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Chapter 4

Application of Design Principles and Guidelines

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Chapter 4 Amendments–December 2005

Revision Register

Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
1	-	First Issue.	Steering Committee	Oct 2000
2	4.3.1	A paragraph on investment strategies added (last paragraph).	Steering Committee	Aug 2001
	4.6.1	Table 4.1 modified.		
	New	Relationship to other Chapters.		
3	All	Complete Chapter reviewed	Steering Committee	Aug 2004
	4.7	New Section – "Rehabilitation/Reconstruction/Restoration"		
4	Title	Name of Chapter changed from "Application of Design Principals and Standards" to "Application of Design Principals and Guidelines"	Steering Committee	Dec 2005
	List of Tables and List of Figures	List of Tables and List of Figures added.		
	Glossary (new)	Glossary added.		
	Various sections	Term "standard" changed to "design criteria", "design parameter" or "design value" where appropriate. Term "desired speed" introduced for the term "speed environment" (the two are largely analogous). Terms "operating speed" and "target speed" introduced where appropriate. Some minor amendments to various sections. References throughout updated where required. References to new Appendices included where appropriate.		

Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
4	Various sections continued	References to the "National Highway" deleted. Where appropriate these references were amended to "Auslink National Network Road Link" or "National Network Road Link". References to the "District Roads" deleted. Where appropriate these references were amended to "Local Roads of Regional Significance" or "LRRS".	Steering Committee	Dec 2005
	Section 4.1	Text added including text in related to the "Design Domain", "Normal Design Domain" and "Extended Design Domain".		
	Sections 4.2.2, 4.3.2 and 4.4.2	Title of sections changed to include "target speed" and "operating speed". Terms "desired speed", "target speed", "operating speed" and "design speed" included where appropriate. Associated text amended to reflect this. Text in Section 4.3.2 amended substantially.		
	Table 4.1	Table caption changed. Notes to table amended. Correction made to desired speed for an outer urban road. Terms "desired speed", "target speed" and "design speed" included.		
	Table 4.2	Table caption changed. Contents of, and notes to, table amended. Correction made to desired speed for an outer urban road. Terms "desired speed", "target speed" and "design speed" included.		
	Figure 4.3	Directional arrows corrected.		
	Sections 4.3.4, 4.3.5 and 4.3.6	Titles of subsections amended. Substantial amount of new text added to Section 4.3.4. Text amended in and/or added to Sections 4.3.5 and 4.3.6.		
	Section 4.4.6	Sub-section renamed from "Intersection spacing" to "Intersection spacing and control". Text added to "Median openings" subsection. Sub-section renamed from "One-way streets" to "One-way roads".		

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Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
4	Section 4.4.6 continued	Sub-section renamed from “Reverse flow and tidal traffic” to “Reverse flow/tidal traffic flow Text added to “Cyclists” subsection. Text added to “Parking” subsection.	Steering Committee	Dec 2005
	Figure 4.4	Caption amended.		
	Section 4.5	New paragraph added. Remaining text deleted because the National Highway scheme no longer exists.		
	Section 4.6 (new)	New Section added. It discusses the Auslink National Network Road Links.		
	Tables 4.4 and 4.5	Table captions changed. Contents of, and notes to, tables amended.		
	Section 4.6 (old) / 4.7 (new)	Former section renumbered – changed from 4.6 to 4.7. Subsections renumbered accordingly. Text added to subsections.		
	Section 4.6.3 (old)/ 4.7.3 (new)	Former section renumbered – changed from 4.6.3 to 4.7.3. Text added regarding geometric and pavement design where/if continuous frontage roads are to be used in maintenance operations. Reference included to local area traffic management devices also included. Sub-section renamed from “Maintain local traffic circulation” to “Maintain local traffic circulation in residential areas”. Sub-section renamed from “Provide access to properties fronting the motorway” to “Provide access to properties fronting a motorway or other major road”. Sub-section renamed from “Collect traffic destined for a motorway and distribute traffic from a motorway” to “Collect traffic destined for a motorway or other major road and distribute traffic from a motorway or other major road”. Sub-section renamed from “Collect and distribute traffic crossing a” to “Collect and distribute traffic crossing a motorway or other major road”. This sub-section was also moved to later in Section 4.7.3.		

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Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
4	Figures 4.12, 4.13 and 4.14	Figure captions changed.	Steering Committee	Dec 2005
	Section 4.6.4 (old)/ 4.7.4 (new)	Former section renumbered – changed from 4.6.4 to 4.7.4. Text added stating that total carriageway width must also be suitable for expected operation. Remark that pavement design is a secondary consideration deleted. Various other significant text amendments. National Highway sub-section deleted (see above)/		
	Sections 4.7.3 (old)/ 4.8.3 (new)	Former section renumbered – changed from 4.7.3 to 4.8.3. Title of sections changed to include "target speed" and "operating speed". Terms "desired speed", "target speed", "operating speed" and "design speed" included where appropriate.		
	Section 4.7 (old) / 4.8 (new)	Former section renumbered – changed from 4.7 to 4.8. Subsections renumbered accordingly. Section renamed from "Rehabilitation/ Reconstruction/Restoration" to "Restoration".		
	Section 4.7.1 (old)/ 4.8.1 (new)	Former section renumbered – changed from 4.7.1 to 4.8.1. Subsections renumbered accordingly. Sub-section renamed from "Design element combination" to "Combination of design elements". Sub-section renamed from "Existing accident history" to "Existing crash history". Text amended significantly.		
	Section 4.7.2 (old)/ 4.8.2 (new)	Former section renumbered – changed from 4.7.2 to 4.8.2. Section renamed from "Essential requirements" to "Essential requirements and documentation". Text amended.		

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Issue/ Rev No.	Reference Section	Description of Revision	Authorised by	Date
4	Section 4.7.3 (old)/ 4.8.3 (new)	Title of section changed to include “target speed” and “operating speed”. Terms “desired speed”, “target speed”, “operating speed” and “design speed” included where appropriate. Associated text amended to reflect this. Remaining text also amended.	Steering Committee	Dec 2005
	Section 4.7.5, 4.7.6 and 4.7.7 (old)/ 4.8.5, 4.8.6 and 4.8.7 (new)	Text amended substantially.		
	Section 4.9	New section “Requirements for geometric assessment and choice of domain” added.		
	References	References added.		
	Appendix 4A	New appendix “Process to follow when using the Extended Design Domain for restoration projects” added.		
	Appendix 4B	New appendix “Guide for evaluating sight distance for roads using the Extended Design Domain” added.		
	Appendix 4C	New appendix “Guide for evaluating sight distance for intersections using the Extended Design Domain” added.		
	Appendix 4D	New appendix “Design Domain for cross sections” added.		
	Appendix 4E	New appendix “Guide for short length right turn lanes using the Extended Design Domain” added.		
	Appendix 4F	New appendix “Guide for the Extended Design Domain for horizontal curves with adverse superelevation” added.		

Chapter 4
Application of Design Principles and Guidelines

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Glossary

Design Speed: Refer to Chapter 6.

Desired Speed: Refer to Chapter 6.

Eighty-fifth (85th) Percentile Speed: Refer to Chapter 6.

Motorway: In Queensland, a motorway is a road that has been declared as such under the legislation. It is a divided road for through traffic with full control of access and with interchanges provided at points where access to the local road system is required. **In this Manual, the term "motorway" is used in a generic sense, to describe a road that has all of the characteristics of a motorway and performs the function of a motorway.** Refer to Section 4.2 for further details.

Operating Speed: Refer to Chapter 6.

Restoration Project: A restoration project is a project where the cross section, structural capacity of the pavement and/or riding quality of an existing road is improved. Restoration projects also usually retain most or all of the existing alignment (i.e. they may also include some realignment works). The nature of the work typically has the potential to change drivers' perception of the standard of the road. In many cases road users will not distinguish between a restored road and a new road. Note the terms "rehabilitation" and "reconstruction" are often used but, in the context of this Manual, these terms fall under the umbrella of restoration projects.

Speed Environment: Refer to Chapter 6.

Standard: Within this Chapter, the term standard simply serves as a comparison of the capability of different road segments/aspects/alignments. For example, a high (geometric) standard road has geometry that permits high operating speeds in free flowing conditions and a high level of service. Conversely a low (geometric) standard road has geometry that results in low operating speeds and probably a lower level of safety. The term is not intended to determine some level of conformance to a prescribed standard. The only exception is where a prescriptive standard (e.g. an Australian Standard) is cited.

Target Speed: Refer to Chapter 6.

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4.1 Introduction

The purpose of this Chapter is to provide guidance on the appropriate general standard of design for the various road functions encountered on state declared Main Roads. The detailed technical chapters of this Manual provide the background and theoretical basis for the development of the parameters to apply to design. The various tables and diagrams in those chapters are necessarily generic and cover the whole range of design criteria that might apply to any road.

The overall philosophy of design is discussed in Chapter 2 and it is necessary for designers to be familiar with that philosophy before attempting to apply this Chapter or the details given in any other Chapter of this Manual, or indeed any other type of guideline or standard such as Austroads Guide to Traffic Engineering Practice series.

There will be a somewhat different approach when designing restoration or rehabilitation works on existing alignments from that used on a "green field" site (i.e. a new road on a new alignment). Section 4.9 specifies the requirements for geometric assessment for various project/work types, and provides guidance in relation to the choice of the Design Domain to be used for a particular project/work type. Guides for the application of the Extended Design Domain are included in the Appendices of this Chapter.

It is important to note that, in general, the design values and design criteria given in this Manual are for the Normal Design Domain unless Extended Design Domain values or criteria are explicitly given.

Generally, any new road on a new alignment should be designed to conform to the Normal Design Domain (refer to Section 4.9 and Chapter 2) for the various design criteria set out in this manual. (Chapter 2 describes the design domain concept.) Specifically the alignment should be designed above, or if necessary to, the desirable minimum value shown/given for a design parameter.

For existing alignments, and possibly for a major re-alignment on an existing road with low traffic volumes, some compromises might have to be made to obtain an economical result. However, every design must abide by the fundamentals of road design, and the design values chosen must be defensible in an objective analysis. An Extended Design Domain has been developed, for certain design criteria, to help achieve this. (Chapter 2 describes the Extended Design Domain concept.) The Extended Design Domain concept helps demonstrate that the original intents of the relevant design criteria have been maintained and that reasonable capability is still provided.

This Chapter provides guidance on the approach to design that should be adopted to achieve an appropriate design for projects on new alignments and projects on existing alignments. Designers should adopt design criteria that will meet the expectations of drivers now and in the future. To meet these expectations, roads performing at the highest functional level (e.g. motorways) would generally require the use of design values that tend towards the upper bound of the design domain. For roads performing at the lower functional levels (e.g. minor rural roads), drivers expectations would generally be met by using lower order design values (i.e. values that tend towards the lower bound of the design domain for a parameter where an increase in its value produces a higher benefit or values that tend towards the upper bound of the design domain for a parameter where an increase in its value produces a lower benefit). Nevertheless higher order design values (i.e. values that tend towards the upper bound of the design domain for a parameter where an increase in its value produces a higher benefit or values that tend towards the lower bound of the design domain for a parameter where an increase in its value produces a lower benefit) may be appropriate for roads performing at the lower functional levels where:

- the terrain and other constraints allow such values to be adopted at negligible increased cost; and
- the design values are consistent with driver expectation (i.e. it produces a context sensitive design).

It is necessary for designers to apply proper analysis to the particular circumstances that apply to the case they are considering and use the appropriate standards to suit that case. This Chapter has been structured to address the different road functions under the headings of Motorways (Section 4.2), Rural Arterial Roads (Section 4.3), Urban Arterial Roads (Section 4.4) and Other Roads (Section 4.7).

National Network Road Links are also briefly discussed (Section 4.6). While designation of a road as a National Network Road Link does not grant or imply a functional class, this set of roads are critically important to national and regional economic growth, development and connectivity with a focus on provision for freight vehicles. They are also subject to the requirements of the federal government.

Within the general functional types, discussion has focussed on the administrative classes used in Queensland to define the road system. It is not always the case that the “functional” class and the “administrative” class coincide and planners and designers should be alert to the difference. For example, some Local Roads of Regional Significance carry heavy volumes of traffic and their function is to connect major population centres with a high quality road. The normal standards applicable to a local road function would clearly not be appropriate in these circumstances even though, administratively, the road is classed as “local”. There will not always be a nexus between the road’s administrative classification and the standards required.

For all roads, the emphasis should be on consistency of standards based on the investment strategies and the vision for the road in question. These in turn must be based of the function of the road in question, its place in the hierarchy of roads in the State, the volume of traffic and the environment through which the road passes (i.e. the solution should be a context sensitive design).

With these provisos, it is reasonable to consider the type of standards required for roads at different levels in the hierarchy and this Chapter attempts to do this.

4.2 Motorways and roads performing a motorway function

4.2.1 General

Where a road has all of the characteristics of a motorway and performs the function of a motorway, the design should be in accordance with the requirements of this

Section, and the rest of this Manual, regardless of whether the road has been declared as a "Motorway" under the legislation.

Motorways are generally:

- high speed, high volume roads with full control of access; and
- grade separated multi-lane roads with no property access allowed.

Legislation allows Main Roads to preclude certain classes of vehicles from using a declared motorway providing appropriate signage is applied. These characteristics lead to the need for high standards producing a very safe driving environment.

Some motorway standard roads have been constructed in stages, the first stage being a two-lane, two-way road with the interchanges constructed in the first stage. The design of the interchange ramps for these roads requires special consideration to avoid inappropriate movements at the ramp terminals on the motorway. If no median is introduced, wrong way movements might be attempted and entering vehicles can move into the oncoming lane with hazardous consequences. A median must therefore be introduced through the interchange. Chapter 16 sets out the requirements for these conditions. In addition the positioning and layout of ramps in each stage should take into account, and make provision for, the layout in the final stage.

4.2.2 Design speed, desired speed and target speed

On motorways, drivers are not subject to the same restrictions experienced by drivers on other arterial roads. There are no at grade intersections and no property access and there is a reasonably large spacing between entering and exiting traffic. Drivers will therefore have a high desired speed; the design will have to cater for this behaviour. This in turn results in generous horizontal and vertical alignments that reinforce the high desired speed.

Drivers expect that a motorway will operate at a consistently high speed along its length, even in difficult terrain. Consequently target speeds of 110km/h or 120km/h should generally be selected for roads in rural and semi rural areas (refer to Table 4.1). In urban areas, the desired speed is often just as high, but it will depend on the area traversed and the level of development in the area (i.e. the built environment).

Operating speeds depend largely on the horizontal alignment as well as the speed limit (refer to Chapter 6). Further operating speeds can be modified by judicious use of horizontal curvature. Careful design of the transitions between sections with different desired speeds (speed environments) is required. However, except at such transitions, restrictions to operating speed should be avoided so as to provide a consistently level of service and high operating speed along the motorway.

In inner urban areas considerable restrictions on the possible alignment of roads exist because development is intense, property values are high and public opinion often defines the limits within which development of transport corridors can occur. In addition the nature of the built environment can influence the desired speeds of drivers. Consequently, in such circumstances, the adoption of a lower target speed may be appropriate.

In outer urban areas where development is less intense, drivers would expect to be able to maintain a high speed unless the surrounding environment (topography and/or development) dictated otherwise. Lower property acquisition costs in these areas usually mean that fewer restrictions to the alignment exist.

Table 4.1 sets out the recommended minimum target speeds. (Note: Speed surveys indicate that desired speeds are often about 10km/h over the speed limit, refer to Chapter 6).

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Table 4.1 Speeds for design of motorways

Area	Speed limit (km/h)	Recommended minimum target speed (km/h)
Rural-level and rolling terrain	110	120
Rural-difficult terrain	100	110
Outer Urban	100	110
Inner Urban	80	90
Note: For existing roads, the target speed would normally equal the road's desired speed (speed environment) which should be measured in preference to using the figure extracted from Chapter 6. The target speed for a new road, restoration project) or upgraded facility must take into account the proposed road width and geometric standards. Whatever the target speed selected, it must be fully justified and documented.		

4.2.3 Level of service

Level of Service is discussed in Chapter 5. For motorways, the assessment of Level of Service is undertaken using the methodology of the Highway Capacity Manual (TRB, 2000). This requires a detailed analysis of the conditions over the length of the project and the adjoining sections of motorway.

In rural areas, a design Level of Service of B is desirable but it should not be less than a Level of Service of C given the expectations of drivers. In rapidly developing areas, it might not be feasible to provide for a high Level of Service over the life of the facility and it is therefore important that a well-designed balance of lane numbers around a reasonable basic number of lanes is achieved (refer to Chapter 16).

In urban areas, it is desirable for the design Level of Service to be set at C but the demands could be such that this cannot be achieved and a minimum Level of Service of D would be acceptable in constrained situations. In any case, the design of urban motorways must be undertaken within the context of the transport strategy for the whole system and their capacity and the Level of Service provided must be in accordance with the role played by the motorway in the system. It is essential that the design of the motorway provide a proper balance in the lane numbers with flexibility to meet changing circumstances as the area develops.

Consistency of operating conditions is both expected and efficient. The design should therefore provide consistency in the Level of Service at whatever level it is set. This requires a consistent basic number of lanes with proper lane balance over the length of

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the facility with interchange capacities designed to achieve that balance (refer to Chapter 16).

4.2.4 Alignment

The alignment design must be consistent with the desired speed adopted for the facility and the operating speed (under free flow conditions) of each element. The highest standards consistent with economy should be adopted where they can be achieved with minimal impact.

Given the style of road expected of a motorway, design criteria should be selected that are toward the upper bound of the Normal Design Domain for each parameter. For example, Table 4.2 sets out desired design criteria for roads built to motorway standard on the assumption that a speed limit of 110km/h is required. On a new road with a speed limit of 110km/h, a target speed of 120km/h is required to accommodate the observed behaviour of drivers and to meet the requirements given in the MUTCD (Main Roads, 2003).

Proper alignment coordination in accordance with Chapter 10 is also required.

4.2.5 Cross section

Lane widths on motorways should not be less than 3.7m for lane locked lanes or less than 3.5m for other lanes. Shoulder widths should not be less than 2.0m on the near side and 1.0m on the off (i.e. median) side. In some cases, shoulder widths of 2.5m or 3.0m will be justified (e.g. to provide for cyclists or to allow enforcement to take place) but generally shoulders should not be wider than 3.0m because some drivers will use the shoulder as another lane, leading to unsafe operation. (Note: A shoulder of 3.5m or more may be required in special cases where regular law enforcement is required - refer to Chapter 7. Care is required in these instances and consideration must be given to the location and extent of such shoulders. The relevant agencies responsible for enforcement [e.g. Queensland Police Service, Queensland Transport] should be consulted to determine the location of wider shoulders for enforcement and whether a width greater than 3.5m is required for enforcement.)

Where the first stage construction includes only a single two-lane, two-way pavement, the constructed pavement should have lane widths of 3.5m and two fully paved and sealed shoulders not less than 2.0m wide. Through the interchanges, a median is required (refer to Chapter 16) to separate opposing traffic flows on the motorway. The design shall also take into account the future planning (e.g. radii suitable for adverse superelevation, crown applied to centre of lanes or shoulder as appropriate, layout of ramps suitable for final stage's layout, etc).

For further information, refer to Chapter 7, which defines the requirements for cross section elements and clearances; it also contains typical cross sections for motorways.

Table 4.2 Desirable design criteria for new rural motorways for a speed limit of 110km/h (i.e. desired speed of 120km/h) for an element with a design speed of 120km/h

Design parameter	General design criteria	Preferred design criteria
Horizontal radius	R=1,350m minimum	R=4,000m minimum
Sag curve	#R=15,000m minimum	#R>15,000m
Crest curve	R=14,000m minimum	R=18,000 minimum
Superelevation or crossfall	3% maximum superelevation	*3% maximum crossfall
Grade	5% maximum	3% maximum
*To facilitate future widening and to reduce potential aquaplaning issues, it is preferable to adopt horizontal alignments that do not need superelevation (i.e. adopt horizontal curve radii that are suitable for adverse superelevation). #Smaller sag vertical curves may be acceptable where excessive earthworks would result from using the value nominated in this table.		

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4.2.6 Operations

Efficient motorway operations depend on:

- spacing interchanges appropriately;
- providing properly designed merge and diverge areas at interchanges;
- minimising weaving manoeuvres (and providing adequate weaving lengths, if required);
- providing for High Occupancy Vehicle (HOV) and/or bus lanes where appropriate; and
- providing appropriate facilities for handling disabled vehicles (e.g. break downs, crashes).

This assumes that the geometry of the road is appropriately designed (refer to the relevant Chapters of this Manual), including design to an appropriate Level of Service.

Chapter 16 provides details of the required spacing of interchanges as well as the design of the merge and diverge areas. Weaving should be minimised if possible. Where weaving sections are included, they require analysis to ensure that the operation is as effective as possible and that a consistent Level of Service is maintained over the length of the motorway. The Highway Capacity Manual (HCM - TRB, 2000) provides the methodology for this and must be used to determine the characteristics of the weaving section.

In most cases the overall Level of Service provided by a motorway system will depend on the proper provision and use of collector-distributor roads and frontage roads. These provide for the efficient collection and distribution of traffic between the local road system and the motorway. Section 4.7 provides details of these roads.

Providing for disabled vehicles is an important consideration in ensuring efficient operation on a motorway. The shoulder of the motorway is available for this purpose and the width required is designed for this purpose. Where there is only a narrow shoulder (i.e. the width is <2.0m), emergency-stopping bays should be provided at regular intervals to accommodate vehicles that have to stop. Help telephones should be co-located with the emergency-stopping bays (refer to Chapter 8 and the Traffic and Road Use Management [TRUM] Manual, Main Roads, 2003). Details of the geometry required for these emergency stopping bays should be in accordance with this Manual and the TRUM Manual (Main Roads, 2003).

Due to the limited access opportunities on a motorway, it is also important the designer take into account the need to provide for emergency vehicles (e.g. access to evacuate casualties, treat spillages, etc). Median crossovers should be provided in accordance with Chapter 13.

Where an enforcement site is required on a motorway, the dimensions of the site should be as described in Chapter 20. Access to the site must be by way of an exit ramp from the motorway carriageway to the site and an entry ramp from the site to the motorway. These ramps are to be designed in accordance with the requirements set out in Chapter 16. Lateral clearance to the near side of the enforcement site is to be not less than the clear zone required (refer to Chapter 7), and desirably be not less than 15m. It is also desirable that the site be shielded from view from the motorway using appropriate planting to avoid congestion problems developing in heavy traffic situations.

4.3 Rural arterial roads

4.3.1 General

Rural arterial roads make up the majority of the state controlled road network. The department's investment strategies for these roads are focused on maximising benefits for all areas serviced by achieving appropriate standards across the whole road network. Over investment in any area will affect the department's ability to upgrade other areas to an appropriate standard.

The interim and vision standards in the investment strategies focus on carriageway and seal widths. Other requirements could be contained in the link strategies. Where neither the investment nor link strategies define standards, they should be derived through an iterative process that examines the entire road link, or at least consistent sections that are selected from obvious changes in character such as topography. Designers should pay particular attention to changes in character along the road to ensure suitable transitions between them and to ensure "no surprises" to motorists.

Within the general term "rural arterial", a range of sub-categories is used to differentiate between the different functions of the various parts of the network. These are:

- National Network Road Links (also refer to Section 4.6 for requirements for these roads);
- the State Strategic Road (SSR) Network;
- Regional Roads (RRs); and
- Local Roads of Regional Significance (LRRS).

The state strategic road network includes the principal intra-state highways and major developmental roads, providing intra-regional links, and links to interstate and National Network Road Links. This network is crucial to the efficient movement of people and goods throughout Queensland and its performance impacts directly on the economic performance of the State. This network requires an overall statewide perspective catering to long distance movements and linking major economic regions within and external to Queensland.

The regional road network caters for movements that link economic areas within the region to one another and to economic areas in adjacent regions. It is a network of roads essential for the development of the regional economy and is therefore planned within a regional context.

The network of Local Roads of Regional Significance makes up the rest of the system and completes access to major commercial centres throughout Queensland. These roads provide for movement between commercial centres within and adjacent to districts and provide access to the regional and state strategic road networks. There are therefore a wide range of circumstances in which Local Roads of Regional Significance are located and consequently a wide range of possible approaches to the standard of road to be adopted depending on its location and function.

The investment strategies together with the link strategies will define the general standard to be applied to specific projects in order to meet the defined objectives. Investment strategies have been developed for:

- National Network Road Links;
- State Strategic Roads (SSRs); and
- Regional Roads (RRs).

Suitable design criteria for the development and maintenance of links in the network are provided in the "Statement of Intent" (i.e. the Executive Summary of the Link Strategy). These documents should be consulted when establishing the requirements for individual projects.

The primary issue is to provide a consistent standard over significant lengths of road between obviously appropriate points of change in terrain, function, land use etc. The selected design criteria should reflect the intent of the link strategies. Where no link strategy exists, the standard of the link should be consistent. Consistent means that there are no surprises for the driver and the road becomes "self explaining" (refer to Chapter 2). **This means that isolated features that are below the standard of the adjacent road should be considered for removal when restoration takes place.** It also means that changes in the standard of the road should be located where the driver can see the change in adequate time to make allowance for that change. **Designers must justify and document any decision to retain isolated lower standard features.** This includes features that are within the Extended design Domain and features that are inconsistent with the contiguous road sections.

4.3.2 Design speed, desired speed and target speed

On the state strategic road network, high-desired speeds, and hence high target and design speeds (of 110km/h or more), are common and appropriate in rural areas. Adoption of a lower target speed should only be contemplated in cases of rough terrain with associated low standard horizontal geometry sections.

On most rural arterial roads, the desired speed, and hence target and design speed for elements, will be dictated by the topography through which the road passes. The link strategy will specify the target speed for the road and this should be used as the basis of the design.

Chapter 6 provides the methodology to be used to establish the appropriate design speed for each geometric element (also refer to Section 4.3.4 for further discussion). The design speed determined for any upgraded feature(s) must deliver consistency and must not result in an isolated feature with a very high or low design speed compared with the adjoining road. The procedure described in Chapter 6 allows designers to determine a design speed appropriate for the expected operating speed, which is estimated for specific elements of the alignment.

4.3.3 Level of service

The Level of Service provided by a rural arterial can be judged using three parameters:

- traffic flow;
- road closures; and
- efficiency of access.

The Level of Service to traffic may be assessed using Austroads Guide to Traffic Engineering Practice – Part 2 (Austroads, 1991) supplemented as required with the Highway Capacity Manual (TRB, 2000). Two major conditions exist and require separate consideration:

- two lane, two-way roads; and
- multi-lane roads.

These factors are dealt with in detail in Chapter 5. Appropriate Levels of Service to be adopted for these roads are also given in Chapter 5.

4.3.4 Alignment

The alignment should be consistent with the desired speed and reflect the role of the road in the network. It then follows that each element should be consistent with its operating/design speed (refer to Section 4.3.2). Careful attention to appropriate design for the conditions is required and proper transitions between sections with different desired speeds will be necessary (refer to Chapter 6) – consistency in the style of road over a link is also important. In the design of the alignment, it is very important to achieve a consistent standard of road over the length of the road or at least over significant lengths of road between obvious points of change (e.g. terrain).

Consistency means that there are no surprises for the driver and the road becomes "self explaining" (refer to Chapter 2). It also means that isolated inconsistent features should be considered for removal when restoration takes place. Further, in upgrading works, which might include substantial lengths of re-construction, isolated sections of high standard road should not be provided if these result in surprises to the driver when the new section connects to the existing road.

The geometric analysis procedure in Chapter 6 recognises that drivers adjust their speed to the prevailing conditions and will operate at a speed (they judge to be) appropriate for those conditions. The operating, and hence design, speed for these elements of the alignment can, therefore, be different from the speed limit. If consistently higher operating speeds can be achieved at minimal cost, a higher design speed should be adopted.

Crash records over many years should be checked, as they often highlight road alignment sections that do not meet driver expectations. Nevertheless, higher crash rates might also be related to factors other than alignment.

State Strategic Road Network (excluding motorways)

As the state strategic road network's role is to cater for high speed, long distance travel at an adequate level of safety, generous horizontal and vertical alignments resulting from high design speeds are typical characteristics. High desired speeds, and hence high operating speeds, can be expected and the design should reflect this (i.e. target speed would normally be 110km/h).

To assist the efficient movement of freight (and reduce the need for climbing lanes), the vertical alignment should be flat in general (5% normal maximum grade but 6% to 7% could be acceptable in rough terrain - refer to Chapter 12 for further details such as maximum lengths for various grades) with vertical curvature appropriate for the operating speed of each element. The operating speed will be determined by the horizontal alignment (rather than the vertical curvature) and it is therefore essential that the design of the vertical alignment reflect this fact.

Horizontal alignments with large radius curves (i.e. with radii >750m – 1000m) are normal and where possible, larger radii are desirable to avoid the need for superelevation. This is particularly so with multi-lane roads where radii that do not require superelevation can minimise aquaplaning problems (refer to Chapter 11 and the Road Drainage Design Manual [RDDM - Main Roads, 2002]). Curves with a radius that is >1500m also have the advantage that sight lines do not pass too far outside the edge of the carriageway and so **may** be less affected by lack of future maintenance or construction of future safety barriers. Nevertheless horizontal sight distances should still be checked to assess if they are adequate.

However in very rough terrain, these standards might not be attainable and might not even be desirable.

Regional Road Network

On the regional road network, some roads will have similar characteristics to the State Strategic Road Network, or even motorways, and similar design speeds and horizontal curves are common. Where the strategic vision and link strategies have been documented for these roads, the general standard will usually be specified in terms of discrete road sections with a target speed for each section. However as the design develops, the operating speeds will be determined using the methodology described in Chapter 6. The operating speeds determined in this manner may or may not match the target or desired speed/s. If the operating design speeds do not match the target or desired speed/s, the design must progress with the determined operating speeds, provided there is no unacceptable inconsistency, or it will be necessary to refine the horizontal alignment in order to get a better match between the operating speeds and desired speeds. The latter option should not be adopted without considering its impact on the link strategy and the road system as a whole.

Grades may be greater than those for the State Strategic Roads if required (refer to Chapter 12) and vertical curvature should match the operating speed/s (determined using the methodology described in Chapter 6).

4

Local Roads of Regional Significance

For Local Roads of Regional Significance there will be many cases where, when compared to design criteria appropriate for roads that are part of the State Strategic Road and Regional Road Networks, it will be satisfactory to adopt more modest design criteria. However, some Local Roads of Regional Significance will be located in areas with high desired speeds and design in accordance with those desired speeds will be appropriate (e.g. use a target speed of 110km/h).

In rural residential areas, the target speed may be reduced to 90km/h for most cases but, in some cases, a lower target speed might produce an appropriate context sensitive design (refer to Chapter 2).

4.3.5 Cross section

Adopting an interim width for the carriageway is a key strategy to deliver the maximum benefits across the entire road network within the available funding. Where link strategies nominate "interim" standards, these should be the basic lane and shoulder widths for upgrading purposes. Nevertheless, there might be locations where increased cross sectional width can be justified (e.g. over crests that only provide for manoeuvre sight distance). Consistency of standard over long lengths of links in the network is required to establish a consistent driving pattern and driver expectancy of behaviour.

State Strategic Road Network (excluding motorways)

Cross section elements on this network should ultimately trend towards the upper bound of the design domain given in Chapter 7. Specific dimensions will depend on the type of project (e.g. new road or restoration of existing carriageway), traffic volumes, topography and the interim and vision standards consistent with the optimum investment level (which should be reflected in the link strategy). Because a high percentage of travel on these roads is at high speed over long distances, driver error through lack of concentration is more likely and a forgiving roadside environment is desirable.

To assist in providing a forgiving roadside environment, batters should be 1 on 3 or flatter and the full clear zone should be provided wherever practical to allow for errant vehicles. Batters on embankments of height less than 1.5m should be 1 on 4 or flatter, with higher embankments being 1 on 3 or flatter for the cases normally encountered. Batters of 1 on 4 or flatter, particularly batters of 1 on 6 or flatter, will tend to compensate for reduced shoulder and formation widths where these are required by the interim and vision standards.

Where multiple lanes in one direction are required, 3.5m lane widths should be adopted (in most cases) and appropriate shoulder widths applied (refer to Chapter 7). If shoulders at the lower bound of the design domain are used, designers should consider providing stopping bays for drivers at intervals of about 15km (refer to Chapter 20) and pull-off areas at more frequent intervals (e.g. at cut-fill transitions – refer to Chapter 7). Medians should desirably be 15m or more wide with side slopes into the median no steeper than 1 on 6 (1 on 10 preferred – refer to Chapter 7). Median widths of more than 15m may be required to adequately cater for the future (e.g. >15m required to cater for widening on the inside with a concrete safety barrier separating the carriageways).

Regional Road Network

Lane and shoulder widths should be appropriate for the expected type and volume of traffic with carriageway widths (lanes plus shoulders) commensurate with the type of work proposed (e.g. restoration project, new road or realignment – refer to Appendix 4D and Chapter 7). Restoration projects may be carried out on narrower formations to keep costs down (refer to relevant investment strategies and Chapters 1 and 2). Chapters 2 and 7 and Section 4.9 provide a comprehensive discussion of the appropriate design domain.

Some Regional Roads are major roads carrying significant volumes of traffic and a few are multi-lane limited access facilities. Such roads should be treated accordingly and the appropriate design criteria used. Where a multi-lane configuration in one direction is appropriate, medians are normally depressed, 9m to 12m wide with median cross slopes desirably 1 on 6 or flatter (maximum 1 on 4).

Raised medians are normally inappropriate on high and intermediate speed (i.e. roads with desired speeds of 90km/h to 110km/h – speed limits of 80km/h to 100km/h) rural roads. Even at rural intersections on high and intermediate speed rural roads, painted medians are often preferred, especially if the intersection is unlit (refer to Chapter 17). In very rugged terrain a narrow median with safety barrier might be appropriate on higher speed roads (refer to Chapter 8). Shy-line requirements apply with any safety barrier (refer to Chapter 7). Such treatments are sometimes used in steep sidelong country and on range sections. Narrower medians may be adopted in semi-rural areas where right of way is limited. However, driving on a road with a narrow median for long distances can be stressful for a driver and such designs should be avoided if possible. Medians wider than 7m should normally be depressed; raised medians would normally be 5m to 6m wide and include route lighting.

Where the cross section provides shoulders of limited width, it is important to provide suitable places for drivers to stop clear of the through lanes (i.e. "pull off" the road) at reasonable intervals (refer to Chapter 7). Where the predicted/design Annual Average Daily Traffic (AADT) exceeds 1000, pull off areas for passenger cars should be approximately 1km apart and be staggered at 0.5km intervals. Where the predicted/design AADT is less than 1000, the intervals between pull off areas may be extended to 5km and be staggered at 2.5km intervals. Suitable pull off areas for heavy vehicles should be available at intervals of 10km and be staggered at 5km intervals.

An opportunity to stop clear of through lanes (i.e. pull off area) may be provided by making use of cut/fill transitions and flat batters on low fills in conjunction with providing formal stopping places (refer to Chapter 20).

Local Roads of Regional Significance

The discussion of standards in this section is based on the assumption that the Local Roads of Regional Significance function at the lower end of the functional hierarchy. It is the case that some Local Roads of Regional Significance are major roads carrying significant volumes of traffic and in some cases can be limited access multi-lane facilities (i.e. they function as roads at the higher end of the functional hierarchy). These types of roads should be treated accordingly and the appropriate design criteria applied.

For Local Roads of Regional Significance that provide service at the lower end of the functional classification scale, lower traffic volumes and tighter controls on right of way will often dictate the cross section to be used. It will be common for most elements to be designed at the lower bound of the design domain to suit the conditions and the budget. Consistency of standard along significant lengths of road is still important.

Where narrow shoulders are provided, it is important to provide suitable places for drivers to stop clear of the through lanes at reasonable intervals (as described in the Regional Road Network section above). This may be achieved by making use of cut/fill transitions and flat batters on low fills in conjunction with providing formal stopping places (refer to Chapter 20).

4.3.6 Operations

A critical issue affecting the operation of rural roads is the question of access. The amount of access and the level of control of that access and the traffic volumes define the operational characteristics of the road. As the traffic volumes increase, this issue becomes more critical. Limiting the amount of access will normally provide a higher level of service over the life of a road, which is generally much longer than the design life of any project.

An issue related to operations is the provision of adequate stopping opportunities. On carriageways with narrow shoulders, drivers should be presented with frequent opportunities to stop their vehicle safely clear of the through lanes (refer to Section 4.3.5 and Chapter 7).

State Strategic Network (excluding motorways)

Highways often provide direct property access. However, this is a minor function for this type of road and should be minimised or removed as traffic volumes increase. Removal of access improves the traffic safety and level of service for through traffic.

Where property access cannot be removed, consideration may be given to widening and sealing the shoulder to provide adequate space for a driver entering the access to decelerate clear of the through lane (refer to Chapter 13). A similar widening should be considered to cater for the right turning vehicles from the other direction. Vehicles entering the road from an access are expected to select a suitable gap to allow acceleration to the required speed.

Similarly, side road access should be rationalised and allowable manoeuvres reduced as the traffic volumes increase. On highways, intersections should not be closer than 5km apart, with a desirable minimum spacing of 10km. In addition the intersections that remain should be to the higher order or arterial roads. Intersections should be highly visible, preferably with approach sight distance to the start of the intersection and safe intersection sight distance (refer to Chapter 13) to the intersection based on at least 3s of observation time plus an appropriate perception/reaction time.

When a need to upgrade highways through semi-rural areas to four lanes or more is identified, designers should consider the appropriateness of staging. For example, removing direct property access to the road through use of service roads may be a cost effective first stage instead of immediately providing additional lanes on the through road. Construction of interchanges could then be included in the second stage and additional highway lanes could be constructed as part of the third stage (or second stage).

When rural roads are upgraded to four lanes or more, direct property access to the road should be removed if possible. Planners and designers should consider the possibility of providing interchanges on high speed divided roads where major roads intersect. If this is done, care will be needed to ensure that driver expectations are not raised to the extent that the presence of at grade intersections elsewhere create an undue hazard (because it is a perceived inconsistency) if all intersections are not grade separated. Interchanges and intersection locations should be rationalised to provide an integrated road network with full access to the SSR limited to the arterial road system where possible.

Chapter 16 discusses the spacing of interchanges.

Regional Road Network

Direct property access is common on the regional road network. For the major roads in this network, this is a minor function and should be minimised or removed, consistent with the function of the road, as traffic volumes increase to improve safety and level of service for through traffic. Side road access should also be rationalised and allowable manoeuvres reduced as traffic volumes increase. When these roads are upgraded to four lanes or more, it is desirable to remove any direct property accesses if possible and rationalise intersections to connections with the arterial road system.

Spacing of intersections on these roads must be carefully considered and is affected by:

- visibility of the intersection sites;
- operating speeds along the road;
- direction signing requirements, with appropriate distance between decision points (of at least 5s);
- physical requirements of tapers;
- deceleration lengths;
- storage lengths;
- location of overtaking lanes and adequate separation distances (refer to Chapter 15);
- potential for increase in crashes;
- form of staggered T-intersections.

(Note: A staggered T-intersection is considered a single intersection in assessing separation distances – spacing should be measured from the individual legs to the next intersection.)

Spacing of intersections on these roads should not be closer than 2km with a desirable minimum separation of 5km.

Priority controlled intersections are normal on rural arterial roads. Traffic signals, where warranted, may be considered in cases where the speed limit does not exceed 80km/h.

Grade separations may be considered where:

- traffic volumes are sufficiently high (refer to Chapter 16);
- adjacent sections of road are grade separated and providing an interchange is consistent with that and necessary to

maintain consistency of driver expectations; or

- grade and topography would make it more economical.

Spacing of interchanges is discussed in Chapter 16.

4

Local Roads of Regional Significance

Direct property access is often a necessary function of Local Roads of Regional Significance although there are cases where the traffic functions overshadow the access function and some rationalisation of accesses is required. As traffic increases and subdivisions occur, direct property access roles tend to be removed where practicable to be replaced by service roads or internal access linked to side roads in conjunction with relatively closely spaced intersections.

Design of accesses should be in accordance with the principles set down in Chapter 13.

Consideration of intersection spacing should include the factors described for Regional Roads and similar conditions adopted for roads with similar operating characteristics. For lower operating speeds, closer spacing of intersections might be tolerable, particularly where the function of the road includes a high level of property access.

4.4 Urban arterial roads

4.4.1 General

Urban arterial roads are the major traffic routes in urban areas. Urban motorways are a special type of urban arterial road and are dealt with separately in Section 4.2. For the purposes of this section, motorways are excluded from the definition of an urban arterial road.

Urban arterials are usually multi-function facilities providing service to:

- through traffic (primary function); and
- local traffic (secondary function); and
- property access (tertiary function).

In some cases, the functions are separated with a service road for the local traffic and property access functions. In other cases, the secondary function is severely restricted and the tertiary function is completely suppressed with access points limited to widely spaced intersections (e.g. a bypass road). Even on bypass roads, the local function often exists, the bypass often being quicker and less congested than the local road system.

Roads are an integral part of the urban fabric providing services to a wide range of users. Careful attention to the needs of all users (e.g. car drivers, truck drivers, cyclists, public transport operators, pedestrians, Public Utility Plant [PUP] owners/operators) is required. The impact on urban form (e.g. the impact the road has on the aesthetics of the area, building styles, materials used, monuments, parks) and the requirements of the Local Government planning schemes and many other issues (refer to Chapter 3) must also be considered when developing a context sensitive design (refer to Chapter 2).

4.4.2 Design speed, operating speed and target speed

Overall operating speeds on urban roads vary considerably, depending on the spacing of intersections, the type of abutting development and the time of day. Off peak operating speeds of 30km/h to

40km/h are common in sections heavily influenced by conflicting traffic movements and pedestrians. Off peak operating speeds of 60km/h to 70km/h are typical (for a zone with a speed limit of 60km/h) where local traffic is separated from the through traffic and intersections are reasonably widely spaced.

Depending on the speed limit, operating speeds of 70km/h to 90km/h will occur where the road has minimal property access, the local function has been suppressed and intersections are widely spaced. Hence target speeds are typically ≥70km/h but ≤90km/h and should reflect the road characteristics. The link strategy will specify the target speed for the road for use in design.

The design speed for an element is the expected operating (85^{th} percentile speed) of the traffic speed in free flow conditions. Uniformity of design speed over long sections enhances safety by promoting operational consistency, and transitions between sections with different desired speeds should be properly designed (refer to Chapters 6 and 11).

However, free flow conditions rarely occur on urban arterial roads and some design elements (e.g. steep grades, start of climbing lanes) require consideration of peak hour speeds to determine realistic solutions. The operating speed is affected by:

- traffic volume;
- width of carriageway;
- grades;
- the presence of parking;
- intersections (e.g. types, spacing); and
- the presence and spacing of property accesses.

Roads with few delay producing characteristics exhibit little increase in overall travel time until flows approach saturation. Roads with many delay producing characteristics exhibit a marked increase in travel time with increasing flow. Figure 4.1 illustrates typical traffic flow/travel time relationships for typical urban roads with different delay-producing characteristics. These curves can be used for guidance in selecting operating speeds in peak hours. Ideally, for a particular road, a study should be undertaken to derive the specific operating speed graph for that road.

The variation of speed with traffic flow on typical urban roads, exclusive of the effect of major intersections and with no parked vehicles present, is illustrated in Figure 4.2.

4.4.3 Level of service

Austroads Guide to Traffic Engineering Practice – Roadway Capacity (Austroads, 1991) sets out the approach to assessing capacity and Level of Service in interrupted flow conditions. More detail can be obtained from the Highway Capacity Manual (TRB, 2000). The Level of Service to be provided in urban areas will often be guided by the regional polices for managing growth, transport, etc. Where such policies do not exist, it is desirable to aim for a Level of Service of C for off-peak travel, accepting that peak hours will operate closer to capacity conditions. It is important to provide a design that has balance between the mid-block and intersection capacity so that the road operates as an entity rather than as a series of discrete segments.

4

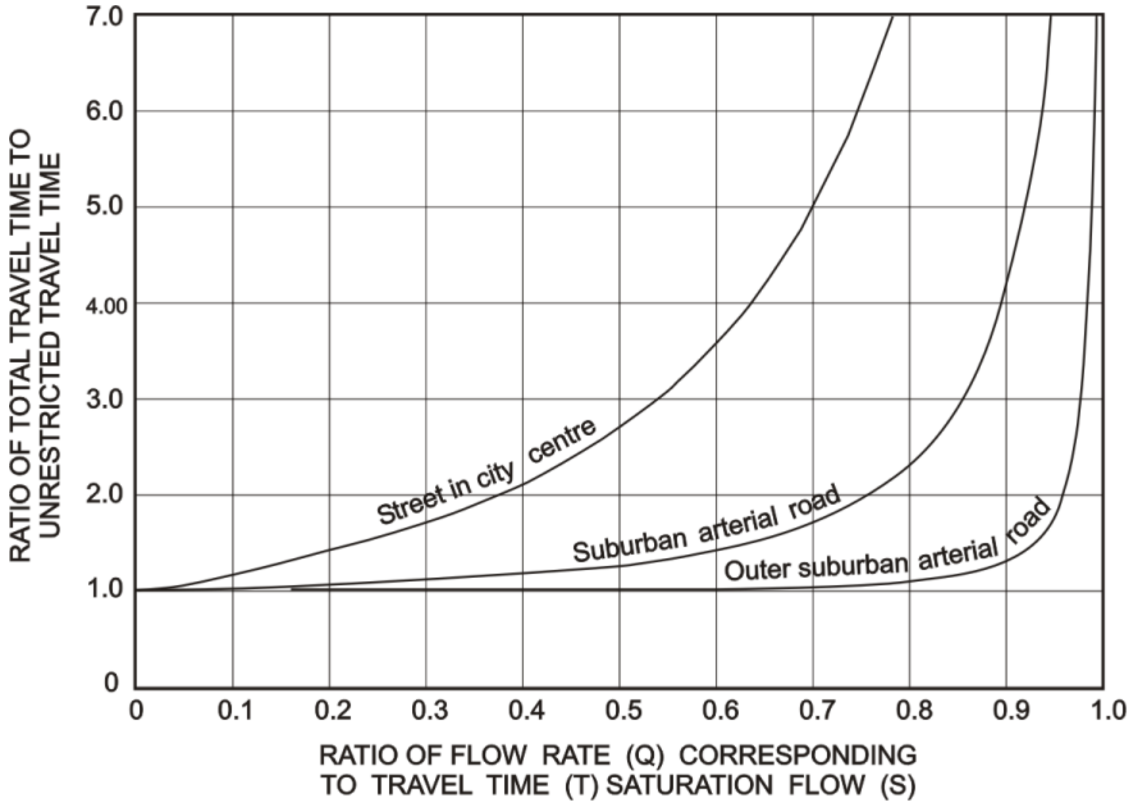


Figure 4.1 Typical relationship of traffic flow to travel time on urban streets with varying delay characteristics

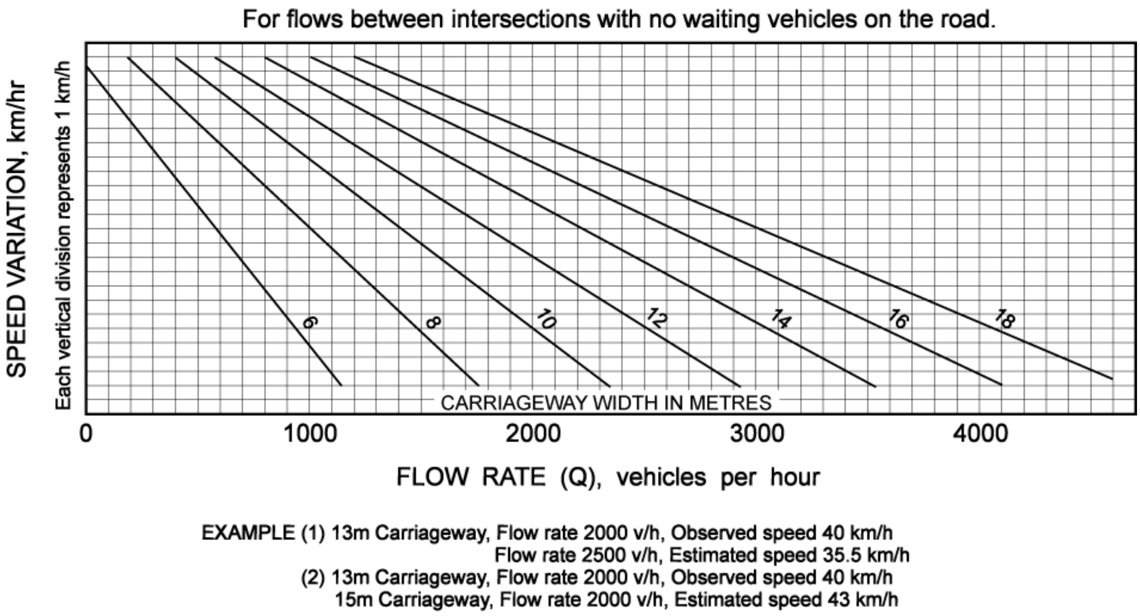


Figure 4.2 Variation of speed with flow for typical two way urban streets

The Level of Service is enhanced by providing:

- lane widths of 3.5m (refer to Chapter 7);
- appropriate (numbers/layout of) stand up lanes at intersections;
- right turn lanes at intersections and accesses where appropriate;
- control or absence of crossing or entering traffic at minor intersections;
- control or absence of parking;
- control or absence of right turns by banning right turns at difficult intersections;
- good coordination of traffic signals; and
- good lighting of the road for night-time driving.

Intersection analysis and level of service assessment is usually undertaken using computer programs such as aaSIDRA (refer to Chapter 13). This tool should not be regarded as a "black box" that always gives the right answer. Users must understand the data input requirements and the significance of the many parameters used. While the default parameters will often be appropriate, the user must understand when the particular circumstances prevailing require different parameters.

The aaSIDRA software provides extensive output detailing the performance of the intersection, individual movements and lanes using many parameters. It is important for the user to be able to extract the pertinent information for the case at hand from these results. The aaSIDRA User Guide provides these details.

Where it is required to analyse a series of intersections, or where other intersections in the wider network can influence demand flows at the intersection in question (e.g. reassignment to a parallel route), other tools might be more suitable for the analysis. Table 4.3 provides guidance in the selection of appropriate tools to use. Planners and designers should seek specialist advice if the more complex analysis tools are required.

Table 4.3 Intersection analysis tools

Situation	Analysis Tools
Single intersection	aaSIDRA.
Series of intersections on single arterial	TRANSYT to determine the coordination followed by aaSIDRA to design the intersections.
Wider network with parallel routes	Assignment packages with intersection analysis capabilities (SATURN, TRIPS). For example, use SATURN or TRIPS to determine the traffic volume and then use aaSIDRA for the intersection design. In some cases, micro-simulation might be appropriate (AIMSUM, PARAMICS, DRACULA), particularly if visual representations are needed.

4

4.4.4 Alignment

The alignment of many urban arterials is determined by the constraints of development adjacent to the road and the access requirements (both property and side road). Design elements should reflect the expected operating speeds, recognising that the speed is governed more by the horizontal alignment than the vertical.

Where there is some freedom to move with the alignment, designers should ensure that the desired speed created is in harmony with the type of road and its location. Curvature can be used to control the speed to the level commensurate with the segment/area. This is a case of bigger (e.g. curves) not necessarily being better. However, adequately designed transitions should be provided.

It is important that the vertical alignment is in harmony with the horizontal alignment in terms of sight distance available and the operating speeds on grades. If grades are significant, the capacity and Level of Service are affected and analysis should be carried out to ensure that there is consistency in the operating characteristics over significant lengths of the facility.

Refer to Chapters 9, 10, 11, 12, 13, 14 and 15 for details under various circumstances.

4.4.5 Cross section

The cross section elements of urban arterials will depend on a range of factors including available right of way. Chapter 7 provides guidance on the design domain appropriate for the various conditions encountered. Appendix 4D contains some discussion regarding the application of the Extended Design Domain to cross sections.

4.4.6 Operations

Operations on urban arterials are affected by:

- intersection spacing and control;
- lane changing;
- weaving;
- merging;
- spacing of median openings;
- one-way streets;
- reverse flow/tidal traffic flow;
- pedestrians;
- cyclists;
- parking;
- transit lanes (e.g. bus lanes and High Occupancy Vehicle [HOV] lanes);
- bus stops;
- property access; and
- driveway spacing and their distance from intersections.

Intersection spacing and control

The proximity of intersections on many arterial roads creates operational problems, and consideration of distances necessary for lane changing, merging, or weaving is necessary. Where adequate distances as defined below cannot be achieved for the particular operation required, control measures such as turn restrictions, signals or the formation of cul-de-sacs could become necessary.

Lane changing

Except when forced, lane changing normally occurs at a rate of lateral movement of 1.0m/s. Thus, for 3.5m lanes lane change distance in metres can be taken as approximately equal to V, where V is speed in km/h (refer to Chapter 15).

As traffic density increases, the number of drivers wishing to change lanes increases, and the opportunity to make the change decreases. Considerably longer distances then become necessary, and the problems then become similar to those of merging and weaving.

Weaving

Analysis of weaving is usually only applicable in motorway or near motorway conditions. The procedures described in the HCM (TRB, 2000) are not applicable to roads with interrupted flow conditions (e.g. most at grade urban arterial roads).

A weaving section handles two classes of traffic, viz:

- traffic entering, passing through, and leaving the section without crossing the normal path of other vehicles; and
- traffic that must cross the paths of other vehicles after entering the section.

On a well designed but short weaving section operating below capacity, the two classes tend to separate themselves from each other almost as positively in practice as they do in theory for simple weaving configurations. However, most urban arterial roads have to function, on occasions, under forced flow conditions. Weaving operations in these cases become virtually impossible, and for this reason, weaving sections should, where practicable, be avoided in arterial road design.

Merging

Figure 4.3 illustrates some simple merging manoeuvres, as in the case of a transition from two lanes to one.

Chapter 15 includes details of the calculation of merging lengths for auxiliary lanes. The treatment of acceleration and deceleration lanes is given in Chapter 13.

Median openings

The control of the spacing of median openings is a means of balancing the local service function with the through traffic function of an arterial road. Thus as the importance of the through traffic function increases, so also does the desirability of increasing the median opening spacing.

On urban arterial roads with an important local service function, and with medians sufficiently wide to accommodate right turn lanes, a spacing of 120m will permit successive development of right turn lanes when the operating speeds are ≤70km/h (Figure 4.4). Greater spacing is required where high storage demands or high desired speeds occur. The minimum dimension of 120m is a statement of the minimum physical space needed to generate the minimum length of turning lane at both intersections. This is applicable only in existing situations where there is limited flexibility. Consequently such an arrangement has a limited storage capacity and may not be appropriate where turning volumes are high. Their operation and capacity should be checked (e.g. using aaSIDRA) to determine if they are an appropriate treatment.

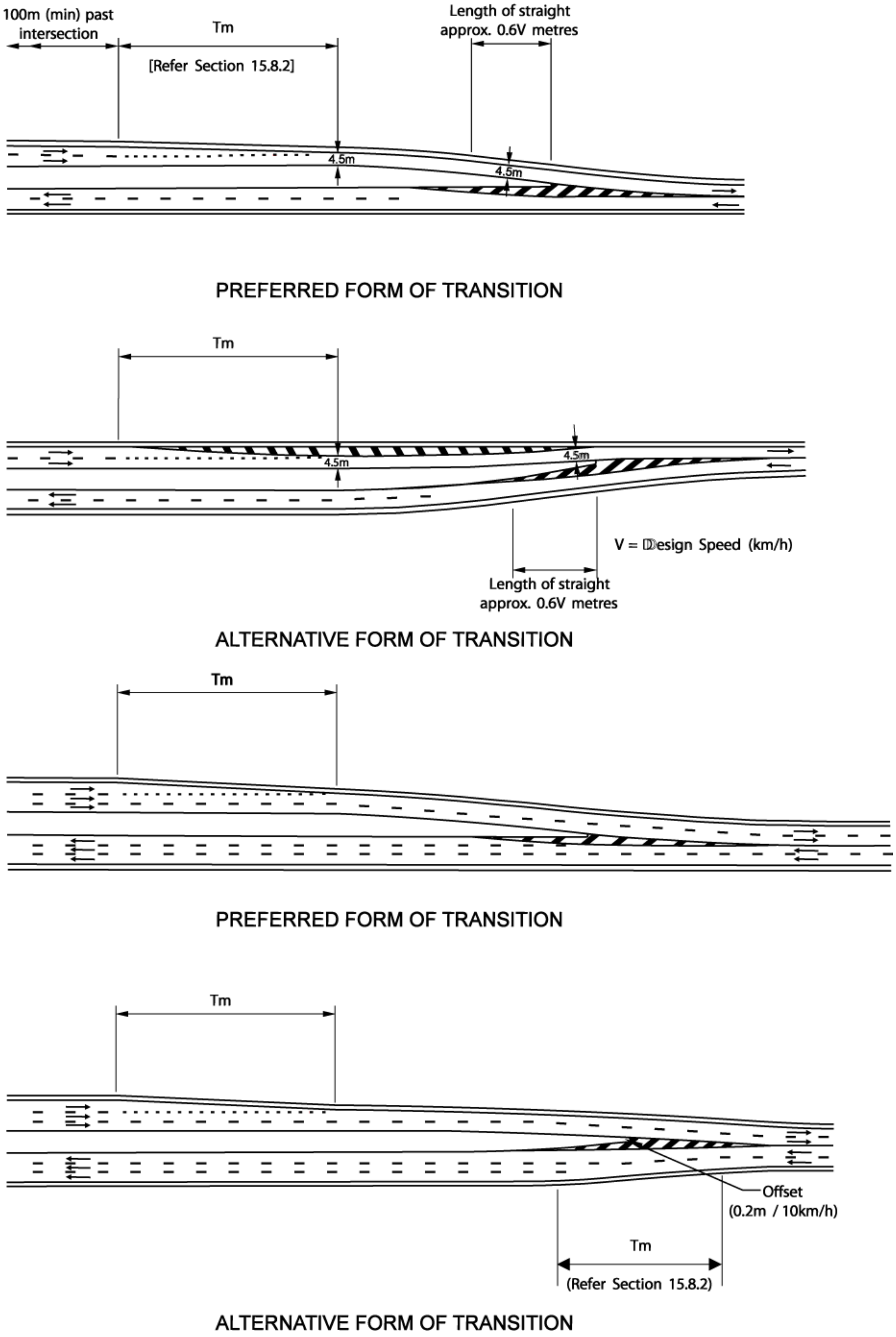


Figure 4.3 Typical median terminal treatments

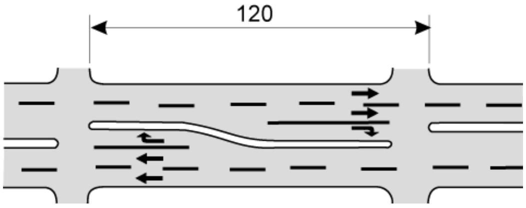
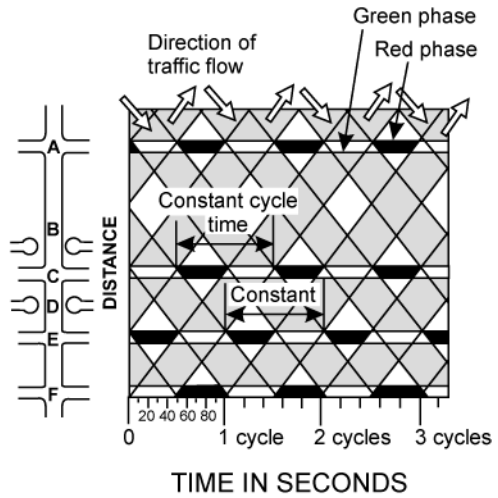


Figure 4.4 Minimum spacing of median crossings for medians 3m and wider for roads with operating speeds ≤70kmh

If traffic volumes are too high to allow median openings to be provided at this close spacing, some side road accesses will have to be modified or closed (e.g. turn into a cul-de-sac or a left-in/left-out only intersection, ban right turns at specified times, ban right turns completely). However, this introduces additional vehicle movements to allow drivers to achieve the manoeuvres they require, and this can affect the operation of other streets in the area. Chapters 7, 8 and 13 provide detailed information on the design of medians. Chapter 13 also discusses median crossovers for emergency or other access.

Where the through road and the intersecting road have a similar function but both have narrow medians, median openings should be provided at intersections except intersections with minor streets. This avoids the right turn demand being concentrated at a small number of locations and allows the turning vehicles to take advantage of the gaps that occur in the opposing traffic stream. This will also minimise the length of travel of drivers and provide more ready access to the local area. A minimum demand of 20 vehicles per day is a reasonable starting point to consider providing a median opening. However, as with all conflict points, adequate sight distance must always be available.

On arterial roads where coordination of signals will ultimately be adopted, a space-time diagram of the type shown in Figure 4.5 should be plotted to verify the adopted spacing. Intervals of 350m to 450m, or multiples of such, become necessary. Specialist advice should be sought with regard to the co-ordination of traffic signals.



Note: From this diagram intersections "B" and "D" are not accommodated in the progressive system and if this pattern were adopted they should be formed into culs-de-sac or given left turn entry only

Figure 4.5 Determination of intersection spacing for co-ordinated signals using space-time diagram

Many practical constraints exert major influences on the median spacing that can be achieved, particularly in the common case of reconstruction within an existing right-of-way with an established street pattern. The location of openings is normally obtained by the following procedure:

1. Rank the more important cross streets in terms of those at which openings must be provided, those where they should be provided, and those where they could be provided.
2. Examine the geometric constraints of alignment, cross section and visibility to ensure that these are compatible with

providing openings at those locations where they must be provided.

3. Select intermediate openings to provide adequate local service, to comply with the functional requirements outlined above, and to satisfy the geometric design standards.

4

One-way roads

Conversion of two existing two-way roads to a one-way pair is an inexpensive method of arterial road development, and for streets carrying high traffic volumes, a considerable improvement to the Level of Service often can be achieved by this technique. Crash rates at intersections are reduced since the numbers of conflicts are reduced and head-on collisions from opposing vehicles are virtually eliminated (however, wrong way movements can occur). Where signals are required, simple two-phase systems rather than three phase systems are normally adequate, thus reducing lost time and thereby increasing the Level of Service. Progression through the signals along the arterial is also easier to establish. (Note: Town planners consider the conversion of streets to one way flow undesirable as it reduces the permeability of the area.)

Lane marking is necessary, particularly with narrow pavements, to encourage maximum lane use. There is evidence that on relatively narrow, unmarked one-way roads, vehicles tend to queue in one lane rather than develop tight two-lane operation, and under these circumstances, greater capacity could be achieved by providing lane marking to facilitate two-lane flow.

The disadvantages that accrue from one-way operation are those of encouragement of extra speed, while at the same time some loss of sight distance of vehicles approaching from the right occurs. In addition, pedestrians who are strangers to the locality might tend to step into the path of vehicles approaching from the left.

Increased travel distances caused by "out of direction" movements result in increased traffic densities (on other roads) and personal inconvenience (and might also affect customers accessing, and deliveries to/from, businesses, etc), although the quality of flow (on the through one-way road) may nevertheless be improved.

The following design requirements should be fulfilled:

- the roads forming the one-way pair should desirably be not more than 150m apart and never more than 200m apart (in the transverse direction);
- cross roads should be permitted to intersect at intervals of 100m to 150m; and
- transition roadways with easy curvature should be provided at the ends of the one-way system.

Reverse flow/tidal traffic

Where the directional distribution of traffic in peak hours is greatly unbalanced maximum use of carriageway widths can be achieved by allocating a greater number of lanes to the predominant traffic flows as shown in Figure 4.6.

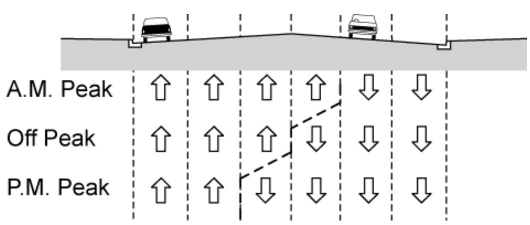


Figure 4.6 Reverse flow

Such a technique is often of value in stage construction, and in other temporary works, but it is not normally to be used in the design of permanent projects.

The use of the reverse flow/tidal traffic technique is more applicable to carriageways with five or more lanes. Its application to four lane roadways is severely restricted. In this case, the opposing traffic in peak periods is reduced to one lane. Overtaking opportunities for the one lane flow are therefore denied and long queues can develop. Vehicle breakdowns in the one lane will stop the flow of traffic, unless special breakdown provision is made.

Advance signing is necessary and it is crucial that it be clear and unambiguous. Control devices are normally in the form of signals or illuminated signs over each lane at approximately 300m intervals.

Because of the inherent danger of head-on collision, all of the following warrants must be satisfied:

- The difference between the flows in the two directions is substantial, being at least sufficient to justify an extra lane in the direction of major flow and the ratio of major to minor movements being at least 2:1 and preferably 3:1.
- Design controls and right of way limitations are such that it is not feasible to provide greater width or provide a parallel roadway.
- Adequate Level of Service cannot be obtained by restricting parking, right turn traffic or other such means.
- Where only one lane is available for the lesser flow, there should nevertheless be provision for a disabled vehicle to be overtaken (i.e. at least a 5.5m width [lane plus shoulder] should be provided in the direction of flow, and parking denied).
- Satisfactory terminal design such as in Figure 4.7 can be implemented.

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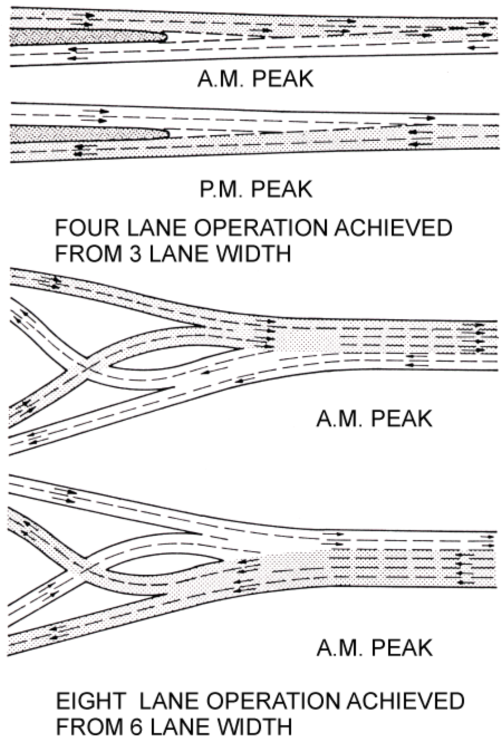
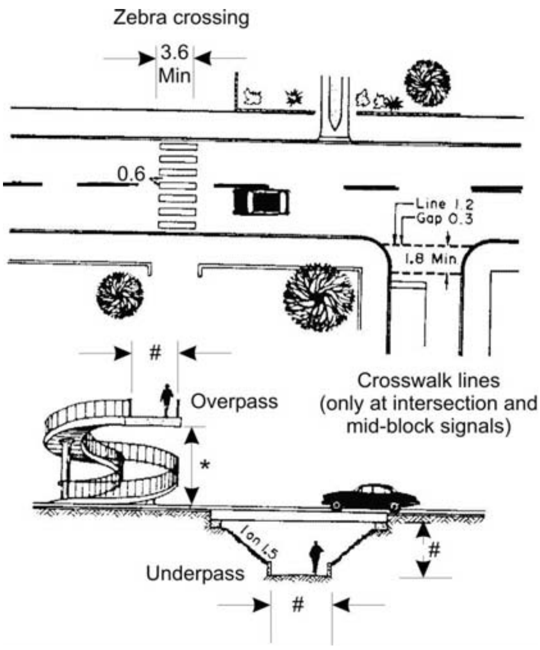


Figure 4.7 Reverse flow terminals

Pedestrians

Pedestrian accidents are almost invariably of considerable severity. On heavily trafficked roads, special facilities are necessary to promote pedestrian safety (e.g. Figure 4.8). In addition, pedestrian movements, especially when not incorporated appropriately into a design, can act restrictively on roadway Level of Service.

Pedestrians tend to take the shortest path to their destination, thus often crossing in mid-block locations, and failing to stay within the crossing itself. They tend also to avoid changing grades when crossing roadways, and thus careful location of grade separated pedestrian facilities to eliminate or reduce this desire is a feature of good design.



*Refer to Chapter 7 for clearances.

#Refer to Chapter 5 for these dimensions.

Figure 4.8 Examples of pedestrian crossings

Where a signalised pedestrian crossing is installed adjacent to an intersection, it is essential that the intersection itself be signalised. Otherwise, drivers of vehicles approaching the pedestrian crossing could interpret a green signal indication as applying to the intersection also, and disregard a vehicle approaching from the cross road.

Considerable care is required in taking decisions on the need for, and type of, pedestrian facilities. Installing a grade separated, "zebra" or signalised crossing is not always the best solution, and providing pedestrian refuges might be more appropriate. The warrants given in the MUTCD (Main Roads, 2003) provide the basis for these decisions. Further advice can be obtained by referring to the TRUM Manual (Main Roads, 2004).

Chapter 5 provides a more comprehensive discussion of pedestrian characteristics and requirements, with guidelines on the design of pedestrian crossing facilities.

Cyclists

Planners and designers must provide specifically for cycling on urban arterials in accordance with Chapters 5 and 7. Specific facilities for cyclists include off-road paths (shared or segregated), on-road cycle (only) lanes and shared lanes (e.g. transit lanes). The provision of sealed shoulders may also adequately provide for cyclists in some instances (e.g. a rural highway). While off-road paths may be preferred, designers must consider many issues when developing a context sensitive design (refer to Chapter 2) and these will influence the decision about what facility or provision for cycling is appropriate.

Planners and designers must provide for bicycles as detailed in Main Roads' Policy for Cycling on State Controlled Roads (Main Roads, 2004).

Main Roads, in planning and delivering the roads program, is to "positively provide" for cycling on identified cycling routes and make other routes "cycle friendly" where appropriate (refer to the policy for full details).

Parking

The provision of parking on arterial roads recognises the local service function of the facility. However, as the through traffic function increases in its relative importance over the local service function, so does the necessity to deny kerbside parking adjacent to the through traffic flow.

Kerbside parking on arterial roads materially increases crash exposure, both pedestrian and vehicular, and considerably reduces the Level of Service to through traffic. Where alternative accommodation for parking can be provided adjacent to existing arterial roads, or where new arterial road deviations are being designed, kerbside parking on the through carriageway should be avoided wherever possible.

However, where it is necessary to provide a kerbside parking lane, recognition of possible future or peak hour usage of the parking lane as a through lane requires that a full lane width be provided (refer to Chapter 7). This width also aids operation as the greater the separation between parked vehicles and through traffic the lesser is the accident potential and the greater is the capacity. In addition, with full width parking lanes, disabled vehicles can find some shelter between parked vehicles and the through lanes, and cause only minor inconvenience to the through traffic flow.

Median parking is not a desirable feature of urban arterial roads irrespective of whether it is parallel, angled or within the median itself. It should be avoided in the design of new arterial roads.

Further details of parking requirements are dealt with in Chapter 7.

Both on-street and off-street parking are dealt with in detail in Austroads Guide to Traffic Engineering Practice (GTEP), Part 11 – Parking (Austroads, 1998). In addition:

- on-street parking is also dealt with in AS2890.5 (Australian Standards, 1993);
- off-street parking is also dealt with in AS/NZS2890.1 (Australian Standards, 2004) and AS2890.2 (Australian Standards, 2002);
- bicycle parking is dealt with in the GTEP Part 14 (Austroads, 2000) and AS2890.3 (Australian Standards, 1993); and
- parking for the disabled is covered in DR04021 (Australian Standards, 2004).

Bus stops

Careful consideration of the location and operation of bus stops is necessary to avoid traffic hazards and delays.

A spacing of not less than 400m is necessary to maintain reasonable operating speeds and minimise traffic interference, but pedestrian access and passenger desires are the prime considerations in the determination of bus stop spacing.

Removal of the buses from the through lanes for embarkation and disembarkation purposes (e.g. indented bus bays) causes the least delays to following vehicles. However, unless special design precautions are taken, it may result in hazardous situations as buses re-enter the through lanes.

Where service roads are available bus stops should, wherever possible, be provided only on the service road. For more details on bus stop considerations, refer to Chapter 20.

Transit (HOV) lanes and bus lanes

Special purpose lanes (i.e. transit lanes) for High Occupancy Vehicles (HOVs) and buses are discussed in Chapter 3. These include lanes provided over long lengths of a road as well as queue-jump facilities at appropriate intersections to assist bus operation. Further details of these facilities are also provided in Chapter 7.

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Property access

A major aspect of the detailed geometric design of an urban roadway is providing access to commercial, industrial, public and private/residential properties.

Each access point is a minor intersection and thus the basic design features applicable to intersections apply to property entrances (refer to Chapter 13). In some cases a two way right turn lane (in the centre of the road) may be an appropriate solution (refer to Chapter 13 for details).

Access levels at property boundaries should be maintained as near as possible to the existing level. Access grades desirably should not exceed 1 on 10 at commercial and industrial establishments, and 1 on 6 at private/residential entrances. In addition, to cater for pedestrians, accesses should include a footpath at least 1.2m wide with a slope not exceeding 2.5% (desirably 2% maximum, refer to Chapters 5 and 7). Steeper access grades are possible and occasionally essential, but in such cases their effects on through traffic operations should receive special consideration. Where an existing access is to be changed, all changes, including changes to the proposed grade, must be discussed with the relevant property owner.

Vertical curves are often necessary to maintain vehicle clearance, and templates are commonly used to check suspect cases (refer to Chapter 7).

An alternative rule of thumb that works well at a footpath crossing is:

- a vehicle template with a 3m wheelbase and a 7½º angle of departure will provide a fully acceptable entrance;
- a profile with a 3m wheelbase and 10º angle of departure will be acceptable, but care is required in negotiating the crossing with a heavily loaded car; and
- a profile that will allow a vehicle with a 3m wheelbase and 10º angle of departure to pass should be redesigned.

Where driveway entrance speeds fall below 15km/h, a rapid increase in interference to through vehicles occurs. Thus, except for minor entrances, the turning geometry should be designed to encourage exit movement from the through traffic at 15km/h to 25km/h. This can be achieved by providing horizontal geometry allowing curves of 10m to 15m radius to be negotiated, and providing vertical geometry suitable for this speed. Where practicable, tapers or (two or) three centred curves from the through lane should be provided (refer to Chapter 13 for details).

Property access spacing and intersection clearances

The location and spacing of driveways and property accesses can have a significant effect on the operation of an arterial road. Care is required when assessing accesses; ideally they would be located to minimise their effect on the through road's operation and provide a reasonable level of service to the user of the access. The impact of these entrances may be assessed by assuming them to be intersections and analysing them in accordance with the methodologies set out in Chapter 13. The desired spacing and location of the accesses can then be determined by comparing the resulting traffic flow characteristics with the required Level of Service for the road in question.

4.5 National Highways

Under the Commonwealth's AusLink framework the "National Highway" classification no longer exists. Instead there is the AusLink National Network which is a Commonwealth responsibility. It is important to note that not all roads previously under the former "National Highway" classification are part of the new AusLink National Network.

4.6 AusLink National Network - National Network Road Links

4.6.1 General

Roads included in the AusLink National Network are called National Network Road Links. The nomination of a road as a National Network Road Link does not imply that the road performs a particular function; such road links can perform the function of a motorway, a rural arterial or an urban arterial. **Generally national (e.g. Austroads) design criteria that are commensurate with the road function should be used (e.g. refer to Sections 4.2, 4.3, 4.4 and 4.6.2).**

When planning and designing National Network Road Links it is desirable to:

- maintain a degree of uniformity for National Network Road Links, irrespective of administrative (e.g. state) boundaries;
- provide the appropriate facilities and Level of Service so that users may move safely and efficiently on National Network Road Links; and
- enable National Network Road Links to be modified when necessary to accommodate changing circumstances.

4.6.2 Commonwealth Government requirements

The Commonwealth does not specify any minimum design values for National Network Road Links. Rather any solution should aim to comply with the following, listed in order of precedence:

1. Austroads Normal Design Domain design criteria (refer to Chapter 2) and Australian Standards;
2. State Normal Design Domain (refer to Chapter 2) design criteria (e.g. those within the Normal Design Domain of this Manual) where national design criteria do not exist; and
3. Where the above design criteria do not exist, other design criteria as is appropriate.

Notwithstanding the above the primary requirement is for the designer/s to produce a context sensitive design (refer to Chapter 2). To this end the use of design criteria lower than say Austroads Normal Design Domain design criteria may be appropriate. However, in these cases, their use must be fully documented and justified and this must be presented to the Commonwealth for its consideration. Such a design solution is only acceptable if Commonwealth approval is received.

4.7 Other roads

This section deals with a range of roads, which do not fall readily into the categories already discussed. Such other roads include:

- service roads ;
- collector-distributor roads;
- frontage roads; and
- temporary roads.

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4.7.1 Service roads

Service roads are roadways parallel to, and separated from, an arterial road to service adjacent property; they are usually continuous.

Service roads are used to provide access to abutting property from an arterial road, or to control access to the arterial road from the abutting property. They also often connect local streets and thus maintain traffic circulation without requiring the use of the main through carriageway (i.e. the arterial).

Both one-way and two-way service roads are used. Problems with one-way operation are those of increased travel distance and traffic density. Problems with two-way operation are those of confusion and glare to arterial road drivers when used with narrow outer separators, and an increase in the number of conflicting movements at cross streets. These problems diminish with increasing outer separator widths. With narrow outer separators, the glare problems and confusion may be alleviated by using:

- dense planting;
- level differences; or
- anti-glare screens

Figure 4.9 illustrates methods of reducing conflicts at cross streets when service roads are present.

Minimum lane widths for service roads with low traffic volumes are shown in Table 4.4.

Combining the lane widths given Table 4.4 gives the minimum service road carriageway widths shown in Table 4.5 for roads with low traffic volumes and low parking demands. For other circumstances, the design elements should be derived from Chapter 7.

Table 4.4 Minimum service road lane widths for roads with low traffic volumes

Lane Type	Minimum single lane width (m) for a service road that primarily provides:	
	Residential access	Industrial access
One-way, through traffic	3.4	3.4
Two-way through traffic	4.4	5.5
Parallel parking	1.8	2.5

Table 4.5 Minimum service road carriageway widths for roads with low traffic volumes and low parking demand

		#Road width (m) for a service road that primarily provides:	
Traffic	Parallel parking	Residential access	Industrial access
One-way, single lane	One side	5.5	5.9
One-way, single lane	Both sides	7*	8.4
Two-way, two lane	One side	6.2	8
Two-way, two lane	Both sides	8	10.5

#Widths are measured between kerb and channel lips/kerb faces (refer to Chapter 13).
*5.5m for staggered parking

The required outer separator width and desirable treatments of it are discussed in detail in Chapter 7.

In most cases, the operating speed on service roads will be similar to that of local streets (i.e. 50km/h to 60km/h) and they should be designed accordingly. At high traffic volumes, the service road can be performing a significant traffic function and the operating speeds could be higher. In these cases, it might not be appropriate to allow parking on the service road. Such service roads will usually be confined to rural or semi-rural areas.

In rural areas, it is preferable that the local road network provides the service road function. This will avoid the service road encouraging ribbon development along the major road. It also probably represents the best use of resources, avoiding the construction of additional road infrastructure.

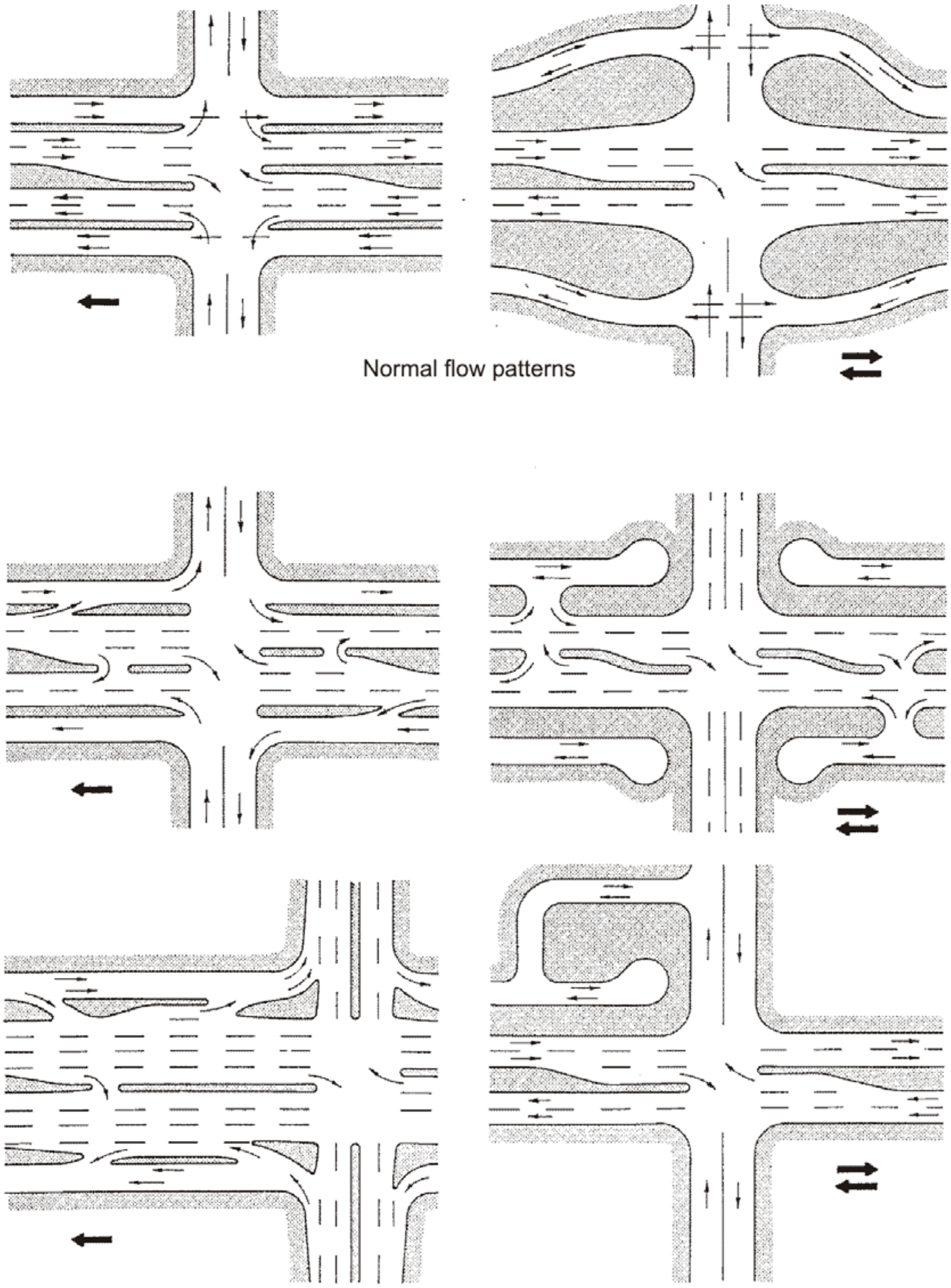

Figure 4.9 Methods of reducing conflicts at cross streets when service roads are present

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4.7.2 Collector-distributor roads

Collector-distributor roads are a special type of service road used in conjunction with motorways and roads that perform a motorway function.

General

Collector-distributor roads consist of carriageways parallel to the main through carriageways of a road but separate from them. Their function is to enhance the capacity of the road by providing:

- extra road space; and
- an area for manoeuvres such as weaving, away from the main traffic flow.

As their name indicates, these roads collect traffic from the local street system and distribute it to the major road, which is usually a motorway, in such a way that the operations of the major road are optimised.

By using collector-distributor roads, one can achieve a desirably long spacing of interchanges on the major road while providing a high standard connection to the major road from local roads at a much closer spacing. In addition, the judicious use of collector-distributor roads can minimise weaving manoeuvres on the through pavements of a motorway.

Figure 4.10 illustrates the use of a collector-distributor road in conjunction with a motorway to gain the benefits described above.

Access control

On motorways, collector-distributor roads could require complete control of access if high volumes and complex manoeuvre patterns occur on the roadways. In these cases, the collector-distributor is an integral part of the motorway. This is a distinguishing feature of collector-distributor roads.

Design criteria

For collector-distributor roads elements should be designed using the same design criteria as those of the main through carriageways except that the design speed in general will be lower than that of the major road. A design speed of 75% of that of the through carriageways may be adopted although in some cases it might be necessary to adopt a design speed equal to that of the through carriageways. In addition the transitions (e.g. ramps) between the main road and the collector-distributor road must be designed to account for the transition in speed and built environment.

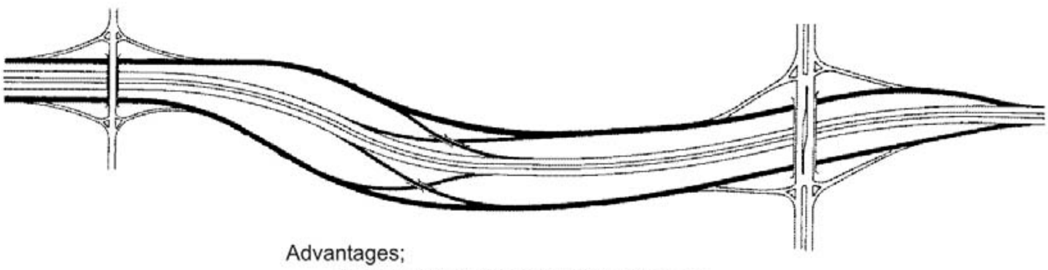


Figure 4.10 Collector-distributor road

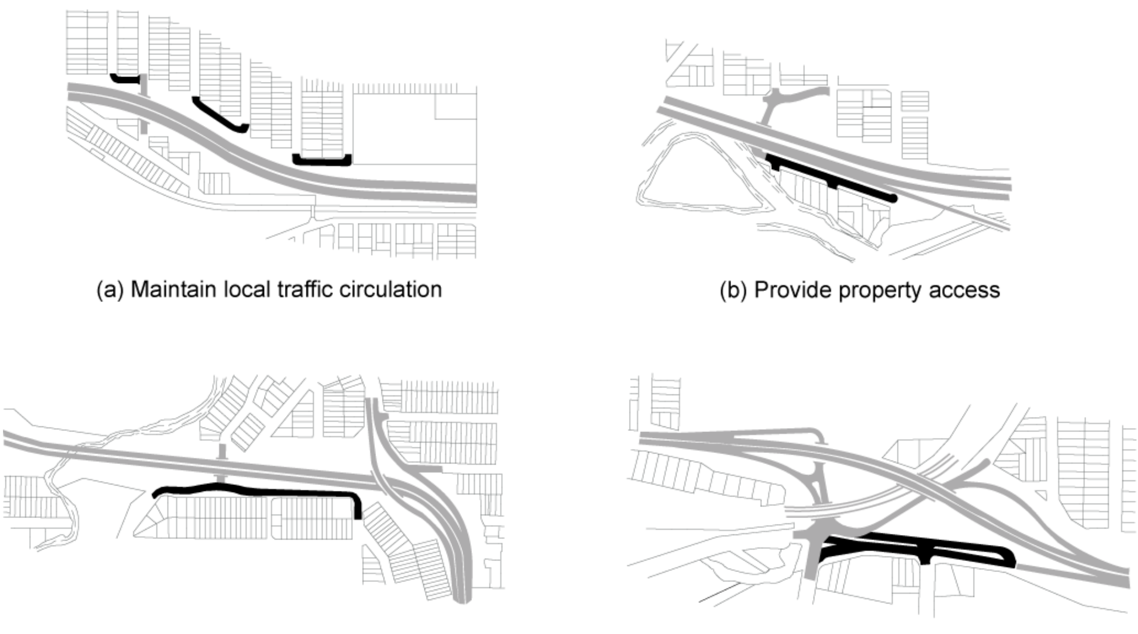
The transverse distance between the through lanes of the major road and a collector-distributor roadway is in general a function of the height difference between the two roads and the batter slope. However where transfer roadways between the two are required, sufficient distance to permit appropriate exit and entrance ramp geometry is necessary. In addition the transverse distance between the roads should not be less than that given in Chapter 7 for outer separators.

4.7.3 Frontage roads

Frontage roads are service roads used in conjunction with motorways and other major roads.

Functions

Frontage roadways are those contiguous with, and running generally parallel to, a motorway or other major road. They serve at least one of the basic functions shown in Figure 4.11 and the geometric standard varies greatly in accordance with these respective functions (illustrated in Figure 4.12, Figure 4.13, Figure 4.14, Figure 4.15 and Figure 4.16). At higher traffic volumes, these roads have similar functions to service roads and the same conditions apply to them (refer to Section 4.7.1).



(a) Maintain local traffic circulation

(b) Provide property access

(c) Collect and distribute traffic crossing the motorway

(d) Distribute traffic to and from the motorway

Figure 4.11 Functions of frontage roads

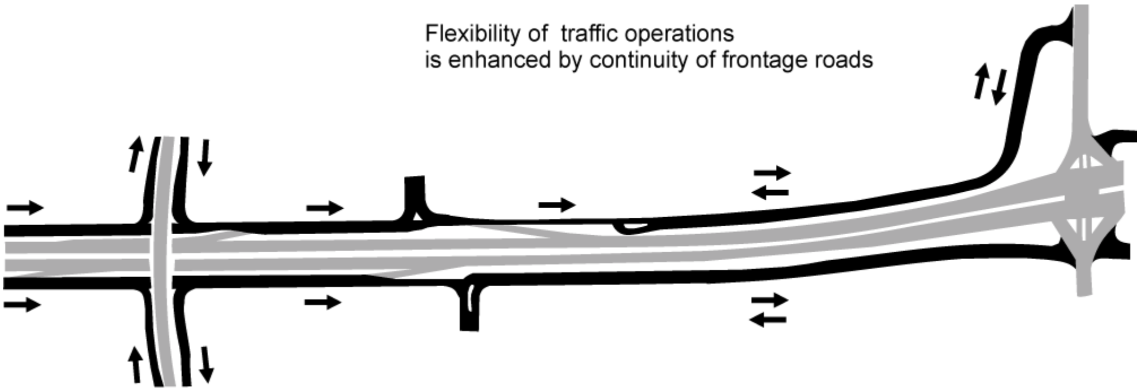


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Figure 4.12 Continuity of frontage roads

Continuity

Where continuity of a frontage road connected to a motorway exists over a reasonably long distance, the operational flexibility of the motorway is improved as traffic may be bypassed to the frontage road following an accident on the motorway or during maintenance operations (Figure 4.12).

If continuity or the capability to serve as a supplementary route is required the geometric and pavement design must take this into account (e.g. provide access points across the outer separator, allow for extra design traffic in the pavement design).

However, continuity also bestows on the frontage road the capability of serving as a supplementary through route, and carrying the motorway (or major road) overloads during peak periods. Such over usage is disadvantageous in the case of a frontage road whose prime function is that of residential property access. In such circumstances, to avoid this over usage:

- continuity should not be provided or be limited;
- the attractiveness of the route can be minimised through the use of geometry; and/or
- the attractiveness of the route can be minimised through the use of local area traffic management devices

This is to ensure a reasonable level of amenity and safety for residents. In industrial areas, a frontage road with some traffic flow function could be acceptable, provided the basic access functions are not compromised.

Design considerations

Maintain local traffic circulation in residential areas

Linkages between successive pairs of severed roadways reduce trip lengths for many delivery and service vehicles while avoiding the undesirability of traffic attraction of continuous frontage roads in a residential environment (Figure 4.13).

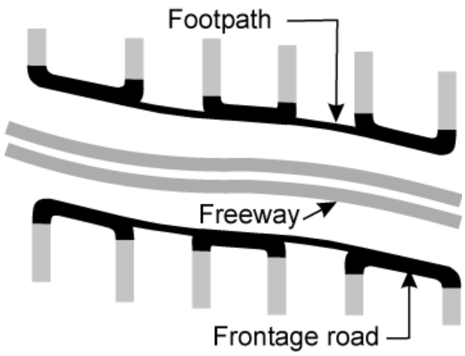

Figure 4.13 Local traffic circulation can be improved by the use of frontage roads

Footpath linkages between the frontage road segments should be generally provided unless there are very strong reasons why this should not be so (Figure 4.13).

Where the residual number of dwellings in a severed roadway is less than six, the roadway would normally be formed into a cul-de-sac.

Use of lower order values (for the Normal Design Domain) for design criteria normally suffice (refer to the relevant Chapters of this Manual). Footpaths should be provided on both sides of the frontage road and at least one of these should be of adequate width to accommodate PUP installations (refer to Chapter 7).

Provide access to properties fronting a motorway or other major road.

Often the property access function is combined in one frontage roadway with other functions such as collection or distribution of major road traffic, or for crossing traffic (Figure 4.14).

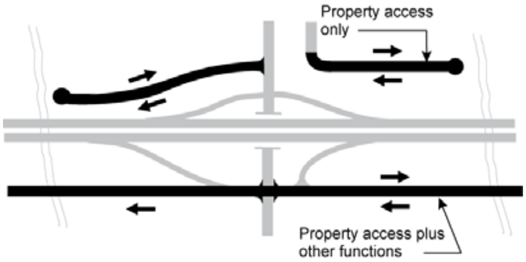

Figure 4.14 Frontage roads can provide access to properties

Ideally a separate facility providing solely for property access should be provided. In such a case, design priority should be given to the entrance geometry of accesses, property drainage, and longitudinal geometry of the frontage road, in that order. The frontage road should terminate in a local street where this is convenient. Otherwise, connection to an arterial roadway crossing the major road is satisfactory, provided adequate capacity and clearance to ramp junctions or other intersections is available and the Level of Service remains acceptable. Such clearance should be greater than the queue length of arterial road vehicles at the ramp junction where possible.

Frontage roads that serve as property access roads only are normally two-way. When serving the functions previously described, frontage roads are commonly one way, as outlined in the next section.

Collect traffic destined for a motorway or other major road and distribute traffic from a motorway or other major road

The traffic collection and distribution function for a motorway is almost always combined in a frontage road with the provision of property access (Figure 4.15). This is also desirable for other major roads.

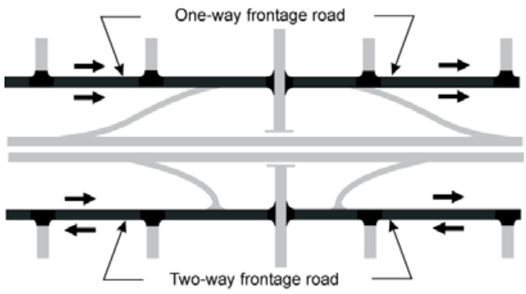

Figure 4.15 Frontage roads can collect and distribute motorway or other major road traffic

Their design standard varies widely with the extent and relative importance of the collection and distribution functions. Frontage roads fulfilling these functions range from a simple two-way roadway to a multi-lane signal-controlled one-way roadway.

The basic design decision is whether the road should operate as a one-way or two-way road. One-way frontage roads enhance

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traffic efficiency on the frontage road and simplify traffic operations at conflict points. However greater trip lengths and greater densities on the total road network result. One-way frontage roads normally require less right-of-way than two-way frontage roads.

Collect and distribute traffic crossing a motorway or other major road

Where practicable the motorway or other major road location is determined such that the existing street pattern can fulfil the collect and distribute traffic crossing function (Figure 4.16) provided that in so doing the volume of diverted traffic is not sufficiently great to adversely affect the neighbourhood. Otherwise separate roadways parallel to the motorway or other major road should be developed. Such new roadways should normally be two-way.

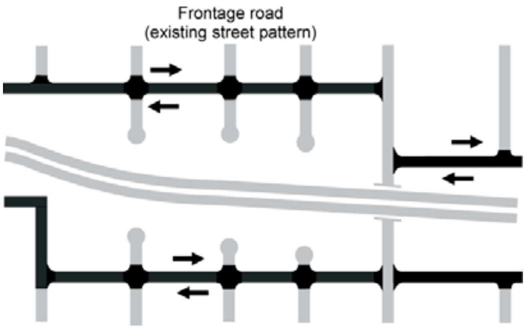

Figure 4.16 Frontage roads can collect and distribute crossing traffic

4.7.4 Temporary roads (including sidetracks)

Temporary roads are those used for construction purposes to facilitate the movement of traffic during construction; they are normally removed once construction has been completed. (This section includes sidetracks in the definition of a "temporary road".) Consequently temporary roads will have only a relatively short life (one to three years at the most) and the structural strength (or design life) of their pavement need only reflect that requirement. Roads, or parts of roads, that are to remain after construction and are required to connect a permanent stage of construction back to the existing road should be considered as a permanent road forming part of a stage of construction and not a temporary road. Such roads should be designed as an integral part of the stage to ensure proper long-term safety and operation.

Construction sequencing

In some cases, the temporary road will be used for a relatively short time to assist with the sequencing of construction as the traffic is progressively moved to cater for the construction program. Even so the geometry will have to be satisfactory for the operating speeds expected and the pavement design adequate for the expected design traffic.

In other cases, the traffic may be placed on part of the final pavement structure as a temporary measure. In these cases, the design of the pavement will need to take into account both the temporary and permanent trafficking. Delineation of travel paths through the job will be needed, even where temporary traffic is to run on the finished surface (level) of the permanent pavement. Once again, it will be necessary to ensure that the geometry of the travel path is satisfactory for the expected operating speed.

Safety of operation

A prime consideration in the design of temporary roads and connections for construction sequencing is safety of traffic operation. The geometry of the connections to the temporary road should be in keeping with the approach road sections and the design of these connections must be in accordance with the requirements of this Manual.

These connections should be designed as transitions between the approach road and the temporary road, using the principles enunciated in Chapter 6. If the speed differentials cannot be kept within the limits given in Chapter 6 signing should be used (perhaps in conjunction with other passive measures) with the aim of achieving the required reduction in speed.

In all circumstances, particular care is required in the design of the delineation of the approaches to the temporary road and the signing required. The layout of the road and the associated signing must be clear for night conditions and adequate warning of changes in features is required. A realistic assessment of the actual desired speed must be made (as per Chapter 6) and the road designed for the resultant operating speed – a speed limit sign will not necessarily control the speeds to the value on the sign.

Cross section

The cross section elements of the temporary road should be in accordance with Chapter 7 but values selected for each of the elements may be at the lower bound of their Design Domain for the volumes and speeds applicable. Narrower cross sections will help to create a lower desired speed and be less costly. Notwithstanding this, designers must also select an overall carriageway width and cross section configuration for the temporary road that suits its operation (e.g. allow for curve widening, allow for heavy vehicles, allow for cyclists if required).

Drivers must receive adequate warning of the narrowing of the cross section and preferably it should be visible for at least 5s of travel before the transition in width. The design should deliver "no surprises" to motorists.

Design considerations

The length of the temporary road and its proximity to the works will have a significant effect on the design criteria to be used. Long temporary roads separated from the works by some form of buffer will require a higher standard of design than a short length temporary road that is adjacent to the works. The required speed limit on the temporary road will also affect the level of detail required in its design.

The geometric design of all temporary roads should be undertaken with the same care and to the same level of detail expected for the permanent features of the road. Because of the temporary nature of the work, it might be appropriate to use geometry that safely results in a lower operating speed for the temporary road but the designer must be confident that the operating speed thus created will be perceived as appropriate by the driver.

The minimum operating speed (and hence design speed) for a temporary road should be based on a design speed of 70km/h (i.e. for a speed limit of 60km/h), unless the considerations discussed in this section justify a higher or lower speed. Specific minimum criteria for the design of a temporary road should be developed from the following:

- horizontal curvature as per Chapters 10 and 11 but the superelevation, if required, should not exceed 5%;
- crest curve radii must at least provide stopping that complies with Extended Design Domain "Base-case" stopping

for cars to a 0.2m high object (refer to Appendix 4B);

- sag vertical curves radii should be designed to at least the comfort criterion of 0.1g given in Chapter 12; and
- the desirable minimum carriageway width is 9m for an AADT ≥3000 or 8m for an AADT <3000, however narrower widths may be appropriate where they can be justified.

Temporary roads on all major roads with more than 1000 vehicles per day (vpd) must be paved and sealed. Temporary roads with volumes less than 1000vpd, or temporary roads of short length that are also in use for only a short time, should be paved but they might not require sealing, depending on the conditions. Design criteria similar to those used for approach roads should be adopted for such a temporary road. In all cases, the safety of operation is the paramount objective.

4.8 Restoration projects

4.8.1 Introduction

For projects where the intention is to restore the existing road essentially on the existing alignment the use of design criteria within the Normal Design Domain can be uneconomic from a network perspective. In such cases the use of the Extended Design Domain concept (refer to Chapter 2) may be required. As will be seen later the Extended Design Domain does not involve the simple use of tables and diagrams. Sometimes, where there is no Extended Design Domain, an even more fundamental approach starting from first principles will be required.

The general approach to restoration projects will be set out in the investment strategy for that road. In developing the strategy for the road, there must be an assessment of the acceptability of the existing geometry in the light of current expectations and economy of construction. This should not be done on the basis of cost alone; it should also include a risk assessment and consideration of what minimum capability (viz. standard) is acceptable. Since it is not a “green field” site, there will be cost advantages in adhering to the existing geometry if it can be justified.

At the project level there should be a full analysis of the geometry which will include an assessment of speeds in accordance with Chapter 6. The results should then be used to ascertain what capability each (geometric) element of the existing road provides and what design criteria are acceptable.

It may be possible to adopt different design values for some of the elements of the road while still adhering to the basic tenets of design. The detailed chapters of this Manual provide the basic reasoning applied to the development of the design criteria set out in this Manual and these basic parameters should be used to develop the design for the road in question. The following general considerations should guide the designer.

Consistency

The road standard should reflect the expectations of the users and not provide any surprises to the driver - it should be “self-explaining” (refer to Chapter 2). Isolated sub-standard elements should be removed, and isolated sections of new road constructed to a high standard, which may lead to "surprises" when the road re-joins the existing road, should be avoided.

Fundamental parameters

The physical realities of, and limitations to, side friction, centripetal force, vehicle dimensions, and vehicle performance must be accommodated.

Human factors

The way drivers perform in practice cannot be ignored. All designs must take the real performance of representative drivers, who take reasonable care for their actions, into consideration and provide for that performance. Consistency of expectation is a predominant requirement, and when the expectation cannot be met, some special design feature is required to ensure that the driver can respond adequately (e.g. providing extra reaction time for the unexpected feature - preferably at least 5s).

Combination of design elements

No design should use lower order design values for all parameters in combination for any one element. Where one of the design values is less (or more) than is desirable, design values for the other parameters need to be greater than the desirable minimum (or lower than the desirable maximum) to compensate (e.g. provide wider pavement over crests where the radius of the vertical curve is of a low standard).

Economy

The principal reason for adopting lower order values for design criteria, rather than desirable values, is one of economy. It is necessary to demonstrate objectively that adopting these lower design criteria is necessary - it is not sufficient to assume that a particular change is "too expensive" without a proper analysis and calculation that is fully documented (refer to Appendix 4A).

Existing crash history

The existing crash history must be evaluated and appropriate action taken where higher than normal crash rates can be attributed to low standard elements.

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4.8.2 Essential requirements and documentation

Where a decision to vary from the recommended values of a parameter is taken, it is essential that the reasoning behind the decision is sound and is properly recorded (refer to Appendix 4A). The decision must be robust and defensible. To be so, it must be based on sound engineering principles and evidence. It is unlikely that convenient tables and graphs will be adequate for such an analysis.

The designer therefore requires a thorough knowledge of the theory (and practical application of it) underpinning the parameter being varied, as well as its design intent. In addition the principles espoused in this Manual must be consistently applied. The analysis of the existing alignment, the factors considered and the reasons for the final decision must be documented and recorded (refer to Appendix 4A). This must be a robust procedure using acceptable, established technical data and practice.

Because the design of these types of projects requires a thorough analysis of the situation and considerable attention to the details of the design based on first principles, design costs will be higher than equivalent projects that have geometry within the Normal Design Domain. This is a small amount compared to the significant savings that will be achieved in the cost of

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the project. In addition, it is a very small investment to make to provide proper documented evidence of the validity of the decisions made.

It is also recommended that the performance of the road be monitored and assessed regularly after the project has been completed.

4.8.3 Design speed, operating speed and target speed

The link strategy will specify the target speed for the road for use in design. Establishing the design speed for each geometric element is fully discussed in Chapter 6, which contains a detailed process for analysing the alignment to estimate the realistic operating speed on each element. Proper application of this procedure will provide an objective assessment of the likely speed of travel on the road, giving a basis for the design speed adopted and subsequent analysis of the each geometric element's capability. Adopting anything less than the speed calculated by using the procedure described in Chapter 6 will:

- not represent the reality of the situation; and
- make any future defence of the geometric issue much more difficult.

Improving the width, ride quality and quality of surface will inevitably change the operating speed with a consequent change in the required design speed of some, or many, elements.

The purpose of the road, as well as its type and function, must be considered as well as the consistency of the operating speed along the road. There is no need (and it is not desirable) to increase the operating speed of an isolated section of a road merely because it is easy to do so if the remainder of the road is to retain a lower operating speed. Conversely, it is sensible to improve the geometry of an isolated section in order to match the operating speed of the adjoining sections to establish continuity of expectations along the route.

4.8.4 Cross section

Chapter 7 sets out the desired lane and shoulder widths for all road types. There is some flexibility in shoulder width as well as lane width (refer to Appendix 4D) depending on the vehicle types expected. The slope of embankment batters is also a consideration, together with the available clear zone. The location of lateral obstructions and the space available to provide safety barrier must also be considered (Chapter 8).

The combination of elements will have a significant bearing on the acceptability of a total cross section. Flat batters (1 on 4 or flatter) will provide additional space for vehicles to pull off the road and would compensate for a narrower carriageway width where formations are low and it is necessary to retain the existing carriageway width (refer to Appendix 4D). This effect is more pronounced if the batters are even flatter (1 on 6 or flatter); flatter batters are preferable.

4.8.5 Horizontal alignment

Chapter 11 sets out the requirements for the design of horizontal curves and the factors that must be considered in their design. Desirable values for side friction, radius, superelevation and transitions are provided. Consistency of operation and proper coordination of the vertical and horizontal alignments is desired (refer also to Chapter 10).

Where an existing horizontal alignment is to be retained, it should be assessed using the techniques provided in Chapters 6 and 11 before adopting it without change. Isolated inadequate or inconsistent curves can then be identified and the extent of reconstruction defined. Note that for horizontal alignment design there is only an Extended Design Domain for sight distance around horizontal curves and for adverse superelevation in urban areas (refer to Appendix 4F). Apart from the latter there is no Extended Design Domain for the horizontal curve size. This is because the absolute maximum side friction factors given in Chapter 11 have been established though empirical research as being what drivers travelling at the operating speed (refer to Chapter 6) are prepared to use, and a strong link between crash rates and horizontal curve radius exists. The primary goal should be to ensure that the geometry adopted is consistent with the future operating speeds and consistent along the route with no surprises. This might be achieved with minimal changes at reasonable cost with significant benefits if the proper analysis is undertaken and implemented.

The operating speed of elements along the road will primarily be established by the horizontal alignment. Chapter 6 provides the information on how to use this to control operating speeds to suit the conditions.

4.8.6 Vertical alignment

Chapter 12 sets out the normal design criteria and Normal Design Domain for the design of vertical alignment. While most of an existing road should comply with the Normal Design Domain, some crest curves may not. The primary control on the design is the provision of adequate sight distance and the basis of the approach is explained. There is also some discussion on the design domain that can be used when considering the existing vertical alignment. In addition, Appendix 4B sets out the Extended Design Domain for sight distance. Generally these are the minimums that should be achieved for restoration projects (refer to Section 4.9). Similarly Appendix 4C sets out the Extended Design Domain for sight distance at intersections. Proper coordination of the vertical and horizontal alignments is desired (refer to Chapter 10).

In many cases, the standard of the vertical alignment of an existing road was considered satisfactory when the road was first built but, compared to today's design requirements for new roads it is not satisfactory for current operating conditions. Reconstruction of the entire vertical alignment is often too expensive to contemplate and it is necessary to consider how best to use the existing construction. However, it should not be assumed that the existing alignment should be accepted regardless of its geometry. It is necessary to provide consistency and adequate safety along the route which might require the reconstruction of isolated crests.

Geometric consistency is just as important a requirement for restoration projects as it is for new road projects. After all, most end users will not distinguish a restored road from a new road.

The erection of a sign after the road has been upgraded does not provide sufficient guidance to the driver. (Note: Currently the MUTCD does not allow the use of advisory speed signs for crest curves in any case.) There is a body of research that shows, for rural highways, the speed of operation over crest curves is dictated primarily by the horizontal alignment and that the vertical alignment has little to no effect on operating speeds. Topography has some effect on the perceptions of drivers about a suitable speed (i.e. it can affect operating speeds) but the horizontal alignment will be the major determinant of operating speeds.

Where crest curves with a radius that is less than the lower bound of the Normal Design Domain are to be retained, analysis will be necessary to determine if additional width (for manoeuvring) to compensate (for the reduced stopping capability is required – refer to Appendix 4B and Chapter 12). This allows additional space for a driver to avoid objects and oncoming vehicles which thereby provides benefits for safety of operation. (Note: Additional width is only beneficial for lanes that are not lane locked. If an overtaking lane exists over a crest curve, providing additional width will not necessarily help).

It is also necessary to ensure that a number of design values below the Normal Design Domain are not used at the same place (i.e. on the one geometric element). Thus if a tight crest curve is retained it must not be associated with a tight radius horizontal curve or narrow cross section. Similarly, small radius crest curves must not be associated with an intersection or property access – designers should relocate the intersection or access or change the crest curve to suit.

Designers should be alert to the potential to achieve the desired design criteria at little to no extra cost by making appropriate adjustments to the vertical alignment. Good design will take advantage of all of the techniques available to produce the best result.

4.8.7 Intersections

Appendix 4C sets out the Extended Design Domain for sight distance at intersections and Appendix 4E sets out the Extended Design Domain for unsignalised intersection layouts.

4.8.8 Other parameters

Careful selection of side friction factors, crossfalls, reaction times, visibility criteria, etc for restoration projects can significantly reduce reconstruction requirements and their extents. However, it is essential that the values chosen provide a realistic assessment of the situation that will exist on completion of construction. For example, not providing "safe intersection sight distance" (refer to Chapter 13) to a property access on the basis that there is no discernable safety impact based on accident records and research into this parameter could be acceptable on a particular road. However, in determining the desired speed and/or operating speed using a speed survey of an existing very rough and narrow road will be difficult to justify when drivers expectations may change after completion of the restoration project (e.g. when the restoration project comprises widening of the formation/carriageway and pavement overlay). (Refer also to Cox 2002 and Cox 2003.)

The factors selected, and the reasons for that selection must be fully documented and approved before completing the design (refer to Appendix 4A).

4.9 Requirement for geometric assessment and choice of Domain

Generally, with the exception of the Extended Design Domain design criteria, the design criteria quoted in this Manual are for the Normal Design Domain (refer to Chapter 2) and so are generally applicable to:

- new construction (i.e. ”green field” sites);
- horizontal and/or vertical re-alignment where more than a few isolated elements require re-alignment (unless it is a very low volume road); and,
- for the new carriageway of a duplication.

Preferably, the “normal” minimum design criteria or design values in this Manual would only be applied in constrained situations.

In general it is recommended that the Extended Design Domain design criteria detailed in this Manual be considered for:

- the assessment of existing roads;
- improving the standard of existing roads in constrained situations;
- the new carriageway of a duplication in constrained situations;
- a major re-alignment of an existing low volume road; and
- a road section where the desired speed and operating speeds will be reduced due to a change in the built environment, because of development, within ten years (e.g. design an element now for 110km/h using the Extended Design Domain criteria which will achieve Normal Design Domain criteria for a future design speed of 90km/h [due for example to a future 80km/h speed limit]).

Sometimes, road authorities may elect to use values within the Extended Design Domain in constrained situations other than those given above. Examples include a significant re-alignment of very low volume road in hilly terrain and a new road in extremely constrained conditions (e.g. sight distance around median barriers on horizontal curves). Designers must not use values within the Extended Design Domain values in these situations unless directed by the relevant road authority; the business case and brief should reflect this requirement. If values within the Extended Design Domain are to be used it is critically important that well documented justification be provided (refer to Section 4.9.1).

Table 4.6 lists situations where a geometric assessment is required and whether use of the Normal Design Domain and/or the Extended Design Domain is appropriate. Figure 4.17 illustrates the process that should be used to make this decision.

4.9.1 Guides for the Extended Design Domain

Guides for the application of the Extended Design Domain are included in the Appendices of this Chapter. Refer to:

- Appendix 4A for guidance in relation to the process that should be followed when using the Extended Design Domain, and how its use may be documented;
- Appendix 4B for the Extended Design Domain for sight distance on roads;
- Appendix 4C for the Extended Design Domain sight distance at intersections;
- Appendix 4D for guidance in relation to evaluating cross sections using the Extended Design Domain;

- Appendix 4E for the Extended Design Domain for short length right turn slots; and
- Appendix 4F for the Extended Design Domain for adverse superelevation on horizontal curves in urban areas.

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Table 4.6 Warrants for geometric assessment and guidelines for selecting the appropriate area of the design domain

Geometric assessment warranted?	Activity	[1]Suggested area of design domain to use		[2]Comments
		Normal Design Domain	When Extended Design Domain may be applied	
No	Re-seal	-	-	Restoring the wearing course, no alterations to geometry, pavement (in the structural context), or formation width. Therefore, it is unlikely that there will be a change in the drivers' perception.
	Routine maintenance (e.g. patching)	-	-	Minor repairs, no alterations to geometry or formation width, nor most of the seal or pavement (in the structural context). Therefore, it is unlikely that there will be a significant change in the drivers' perception.
	Part shoulder seal	-	-	Intention is to improve safety by slightly increasing the sealed width. However, it is unlikely that there will be a change in the drivers' perception unless the appearance of the rest of the shoulder is changed through repaving (in which case a geometric analysis is desirable).
	Re-sheet of unsealed road	Preferred	In constrained situations.	Intention is to restore road to previous level of service and safety. **However geometric assessment should be undertaken for at least the first occurrence or if formation is altered.**
	Asphalt overlay of a sealed road	Preferred	In constrained situations.	Intention is to restore road to a level of service and safety that is similar to its former state. **However geometric assessment should be undertaken for at least the first occurrence or if formation is altered. (**Roughness of the road likely to be significantly reduced, especially if overlaying a seal, leading to a possible change in speed. The first overlay of a seal frequently includes trimming and reformation of shoulders. The overlay may also alter superelevation and crossfall. The former two may change the drivers' perception; the latter may affect the acceptability of a horizontal curve's design.)
Desirable	Full shoulder seal	Preferred	In constrained situations.	Intention is to improve safety by substantially increasing the sealed width. It may change the drivers' perception.
Yes	Sealing of an unsealed road	Preferred	In constrained situations.	Intention is to improve service and safety. It may change the drivers' perception.

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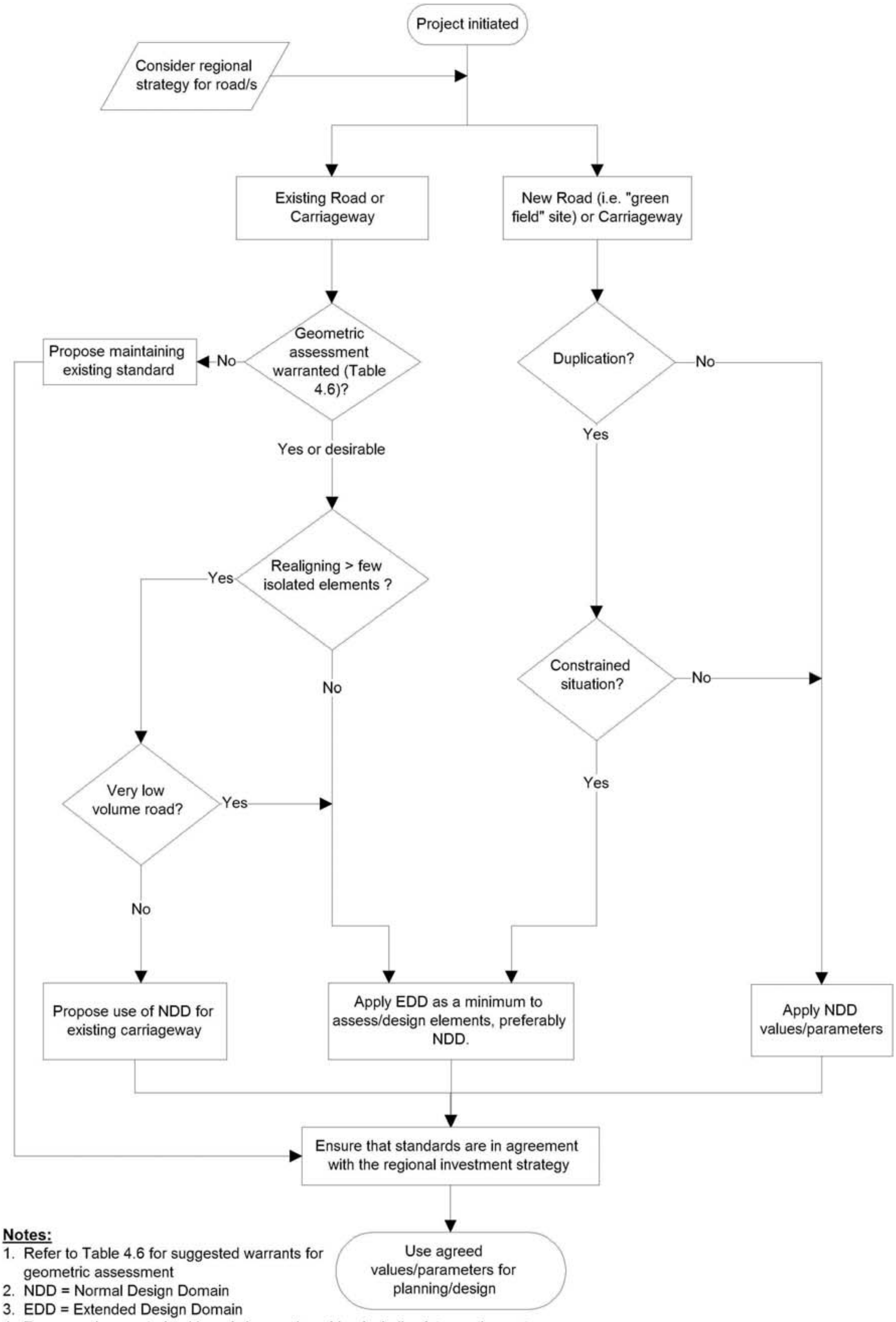
Geometric assessment warranted?	Activity	[1]Suggested area of design domain to use		[2]Comments
		Normal Design Domain	When Extended Design Domain may be applied	
Yes	Shoulder widening	Preferred	In constrained situations.	Intention is to improve service and safety by substantially increasing the pavement width and the sealed width. It may change the drivers' perception.
	Overlay and widening	Preferred	In constrained situations.	Intention is to improve service and safety by substantially increasing the sealed width and strengthening the pavement. It may change the drivers' perception.
	Rehabilitation (e.g. stabilisation) and widening	Preferred	In constrained situations.	Intention is to improve service and safety by substantially increasing the sealed width and strengthening the pavement. It may change the drivers' perception.
	Horizontal and/or vertical re-alignment of an existing road	Preferred	In constrained situations where a few, in relative terms, isolated elements are constrained. Extended Design Domain should only be applied to the constrained elements.	Intention is to improve service and safety by improving the geometry of the road. It is likely to change the drivers' perception.
	Duplication of an existing carriageway	Preferred	In constrained situations for the existing carriageway. For new carriageway only if extremely constrained.	Intention is to improve service and safety by adding a new carriageway and possibly treating the existing carriageway. It is likely to change the drivers' perception. (N.B. If the new and existing carriageways are close, the geometry of one may influence that of the other.)
Desirable/ Yes	Any of the above activities where geometric assessment is warranted or desirable.	Preferred	In constrained situations, where speeds will reduce within ten years	Applicable where meeting Extended Design Domain criteria in the present will result in Normal Design Domain criteria being met when speeds reduce in the future.

Notes:

1. Normal Design Domain minimum criteria or better are highly desirable in all cases. Values better than "desirable minimum" are preferred. However, where it is not possible to achieve this standard the application of the Extended Design Domain may be considered as detailed in the table above.
2. A driver's expectations may increase due to a perceived increase in the standard of the road, irrespective of whether the geometric standard of the road has actually been improved or not.



Notes:
1. Refer to Table 4.6 for suggested warrants for geometric assessment
2. NDD = Normal Design Domain
3. EDD = Extended Design Domain
4. For example, constrained by existing road corridor, including intersections, etc.

Figure 4.17 Guideline for selecting the appropriate design domain

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Relationship to Other Chapters

This Chapter relates to all Chapters of this Manual but in particular it relates to:

- the principles espoused in Chapters 1 and 2 for the overall approach to design;
- the chapters which follow this Chapter and which provide the detail for application of the principles espoused and design criteria given in this Chapter;
- issues which arise in several of the other Chapters, in particular:
    - Chapter 5;
    - Chapter 7;
    - Chapters 10, 11 and 12;
    - Chapters 13, 14, 15 and 16; and
    - Chapter 20.

Appendix 4A: Process to follow when using the Extended Design Domain

This Appendix details the process that designers should follow when applying the Extended Design Domain concept and Extended Design Domain design criteria (Cox, 2004).

Analyse crash data

Analysis of the crash data for an element or road link may indicate problems with the element or road link. Such an analysis is likely to indicate problems associated with:

- horizontal curves;
- intersections;
- accesses;
- events the driver may not anticipate such as;
  - o the onset of fatigue (e.g. in a "fatigue zone");
  - o deception and/or distraction from the driving task;
  - o aquaplaning of the vehicle; and
  - o encountering inconsistent design (or geometry, e.g. sudden increase in side friction demand [i.e. unexpected "tight" horizontal curve], isolated raised island).

However crash data analysis is less likely to indicate problems associated with sight distance deficiencies (on vertical and/or horizontal curves). If problems with sight distance can be identified from the analysis it usually means there are significant sight distance related problems.

An element with a standard below that of the Extended Design Domain should not be considered for retention unless the crash data indicates that there is no evidence of crashes related to the relevant "sub-Extended Design Domain" parameter/s.

Assess the effect of any change in cross section

Restoration projects often incorporate a change to the cross section of the existing road. If the change is significant the road users' perception of the road may change and consequently:

- vehicle speeds may increase;
- there may be higher variation in vehicle speeds;
- deception/distraction may increase; and/or
- visual cues/backdrops may be affected.

In addition the change may also:

- result in a change in safety barrier requirements;
- mean larger vehicles will use the route; and/or
- attract more traffic or other types of drivers (e.g. tourists).

Designers therefore need to consider what affect any change in cross section will have on road use and, where appropriate, take account of it (e.g. undertake geometric analysis and upgrade elements below the Extended Design Domain).

Undertake a geometric assessment using the Extended Design Domain where appropriate

Where appropriate (refer to Section 4.9, Table 4.6 and Figure 4.17) a geometric assessment of the road should be undertaken. This should include:

- a speed assessment; and

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- an assessment of available sight distance.

A speed assessment, in accordance with Chapter 6, will estimate realistic operating (i.e. design) speeds for each element; the adequacy of elements and the available sight distances can then be assessed using the operating speeds along the road.

Assessment of the available sight distance along the road may be aided by:

- setting target Extended Design Domain capabilities;
- using plans and diagrams to document capabilities (e.g. Figure 4.18);
- using plans and diagrams to document design intent (e.g. Figure 4.19);
- using sight distance profiles and tables (e.g. Table 4.7, Table 4.8 and Table 4.9).

Sight distance profiles may be constructed using varying eye heights (e.g. 1.15m for a car and 2.4m for a truck) and object heights (e.g. 0.2m, 0.4m, 0.6m, and 1.15m). These available sight distances along the road section in question can then be assessed against the target capabilities.

When setting target capabilities designers should determine the acceptable minimums for the:

- minimum manoeuvre time (to say a 0.2m hazard – also refer to Chapter 9);
- minimum stopping capability (for cars, trucks, if applicable, and to what object height – also refer to Chapter 9); and
- minimum stopping capability at intersections (and accesses - refer to Chapter 13).

Identify any geometric deficiencies

Geometric deficiencies include:

- “tight” horizontal curves (which may or may not have an crash history);
- sight distance below the Normal Design Domain for:
  - o intersections (and accesses);
  - o vertical curves; and
  - o horizontal curves;
- the potential for vehicles to aquaplane;
- the potential for water and gravel to be directed onto the road.
- “local” width constraints (e.g. due to presence of drainage structures, right of way);
- other width issues such as presence or need for:
  - o pull off areas;
  - o run off areas;
  - o clear zones;
  - o traversable width (viz. the Extended Design Domain);
  - o safety barriers; and
  - o curve widening to suit any larger vehicles.

Table 4.7 Example tabulation of available sight distance and sight distance deficiency

	110km/h	S.D. 190m	110km/h	S.D. 165m	110km/h	S.D. 165m	110km/h	S.D. 165m
	(2 second reaction time, cars)							
	Observer Ht	1.15m	Observer Ht	1.15m	Observer Ht	1.15m	Observer Ht	1.15m
	Target Ht	0.2m	Target Ht	0.2m	Target Ht	0.6m	Target Ht	1.15m
	Visibility		Visibility		Visibility		Visibility	
Chainage (m)	Distance (m)	Deficit (m)	Distance (m)	Deficit (m)	Distance (m)	Deficit (m)	Distance (m)	Deficit (m)
83720	190	0	165	0	165	0	165	0
83730	190	0	165	0	165	0	165	0
83740	187.272	-2.728	165	0	165	0	165	0
83750	173.277	-16.723	165	0	165	0	165	0
83760	165.341	-24.659	165	0	165	0	165	0
83770	157.975	-32.025	158.015	-6.985	165	0	165	0
83780	146.333	-43.667	146.366	-18.634	165	0	165	0
83790	139.218	-50.782	139.268	-25.732	165	0	165	0
83800	133.224	-56.776	133.256	-31.744	155.490	-9.510	165	0
83810	129.670	-60.330	129.671	-35.329	148.682	-16.318	165	0
83820	119.506	-70.494	119.509	-45.491	148.411	-16.589	165	0
83830	119.811	-70.189	119.906	-45.094	137.519	-27.481	159.149	-5.851
83840	112.495	-77.505	112.581	-52.419	135.344	-29.656	157.154	-7.846
83850	100.000	-90.000	100.000	-65.000	130.003	-34.997	150.004	-14.996
83860	100.012	-89.988	100.012	-64.988	130.017	-34.983	150.018	-14.982
83870	100.019	-89.981	100.019	-64.981	130.026	-34.974	165	0
83880	100.028	-89.972	100.028	-64.972	165	0	165	0
83890	110.044	-79.956	110.044	-54.956	165	0	165	0
83900	190	0	165	0	165	0	165	0

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Table 4.8 Example of assessment summary – stopping capability

Start chge[1] (m)	Length (m)	Cars			Trucks			Is lowest capability reasonable?[5]
		Operating speed (V_{85}) (km/h)	Lowest Extended Design Domain sight distance capability[2]	Length below target Extended Design Domain capability (m)	Operating speed (V_{85}) (km/h)	Lowest Extended Design Domain sight distance capability[3]	Length below target Extended Design Domain capability (m)	
88000	190	110	Norm-Day-2.0s-Wet-0.5m Stopping. 4.5s Manoeuvre.	0	105	6.7s Manoeuvre	Zero - with visibility bench on horizontal curve	Yes - with visibility bench on horizontal curve.
88420	120	110	Norm-Day-2.0s-Wet-0.8m, Norm-Day-1.5s-Wet-0.5m Stopping. 3.9s Manoeuvre.	0	100	Truck-Day-2.0s-0.4m Stopping. 5.7s Manoeuvre	0	Probably (minimum of 4.0s of car manoeuvre time for this road).
89020	240	110	Norm-Day-2.0s-Wet-0.6m Stopping. 4.3s Manoeuvre.	0	105	6.0s Manoeuvre.	Zero - with visibility bench on horizontal curve	Yes - with visibility bench on horizontal curve.
89520	220	110	Norm-Day-2.0s-Wet-0.6m Stopping. 4.3s Manoeuvre.	0	100	Truck-Day-2.0s-0.5m Stopping. 6.1s Manoeuvre.	0	Yes.
89880	250	110	Norm-Day-2.0s-Wet-0.9m, Norm-Day-Wet-1.5s-0.6m Stopping. 4.1s Manoeuvre.	0	105	Truck-Day-2.0s-0.8m Stopping. 5.7s Manoeuvre.	110	Probably.
90480	70	110	Norm- Day-2.0s-Wet-0.2m Stopping.	0	105	Design stopping for 0.2m object.	0	Yes.
91820	180	110	Norm-Day-2.0s-Wet-0.6m Stopping. 4.3s Manoeuvre.	0	105	Truck-Day-2.0s-0.4m Stopping.	0	Yes.

Start chge[1] (m)	Length (m)	Cars			Trucks			Is lowest capability reasonable?[5]
		Operating speed (V_{85}) (km/h)	Lowest Extended Design Domain sight distance capability[2]	Length below target Extended Design Domain capability (m)	Operating speed (V_{85}) (km/h)	Lowest Extended Design Domain sight distance capability[3]	Length below target Extended Design Domain capability (m)	
92590	270	110	Norm-Day-2.0s-Wet-0.6m Stopping. 4.6s Manoeuvre.	0	103	Truck-Day-2.0s-0.4m Stopping.	0	Yes.
93490	350	110	Norm-Day-2.0s-Wet-1.0m, Norm-Day-1.5s-Wet-0.6m, Norm-Day-1.5s-Dry-0.2m Stopping. 3.9s Manoeuvre.	0	95	Design stopping for 0.2m object on +4% grade	0	Yes (but horizontal curvature no longer ensures alertness **beyond** this zone).

Notes:

1. A zone starts where the sight distance falls below 190m design stopping distance for a car operating speed (V_{85}) of 110km/h or falls below the truck design stopping distance for the truck operating speed (V_{85}) at that point.
2. The label for the lowest car Extended Design Domain stopping/manoeuvring capability is in accordance with the Extended Design Domain guide in Appendix 4B. A perception-reaction time of 2.0s is used for some "Norm" capabilities; 1.5s is used for some other "Norm" capabilities. The latter case is only applicable if the driver is constantly/continuously alert (refer to the Extended Design Domain guide in Appendix 4B). In order of decreasing Extended Design Domain stopping capability for sight distance restricted in the vertical plane, these are:
   - Norm-day-2.0s-wet-0.2m – gives normal daytime stopping in wet conditions for a 0.2m high object;
   - Norm-day-2.0s-wet-0.4m;
   - Norm-day-2.0s-wet-0.6m – Also, ≈ Norm-day-2.0s-dry-0.2m;
   - Norm-day-1.5s-wet-0.6m – Also, ≈ Norm-day-1.5s-dry-0.2m ≈ Norm-day-2.0s-wet-1.15m; and
   - Norm-day-2.0s-dry-1.15m.
3. The label for the lowest truck Extended Design Domain stopping capability is in accordance with the Extended Design Domain guide in Appendix 4B. A perception-reaction time of 2.0s is used. In order of decreasing Extended Design Domain stopping capability, these are:
   - Truck-day-2.0s-0.2m – gives daytime stopping in wet and dry conditions for a 0.2m high object, braking torque limits do not give any further advantage for dry conditions;
   - Truck-day-2.0s-0.4m;
   - Truck-day-2.0s-0.6m; and
   - Truck-day-2.0s-1.15m.
4. Within a zone of sight distance deficiency, sight distance usually reduces progressively below the design sight distance to a value that is then maintained for some length to a point where the design sight distance is quickly regained.
5. EDD = Extended Design Domain

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Table 4.9 Example of assessment summary – effect of improving crests (110km/h design speed)

(Courtesy of Main Roads Western Australia)

Crest location		Effect of increasing crest to meet:					
		Austroads "Rural Road Design Guide" (R=9,800m)		EDD Norm-Day-2.0s-Dry-0.2m and Norm-Day-2.0s-Wet-0.6m (R=4,200m)		EDD Norm-Day-1.5s-Dry-0.2m and Norm-Day-2.0s-Wet-0.6m (R=2,600m)	
Vertical Intersection Point (VIP) No.	Chainage (m)	Max. depth of cut required (m)	Length of cutting required (m)	Max. depth of cut required (m)	Length of cutting required (m)	Max. depth of cut required (m)	Length of cutting required (m)
2	153,425	1.0	220	0.3	130	0.1	80
8	153,675	0.1	160	0.1	80	0	0
10	153,940	3.8	500	1.4	240	0.4	150
15[1]	154,480	3.8	440	1.2	240	0.6	160
25	155,770	0.1	120	0	0	0	0
32	156,675	0.1	160	0	0	0	0
41[2]	157,250	0.6	220	0.1	130	0	0
47[3]	157,745	2.5	400	0.8	250	0.3	110
64	159,085	5.0	750	0.1	200	0.1	100
72[4]	159,775	0.2	200	0.1	100	0	0
80	160,400	7.4	620	3.8	360	1.8	240
88[5]	161,030	0.1	120	0.1	60	0	0
99	161,935	2.2	280	1.0	200	0.5	180
102	162,180	1.0	240	4.0	160	0.1	140
104	162,485	0.1	180	0.1	60	0.1	20
108	162,980	0.2	160	0.1	80	0.1	40
122[6]	164,420	3.8	540	0.8	280	0.1	120
130[7]	165,275	0.4	240	0.1	100	0	0
137	166,050	0.1	180	0	0	0	0

Notes:
1. Note that there is an access adjacent to VIP No. 15.
2. Note that VIP No. 41 lies within a section where it is recommended that realignment be undertaken to improve the horizontal geometry. There is also an access within the vicinity of VIP No. 41.
3. Note that VIP No. 47 lies within a section where it is recommended that realignment be undertaken to improve the horizontal geometry.
4. Note that an unsealed side road intersects the through road near VIP No. 72.
5. Note that VIP No. 88 lies at the end of a section where it is recommended that realignment be undertaken to improve the horizontal geometry.
6. Note that VIP No. 122 lies within a section where it is recommended that realignment be undertaken to improve the horizontal geometry.
7. Note that VIP No. 130 lies at the end of a section where it is recommended that realignment be undertaken to improve the horizontal geometry.

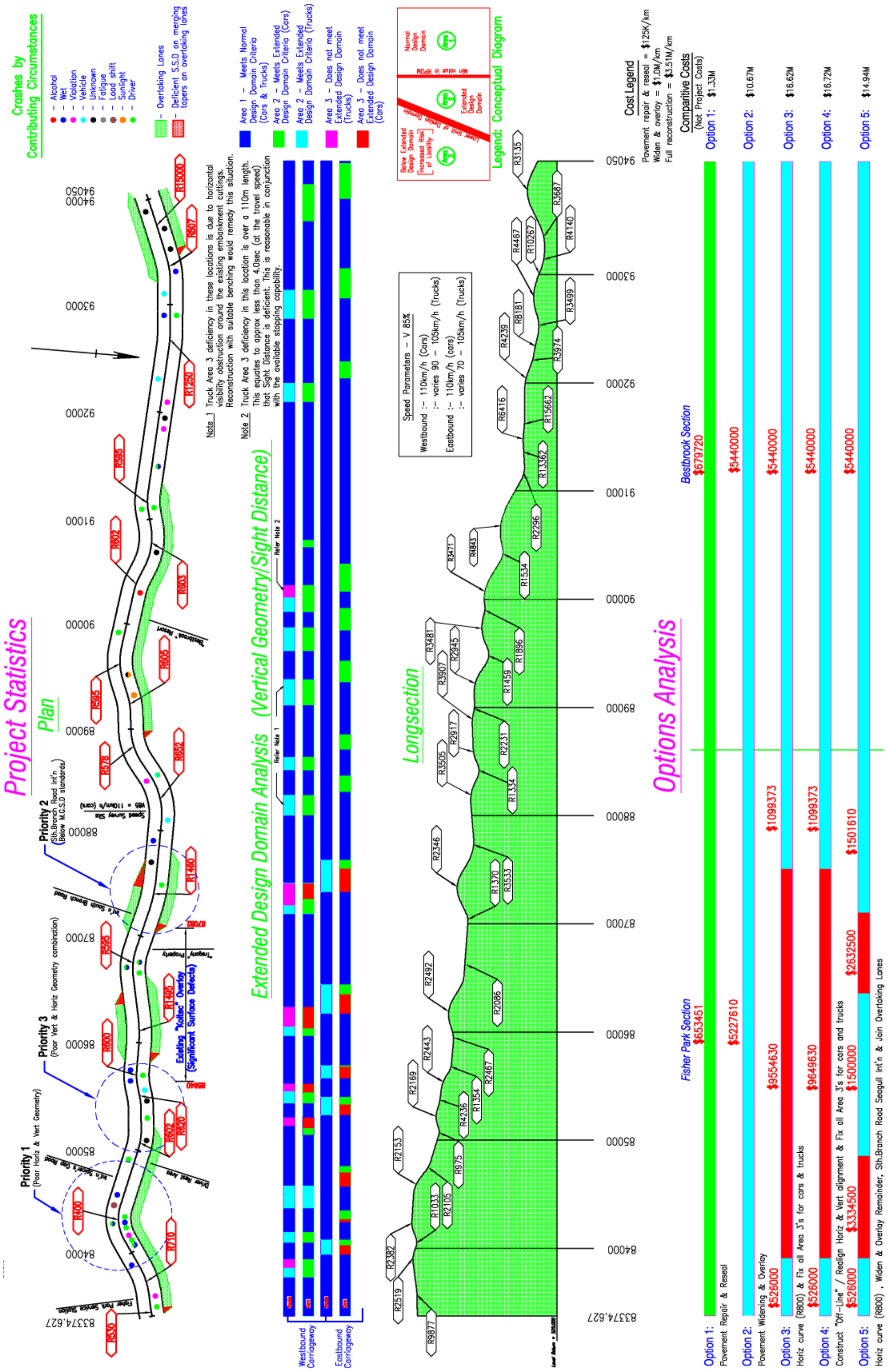

Figure 4.18 Example of diagrammatic representation of assessment of stopping capability

(Courtesy of Main Roads' Southern District)

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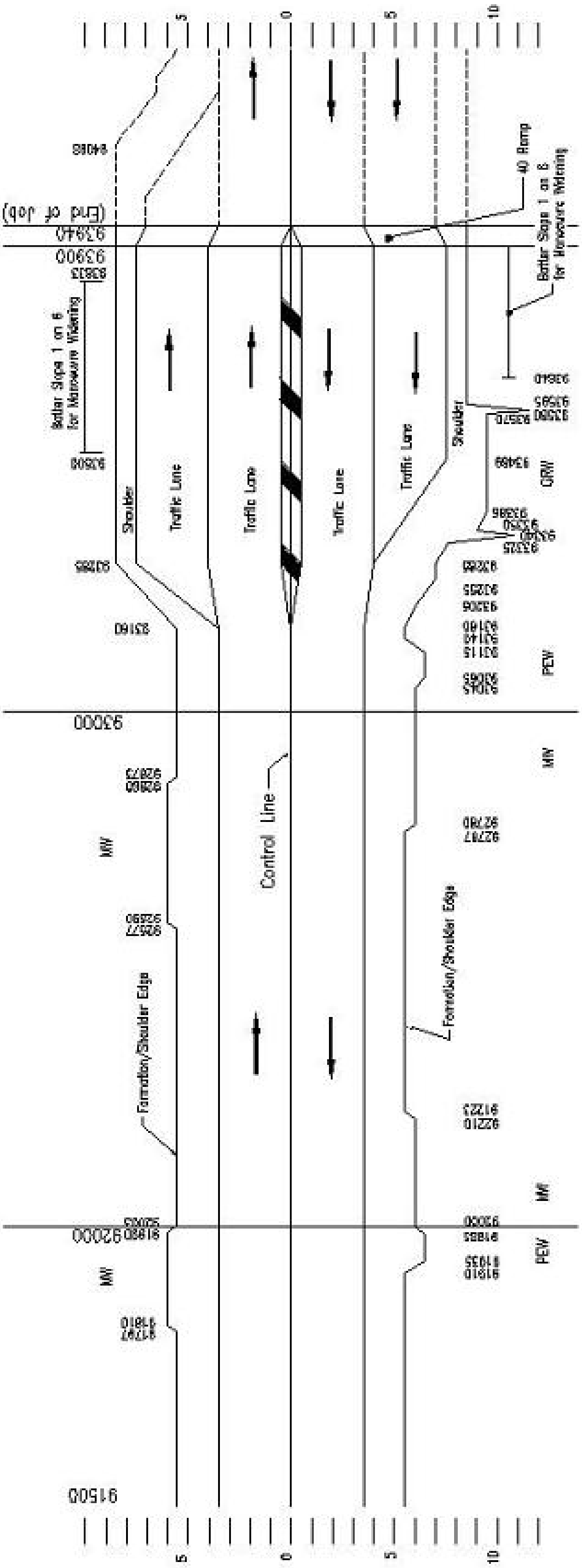

Figure 4.19 Example of plan showing intent of widening

Geometric deficiencies can be identified as a result of the geometric assessment. It may also reveal "concealed dangers", or identify something that may not currently be a problem but will be after the project has been completed. The latter may arise due to a change in:

- road users' perception of the road;
- the expectations of road users (e.g. drivers unlikely to distinguish between a restoration project and a new road project);
- operating conditions (e.g. increase in operating speed);
- tracking position of vehicles; and
- pavement type/area.

Assess any geometric deficiencies, using Extended Design Domain where appropriate

Where elements for the road section under consideration are below the Normal Design Domain for a new road (i.e. in "Area 2" or "Area 3", refer to Chapter 2), the road section should be assessed using the Extended Design Domain. In so doing it is important to note that, for the element concerned:

- there should be nothing present, either now or in the future, that will deceive and/or distract road users;
- designers should avoid situations where other deficiencies or minima are combined (with the Extended Design Domain);
- existing traversable areas/widths should not be reduced in size; and
- the assessment should be fully documented, filed and retained over a long time period for future reference.

Elements within the Extended Design Domain

An element can be considered to be within the Extended Design Domain (i.e. in "Area 2", refer to Chapter 2) if a reasonable capability is identified for that element. An example of this is where the assessment reveals that the element has a reasonable combination of stopping and manoeuvring capabilities appropriate for:

- the road's function;
- the road type;
- the characteristics of the present and future traffic (e.g. volume, percentage heavy vehicles, vehicle type); and
- future operating conditions (e.g. increased operating speeds).

If a reasonable capability is not identified then the element can be considered to be outside the Extended Design Domain (i.e. outside the design domain/in "Area 3", refer to Chapter 2).

Elements outside the Extended Design Domain/Design Domain – the design exception

If an element is outside the Extended Design Domain/Design Domain the road authority is relying on there being a low probability of road users encountering a hazard. If the assessment reveals an element is outside the Extended Design Domain/Design Domain the road authority should consider "local realignment" (i.e. upgrade to Extended Design Domain or greater standard) or address the greater potential for legal liability. If "local realignment" is not possible then the potential for legal liability **MAY** be reduced by:

- designing and installing mitigating devices (e.g. signage in accordance with the MUTCD);
- providing adequate clearance to hazards (e.g. traversable width);
- reducing the likelihood of road users encountering certain hazards (e.g. install fences to catch rocks, install fences/grids to prevent stock wandering onto the road, etc);
- demonstrating, using the crash data, that there is no crash history related to the relevant "sub-Extended Design Domain" criteria/parameter;
- considering if there are any fatigue related accidents;
- using risk management principles (e.g. assess the magnitude, probability and consequence of each risk);
- identifying the competing priorities that result in no funds being available for "local realignment";
- identifying any environmental constraints that may prevent "local realignment"; and
- calculating supporting BCRs where possible.

It is important to note however that a BCR in itself may not justify the retention of a design exception. This is because some safety issues are likely to be considered "so basic" that a court is unlikely to find the retention reasonable.

Irrespective of whether the element is outside or within the Extended Design Domain it is essential that the assessment of all elements along the road link under consideration be documented.

Monitor continually and review regularly

If Extended Design Domain is utilised for a road restoration project, the performance of the affected length of road should be monitored over time (e.g. increase or changes to accident rate and accident type); its performance should also be reviewed regularly. If the road's performance is unsatisfactory measures may have to be taken that aim to improve it to an acceptable level (e.g. improve the geometry of the road via a realignment).

Documentation to cover potential liability

The justification of the geometric standard adopted or retained for a road link is ultimately contestable in court. For this reason documentation that justifies the decisions, and retention of those records, is essential. Such records should document:

- all of the alternatives investigated and costed;
- any major constraints (e.g. based on social or community grounds, environmental grounds, geotechnical grounds, presence of major PUP installations);
- the competing priorities within the road system;
- the available funding;
- a risk analysis;
- supporting BCR calculations (if these are possible);
- the crash history;
- any "special needs" (e.g. of road users and/or vehicles, special events, etc);
- any trade-offs made in the assessment/design; and

- why the end result is a context sensitive design.

Elements within the Extended Design Domain

In the case of an element being within the Extended Design Domain (i.e. in "Area 2", refer to Chapter 2) the documentation should also record:

- the capabilities provided and why they are likely to be reasonable;
- the extent to which the intents of design criteria have been achieved, such as:
  - how well the intents have been met;
  - how relevant the intents are to the situation; and
  - if the consequences of the adopted solution are acceptable.

Elements outside the Extended Design Domain/Design Domain – the design exception

In the case of an element being outside the Extended Design Domain/Design Domain (i.e. a design exception which equates to being in "Area 3", refer to Chapter 2) the documentation should also record:

- the capabilities provided;
- any safety benefits (due to the capabilities provided);
- any mitigating devices or measures that can be used;
- any hazard reduction or prevention measures or works that can be constructed;
- what can be done in the long term if a problem occurs; and
- any experience with similar cases.

Examples of documentation

Figure 4.18, Table 4.7, Table 4.8 and Table 4.9 are all examples of some of the documentation that may be included in the records of the assessment of a road section. Figure 4.19 is an example of how the intent of works can documented for construction purposes and for the long term record.

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Appendix 4B: Guide for the Extended Design Domain for stopping sight distance

Intent of this guide

In line with the intent of the sight distance requirements for a new road, application of the Extended Design Domain for sight distance is all about ensuring that a reasonable and defendable combination of stopping and manoeuvring capability is provided on roads at all locations; approaches to intersections have additional requirements. **For intersections refer to the "Guide for the Extended Design Domain for sight distance at intersections" in Appendix 4C.**

Application of the Extended Design Domain

The Extended Design Domain is primarily for assessing sight distance on existing roads, including intersections. However it can be applied to improvements to existing roads (and intersections) - refer to Section 4.9 for a discussion of this issue. What is a reasonable combination of stopping capability and manoeuvring capability depends upon the probability and type of hazard as well as traffic volume, traffic characteristics and road function. For example, a greater traffic volume will warrant the provision of a greater manoeuvre sight distance capability.

A fundamental objective of this guide is to provide increased stopping capability (e.g. provide stopping to 0.2m high object rather than stopping to a 0.4m high object) as:

- the probability of encountering a hazard increases;
- the size of the most likely hazard decreases; or
- the traffic volume increases.

This also ensures greater manoeuvring capability.

Application of the Extended Design Domain involves identification and documentation of capability. Ultimately, the capabilities that are accepted may have to pass the test of what is reasonable capability. Note: A reasonable capability is the capability that a court decides a motorist can reasonably expect when they are taking reasonable care for their own safety.

The use of the Extended Design Domain allows and requires a detailed assessment of sight distance capabilities on the upgraded road, including intersections, in line with the predicted operating (i.e. 85th percentile) speeds at all points along the road. It is essential to gain a full understanding of the sight distance capabilities and the extent to which the intents of normal sight distance criteria are achieved. The effects of grade and coincident horizontal curves are more critical. It also involves a careful assessment for cases of possible driver distraction or deception since these may preclude the use of the Extended Design Domain at these locations, or require increased stopping capability.

Use of this guide

Using the Extended Design Domain, the minimum capability that can reasonably be defended should satisfy ALL of the following conditions:

1. It must be at least equal to the maximum value derived from the following:
   i. The appropriate Manoeuvre Sight Distance (MSD) base case given in Table 4.10; and

ii. The appropriate Stopping Sight Distance (SSD) cases given in Table 4.11.

2. When an object height of greater than 0.4m is used for the SSD base cases (i.e. Table 4.11), the SSD check cases in Table 4.13 should also be checked for satisfactory performance. For borderline cases, SSD checks can also be undertaken using Table 4.14. Similarly the additional checks described above should also be undertaken when several minima are being combined (e.g. R_T=2s with dry conditions with 1.15m eye height to 1.15m object height).

3. The minimum shoulder/traversable width criteria given in Table 4.12.

4. The "General considerations" and "Notes for horizontal curves" (given below in this Appendix)

Note that for convenience of documentation of the use of the Extended Design Domain within project reports etc, Table 4.11, Table 4.13 and Table 4.14 provide the nomenclature for concisely defining the available stopping capability.

General considerations

The following must be considered whenever the Extended Design Domain is applied to roads, including intersections:

1. The minimum stopping capability calculated from the criteria given above and below can only be justified provided it meets the following conditions:

   i. It is not combined with any other lower order values for the same element (i.e. only one lower order value per element is justifiable, e.g. if an element only meets minimum standard horizontal curvature in conjunction with minimum standard vertical crest radius it can not be justified);

   ii. Future arrangements/planning must be satisfied. (For example allow for future planning layouts, fencing, safety barriers, noise barriers, etc as appropriate. This includes taking account of their effects on sight lines/distances [e.g. a noise barrier may reduce horizontal visibility].)

   iii. Geometric features and other features of the road do not distract drivers;

   iv. Crash data indicates that there are no sight distance related crashes; and

   v. If an intersection exists the "Guide for the Extended Design Domain for sight distance at intersections", contained in Appendix 4C, must be used in conjunction with this guide to determine the minimum acceptable standard.

2. Horizontal curves and vertical curves should not be considered in isolation. Check sight distances/lines in both the vertical and horizontal planes taking into account both the horizontal and vertical curvature.

3. Particular attention must be given to checking truck requirements on routes with high proportions of heavy vehicles. Some capability for trucks should be provided on any road.

Designers and planners should note that for drivers travelling at the operating (85th percentile) speed it is reasonable to assume that they are conscious of their speed (commonly around 10km/h above the speed limit when not constrained by horizontal

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curvature). Consequently it is likely they will be prepared to brake harder in emergencies.

Designers and planners should also note that providing stopping capability for drivers travelling at the operating (85th percentile) speed will usually cater for less capable drivers (e.g. mean-day). This should not be assumed however; calculations and checks should always be undertaken for all relevant cases.

In addition, providing stopping capability for the "Norm-day-wet-0.6m high object" case will often cater for the "Norm-day-dry-0.2m high object" case. This should not be assumed however; calculations and checks should always be undertaken for all relevant cases.

Notes for horizontal curves

Whenever the Extended Design Domain is applied to roads and a horizontal curve exists, whether it be in isolation or in combination with a vertical curve, the following must be considered:

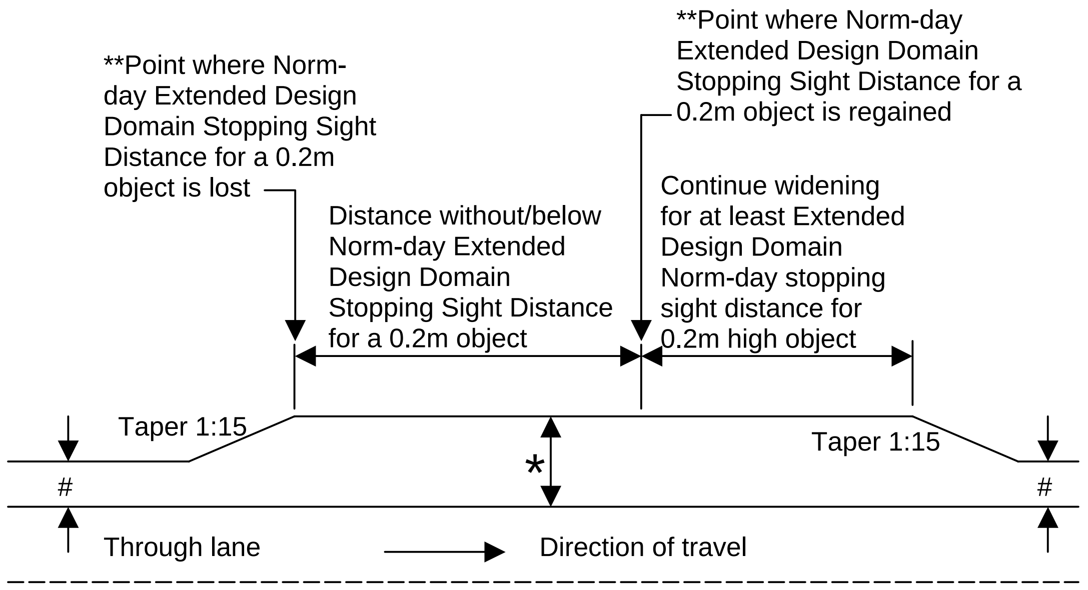
1. Where sight distance is only restricted in the horizontal plane, the height of the object has no effect.
2. For any horizontal curve with a side friction factor greater than the desirable maximum (i.e. $f_{des\ max}$ given in Chapter 11 for the operating speed), the co-efficient of deceleration used to calculate any of the stopping sight distance cases should be reduced by 0.05.
3. Consider the likely maintenance strategy and make allowance for it. (For example, if grass is allowed to grow up to the edge of seal the available offset for horizontal sight distance may be only about 3m. Allowance must be made for the height of vegetation, including grass, on benches, in table drains, etc that results from the maintenance strategy).
4. Cars and trucks require different offset values for horizontal sight distance due to differences in:
   i. stopping sight distances; and
   ii. the eye position of drivers.
5. The offset required for trucks will be affected by the direction of the curve (i.e. a left turning curve requires a different offset to a right turning curve).
6. The adequacy of horizontal curves should also be assessed as discussed in Chapters 6 and 11 (e.g. in terms of side friction demand, geometric consistency, etc).

How to apply widening to provide manoeuvre/traversable width

Widening to provide manoeuvre/traversable width should be applied as depicted in Figure 4.20.

Spreadsheet tool

A spreadsheet tool has also been developed to assist in the assessment of geometry against Extended Design Domain standards. A copy may be obtained by contacting the Principal Engineer (Road Engineering Standards).



*Extended Design Domain manoeuvre/traversable width.

**Other parameters (e.g. value for R_T and wet or dry conditions) as per Norm-day base case. Refer to notes and tables in Appendices 4B and 4C for nomenclature.

#Normal width.

Figure 4.20 Application of widening to provide Extended Design Domain manoeuvre/traversable width

Formulae

Chapter 9 provides formulae for the calculation of manoeuvre and stoping sight distances.

Chapter 11 provides formulae for the calculation of offsets required to obtain stopping sight distance around horizontal curves. It also has a graph that can be used to determine this offset.

Chapter 12 provides formulae for the calculation of vertical curve radii required to obtain stopping sight distance for a crest or sag curve.

Where horizontal and vertical curves overlap or coincide it is usually necessary for the designer to determine and check stopping sight distance via plots or Computer Aided Drafting and Design (CADD) packages (rather than formulae).

Table 4.10 Manoeuvre sight distance base cases for the Extended Design Domain

Type of restriction	Condition	Typical AADT	Minimum manoeuvre time, t (s)		"h_1" (m)		"h_2" (m)	
			Car	Truck	Car	Truck	Car	Truck
[1]Vertical curve only.	-	> 4000	4.0	4.0	1.15 - eye height for driver of passenger car.	2.4 - eye height for driver of truck.	0.2 - standard object.	0.6 – tail light/ reflector of car.
	-	400 to 4000	3.5	3.5				
	-	< 400	3.0	3.5				
[1]Horizontal curve only or a case of a horizontal curve overlapping a vertical curve.	[3]Horizontal curves with side friction demand greater than desirable maximum given in Chapter 11.	> 4000	4.5	4.5				
		400 to 4000	4.5	4.5				
		< 400	4.0	4.0				
	[3]Horizontal curves with side friction demand less than or equal to the desirable maximum given in Chapter 11.	> 4000	4.0	4.0				
		400 to 4000	4.0	4.0				
		< 400	3.5	3.5				

Notes to Table 4.10:

1. **Manoeuvre sight distance cannot be applied to lane locked lanes, as the possible presence of vehicle in adjacent lanes means it must be assumed that there is no width/room available for safe manoeuvring.**
2. It is unlikely drivers will have the option to manoeuvre in urban situations (e.g. due to reduced widths, use of lane plus kerbing and footpath instead of lane plus shoulder, etc). Therefore designers/engineers should not rely on a manoeuvre capability in an urban situation unless:
   a. there is sufficient width and length to manoeuvre; and
   b. there are no other constraints to manoeuvring (e.g. due to presence of pedestrians, pedestrian crossings, parked vehicles, etc).
3. The side friction must be checked for each design vehicle considered, using their respective operating (85^{th} percentile) speed. It must be a value that is appropriate for the vehicle, the vehicle's speed and the surface to be checked (as the side friction limits for cars, trucks and unsealed surfaces vary as do their speeds).
4. The manoeuvre times given in Table 4.10 provide some stopping capability (for some driver/vehicle combinations).
5. When the sight distance is restricted in the vertical plane, 3.5s manoeuvre time for cars is usually approximately equivalent to 4.6s manoeuvre time for trucks at the same speed. However, in each case, this equivalency should always be checked when truck stopping capability is being assessed.

Table 4.11 Stopping sight distance base cases for the Extended Design Domain

Case Code	Case description	Speed, "V" (km/h)	Reaction Times "R_T" (s)	[3]Coefficient of deceleration, "d"	"h_1" (m)	[2] "h_2" (m)
Norm-day.	Normal car driver travelling at the operating (85th percentile) speed in daylight hours.	Operating (85th percentile) car speed.	2.5 - isolated element where V >70km/h. 2 - normal cases for roads with V >70km/h. 1.5 - normal cases for roads with V ≤70km/h [4]1.5 - roads with alert driving conditions and V >70km/h	0.61 - predominantly dry area with low traffic volumes. 0.46 - all other cases.	1.15 - eye height for driver of passenger car.	0.2 - standard object. 0.4 - dead animal. 0.6 - tail light/reflector of car. 1.15 - top of car.
[1]Truck-day.	Truck in daylight hours.	Use speed of average laden design prime-mover and semi-trailer in free flowing conditions.	2 - normal cases for roads with V >70km/h. 1.5 - normal cases for roads with V ≤70km/h [4]1.5 - roads with alert driving conditions and V >70km/h	[1]0.29 - all cases (except Type 1 and 2 road-trains).	2.4 - eye height for driver of truck.	0.6 - tail light/reflector of car. 1.15 - top of car.

<u>Notes to Table 4.11:</u>

1. These cases cover design single unit trucks, semi-trailers and B-doubles. The deceleration rates given above allow for the brake delay times associated with the air braking systems used on these vehicles. Where it is necessary to check for the operation of Type 1 road-trains, use a coefficient of deceleration rate of 0.28. Where it is necessary to check for the operation of Type 2 road-trains, use a coefficient of deceleration rate of 0.26.
2. For a car in a lane locked lane an object height of 0.2m should be used. For a truck in a lane locked lane an object height of 0.6m should be used. Otherwise the choice of object height depends on:
    a. the probability of the object occurring on the roadway; and
    b. the traffic volume.
3. Refer to Note 2 above (in "Notes for horizontal curves" section in Appendix 4B) for the effect of horizontal curves.
4. Must only be used where Designer/Engineer is confident that drivers will be constantly/continuously alert and that there is nothing unusual present that will deceive or distract the driver. For this case the physical and/or built environment should increase drivers' expectation that they will have to react quickly/stop. For example:
    a. a road in a rural area with a horizontal alignment that requires the driver to maintain a high level of awareness due to the presence of a continuous series of curves with a side friction demand > $f_{des\ max}$; or
    b. a road in a heavily built up urban area with many direct accesses and intersections.
5. For convenience, a stopping distance case (or capability) can be described in terms of the following nomenclature: Case Code-R_T-wet/dry-h_2 (For example, Norm-day-2-wet-0.4 describes the capability corresponding to a normal car driver travelling at the operating [85th percentile] speed in daylight hours with an R_T of 2s when stopping in wet conditions for a 0.4m high object.)

Table 4.12 Minimum shoulder/traversable widths when the Extended Design Domain is used

Type of restriction	For cars		For trucks	
	Case	**[1,4]Minimum Shoulder / Traversable Width (m)**	**Case**	**[1,4]Minimum Shoulder / Traversable Width (m)**
Vertical curve only.	Norm-day stopping sight distance base case in Table 4.11 with an object height of 0.2m.	Normal.	Truck-day stopping sight distance base case in Table 4.11 with an object height of 0.6m.	Normal.
Vertical curve only.	Norm-day stopping sight distance base case in Table 4.11 with an object height of 0.4m.	1.5 (on each side).	Truck-day stopping sight distance base case in Table 4.11 with an object height greater than 0.6m.	3.0 (on each side).
Vertical curve only.	Norm-day stopping sight distance base case in Table 4.11 with an object height greater than 0.4m.	2.5 (on each side).	Truck-day stopping sight distance base case in Table 4.11 with an object height greater than 0.6m.	3.0 (on each side).
[3]Horizontal curve only.	Norm-day stopping sight distance base case achieved.	Normal.	Truck-day stopping sight distance base case achieved.	Normal.
[3]Horizontal curve only.	Norm-day stopping sight distance base case not achieved.	2.5 on inside of curve (i.e. on side towards the centre of the curve). 1.0 on outside of curve (i.e. on side away from the centre of the curve).	Truck-day stopping sight distance base case not achieved.	3.0 on inside of curve (i.e. on side towards the centre of the curve). 1.0 on outside of curve (i.e. on side away from the centre of the curve).
[3]Horizontal curve overlapping a vertical curve.	All	Inside of curve (i.e. the side towards the centre of the curve) – as for horizontal only Outside of curve (i.e. the side furthest from the centre of the curve) – as for vertical only	All	Inside of curve (i.e. the side towards the centre of the curve) – as for horizontal only Outside of curve (i.e. the side furthest from the centre of the curve) – as for vertical only

<u>**Notes to Table 4.12:**</u>

1. **Manoeuvre sight distance cannot be applied to lane locked lanes, as the possible presence of vehicle in adjacent lanes means it must be assumed that there is no width/room available for safe manoeuvring.**
2. The minimum traversable/shoulder width given in this table is for a two lane, two way road. For other road types an equivalent minimum traversable/shoulder width is to be used.
3. The side friction must be checked for each design vehicle considered, using their respective operating (85th percentile) speed. It must be a value that is appropriate for the vehicle, the vehicle's speed and the surface to be checked (as the side friction limits for cars, trucks and unsealed surfaces vary as do their speeds).
4. The width of seal on the shoulder must be at least 0.5m to avoid edge drop-off. The minimum widths are based on a minimum lane width of 3.5m. Where the proposed lane width is less than 3.5m, the minimum shoulder/traversable width must be increased by an amount equal to the difference between the proposed lane width and 3.5m (e.g. if 3m wide lanes are proposed, the minimum widths must be increased by 0.5m).
5. It is unlikely drivers will have the option to manoeuvre in urban situations (e.g. due to reduced widths, use of lane plus kerbing and footpath instead of lane plus shoulder, etc). Therefore designers/engineers should not rely on a manoeuvre capability in an urban situation unless:
   a. there is sufficient width and length to manoeuvre; and
   b. there are no other constraints to manoeuvring (e.g. due to presence of pedestrians, pedestrian crossings, parked vehicles, etc).

Table 4.13 Stopping sight distance checks for the Extended Design Domain

Case Code	Case description	Speed, "V" (km/h)	Reaction Times "R_T" (s)	[3]Coefficient of deceleration, "d"	"h_1" (m)	[2] "h2" (m)
Norm-night.	Normal car driver travelling at the operating (85^{th} percentile) speed at night.	Operating (85^{th} percentile) car speed.	2 - normal cases for unlit roads with V >70km/h. 1.5 - normal cases for unlit roads with V ≤70km/h [4]1.5 - unlit roads with alert driving conditions and V >70km/h	0.61 - predominantly dry area with low traffic volumes. 0.46 - all other cases.	0.75 - height of car headlight.	0.6 - tail light/reflector of car. 1.15 - top of car.
					1.15 - eye height for driver of passenger car.	0.6 - tail light/reflector of car.
[1]Truck-night	Truck travelling at night.	Use speed of average laden design prime-mover and semi-trailer in free flowing conditions.	2 - normal cases for unlit roads with V >70km/h. 1.5 - normal cases for unlit roads with V ≤70km/h [4]1.5 - unlit roads with alert driving conditions and V >70km/h	[1]0.29 - all cases (except Type 1 and 2 road-trains).	1.1 - height of truck headlight.	0.6 - tail light/reflector of car. 1.15 - top of car.
					2.4 - eye height for driver of truck.	0.6 - tail light/reflector of car.
Mean-day	Car driver travelling at the mean free speed in daylight hours.	Mean car speed ≈ 0.85 times operating (85^{th} percentile) car speed.	2.5 - isolated element with V >70km/h. 2 - all other cases.	0.51 - predominantly dry area with low traffic volumes 0.41 - all other cases	1.15 - eye height for driver of passenger car.	0.2 - standard object. 0.4 - dead animal. 0.6 - tail light/reflector of car. 1.15 - top of car.
Mean-night	Car driver travelling at the mean free speed at night	Mean car speed ≈ 0.85 times operating (85^{th} percentile) car speed.	2 - all cases.	0.51 - predominantly dry area with low traffic volumes 0.41 - all other cases	0.75 - height of car headlight.	0.6 - tail light/reflector of car. 1.15 - top of car.
					1.15 - eye height for driver of passenger car.	0.6 - tail light/reflector of car.

Notes to Table 4.13:

1. These cases cover design single unit trucks, semi-trailers and B-doubles. The deceleration rates given above allow for the brake delay times associated with the air braking systems used on these vehicles. Where it is necessary to check for the operation of Type 1 road-trains, use a coefficient of deceleration rate of 0.28. Where it is necessary to check for the operation of Type 2 road-trains, use a coefficient of deceleration rate of 0.26.
2. For a car in a lane locked lane an object height of 0.2m should be used. For a truck in a lane locked lane an object height of 0.6m should be used. Otherwise the choice of object height depends on:
    a. the probability of the object occurring on the roadway; and
    b. the traffic volume.
3. Refer to Note 2 above (in "Notes for horizontal curves" section in Appendix 4B) for the effect of horizontal curves.
4. Must only be used where Designer/Engineer is confident that drivers will be constantly/continuously alert and that there is nothing unusual present that will deceive or distract the driver. For this case the physical and/or built environment should increase drivers' expectation that they will have to react quickly/stop. For example:
    a. a road in a rural area with a horizontal alignment that requires the driver to maintain a high level of awareness due to the presence of a continuous series of curves with a side friction demand > $f_{des\ max}$; or
    b. a road in a heavily built up urban area with many direct accesses and intersections.
5. For convenience, a stopping distance case (or capability) can be described in terms of the following nomenclature: Case Code-R_T-wet/dry-h_2 (For example, Norm-night-2-wet-0.4 describes the capability corresponding to a normal car driver travelling at the operating [85^{th} percentile] speed at night with an R_T of 2s when stopping in wet conditions for a 0.4m high object.)

Table 4.14 Stopping sight distance, optional checks for borderline cases for the Extended Design Domain

Case Code	Case description	Speed, "V" (km/h)	Reaction Times "R_T" (s)	[2]Coefficient of deceleration, "d"	"h_1" (m)	[1] "h_2" (m)
Skill-day	Skilled car driver travelling at the operating (85th percentile) speed in daylight hours.	Operating (85th percentile) car speed.	1.5 - all cases.	0.71 - predominantly dry area with low traffic volumes. 0.56 - all other cases.	1.15 - eye height for driver of passenger car.	0.2 - standard object. 0.4 - dead animal. 0.6 - tail light/reflector of car. 1.15 - top of car.
Skill-night	Skilled car driver travelling at the operating (85th percentile) speed in daylight hours.	Operating (85th percentile) car speed.	1.5 - all cases.	0.71 - predominantly dry area with low traffic volumes 0.56 - all other cases	0.75 - height of car headlight.	0.6 - tail light/reflector of car. 1.15 - top of car.
					1.15 - eye height for driver of passenger car.	0.6 - tail light/reflector of car.

<u>Notes to Table 4.14:</u>

1. For a car in a lane locked lane an object height of 0.2m should be used. For a truck in a lane locked lane an object height of 0.6m should be used. Otherwise the choice of object height depends on:
   a. the probability of the object occurring on the roadway; and
   b. the traffic volume.
2. Refer to Note 2 above (in "Notes for horizontal curves" section in Appendix 4B) for the effect of horizontal curves.
3. For convenience, a stopping distance case (or capability) can be described in terms of the following nomenclature: Case Code-R_T-wet/dry-h_2 (For example, Skill-day-1.5-wet-0.4 describes the capability corresponding to a skilled car driver travelling at the operating [85th percentile] speed in daylight hours with an R_T of 1.5s when stopping in wet conditions for a 0.4m high object.)

Appendix 4C: Guide for the Extended Design Domain for sight distance at intersections

Intent of this guide

In line with the intent of the sight distance requirements for a new road, application of the Extended Design Domain for sight distance at intersections is all about ensuring that a reasonable and defendable sight distance capability is provided for all approaching, entering, crossing and turning vehicles. For the Extended Design Domain stopping capabilities on all roads, including through intersections, refer to the "Guide for the Extended Design Domain for stopping sight distance" in Appendix 4B.

Application of the Extended Design Domain

The Extended Design Domain is primarily for assessing sight distance on existing roads, including intersections. However it can be applied to special cases of new road and/or intersection projects, or to improvements to existing roads and intersections - refer to refer to Section 4.9 for a discussion of this issue. What is a reasonable sight distance capability at intersections depends upon the traffic volume, traffic characteristics and road function. For example, a traffic stream with a high proportion of heavy vehicles will warrant the provision of a greater sight distance capability.

Application of the Extended Design Domain involves identification and documentation of capability. Ultimately, the capabilities that are accepted may have to pass the test of what is reasonable capability. (Note: A reasonable capability is the capability that a court decides a motorist can reasonably expect when they are taking reasonable care for their own safety.)

The use of the Extended Design Domain allows and requires a detailed assessment of sight distance capabilities on the upgraded road, including intersections, in line with the predicted operating (i.e. 85^{th} percentile) speeds at all points along the road. It is essential to gain a full understanding of the sight distance capabilities and the extent to which the intents of normal sight distance criteria are achieved. The effects of grade and coincident horizontal curves are more critical. It also involves a careful assessment for cases of possible driver distraction or deception since these may preclude the use of the Extended Design Domain at these locations, or require increased stopping capability.

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Use of this guide

Using the Extended Design Domain, the minimum stopping capability that can reasonably be defended should satisfy ALL of the following conditions:

1. It must be at least equal to the maximum value derived from the following:
   i. Approach Sight Distance (ASD) base cases given in Table 4.15 for any one of the following circumstances:
      a. important intersections;
      b. complex intersection layouts;
      c. in situations where drivers may be distracted by other features; or
      d. where adequate perception of the intersection is not provided through means other than ASD.

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ii. Minimum Gap Sight Distance (MGSD) as per Chapter 13.

iii. Safe Intersection Sight Distance (SISD) base cases given in Table 4.16.

2. When a Decision Time (D_T) of less than four (4) seconds is used for the SISD base cases (i.e. Table 4.16), the SISD cases in Table 4.17 should also be checked for satisfactory performance. For borderline cases, checks can also be undertaken using Table 4.18.

3. The criteria given in the "Guide for the Extended Design Domain for stopping sight distance" in Appendix 4B.

4. The "General considerations" and "Notes for horizontal curves" (given below in this Appendix).

Note that for convenience of documentation of the use of the Extended Design Domain within project reports etc, Table 4.15, Table 4.16, Table 4.17 and Table 4.18 provide the nomenclature for concisely defining the available stopping capability.

General considerations

The following must be considered whenever the Extended Design Domain is applied to intersections:

1. Zones clear of obstructions, defined by "sight triangles" for each of the appropriate sight distance models, are required at intersections and must be maintained (e.g. resumptions, grass mowing practice/schedule, vegetation maintenance strategy, interference by signage, effect of installation of noise barriers, etc are all taken into account).

2. The minimum stopping capability calculated from the criteria given above can only be justified provided it meets the following conditions:

   i. It is not combined with any other lower order value for the same element (i.e. only one lower order value per element is justifiable, e.g. if an element only meets minimum standard horizontal curvature in conjunction with minimum standard vertical crest radius it can not be justified);

   ii. Future arrangements/planning must be satisfied. (For example allow for future planning layouts, fencing, safety barriers, noise barriers, etc as appropriate. This includes taking account of their effects on sight lines/distances [e.g. a noise barrier may reduce horizontal visibility].)

   iii. Geometric features and other features of the road do not distract drivers;

   iv. Crash data indicates that there are no sight distance related crashes; and

   v. The "Guide for the Extended Design Domain for stopping sight distance", contained in this Appendix 4B, must be used in conjunction with this guide to determine the minimum acceptable standard.

3. Horizontal curves and vertical curves should not be considered in isolation. Check sight distances/lines in both the vertical and horizontal planes taking into account both the horizontal and vertical curvature.

4. Particular attention must be given to checking truck requirements on routes with high proportions of heavy

vehicles. Some capability for trucks should be provided on any road.

Designers and planners should note that for drivers travelling at the operating (85^{th} percentile speed) it is reasonable to assume that they are conscious of their speed (commonly around 10km/h above the speed limit when not constrained by horizontal curvature). Consequently it is likely they will be prepared to brake harder in emergencies.

Designers and planners should also note that providing stopping capability for drivers travelling at the operating (85^{th} percentile) speed will usually cater for less capable drivers (e.g. mean-day). This should not be assumed however; calculations and checks should always be undertaken for all (relevant) cases.

Finally, it should be noted that only stopping for wet conditions is included in this guide. This is because at intersections there is increased exposure and therefore an increased probability that a hazard will be encountered during wet conditions.

Notes for horizontal curves

Whenever the Extended Design Domain is applied to roads and a horizontal curve exists, whether it be in isolation or in combination with a vertical curve, the following must be considered:

1. Where sight distance is only restricted in the horizontal plane, the height of the object has no effect.
2. For any horizontal curve with a side friction factor greater than the desirable maximum (i.e. $f_{des\ max}$ given in Chapter 11 using the operating speed), the co-efficient of deceleration used to calculate any of the stopping sight distance cases (for ASD and SISD) should be reduced by 0.05.
3. Consider the likely maintenance strategy and make allowance for it. (For example, if grass is allowed to grow up to the edge of seal the available offset for horizontal sight distance may be only about 3m. Allowance must be made for the height of vegetation, including grass, on benches, in table drains, etc that results from the maintenance strategy.)
4. Cars and trucks require different offset values for horizontal sight distance due to differences in:
   i. stopping sight distances; and
   ii. the eye position of drivers.
5. The offset required for trucks will be affected by the direction of the curve (i.e. a left turning curve requires a different offset to a right turning curve).
6. The adequacy of horizontal curves should also be assessed as discussed in Chapters 6 and 11 (e.g. in terms of side friction demand, geometric consistency, etc).

Spreadsheet tool

A spreadsheet tool has also been developed to assist in the assessment of geometry against Extended Design Domain standards. A copy may be obtained by contacting the Principal Engineer (Road Engineering Standards).

Formulae

Chapter 9 provides formulae for the calculation of manoeuvre and stoping sight distances.

Chapter 11 provides formulae for the calculation of offsets required to obtain stopping sight distance around horizontal curves. It also has a graph that can be used to determine this offset.

Chapter 12 provides formulae for the calculation of vertical curve radii required to obtain stopping sight distance for a crest or sag curve.

Chapter 13 provides formulae for the calculation of stopping sight distance required at intersections, and accesses (where appropriate).

Where horizontal and vertical curves overlap or coincide it is usually necessary for the designer to determine and check stopping sight distance via plots or Computer Aided Drafting and Design (CADD) packages (rather than formulae).

Table 4.15 Approach sight distance base cases for the Extended Design Domain

Case Code	Case description	Speed, "V" (km/h)	Reaction Times "R_T" (s)	[1]Coefficient of deceleration, "d"	"h_1" (m)	"h_2" (m)
ASD.	Normal car driver travelling at the operating (85^{th} percentile) speed in daylight hours.	Operating (85^{th} percentile) car speed.	2.5 - isolated element where V >70km/h. 2 - normal cases for roads with V >70km/h. 1.5 - normal cases for roads with V ≤70km/h [2]1.5 - roads with alert driving conditions and V >70km/h	0.61 - predominantly dry area with low traffic volumes. 0.46 - all other cases.	1.15 - eye height of passenger car.	0.0- road surface.

<u>Notes to Table 4.15:</u>

1. Refer to Note 2 above (in "Notes for horizontal curves" section in Appendix 4C) for the effect of horizontal curves.
2. Must only be used where Designer/Engineer is confident that drivers will be constantly/continuously alert and that there is nothing unusual present that will deceive or distract the driver. For this case the physical and/or built environment should increase drivers' expectation that they will have to react quickly/stop. For example:
   a. a road in a rural area with a horizontal alignment that requires the driver to maintain a high level of awareness due to the presence of a continuous series of curves with a side friction demand > $f_{des\ max}$; or
   b. a road in a heavily built up urban area with many direct accesses and intersections.
3. For convenience, an ASD case (or capability) can be described in terms of the following nomenclature: Case Code-R_T-wet/dry (For example, ASD-2-wet describes the capability corresponding to a normal car driver travelling at the operating [85^{th} percentile] speed in daylight hours with an R_T of 2s when stopping in wet conditions for a 0m high object.)

Table 4.16 Safe Intersection Sight Distance base cases for the Extended Design Domain

Case Code	Case description	Speed, "V" (km/h)	[3]Decision Times "D_T" (s)	[2]Coefficient of deceleration, "d"	"h_1" (m)	"h_2" (m)
Norm-day.	Normal car driver travelling at the operating (85th percentile) speed in daylight hours.	Operating (85th percentile) car speed.	4.0 - isolated element where V >70km/h. 3.5 - normal cases for roads with V >70km/h. 3.0 - normal cases for roads with V ≤70km/h [4]3.0 - roads with alert driving conditions and V >70km/h	0.46 - all cases.	1.15 - eye height for driver of passenger car.	1.15 - top of car.
[1]Truck-day.	Truck in daylight hours.	Use speed of average laden design prime-mover and semi-trailer in free flowing conditions.	3.5 - all cases.	[1]0.29 - all cases (except Type 1 and 2 road-trains).	2.4 - eye height for driver of truck.	1.15 - top of car.

Notes to Table 4.16:

1. These cases cover design single unit trucks, semi-trailers and B-doubles. The deceleration rates given above allow for the brake delay times associated with the air braking systems used on these vehicles. Where it is necessary to check for the operation of Type 1 road-trains, use a coefficient of deceleration rate of 0.28. Where it is necessary to check for the operation of Type 2 road-trains, use a coefficient of deceleration rate of 0.26.
2. Refer to Note 2 above (in "Notes for horizontal curves" section in Appendix 4C) for the effect of horizontal curves.
3. D_T = decision time (s) = observation time (s) + reaction time (s).
4. Must only be used where Designer/Engineer is confident that drivers will be constantly/continuously alert and that there is nothing unusual present that will deceive or distract the driver. For this case the physical and/or built environment should increase drivers' expectation that they will have to react quickly/stop. For example:
    a. a road in a rural area with a horizontal alignment that requires the driver to maintain a high level of awareness due to the presence of a continuous series of curves with a side friction demand > $f_{des\ max}$; or
    b. a road in a heavily built up urban area with many direct accesses and intersections.
5. For convenience, a stopping distance case (or capability) can be described in terms of the following nomenclature: Case Code-D_T (For example, Norm-day-4 describes the capability corresponding to a normal car driver travelling at the operating [85th percentile] speed in daylight hours with an D_T of 4s when stopping in wet conditions for a 1.15m high object.)

Table 4.17 Safe Intersection Sight Distance checks for the Extended Design Domain

Case Code	Case description	Speed, "V" (km/h)	[3]Decision Times "D_T" (s)	[2]Coefficient of deceleration, "d"	"h_1" (m)	"h_2" (m)
Norm-night	Normal car driver travelling at the operating (85th percentile) speed at night	Operating (85th percentile) car speed	[4]2.5 - all cases	0.46 - all cases	[7]0.75 - height of car headlight	[7]1.15 - top of car
[1]Truck-night	Truck travelling at night	Use speed of average laden design prime-mover and semi-trailer in free flowing conditions.	[4]2.5 - all cases	[1]0.29 - all cases (except Type 1 and 2 road-trains).	1.1 - height of truck headlight	1.15 - top of car
Mean-day	Car driver travelling at the mean free speed in daylight hours	Mean car speed ≈ 0.85 times operating (85th percentile) speed	4.0 - isolated element where V >70km/h. 3.5 - normal cases for roads with V >70km/h. 3.0 - normal cases for roads with V ≤70km/h [5]3.0 - roads with alert driving conditions and V >70km/h	0.41 - all cases	1.15 - eye height for driver of passenger car	1.15 - top of car
Mean-night	Car driver travelling at the mean free speed at night	Mean car speed ≈ 0.85 times operating (85th percentile) speed	3.5 - all cases	0.41 - all cases	[7]0.75 - height of car headlight	[7]1.15 - top of car

Notes to Table 4.17:

1. These cases cover design single unit trucks, semi-trailers and B-doubles. The deceleration rates given above allow for the brake delay times associated with the air braking systems used on these vehicles. Where it is necessary to check for the operation of Type 1 road-trains, use a coefficient of deceleration rate of 0.28. Where it is necessary to check for the operation of Type 2 road-trains, use a coefficient of deceleration rate of 0.26.
2. Refer to Note 2 above (in "Notes for horizontal curves" section in Appendix 4C) for the effect of horizontal curves.
3. D_T = decision time (s) = observation time (s) + reaction time (s).
4. In reality, this is a check to ensure that a vehicle on the through road can see and stop for a stalled vehicle.
5. Must only be used where Designer/Engineer is confident that drivers will be constantly/continuously alert and that there is nothing unusual present that will deceive or distract the driver. For this case the physical and/or built environment should increase drivers' expectation that they will have to react quickly/stop. For example:
   a. a road in a rural area with a horizontal alignment that requires the driver to maintain a high level of awareness due to the presence of a continuous series of curves with a side friction demand > $f_{des\ max}$; or
   b. a road in a heavily built up urban area with many direct accesses and intersections.
6. For convenience, a stopping distance case (or capability) can be described in terms of the following nomenclature: Case Code-D_T (For example, Mean-day-4 describes the capability corresponding to a car driver travelling at the mean free speed in daylight hours with an D_T of 4s when stopping in wet conditions for a 1.15m high object.)
7. This also achieves stopping for an eye height of 1.15m (the eye height for driver of passenger car) to an object height of 0.75m (height of car headlight).

Table 4.18 Safe Intersection Sight Distance, optional checks for borderline cases for the Extended Design Domain

Case Code	Case description	Speed, "V" (km/h)	[2]Decision Times "D_T" (s)	[1]Coefficient of deceleration, "d"	"h_1" (m)	"h_2" (m)
Skill-day	Skilled car driver travelling at the operating (85^{th} percentile) speed in daylight hours	Operating (85^{th} percentile) car speed	3.0 - all cases	0.56 - all cases	1.15 - passenger car	1.15 - top of car
Skill-night	Skilled car driver travelling at the operating (85^{th} percentile) speed at night	Operating (85^{th} percentile) car speed	3.0 - all cases	0.56 - all cases	[4]0.75 - height of car headlight	[4]1.15 - top of car

<u>Notes to Table 4.18:</u>

1. Refer to Note 2 above (in "Notes for horizontal curves" section in Appendix 4C) for the effect of horizontal curves.
2. D_T = decision time (s) = observation time (s) + reaction time (s).
3. For convenience, a stopping distance case (or capability) can be described in terms of the following nomenclature: Case Code-D_T (For example, Skill-day-3 describes the capability corresponding to a skilled car driver travelling at the operating [85^{th} percentile] speed in daylight hours with an D_T of 3s when stopping in wet conditions for a 1.15m high object.)
4. This also achieves stopping for an eye height of 1.15m (the eye height for driver of passenger car) to an object height of 0.75m (height of car headlight).

Appendix 4D: Guide to evaluating cross sections using the Extended Design Domain

The information provided in this section is consistent with the current version of Chapter 7. It does not in any way conflict with Chapter 7 but it does provide additional information with regard to projects that retain or improve the carriageway of existing formations.

There are a number of existing roads in the state controlled road network that have a total carriageway width in the order of 7.9m to 8.6m whereas a 9m or wider carriageway would be justified if it were a new road. The following discussion pertains to existing carriageways with widths in the order of 7.9m to 8.6m widths. It is appropriate to keep such carriageway widths where the primary intention is to improve the seal width on existing formations.

(This section is based on a cross section presentation given at an Extended Design Domain training course [Cox, 2005]).

Traffic lane widths below the Normal Design Domain

Currently there is no Extended Design Domain for traffic lane widths on new roads. Lane widths of less than 3m have not been used in rural areas. In urban areas, road authorities have used lane widths of less than 3m, principally on existing roads. An absolute lower limit for lane width has not been developed. However, lane widths of down to 2.7m have been used in urban areas in Sydney. In addition, the Guide to Traffic Engineering Part 5 (Austroads, 1988) notes turn lanes may reduced to a minimum of 2.5m and further that it is preferable to reduce turn lane widths before through lanes widths are reduced.

Careful consideration is required before adopting lane widths below 3m. Adopting a traffic lane width of less than 3m requires the designer to consider aspects such as:

- the characteristics of the traffic stream in the lane (e.g. proportion of heavy vehicles using the lane concerned);
- the characteristics of the (predominant) driver (type, e.g. regular commuter versus tourist, refer to Chapter 5);
- the lane type (e.g. if designated as an exclusive HOV/bus lane, or simply if the lane has a high proportion of these vehicles such as a kerbside lane on a designated bus route);
- the degree of shared use (e.g. if the lane is highly used by cyclists or if it is on a priority cycling route [refer to Main Roads Cycling Policy]);
- whether the lane is “locked”;
- the length of lane less than 3m wide;
- the lane use (e.g. right turn only versus through);
- whether there is adequate clearance from vehicles (including their external mirrors) in the lane to:
  - adjacent vehicles;
  - adjacent footpaths, particularly where pedestrian use is high; and
  - road furniture (e.g. gantries, sign faces, safety barriers).

(Note: The above list is not comprehensive.)

The designer should consider relevant factors before deciding the reasonableness of adopting a lane width of less than 3m. Normally a 2.7m wide lane is not suitable

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for designated bus or HOV lanes, kerbside lanes on bus routes, kerbside shared use lanes on designated cycling routes or kerbside lanes adjacent to high volume pedestrian footpaths.

Shoulder widths

Lower bound for restoration works

While wider shoulders are often necessary or preferred, Chapter 7 does recognise that shoulder widths of 0.5m to 1.0m may be appropriate, but usually only for restoration projects when widening of the carriageway/formation is not warranted (refer to the link strategy). Factors supporting the lower bound for restoration works include:

- It allows continued use of many existing carriageways that are 7.9m to 8.6m wide by:
  - avoiding impractical "sliver" widening (where the existing shoulder is full depth pavement, e.g. it avoids a 0.5m widening to bring carriageway width up to 9m) until widening to a carriageway width ≥10m is warranted and practical (refer to the link strategy);
  - avoiding changes to cross drainage structures (although the safety of these need to be assessed, refer to Chapter 8);
  - reducing the environmental impact of a restoration project by not changing batters, roadside vegetation (viz. canopy connectivity), etc; and
  - supporting the achievement of network priorities contained in investment strategies (i.e. affordable interim standards).
- There are low current and predicted traffic volumes since:
  - road train drivers tend to straddle centre line to reduce steering effort; and
  - unused seal deteriorates on low volume roads (so providing width that will not be used may be inappropriate or wasteful).
- Safety is better when compared to no shoulder.
- It provides some pavement support.
- It allows for occasional mistracking of heavy vehicles (although not as well as practical lower limit).

Sealing of the existing shoulder may **partially**:

- improve the structural life of a pavement (e.g. by reducing the amount of water that reaches the outer wheel path of the through lane);
- provide a structurally suitable area for truck jacks (from anecdotal industry feedback); and
- promote safe operation of heavy vehicles (as described above).

Factors to consider when retaining existing carriageways

When contemplating the retention of existing shoulders designers should consider the following:

- Vehicles may track closer to centre line when there is no oncoming traffic, especially if there is no centre line marking.
- Pavement life may be affected, for example:
  - life may be reduced as the wheel distribution may be concentrated

into a narrower wheel path when combined with narrow lanes; and

- o life may be higher as the outer wheel path may be further from the edge of the seal.

- Anecdotally 1m (sealed) is the minimum shoulder width preferred by the heavy vehicle industry.
- Shy line effects.
- Widening (e.g. to achieve a carriageway width of 9m or 12m) may be required for elements where the Extended Design Domain for sight distance requires manoeuvre capability.

Designers should consult a pavement specialist to ascertain the consequences of retaining the existing shoulder and its effects in relation to pavement life (e.g. to check whether water ingress into outer wheel path will cause rutting and/or a reduction in pavement life) and how the location of longitudinal pavement joins may affect the design of a cross section (e.g. dimensions, location of transverse line marking).

Total carriageway width

Restoring existing carriageways

For such carriageways a context sensitive design is often achieved by retaining the existing carriageway width. If a context sensitive design requires widening the justification for it and the benefit/s resulting from it must documented. Irrespective of the above it important to note that the use of the Extended Design Domain may require local widening on some elements (e.g. widening to allow for manoeuvre on over a "tight" crest, refer to Appendix 4A).

Keeping existing carriageway widths

In addition to the reasons discussed in the preceding sections, it often appropriate to retain an existing carriageway for the following reasons:

- To make maximise the investment made in the existing asset.
- Operation is acceptable (i.e. widths are reasonable and fit within the design domain, e.g. for a low volume road).
- More benefit can be gained by sealing a longer length of existing carriageway.
- To provide consistency across the road network.
- To provide consistency along the road link.
- There are higher network priorities.
- Sliver widening of <2m is not a cost effective treatment. It is difficult and expensive to construct a widening of <2m. However, if the pavement material in the shoulder is not suitable to form part of the restored pavement (e.g. can not be stabilised due to insufficient depth, unsuitable type of material) for trafficking, then widening to say 9m in the first instance may be appropriate.

In addition a risk management approach needs to be taken where cross drainage structures and other hazards exist (refer to Chapter 8 for detailed discussion).

Sealing existing carriageways

When sealing existing carriageways, the use of lane widths of between 3m and 3.5m (inclusive, i.e. at the "lower bound") in conjunction with a wider shoulder may be required:

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- to account for the transverse position of longitudinal pavement joints (e.g. if possible avoid marking the pavement so that wheel paths concentrate on longitudinal pavement joints);
- for maintenance (e.g. reduces edge break and edge drop off); or
- to minimise the ingress of water into the pavement under the outer wheel path of the through lane.

Designers should seek advice from relevant personnel (e.g. pavement specialists, maintenance personnel) when designing the cross section and line marking.

MCVs and caravans

Carriageways with single lane seals are also unlikely to be appropriate for road train routes where tourist vehicles with caravans are also common. Unlike with most other vehicles, drivers of cars towing caravans, and even many drivers of four wheel drives, want to pull off and stop well clear of passing road trains (provided the shoulders are in suitable condition - Figure 4.21). This is to avoid problems with the vehicle becoming unstable due to the wind effect of the passing road train.

Examples

Figure 4.22 and Figure 4.23 illustrate what can be done with existing carriageways.

Suitability of existing carriageway widths for Multi-Combination Vehicle (MCV) routes

Some existing carriageways with widths of 7.9m to 8.6m can be used by MCVs and anecdotal industry feedback supports this notion. However they are only suitable for MCVs in appropriate circumstances. In addition it is imperative that widening with full pavement be provided where necessary to allow for manoeuvre (e.g. where Extended Design Domain stopping is not available to a 0.2m high object).

Existing seals

Some existing carriageways only have a single lane seal or a narrow two-lane seal (i.e. seal width <6m), but these have proved to be problematic on road train routes as evidenced by Figure 4.24. In this example road trains using the route do not move off the sealed pavement. As a consequence there is excessive edge wear and edge drop off which is caused by vehicles having to frequently move off the seal to allow approaching road trains to pass, and then move back onto it. Providing a wider seal can alleviate this problem (Figure 4.25). However the batter slopes need to be flat when the retention of existing carriageways with widths in the order of 7.9m to 8.6m is contemplated (see below).

Road trains drivers operating vehicles on very low volume roads with narrow seals will tend to drive only on the sealed pavement and not move off the seal when other vehicles approach [Figure 4.26]. This is an operational necessity as moving one side of vehicle off the seal can cause the road train to become unstable. In wet conditions the problem is even worse and it can have disastrous consequences it the shoulder is slippery or is not able to take the wheel loads.

Existing lanes

Tests on a sealed, rough, straight road show MCVs, including Type 2 road trains, can track (i.e. stay) within lanes 3m wide (to 3.5m wide, refer to Figure 4.27 - Haldane, 2002). This is supported by observations in the field where there is a clear lack of edge wear where lanes 3.5m wide have been used (Figure 4.25 and Figure 4.28). However it is important to note that shoulders provide operating clearance for MCVs and so provision of some width of shoulder is always preferred.

Batter slopes

When the side slope of the batter is steeper than 1 on 4 designers need to assess the need for local widening, safety barriers and environmental problems, etc. This should include calculation of the costs and benefits of maintaining the status quo versus constructing various treatments (e.g. using the Roadside Impact Severity Calculator, refer to Chapter 8). Engineering judgement should then be applied in determining the final solution (which may be to maintain the status quo); the Cost/Benefit Ratios calculated should be considered when making this decision (refer to Chapter 8).

Suitable cross sections widths for MCVs

On low volume roads with full width seals, carriageways 7.9m to 8.6m wide (with flat batters) will result in acceptable two way operation on routes with a high proportion of both Type 2 road trains and cars towing caravans.

On National Network Road Links or routes with higher traffic volumes wider cross sections may be required (refer to Section 4.6 and Chapter 7).

Cross sections suitable for MCV operation on existing roads are given in Table 4.19. These details are based on long-term experience and are consistent with current investment strategies.

Table 4.19 Minimum carriageway and seal widths in rural areas for MCV routes

Forecast AADT	Existing alignments						New alignments (for comparison purposes only)	
	Absolute minimum widths (m)		Desirable minimum widths (m)					
			Limited tourist traffic		Prolonged periods with > 5% caravans			
	Seal width	Carriage-way width	Seal width	Carriage-way width (m)	Seal width	Carriage-way width (m)	Seal width	Carriage-way width (m)
<150	- [2]	8.0	6.0	8.0	8.0	8.0	6.0[3] 9.0	8.0 9.0
150 to 500	6.0	8.0	7.0[4]	8.0	8.0	8.0	9.0	9.0
>500 to 1000	6.5	8.0	8.0	8.0	8.0	8.5	9.0	9.0
>1000	-	-	-	-	9.0	9.0	9.0	10.0

Notes:

1. The available seal and carriageway width on horizontal curves (i.e. what curve widening has been provided) will determine the suitability of the route for a particular type or types of MCV.
2. A sealed pavement is not mandatory for this traffic volume. In practice, many existing roads will have a 3.7m wide (or greater) single lane seal. Some roads may have a 6.0m seal which may function as a single lane (see Note 3) or two-lanes if marked with a centre line.
3. The 6.0m seal is not marked and operates as a single 4m lane with partially sealed shoulders. An 8.0m seal provides acceptable two-lane operation.
4. Preferably 7.4m to reduce maintenance.
5. Carriageway widths <9.0m on two-lane roads must be accompanied by embankment and table drain slopes 1 on 4 or flatter together with clear areas to prevent “shying” towards the centre of the road. However, some short local exceptions (<200m long) are possible.
6. Carriageway widths <10.0m on roads with a single-lane seal must be accompanied by embankment and table drain slopes of 1 on 6 or flatter so smaller vehicles can move over to clear an oncoming MCV that stays on the seal. However, some short local sections are possible where visibility allows drivers of smaller vehicles to move over and stop prior to the restricted width section if there is an oncoming MCV.

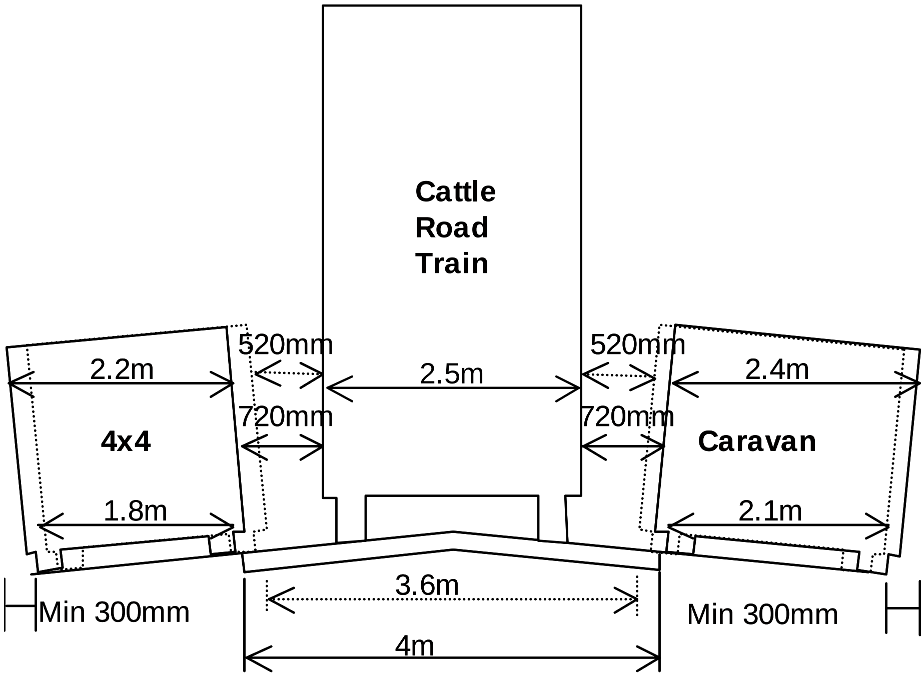

Figure 4.21 A heavy vehicle operating on route with a single lane seal with caravans (Potter, 2002)

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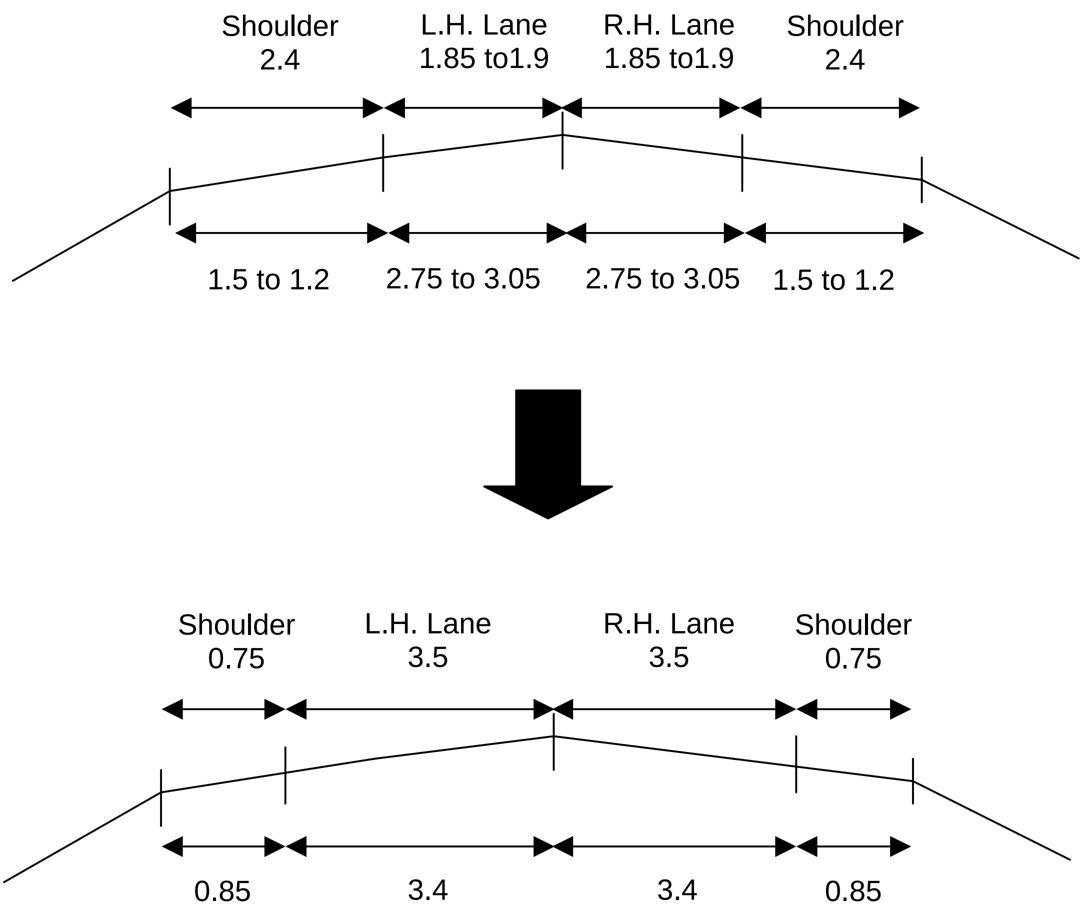

Figure 4.22 What can be done with existing 8.5m or 8.6m carriageway

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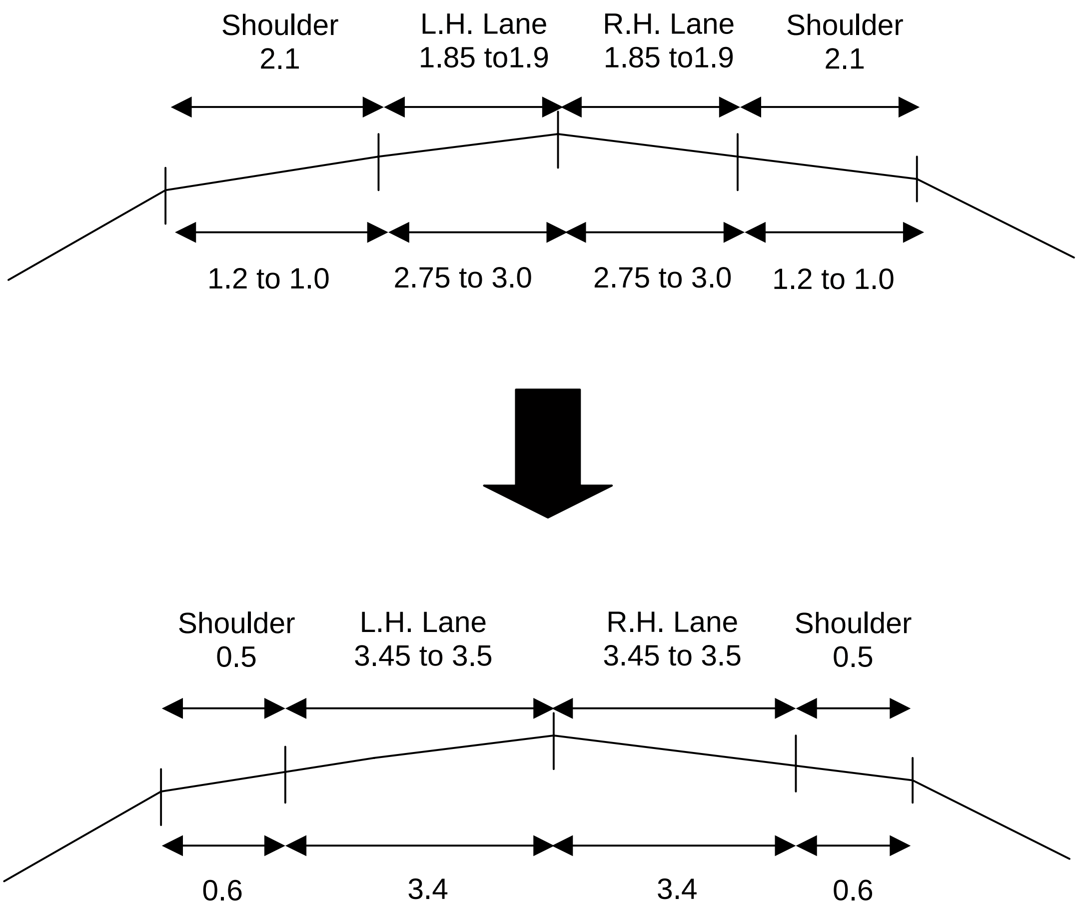

Figure 4.23 What can be done with existing 7.9m or 8m carriageway

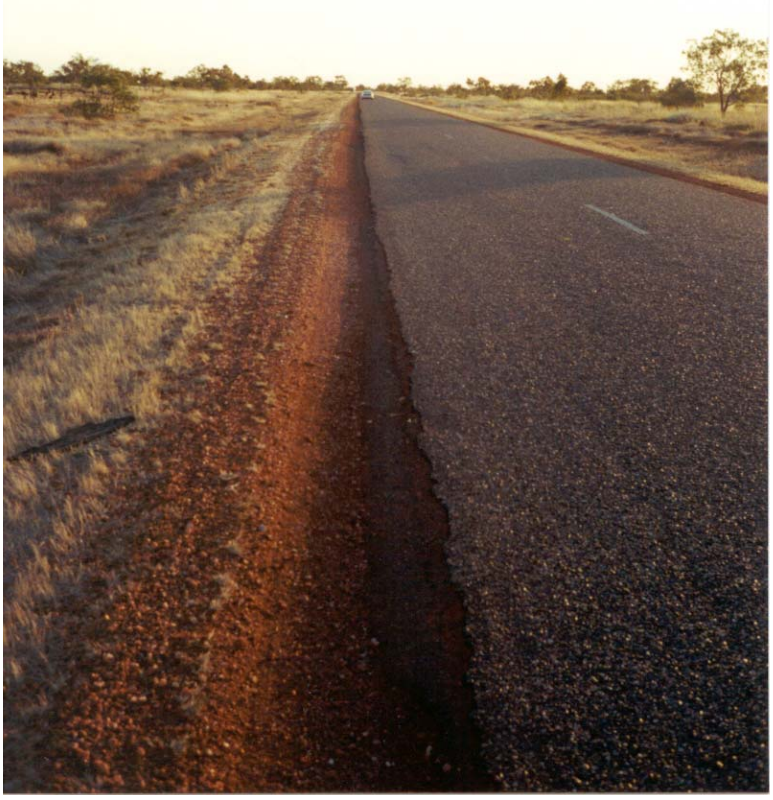

Figure 4.24 Example of inadequate single lane (5.6m) seal on a Type 2 road train route (AADT of 400 with 30% heavy vehicles)

Figure 4.25 Example of Type 2 road train operating on a 7.9m carriageway with full width seal on a low formation

Figure 4.26 Example of road train operation on a single lane seal - Type 2 road trains remain wholly on the seal - approaching vehicles must therefore move off the seal

Figure 4.27 Testing the tracking characteristics of a MCV on a rough surface and narrow formation with 3m to 3.5m lanes (Haldane, 2002)

Notes to Figure 4.28:

1. Note the lack of shoulder wear, edge wear and edge drop off.
2. Note how the low formation with flat batters obviates shying effects and provides flat run-out areas.

Figure 4.28 Example of two-lane, two-way road with narrow formation and seal on a Type 2 road train route (AADT of 550 with 15% MCVs and 15% other heavy vehicles)

Appendix 4E: Guide for the Extended Design Domain for Intersection Turn Treatments

This Appendix contains the current guide for short length left and right turn lanes for the Extended Design Domain.

Intent of this guide

The intent of this guide is to maximise the use of Channelised Right-turn (CHR) and Auxiliary Left-turn (AUL) treatments at existing intersections. The study titled 'Relationship Between Unsignalised Intersection Geometry and Accident Rates' (Arndt, 2004) has shown that these turn types are considerably safer than other types of turn treatments, namely BAR, AUR and BAL (refer to Chapter 13 for details). This is especially true for the right-turn treatments.

Use of this guide

This guide presents Extended Design Domain dimensions for CHR and AUL turn treatments that are smaller than the minimums used for the Normal Design Domain (i.e. those used for a new intersection). In general, these treatments are intended to replace lower order turn types (e.g. linemarking an existing AUR turn treatment to form a CHR turn treatment). The Extended Design Domain dimensions have been found to operate effectively in practice, providing a higher level of safety than any of the lower order treatments.

The treatments shown in this guide are predominantly for application to existing intersections, where sufficient area of pavement exists for them to be incorporated. Sometimes, they may be applied to existing intersections for new construction, where insufficient length is available to introduce a turn-slot with dimensions as per the Normal Design Domain.

The following three turn treatments are provided in this guide.

Minimum Extended Design Domain Channelised Right-turn Treatment for Roadways without Medians

Figure 4.29 shows a minimum Extended Design Domain CHannelised Right-turn treatment for roadways without medians.

The primary intent of this treatment is to enable an AUR turn treatment to be linemarked as a CHR turn treatment. This is only possible if full depth pavement exists under the original auxiliary lane and, if required, the shoulder. In this treatment, the through road deviates by the width of the turn lane. The dimensions of the lateral movement length "A" are deemed suitable for horizontal straights and larger radius horizontal curves. On smaller curves, "A" will need to be increased above the lengths given in Figure 4.29 so that the resulting alignment of the through lane means that no decrease in speed is required as drivers, who are continuing through, negotiate the curve and intersection layout.

Minimum Extended Design Domain Channelised Right-turn Treatment for Roadways with Medians

Figure 4.30 shows a minimum Extended Design Domain Cannelised Right-turn treatment for roadways with medians.

This treatment can be used at intersections on existing roads where sufficient area of pavement already exists to introduce a right-turn slot. Alternatively, the treatment may be applied as new construction where insufficient length is available to introduce

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a right-turn slot with dimensions as per the Normal Design Domain.

Minimum Extended Design Domain Auxiliary Left-turn Treatment

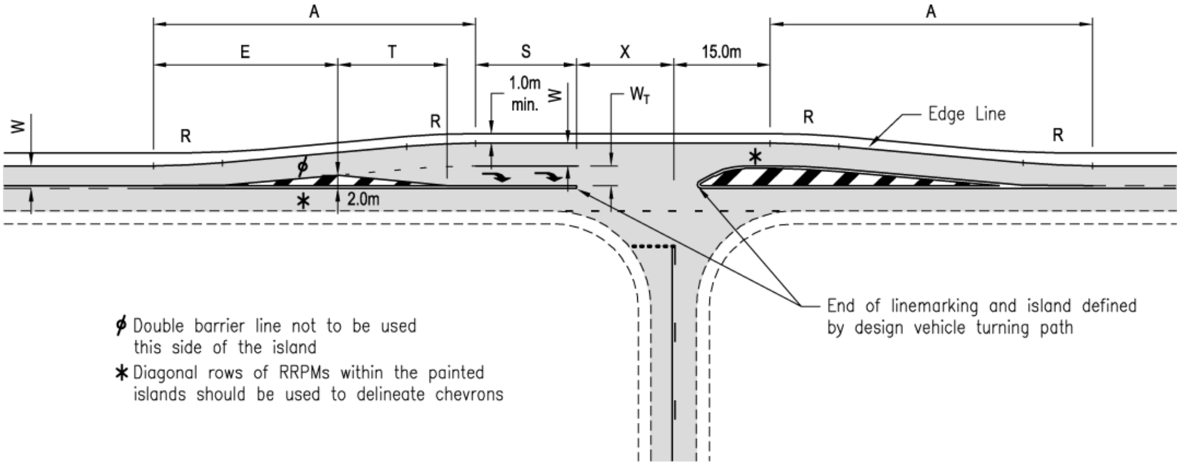
Figure 4.31 shows a minimum Extended Design Domain Auxiliary Left-turn treatment.

This treatment can be used at intersections on existing roads where sufficient area of pavement already exists to introduce a left-turn slot. Alternatively, the treatment may be applied as new construction where insufficient length is available to introduce a left-turn slot with dimensions as per the Normal Design Domain.

General considerations

The use of the Extended Design Domain turn treatments can only be justified provided they meet the following conditions:

1. They are not combined with other minima (e.g. tight horizontal curves, limited visibility, steep downgrades);
2. Future arrangements/planning must be satisfied (e.g. allow for future traffic growth, which may well affect storage lengths);
3. Geometric features and other features of the road do not distract drivers; and
4. Accident data indicates that there is not a high crash rate related to the use of the shorter dimensions eg not a high rear-end crash rate at the start of the turn slots.



Design speed of approach road (km/h)	[1]Minimum lateral movement length, "A" (m)	Desirable radius, "R" (m)	[2]Taper length, "T" (m)
60	[3]40	175	10
70	[3]50	240	15
80	[3]55	280	15
90	60	350	15
100	70	425	20
110	75	500	20
120	80	600	20

1. Based on a diverge rate of 1.25m/s and a turn lane width of 3.0m. Increase lateral movement length if turn lane width >3m. If the through road is on a tight horizontal curve, increase lateral movement length so that a minimal decrease in speed is required for the through movement.
2. Based on a turn lane width of 3.0m.
3. Where Type 2 road trains are required, A≥60m.

W = Nominal through lane width (m), including widening for curves.

W_T = Nominal width of turn lane (m), including widening for curves based on the design turning vehicle); $W_T \geq 2.8$m.

E = Distance from start of taper to 2.0m width (m); $E = 2.0 \times \left(\frac{A}{W_T}\right)$

S = Storage length (m), greater of:

1. The length of one design turning vehicle; or
2. (Calculated number of car spaces – 1) x 8m (refer to Appendix 13A or use a computer program, e.g. aaSIDRA).

T = Taper length (m); $T = \frac{0.2 \times V \times W_T}{3.6}$

V = Through operating speed (km/h).

X = Distance based on design vehicle turning path, typically 10m to 15m.

Note: Diagram shown for a rural intersection layout. The dimensions shown are also suitable for an urban intersection layout, except that the shoulder width criterion does not apply.

Figure 4.29 Minimum Extended Design Domain channelised right-turn treatment for roadways without medians

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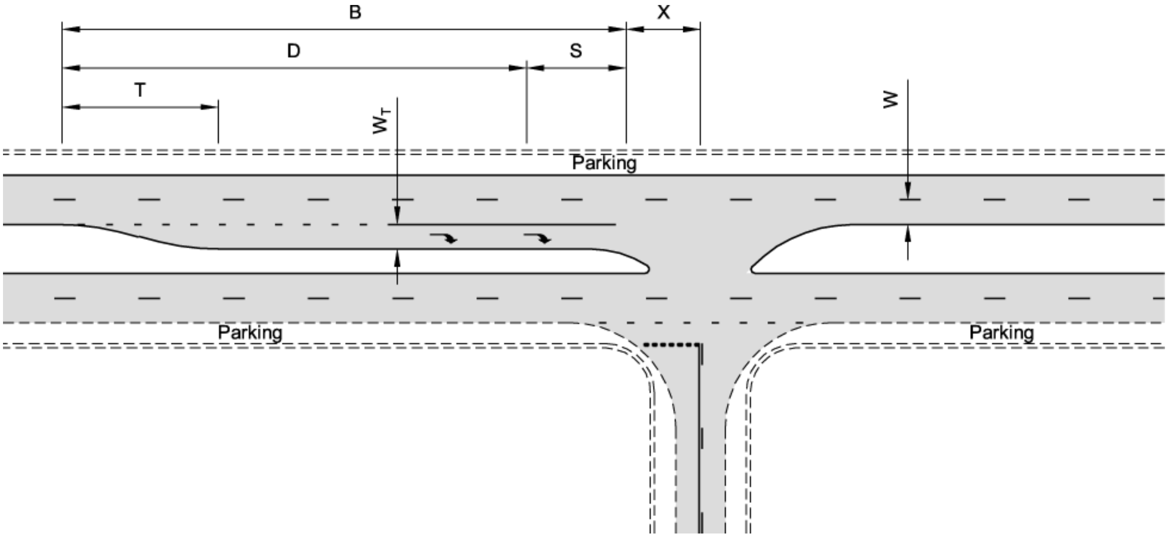

Design speed of approach road (km/h)	[1]Minimum diverge/deceleration length, "D" (m)	[2]Taper length, "T" (m)
50	15	10
60	20	10
70	25	15
80	35	15
90	45	15
100	55	20
110	65	20
120	80	20

1. Based on a 30% reduction in through road speed at the start of the taper to a stopped condition using a value of deceleration of $3.5 m/s^2$. Adjust for grade.
2. Based on a turn lane width of 3.0m

W = Nominal through lane width (m), including widening for curves.

W_T = Nominal width of turn lane (m), including widening for curves based on the design turning vehicle); $W_T \geq 2.8$m.

B = Total length of auxiliary lane (m), including taper, diverge/deceleration and storage.

S = Storage length (m), greater of:

1. The length of one design turning vehicle; or
2. (Calculated number of car spaces – 1) x 8m (refer to Appendix 13A or use a computer program, e.g. aaSIDRA).

T = Taper length (m); $T = \dfrac{0.2 \times V \times W_T}{3.6}$

V = Through operating speed (km/h).

X = Distance based on design vehicle turning path, typically 10m to 15m.

Note: Diagram shown for a rural intersection layout. The dimensions shown are also suitable for an urban intersection layout.

Figure 4.30 Minimum Extended Design Domain channelised right-turn treatment for roadways with medians

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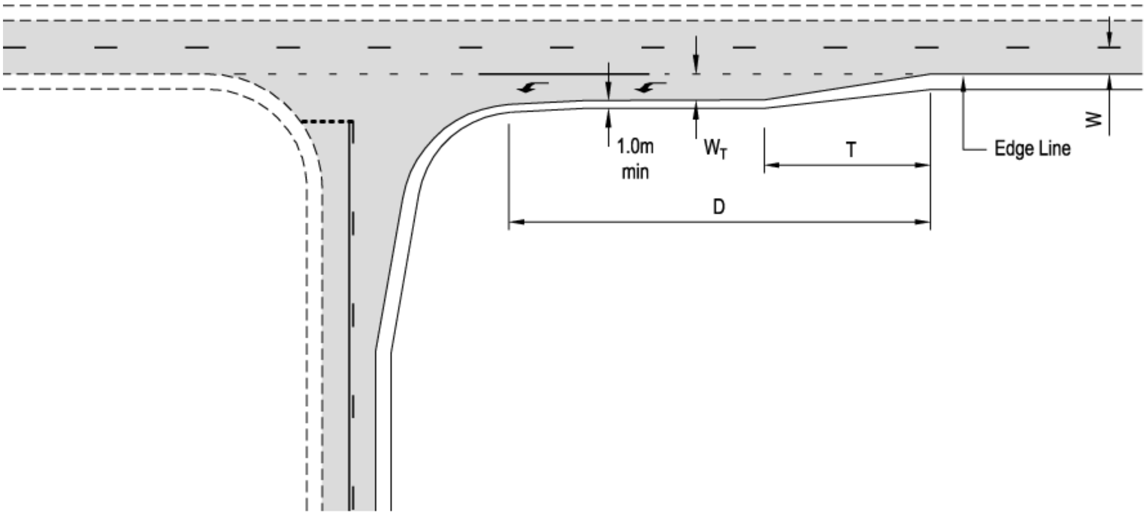

Design speed of approach road (km/h)	[1]Minimum diverge/deceleration length, "D" (m)	[2]Taper length, "T" (m)
50	15	10
60	20	10
70	25	15
80	35	15
90	45	15
100	55	20
110	65	20
120	80	20

1. Based on a 30% reduction in through road speed at the start of the taper to a stopped condition using a value of deceleration of $3.5 m/s^2$. Adjust for grade.
2. Based on a turn lane width of 3.0m

W = Nominal through lane width (m), including widening for curves.

W_T = Nominal width of turn lane (m), including widening for curves based on the design turning vehicle); $W_T \geq 2.8$m.

T = Taper length (m); $T = \frac{0.2 \times V \times W_T}{3.6}$

V = Through operating speed (km/h).

Note: Diagram shown for a rural intersection layout. The dimensions shown are also suitable for an urban intersection layout, except that the shoulder width criterion does not apply.

Figure 4.31 Minimum Extended Design Domain auxiliary left-turn treatment

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Appendix 4F: Guide for the Extended Design Domain for horizontal curves with adverse superelevation

This Appendix contains guidance on application of the Extended Design Domain concept to horizontal curves with adverse superelevation.

The practice of limiting the side friction demand on adverse horizontal curves to half the relevant absolute maximum of side friction factor given in Chapter 11 is considered to be "good working practice" rather than a reflection what side friction drivers use in practice. Limiting the side friction demand on a curve in this way means that it is less likely the curve will be overdriven. However when negotiating a curve, drivers can, and often do, use a side friction factor up to the design maximum for their speed of travel irrespective of the superelevation. Consequently there is scope to use the Extended Design Concept for some horizontal curves with adverse superelevation.

The Extended Design Domain for horizontal curves with adverse superelevation must comply with all of the following conditions:

- It is only applicable to a restoration or widening project on an existing road in an urban area.
- It is only applicable to geometric elements where the operating speed (85th percentile speed) is less than or equal to 80km/h. Note that this would preclude it from being used on most roads with a speed limit of 80km/h or higher.
- Side friction demand on the geometric element concerned does not exceed the absolute maximum value of side friction for cars (refer to Chapter 11) at the operating speed of cars (refer to Chapter 6).
- Its use must support truck operating speeds. That is, the side friction demand on the geometric element concerned is not excessive for trucks (refer to Chapter 11) at the operating speed of trucks (refer to Chapter 6). Note also that the static roll threshold for trucks is 0.35 and that this is numerically equivalent to the co-efficient of side friction. This means the side friction demand must not exceed 0.35 for trucks when tested at, say, the truck operating speed plus 10km/h, and preferably should not exceed the absolute maximum side friction value for trucks given in Chapter 11.
- The road surface must be capable of providing a high degree of skid resistance.
- The adverse superelevation must not exceed 3% and preferably not exceed 2.5%.
- It use must be supported by crash data at the site and possibly other similar sites. This review would have to show an absence of crashes related to the presence of adverse superelevation, particularly single vehicle crashes.
- It should not be used in conjunction with other minima (e.g. with a vertical curve that provides for Extended Design Domain stopping) or undesirable geometric features (e.g. compound curves).

It should be noted the presence or use of adverse superelevation can be problematic for some road users who are unfamiliar with the road (e.g. motorcyclists, refer to Chapter 5 and the Guide to Traffic Engineering Practice Part 15, Motorcycle Safety - Austroads, 1999).