and a 2.0 m wide footpath. Determine the minimum distance that the ramp terminal should be located from the end of the bridge railing.

Solution: $x = 3.5/2 + 2.0 = 3.75 \text{ m}$

From the graph in Figure B1, $x = 3.75$ and an 80 km/h speed, $y = 44.8 \text{ m}$. The driver's eye should therefore be a distance of 44.8 m from the end of the bridge railing.

Appendix C Examples of Ramp Signal Layouts

The detailed geometric design of freeway/motorway ramp signal treatments may vary between jurisdictions. However, the following examples (Figure C 1 and Figure C 2) show the principal features required in ramp signal layouts.

Figure C 1: Example ramp signal layout – two lanes at the ramp signal and one-lane freeway merge

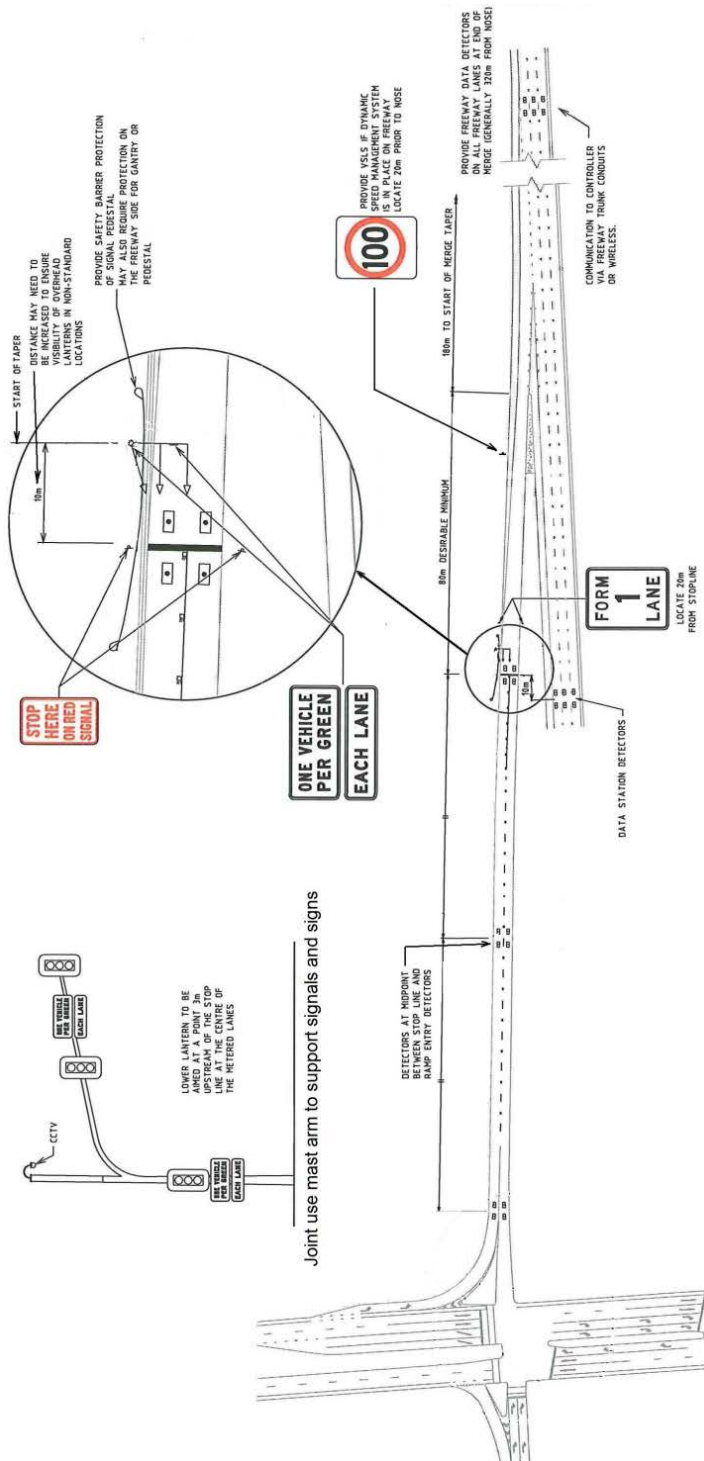
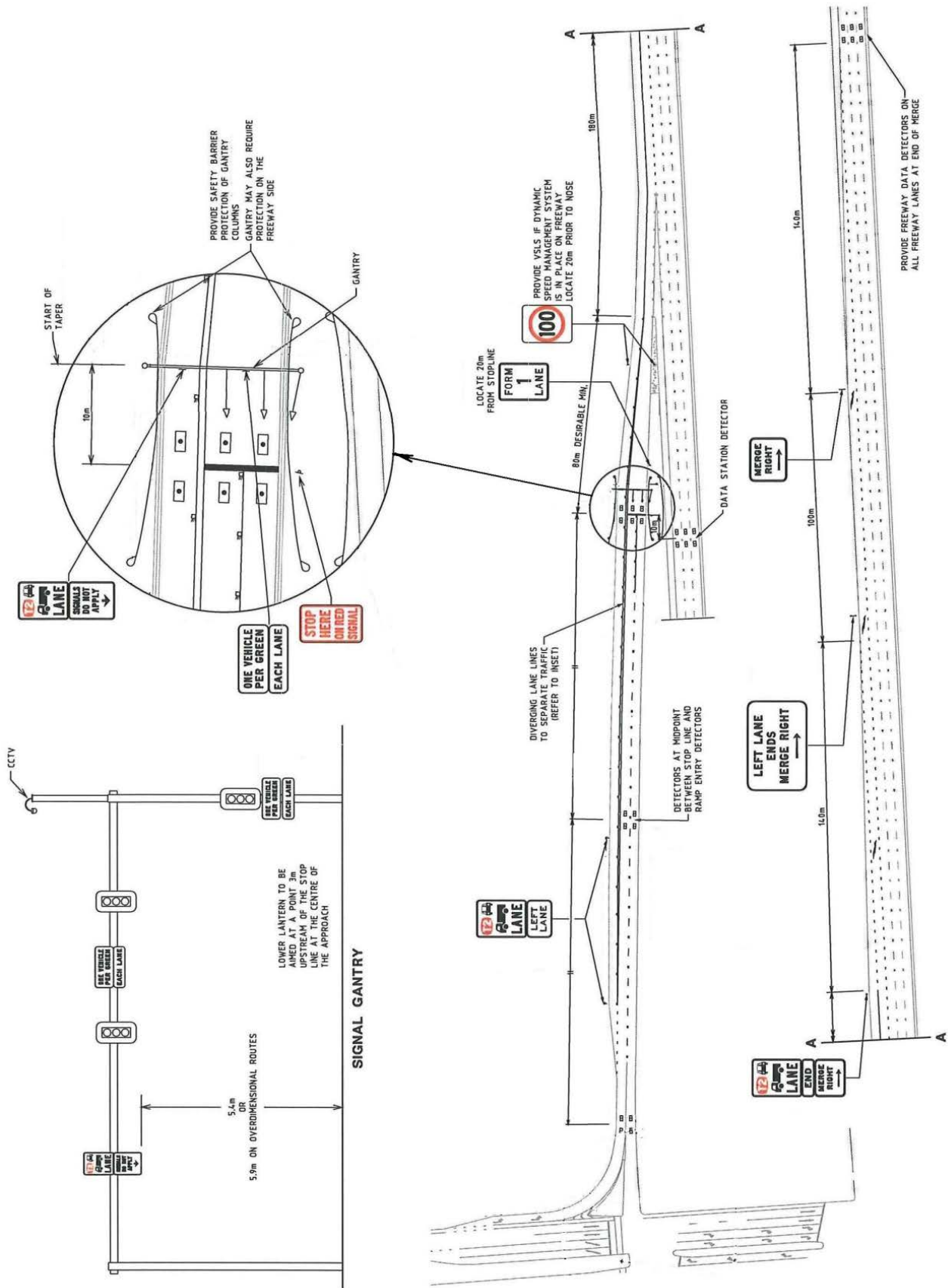


Figure C 2: Example ramp signal layout – three lanes at the signals and one-lane freeway merge



Commentary 1

The following points need to be considered in relation to exit ramps on the back of curves:

- curves requiring greater than the desirable maximum design side friction factor are not to be used as they can inhibit vehicle control (true for both right-hand and left-hand curves)
- the taper can inadvertently lead vehicles on to the exit ramp
- the driver's attention is likely to be directed elsewhere on a tight curve
- sight distance can be interrupted by vehicles in adjoining lanes
- the sight line could be blocked by a median safety barrier.

If the alignment of the proposed road cannot be changed, a possible solution is to provide a parallel auxiliary lane on the approach to the exit with a very sharp taper to enhance the delineation of the exit. This provides an additional visual cue to the presence of the terminal and it is less likely that a driver will be inadvertently led off the through road. The parallel lane treatment also provides greater scope to make the necessary reverse curve manoeuvre compared with the scope available on a taper-only type terminal.

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Commentary 2

At entry ramp merges, it is necessary for drivers on each carriageway to be able to see the impending merge followed by the need to have mutual visibility between vehicles on the ramp and vehicles on the through lanes and the need to be able to see the far end (or terminal) of the merge.

With respect to sight distance on the approach, drivers on the ramp need to see in advance where they will have to start looking for vehicles on the through road. Drivers in the through lanes initially need to be able to see that there is likely to be entering traffic and not just rely on signs for this information. This gives drivers in the left lane the chance to decide to change lanes to avoid possible impedance from entering traffic. Drivers in the adjacent through lanes need to be aware of possible lane changes by vehicles in the left lane and possible impedance from the entering vehicles and vehicles changing from the left lane.

Closer to the merge, but still prior to where any merging or lane changing may occur, mutual visibility allows drivers on the ramp to detect gaps in the traffic in the left through lane and judge vehicle speeds. Drivers in the left through lane are able to see entering vehicles and may have to adjust speed accordingly.

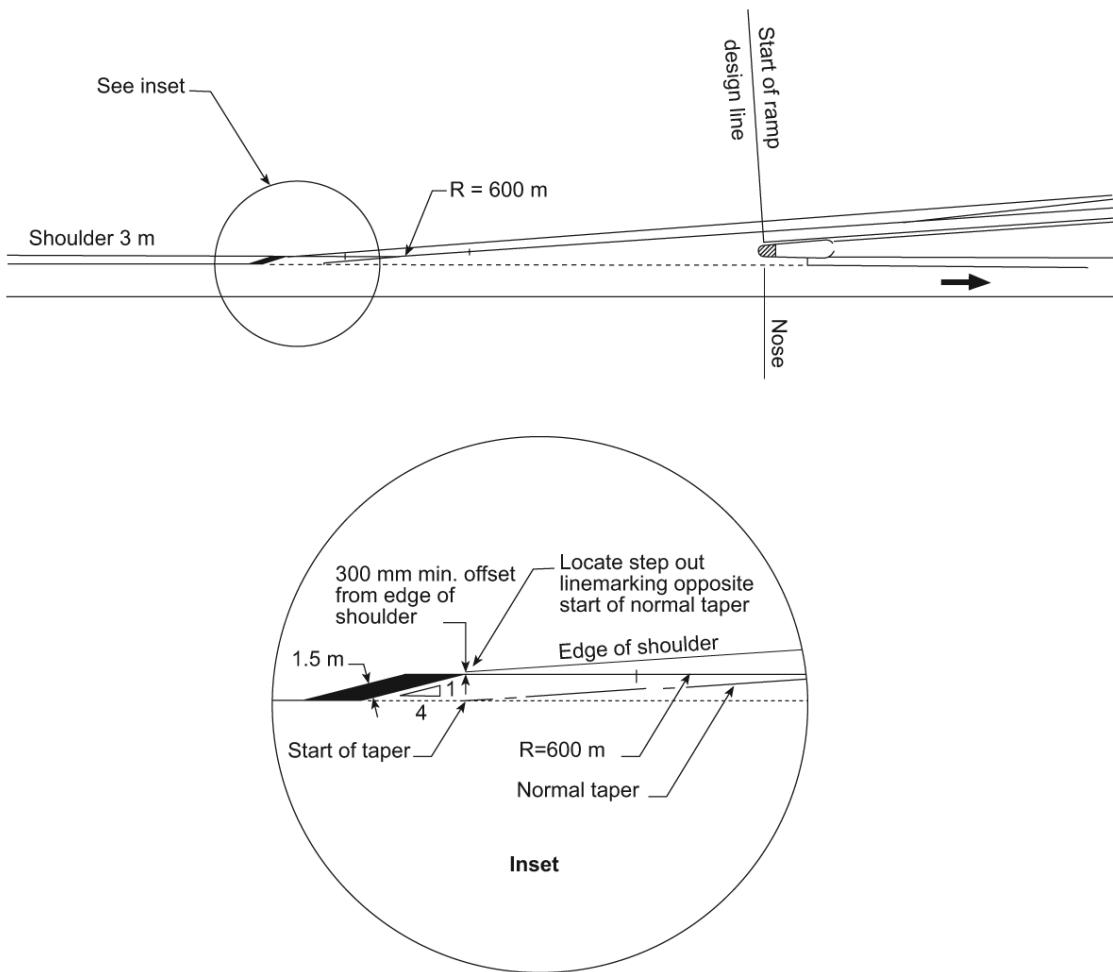
Before the end of any merge, drivers need to be able to see the end of the merge and take appropriate action.

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Commentary 3

It is suggested that freeway exits be constructed and line marked so that the exit is easily recognised as such and is well delineated. Figure C3 1 shows a typical arrangement comprising a wide painted strip across the shoulder on an abrupt taper. It is suggested that this type of treatment be used on all rural freeways and on urban freeways where the ramp is located on the outside of a curve that has a radius less than 900 m. On new work the width of the exit lane should be 3.5 m and for retrofitted exits the minimum width should be 3.0 m to the edge of the shoulder or line of kerb.

Figure C3 1: Typical preferred style of marking at rural freeway exits



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Commentary 4

Whilst urban freeways which have 3.0 m wide sealed shoulders provide a comfortable and reasonably safe environment for cyclists in mid-block situations, the prevailing conditions at many locations give rise to concern about cyclist safety. Locations which are deemed to be unreasonably hazardous for cyclists include:

- shoulders which are too narrow, in some instances only 0.6 m wide
- off-ramps and on-ramps which carry very heavy volumes of high-speed traffic throughout the day and night
- sections of freeway where the shoulders are used as bus lanes to provide a relatively high-speed express bus service
- high bridges where prevailing crosswinds and turbulence from large motor vehicles can destabilise cyclists
- weaving areas between entry ramps and exit ramps
- places where vehicles stop in the emergency stopping lane (i.e. shoulder).

The prevalence of these conditions on most urban freeways makes it less likely that these routes will be satisfactory for cyclists unless substantial treatments are implemented to overcome these problems.

The following factors should be considered in assessing the suitability of a freeway for use by cyclists:

- The freeway should provide a safer and more convenient route than alternative non-freeway routes.
- Potential for use of the freeway by children should be low and should also be actively discouraged through education programs. Such use is likely to be low because the kinds of trips undertaken by children, short distance trips to school and for recreation, are not well served by freeways.
- Sealed outer shoulders are essential on freeways which carry heavy volumes of motor vehicles and significant numbers of cyclists. In such situations and where the prevailing traffic speeds are 100 km/h a 3.0 m wide shoulder is desirable but a minimum width of 2.0 m may be used, particularly at squeeze points. Where a section of freeway has an 80 km/h speed zone the corresponding widths are 2.0 m and 1.5 m.
- Ramp volumes should be such that adequate gaps occur in the traffic stream to allow a safe and convenient crossing of the ramp by cyclists. If volumes are too high then an alternative route through or around the interchange should be devised.
- All ramps should have an outer shoulder at least 1.2 m wide, preferably sealed.
- Ramps exiting and entering the freeway from the right-hand lane are likely to be unsuitable for cyclists as they have to cross two lanes of high-speed traffic to access them. Alternative routes have to be examined.
- Sight distance in accordance with a pedestrian crossing at an intersection (refer to *AGRD Part 4A* (Austroads 2010a)) should be provided at the bike crossing of the ramp where cyclists are directed to cross freeway ramps.
- Under special circumstances such as very high traffic volumes or difficult geometry which cause serious safety hazards, short sections of off-carriageway cycling path may need to be provided to enable cyclists to bypass the hazardous area.

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Commentary 5

It is estimated that a cyclist requires a gap of seven seconds in order to cross the ramp safely (Ove Arup and Partners 1989). This gap was determined using the assumption that both the bicycle length and the car width are 2.0 m. Assuming that the speed of the bicycle is 5 km/h (1.4 m per second) at the crossing, it will take almost three seconds for the bicycle to pass in front of the motor vehicle. If it is further assumed that at least two seconds clearance is required after the passage of the first vehicle and also before passage of the second vehicle, it follows that a minimum gap of seven seconds is required.

If the ramp is an exit ramp or the entry ramp is not controlled by traffic signals it may be reasonable to assume that vehicles using the ramp arrive at random and gap acceptance theory should be used to estimate the delay likely to be suffered by cyclists in crossing these ramps. If an entry ramp is controlled by traffic signals then the ability of cyclists to cross the ramp should be evaluated in relation to the signal cycle and phasing and other traffic movements which may not be controlled by signals.

If analysis indicates that the average delay to cyclist is greater than 15 seconds (over which they are assumed to accept unsafe gaps of less than seven seconds) in the peak hour, then cyclists should be directed to use the exit ramp, cross the minor road at the ramp terminal and re-enter the freeway via the entry ramp. Grade separation of cyclists or an alternative route for them should be evaluated.

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Austrroads' **Guide to Road Design Part 4C: Interchanges** provides guidance on the geometric design of interchanges on freeways/motorways and on major arterial roads. The Guide covers the design of interchanges between: freeways and arterial roads; two freeways; and two major arterial roads. It covers the geometric design of all the elements of an interchange including the: alignment and cross-section of the freeway in the vicinity of the interchange, the intersecting road and the ramps; merge and diverge ramp terminals at the freeway; and ramp terminals at the intersecting road.

Guide to Road Design Part 4C



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