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Chapter 5
Traffic Parameters and Human Factors

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Chapter 5 Amendments - August 2004

Revision Register

Issue/ Rev.No	Reference Section	Description of Revision	Authorised By	Date
1		First Issue	Steering Committee	Nov 2000
2	5.2.4	Figure 5.5 - two notes added to define terms	Steering Committee	Aug 2001
	5.4.4	• Additional dot point re older pedestrians • 5th paragraph modified • Table 5.8 (was 5.7) Note 2 modiffied • New paragraph added re pedestrian waiting time		
	5.5.1	Extra sentence added to 2nd paragraph		
	5.5.2	Comment re cycle tourers added		
	5.5.3	Extra reference given		
	5.5.4	• Table 5.10 (was 5.8) extra note added • Correction to paragraph on pavement markings & signs		
	5.5.6	• Table 5.12 (was 5.10) replaced with Table 5.12(a) • New Table 5.12(b) added • Additional comments		
	5.6	Term “Impaired road users” replaced with “road users with a disability”		
	5.6.3	• Correction to 4th dot point • Comment re conflict between different users included		
	New	Relationship to other Chapters.		
3	5.1.4	Additional dot points	Steering Committee	May 2002
	5.5.4	“Seperate Bicycle Paths” additional paragraph		
	5.5.5	“Handrails” - additional paragraph and diagram		
4	All	Minor additions/deletions of text and grammar corrections throughout. Chapter reformatted - some figures and tables renumbered.	Steering Committee	Aug 2004
	-	List of Tables added.		
	-	List of Figures added.		
	5.1.2	Amendments to text and paragraph added at end of section.		
	Table 5.1	Caption amended		
	5.1.4	Dot points amended, new text and dot points added.		
	5.2.1.4	Paragraph added.		
	5.2.2	Dot point added.		

cont. Chapter 5 Amendments - August 2004 Revision Register

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4	5.2.4	Captions for photos added.	Steering Committee	Sept 2004
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	5.3.1	Text added/deleted.		
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	5.3.6.2	New section added – "Designing for the Older Driver"		
	5.4.1	Text added/deleted. Part of previous Section 5.6 "Road user with a disability" moved to this section.		
	5.4.2.2	Part of previous Section 5.6 "Road user with a disability" moved to new Section 5.4.2.2.		
	5.4.4	Previous Section 5.4.4 "Planning and Design Implications" replaced by new Sections 5.4.4 "Planning Implications" and 5.4.5 "Design Implications". Includes part of previous Section 5.6 "Road user with a disability".		
	5.4.5	New Section added – "Design Implications". Includes part of previous Section 5.6 "Road user with a disability".		
	5.5.1	Text added/deleted.		
	5.5.1	Text added/deleted at end of section.		
	5.5.4.7	Text added.		
	5.5.5	Text added/deleted.		
	5.5.5.1	Text added/deleted.		
	5.5.5.3	Test added.		
	5.6	Previous Section 5.8 "Motorcycles" moved to Section 5.6. Previous Section 5.6 "Road user with a disability" moved to new Section 5.4.2.2.		
	5.6.4.2	Paragraph added.		
	5.7.2	New section – "Check Vehicle"		
	5.7.6	New section – "Higher Order Vehicles"		
	5.8 (old)	Previous Section 5.8 "Motorcycles" moved to Section 5.6.		
	Appendix 5B	New Appendix added – "Guideline for Motorway Cycling"		

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Chapter 5
Road Planning and Design Fundamental

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5.1 Introduction

5.1.1 General

Traffic parameters and an understanding of the human factors involved are essential prerequisites for the proper planning and design of road facilities. Traffic parameters can be expressed in many forms, all of which have their place in various aspects of planning and design. It is also necessary for planners and designers to have an appreciation of the effect of the human factors on the parameters involved. The way data is collected, and the limitations of that data, influence the way in which it is most appropriately used.

This Chapter sets out the range of traffic parameters required for planning and design and includes a discussion of traffic in general, traffic characteristics, driver, characteristics, pedestrians, bicycles, motorcycles and design vehicles. The special needs of road users with a disability are also discussed. Data for design and planning is provided with commentary on how and where to use it. More detail can be obtained from the references at the end of the chapter.

5.1.2 The Traffic Stream

The traffic stream is a complex system comprised of three interacting components:

- the driver;
- the vehicle; and
- the environment.

Traffic flow consists of the movement of individual units each under the control of a driver, generally operating independently, but interaction can occur. The behaviour of these units exhibits randomness brought about by the multitude of individual decisions made by each of the drivers of the units.

The three components of the stream interact with each other and as a consequence, the characteristics of the stream are different from those of the individual elements. Knowledge of the traffic stream behaviour provides the means of understanding situations involving manoeuvres such as queuing, car following, turning, crossing, merging and weaving. Together with travel speeds, traffic volumes and traffic density, these parameters provide the major determinants of traffic capacity in any given situation.

Understanding these factors and traffic behaviour provides the basis of quantifying warrants for traffic control systems and for the types of treatment required to cope with the various traffic situations that arise.

A traffic stream is defined as a flow of traffic in a particular direction on a carriageway (Austroads, 1988a). Traffic streams vary according to the lane or lanes occupied by the flow and the type of traffic in the stream (e.g. heavy vehicles, pedestrians, bicycles). The speed, overtaking opportunities, formation of bunches (or platoons), density of traffic and efficiency of flow are all affected by the number and configuration of lanes, and the mix and distribution of vehicles in the stream. Understanding the interaction of all of these factors is important in estimating the capacity of a given road and the quality of service provided under various conditions.

Traffic stream performance and therefore capacity is affected by physical conditions such as:

- carriageway width;
- width, number and separation of lanes;
- vertical and horizontal alignment;
- type and condition of the road surface;
- gradient;
- sight distance;
- frequency and form of intersections;
- road furniture; and
- terrain and attractiveness of route.

Other factors affecting performance include:

- the presence of parking, bus stops, tram tracks and the abutting land uses (since these affect lane formation, lane discipline and vehicle distribution);
- the configuration/presence of signs, traffic signals, pavement markings and traffic regulations;
- the presence of cyclists, pedestrians and other road users;
- the configuration/presence of street lighting; and
- weather and other environmental conditions.

Understanding and quantifying the traffic parameters is therefore an essential part of the road planning and design process. Traffic information indicates whether improvements need to be undertaken, provides a measure of the performance of the road and directly affects decisions on the geometric features of design. As an analogy, traffic information serves to establish the loads for geometric road design.

Traffic data can be obtained for a section of road by direct count and from the traffic census data collected by Main Roads' District Offices. Traffic data available from the traffic census usually contains limited detail; it may not contain cycle and pedestrian data.

Traffic data collected from direct counting includes traffic volumes by time of day, day of week and time of year. It also has data on the type of vehicles and their distribution (Figure 5.1), particularly of heavy vehicles. Trends in traffic growth are also available. Details of these parameters are discussed in following sections.

Some traffic data from traffic signals installations may also be obtained through Main Roads or local authority traffic control centres.

5.1.3 Types of Traffic Facilities

Traffic Design, as part of the planning and design process in Main Roads, is required to cover a broad range of facilities in both urban and rural environments. Such facilities include, but are not limited to, streets highways, transit facilities, pedestrian facilities and bicycle facilities. For this reason, and for the purpose of technical and design analysis, these facilities may generally be classified into one of the two following categories:

- *Uninterrupted Flow* – has no fixed elements external to the traffic stream that cause interruptions to traffic flow, such as traffic signals. The traffic flow conditions are the result of interactions among vehicles in the traffic stream and the geometric and environmental characteristics of the facility.
- *Interrupted Flow* - Has fixed elements external to the traffic stream that cause periodic interruptions to traffic flow irrespective of how much traffic exists. Such elements include traffic signals, stop signs, and other types of controls.

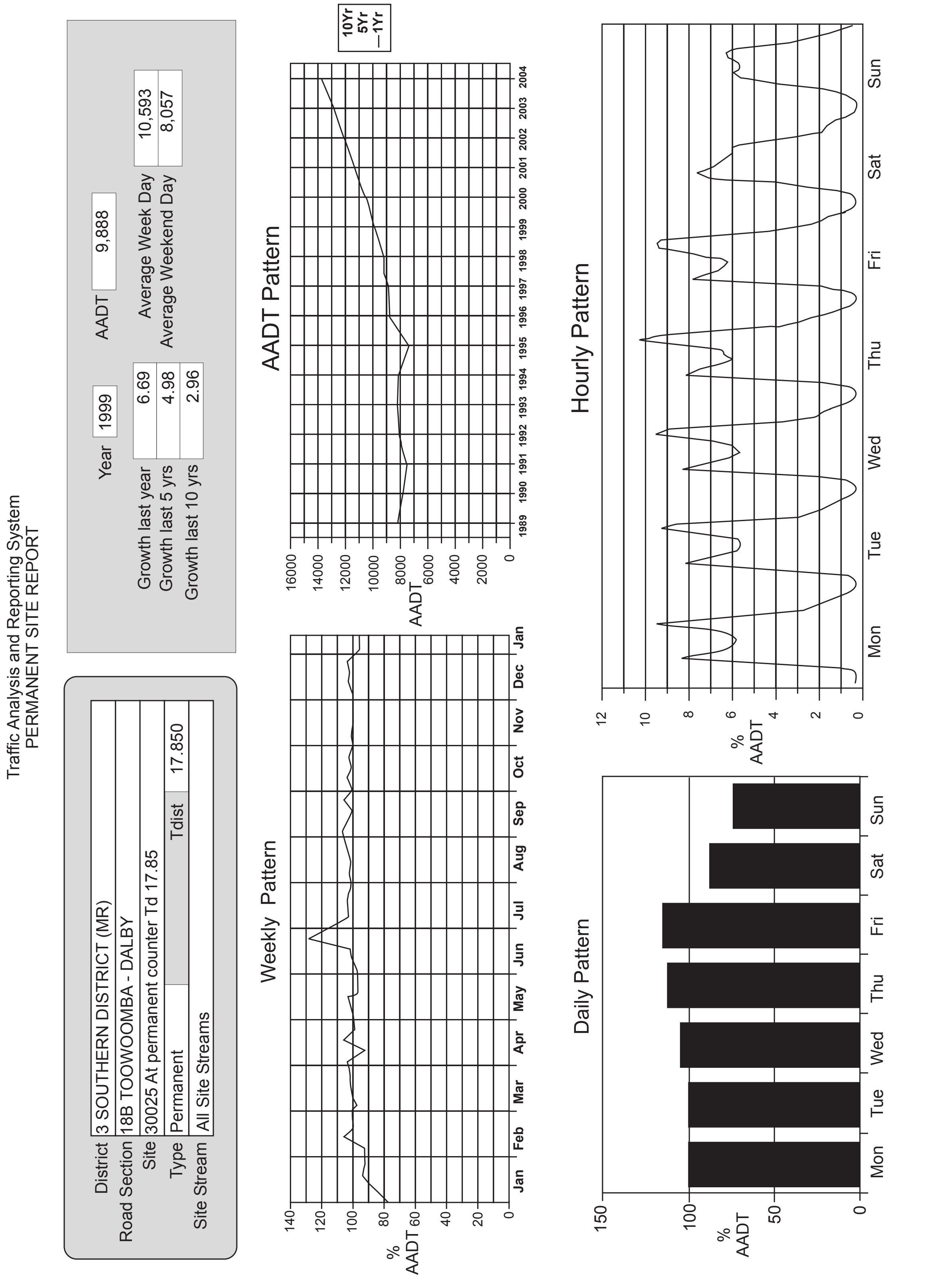

Figure 5.1 Typical Permanent Traffic Counting Report.

Figure 5.1 Typical Traffic Counting Station Report

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Table 5.1 lists the types of facilities generally classified under the two terms namely, uninterrupted and interrupted flow.

Table 5.1 Typical uninterrupted flow and interrupted flow facilities.

Category	Facility
Uninterrupted Flow	Freeway sections Weaving areas Ramps and ramp junctions Multi-lane highways Two-lane highway
Interrupted Flow	Signalised intersections Unsignalised intersections (including STOP, GIVE-WAY) Arterials, Transit Lanes Footpaths, Bikeways* Toll Booths
* These facilities are generally considered to be interrupted flow. However, uninterrupted flow may occur in certain circumstances (e.g. transit bus lanes, rural arterial roads).	

It should be noted that the terms, uninterrupted and interrupted flow describe the type of facility, not the quality of traffic flow at any given time. Appropriate traffic measures used to determine the quality of traffic flow at any given time are discussed in Sections 5.2.2 and 5.2.4.

5.1.4 Road User Characteristics

The term "road user" includes the driver of a car, the driver of a truck, a motorcyclist, a pedestrian and a cyclist. In their travels road users receive information from the surrounding operating traffic environment, analyse the situation, make decisions based on the information received and take action accordingly.

As the skills and ability of the individual road user can vary widely, the behaviour of the road user in performing these actions will also vary significantly.

Human factors that affect the behaviour of the road user include:

- Vision, including colour deficiency;
- Reaction time;
- Driver eye height;
- Familiarity with vehicle being operated;
- Bicycle space requirements;
- Walking speed;
- Pedestrian body dimensions (i.e. body ellipse 0.21m²);
- Psychological traits; and
- Medical factors.

Where high populations of special road user groups (e.g. at a retirement village, at a school, at a hospital, etc.) are represented within the traffic study area, more detailed consideration should be given to the specific needs of that type of road user in the road design process.

Vehicle factors also affect the behaviour of the road user, and include:

- Vehicle performance (e.g. acceleration, deceleration, manoeuvrability, power to weight ratio);
- Vehicle size;
- Vehicle configuration;
- Trailers including number and size; and
- Load.

The combined effect of human and vehicle factors will result in significantly different driving techniques by the same driver in different vehicles.

The specific needs for the individual types of road user are further described and considered in the following sections of this Chapter.

5.2 Traffic Characteristics

5.2.1 Volume

5.2.1.1 Traffic Volume Patterns

The traffic volume on a specific road section can vary significantly between hours, (e.g. peak versus non peak), days (e.g. weekdays versus weekends) and seasons (e.g. tourist versus non-tourist, school holidays). Patterns of traffic demand are important, particularly in Queensland, where there is a large tourist demand especially in urban coastal areas.

The extent of the variation depends on such factors as the road function, the traffic conditions and environment. Underwood (1995) provides typical hourly, daily and seasonal traffic volume patterns for Australian conditions.

Localised information on seasonal variations and periods within a specific traffic system should be used in the design of road network elements. It should be obtained by collection of appropriate traffic data. This information can also be obtained by local knowledge where no traffic studies, statistics or comparative counts are available.

5.2.1.2 Average Daily Traffic and Annual Average Daily Traffic

The Average Daily Traffic (ADT) is the total number of vehicles in a time period (more than one day and less than a year) divided by the number of days in the period. It is a figure that may be used for a specific time period for purposes relating to that time period.

The Annual Average Daily Traffic (AADT) is the total volume of traffic for the whole year divided by the number of days in the year.

These parameters can be readily established when continuous counts are available. When only periodic counts are undertaken, the ADT and AADT can be estimated by applying relevant factors to account for season, month and day of week.

ADT and AADT are used in:

- assessing annual usage;
- undertaking strategic link analysis;
- justifying expenditure of funds on projects; and
- designing structural elements of the road (e.g. pavement).

They are of limited use in designing the geometric elements of the roadway since they do not provide the necessary information on the variation of the traffic at different times of the day, the week and the year. The volume of traffic on a day can exceed the AADT by a considerable amount so to design on the AADT alone can be misleading. A road designed on the basis of the average volume will have to carry much larger volumes for a considerable portion of the year. Figure 5.1 illustrates the variation in volumes that can occur. For low volume roads, the AADT provides a guide for some of the geometric elements and the variation in the daily flows will be sufficiently low to avoid over-taxing the road from a capacity point of view. For higher volume roads, the AADT is an inappropriate parameter to use for geometric elements.

5.2.1.3 Design Hour Traffic

Hourly volumes provide a much better measure of the operating conditions to be met by the design of the road. All roads exhibit a propensity to have brief periods of intense activity repeated regularly. This is particularly obvious in urban conditions but it is also the case that rural roads have significant variation in hourly volumes throughout the year.

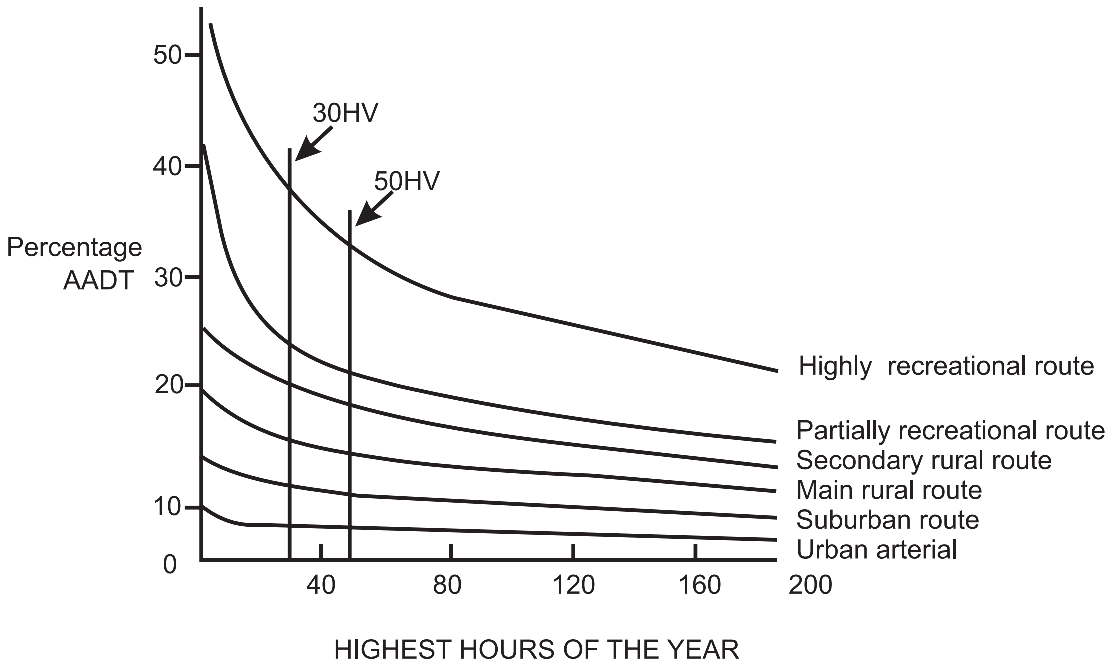

Figure 5.2 Typical Relationship between Hourly Volumes and AADT (Austroads, 1988)

For design purposes, it would be unreasonable to have to cater for the maximum hourly volume since the facility provided would be under used (i.e. over capacity) for most of the time. A balance between the inadequacy of the average traffic volume and the wastefulness of the maximum volume must be struck.

Figure 5.2 shows a typical relationship between the hourly volume and the typical percentage of the AADT it represents. The design hour should be one that is “not exceeded very often or by much” (AASHTO, 1994). Nor should the design hour be so high that there is a large number of hours with traffic volumes very much less than that hour. Typically, such an hour is the 30th highest hour. This figure is typically one where a large increase in expenditure is required to provide for not many more hours, and there are a large number of hours where the volume is not much less. Ideally, design flows should be selected by maximising the benefit-cost ratio of the project including the cost of the occasional traffic failure implied by using a design figure less than the maximum volume.

Whether this point is the 30th highest hour or some other figure has to be determined from actual traffic data (refer to Austroads 1988c). The appropriate figure may vary from the 10th to the 100th highest hour depending on the pattern of traffic. However, the 30th highest hour is a good approximation of the required design hour for most roads.

In urban areas, the peak hour is a regular phenomenon that occurs each morning and afternoon and varies in actual volume depending on the time of year and other circumstances. There will be little difference between the 30th highest hour and the 200th highest hour so the 30th highest hour represents a reasonable approximation of the conditions to cater for in design. The 100th highest hour has been adopted for design on National Highways.

Care is required where concentrated recreational travel or other special circumstances occur and special analysis of these cases is required; specialist advice may be required.

Typical values for the 30th Highest Hour (30th HH) as a percentage of the AADT are shown in Table 5.2.

Table 5.2 Typical Values of 30th HH as % AADT (Austroads 1994b).

Type of Road	30th HH (%AADT)
Recreational Roads	25
Rural Arterials	15
Outer Urban Arterials	12
Inner Urban Arterials	10

As a guide, the 80th highest hour is about 85% of the 30th highest hour.

In the absence of other information, the design hour can be estimated from the AADT using the factor from Table 5.2. However, better information will be obtained from studies of the road in question and from continuous traffic counting information, which is available for many roads

The design hour must be assessed for the design year – refer Section 5.2.1.6

5.2.1.4 Distribution – transverse, longitudinal, regional

Traffic may be distributed transversely, longitudinally and/or across regions.

Transverse

The transverse distribution of vehicles on a road has three components:

- position of the vehicles within lanes;
- distribution of the vehicles across the lanes of a multi-lane carriageway; and
- directional distribution of the vehicles (i.e. the split of traffic in the opposing directions, usually expressed as a percentage of the two-way volume).

Within a single lane, drivers will position the vehicle in some optimum position. Usually this will be the centre of the lane in the absence of lateral obstructions in which case, the driver will move away from the obstruction. (Note: On straights motorcycles usually travel in a wheel path.) The offset of the fixed obstruction or hazard from the edge of the lane where the movement occurs is known as the "shy" line. Details of shy line distances are detailed in Chapter 7 of this manual.

Where two lanes or more are available in each direction, traffic will apportion itself between the lanes in an uneven way. The distribution of the traffic between the lanes will depend on the traffic volumes, geometry (e.g. long climbs) proportion of heavy vehicles, frequency and form of intersections, median and kerbside factors. When flows are low, about 80% of vehicles will travel in the left-hand lane of a two-lane one-way carriageway. As volumes increase, the proportion of traffic in each lane increases to about 50% at 50% capacity of the carriageway. Above that volume, traffic flow in the right-hand lane is greater than that in the left-hand lane (Austroads, 1988a). More detailed discussion and application of these factors in capacity calculations can be found in the Highway Capacity Manual (TRB, 2000).

(Note: Volume split is not the only consideration; the split may differ for different vehicles. For example, while 60% of the flow may be in the left lane, 80% of heavy vehicles may travel in the left hand lane. This may affect design (e.g. pavement design). Therefore the characteristics of the traffic stream in each lane may differ).

On two-lane two-way rural roads, the Design Hourly Volume (DHV) is usually the total volume for both directions. For roads with more than two lanes or where a two-lane road is to be widened at a later date, the volume in each direction must be known. In peak hours on multi-lane roads, the volume in the peak direction can vary from 55 to 70 percent of the total flow depending on the origins and destinations of the traffic. The directional split may be greater on a highly recreational route. The design must therefore consider the proportion of traffic in one direction to ensure a proper design of the components.

Longitudinal

The longitudinal distribution of vehicles refers to the relative position of the vehicles along the road. In a one-way traffic stream, this distance is determined by the "gaps" between the vehicles and the physical length of the vehicles. The time gap is referred to as "headway" while the equivalent distance gap is referred to as "spacing".

The sequence of headways under uninterrupted flow conditions is best described using statistical distributions. These may be in terms of the headways between individual vehicles or between bunches (or platoons) of vehicles. The mean headway h is equal to the reciprocal of the volume q:

$$h = 1 / q$$

The sequence of spacings can also be described by statistical distributions, and the mean vehicle spacings is the reciprocal of the density k of the traffic stream:

$$s = 1 / k$$

These two parameters can be used to describe the longitudinal distribution of vehicles in the traffic stream.

An individual road user will select a gap of a suitable size to perform a safe manoeuvre in traffic. This is known as "Gap Acceptance" and is a parameter used frequently in intersection analysis (refer to Chapters 13 and 14 of this manual).

For some situations, it is more convenient to describe the traffic in terms of bunches or platoons (refer to Chapter 15 of this manual). The bunch may be formed because of limited overtaking opportunities on rural roads. In urban areas, bunches may be caused by the release from traffic signals and platoon management is an important element of traffic management in these areas.

Regional

Since the road system forms a network with more than one path between an origin and a destination, traffic will distribute itself between the elements of the network according the perceived advantages of one route over another. This distribution can be estimated in studies by using algorithms based on the travel times between nodes of the network. Various network analysis tools can be used to assist in assessing this distribution. (Refer to Austroads, 1988a and Lay, 1998 for further discussion.)

It is important to consider the implications of the use of the network in developing improvement programs. It may be possible to effect an improvement on one link to overcome a problem on another link by attracting traffic to the improved link. This type of strategy can lead to efficiencies in the use of scarce resources and optimise the use of the road network.

5.2.1.5 Traffic Composition

With society's increasing emphasis on environmental, physical and financial constraints, traffic planning and demand management in the urban transport network are focusing on improved facility planning and design for all road users. This focus is encouraging greater proportions of pedestrians, cyclists and higher occupancy vehicle modes of transport in the road corridor. Analysis of traffic composition highlights the various modes of travel present in a road system and provides the proportions of various types of vehicles in a traffic stream.

The different vehicles in the traffic stream have different operating characteristics and these differences can have a significant effect on design parameters. Heavy vehicles are larger, generally slower and have lower acceleration ability than cars. They therefore occupy more space than cars and operate more slowly on grades thus having a significant effect on the traffic stream. For analysis purposes, the trucks are treated as a number of equivalent passenger cars, the actual number depending on the size of the truck, the gradient and the overtaking sight distance available.

The vehicles in the stream can be divided into groups as follows:

- Passenger cars – all passenger cars and light delivery trucks;
- Trucks – all buses, single unit trucks and combination vehicles (combination vehicles should also be subdivided into semi-trailers, B-Doubles, Road Trains and other Multi Combination Vehicles (MCV) as appropriate);
- Motorcycles; and
- Bicycles.

Cars towing caravans often have the characteristics of trucks in their effect on the traffic stream. Where there is a significant proportion of these vehicles in the traffic stream, analyses should take account of their presence by assigning equivalence to passenger vehicles similar to single unit trucks. This will be very important on roads where steeper grades predominate.

Motorcycles will rarely have an adverse effect on the operation of the traffic stream. Their performance exceeds that of the other vehicles and will not therefore adversely affect the capacity of the road. However, the design of some of the components of the road should take account of the needs of motorcycles (e.g. alignment, surface characteristics, crash barrier design - refer to Section 5.6).

Bicycles are an increasingly important element of the traffic stream particularly in urban areas and their presence will have an effect on the capacity of a section of road, particularly if significant numbers are present. Road improvements (cross section and grade) will make the road more attractive to bicycle riders and this may increase their numbers. In addition, the safety implications of their presence must be accommodated (refer to Section 5.5).

For the design of a particular road, data on the composition of the traffic stream is essential. On more heavily trafficked roads, the data should define the distribution of trucks throughout the day since it is likely that they will avoid the peak periods.

In urban areas, the percentage of trucks must be ascertained for the design hour and not taken from the overall daily figures. The percentage of trucks in the design hour will usually be significantly less than the daily average and the design will be too conservative (and costly) if this distinction is not made.

5.2.1.6 Projection of future traffic

For most design purposes, an estimate of the traffic in the design year is required. The nominated design year is used to define the design life of a traffic system. Design parameters are based on traffic forecasts for the design year, which are often standardised for design and analysis.

The design year to be adopted depends on the elements of design being considered and on the type of facility. In general, designs are based on traffic volumes 20 years after the date of opening the facility.

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This planning horizon should be adopted for sizing the various elements of the design but operational decisions (e.g. traffic signal timing) must be based on a shorter time frame. Some pavement designs are based on longer time frames, particularly for heavy-duty pavements. Irrespective of the design year, where practical and economical to do so, designs should allow for future expansion of the facility.

Where a different design year is to be adopted for particular elements, the requirement is discussed in the relevant part of this Manual.

Projection of the current volumes to the design year based on known growth rates and future land development expectations is a common approach. This approach will be adequate on many rural roads of relatively low volumes where the design is relatively insensitive to the total volume of traffic.

On higher volume roads and where development is occurring rapidly, more comprehensive methods should be used to assess future traffic volumes. Transport planning models and therefore specialist advice may be required to produce results with a high level of confidence.

In urban areas, more sophisticated planning methods using complex modelling techniques may be needed to produce acceptable results. Local traffic impact analysis can be done using growth rate plus traffic generation. Some traffic generation rates are included in Chapter 3, Appendix 3A, for various land uses. Only minor road improvements could be undertaken with confidence using simple projection techniques in the urban environment.

A risk analysis should be undertaken to determine the level of sophistication required to obtain a reasonable estimate of the future design traffic (refer to Chapter 3 of this manual).

5.2.2 Basic Relationships

The basic parameters describing a traffic stream are:

- *Volume* (or flow rate), q, is the number of vehicles passing a point per unit of time. Typical units for volume are veh/day, veh/hour, and veh/sec;

- *Speed* (or velocity), V or v, is the distance travelled by a vehicle per unit of time. Typical units for speed are km/h (symbol V) or m/s (symbol v). A comprehensive discussion of speed parameters is provided in Chapter 6 of this manual.

- *Density* (or concentration), k, is the number of vehicles per unit length of lane or roadway at a given instant of time. The typical unit for density is veh/km.

These are related to each other by the equation:

$$q = kv_s$$

(v_s is the space mean speed). This equation applies only to uninterrupted flow conditions.

Space mean speed Vs for a length of lane, L, can be defined as either:

- the average of the simultaneous spot speeds, V_i, of each vehicle in L. If speeds are constant, this is the same as the average speed of the vehicles passing some point in L (refer to Austroads 1998a); or

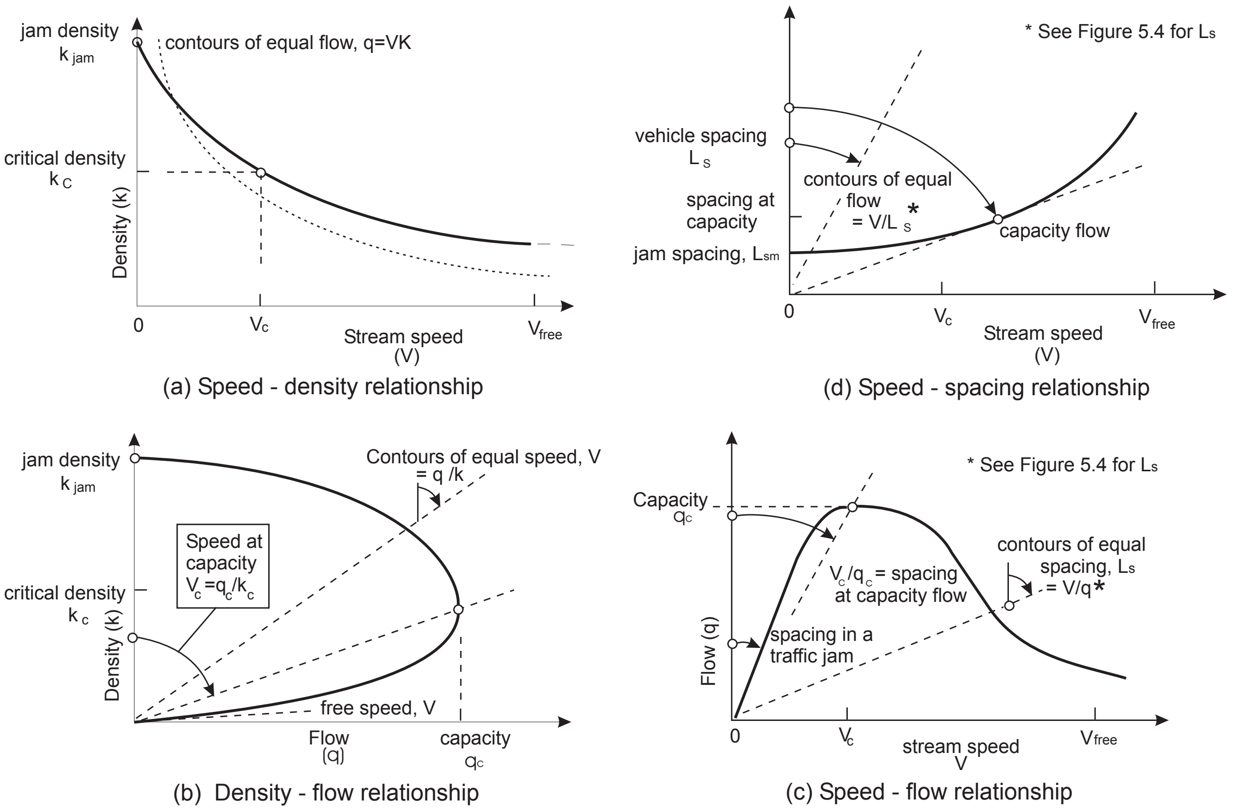
- an estimate made from measurements of the time the vehicles take to traverse L (refer to Lay, 1998).

Other traffic flow parameters frequently used to describe conditions are (Austroads, 1998a):

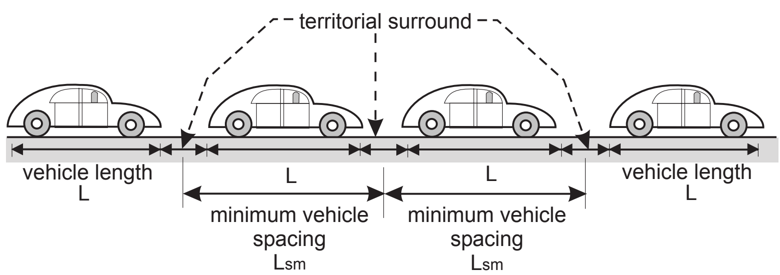
- *Headway,* t_h is the time gap between successive vehicles in the traffic stream.

- *Spacing,* s, is the distance between the same physical point on two successive vehicles in the traffic stream; and

- *Occupancy,* Ω, is the proportion of time that vehicles cover a designated point in the traffic lane. Occupancy is directly related to density.



Figures 5.3 (a) (b) (c) and (d) Basic Traffic Flow Relationship (Lay, 1998)



Note that the minimum vehicle spacing, L_{sm}
which exceeds L, defines the maximum lane occupancy

Figure 5.4 Traffic Stopped in the Stalled Condition (Lay,1998)

For uninterrupted flow conditions, these parameters are interrelated through simple equations (AASHTO 1994, Austroads 1988a, Lay 1998). For interrupted flow conditions, more complex analyses are required. Austroads (1988a) and Lay (1998) provide a more comprehensive discussion of these relationships and should be consulted for further information. This level of discussion is beyond the scope of this manual but the following brief summary provides an overall picture.

Density increases as vehicles travel closer and closer together. This occurs as the volume increases and is accompanied by a reduction in speed (which is required for drivers to feel comfortable with the distance to the vehicle in front). Figure 5.3(a) shows the relationship between speed and density and Figure 5.3(b) shows the relationship between density and flow. Figure 5.3(c) shows the relationship between speed and flow.

Traffic volumes vary with density from points of zero flow to a maximum at a certain density as illustrated in Figure 5.3(b). The zero points represent no vehicles at all or so many vehicles that the vehicles have come to a stop.

Figure 5.3(d) illustrates the relationship between speed and spacing. Figure 5.4 represents the stalled condition. It shows the maximum density possible (jam density, kjam) and illustrates the maximum lane occupancy.

The speed of the traffic stream is affected by interference caused by:

- weather conditions;
- cross traffic;
- weaving traffic;
- disabled vehicles;
- accidents; and
- other marginal conditions.

As speed decreases, vehicles travel closer together (i.e. density increases). As interference increases, the volume can be maintained within certain limits, but with reduced speed and increased density. When the interference becomes so great that the average speed drops below the value at which stable flow can be maintained, there is a rapid decrease in speed and traffic flow and severe congestion sets in.

Bottlenecks occur when the roadway capacity reduces in a single area. Provided the approach flow does not exceed the outflow capacity of the section, the flow will be stable. Once the inflow exceeds the outflow capacity, queuing begins and breakdown of flow occurs. Speeds are reduced and the queuing continues until the inflow to the section is equal to the outflow capacity. Bottlenecks can be avoided by designing a road link with consistent roadway capacity (i.e. consistent level of service).

Intersections are typical bottlenecks – refer to Chapters 13 and 14 of this manual for further discussion.

5.2.3 Traffic Studies

Traffic studies include both the collection and the analysis of useful data relating to traffic and its characteristics.

5.2.3.1 Purpose of Traffic Studies

The purposes for which traffic data is required are:

- *Monitoring* – using information about existing traffic conditions to take action to improve flow conditions (if warranted);
- *Forecasting* – using existing traffic data to estimate future traffic demands in changed traffic conditions;

- *Calibration* – using traffic data to estimate the values for one or more parameters in a theoretical or simulation model;
- *Validation* – verifying a theoretical or simulation model against information independent of that used to calibrate the model; and
- *Evaluation* – using traffic data to assess whether changes to the traffic system have resulted in the desired improvement in the traffic conditions.

For further details, application and implementation of these traffic studies for the purposes of planning, design and improvement to a traffic system, refer to Austroads Guide to Traffic Engineering Practice (GTEP) Part 3 (Austroads, 1998c).

5.2.3.2 Types of Traffic Studies

In general, the common types of traffic studies undertaken and the information obtained on the State controlled road network include:

- *Traffic volume counts* – road user volumes;
- *Road user classification* – including classification of vehicles, motorcyclists, pedestrians, cyclists, number of occupants, and vehicle masses;
- *Speed surveys* – vehicle speeds, fuel consumption and emissions;
- *Origin and destination surveys* – origins, destinations and routes of journeys;
- *Travel time and delay studies* – travel times, delays and their components for all road users;
- *Road crash studies* – number and location of reported accidents (including severity, incident type and details); and
- *Parking studies* – number of parked vehicles, location, and timeframe.

These types of studies are critical in determining the trends and characteristics of traffic in a transport system.

Where a more comprehensive transport study is necessary, additional detailed studies such as land use patterns, vehicle ownership, trip generation, and socio-economic characteristics may need to be carried out. Further details of the necessary investigations and studies in this instance are documented in Chapter 3 of this manual.

Traffic studies providing data on accident history are beneficial in identifying problems within an existing traffic system for the purposes of maintaining, upgrading or designing a new traffic system. This data also provides the basis for decisions on accident reduction measures. In most areas, road crash data is available in an electronic format to assist in planning and design of improvements to the traffic system.

A traditional technique for crash reduction has been the treatment of 'black spots' (i.e. locations known to have a high accident frequency). In order to achieve further crash reduction within the State controlled road network, emphasis has been placed on conducting Road Safety Audits at critical stages of the concept and development phases to avoid incorporating features that have been shown to have higher than usual crash rates. Further details of Road Safety Audit requirements are documented in Austroads' Road Safety Audit (Austroads, 2002). In addition, a guideline for road safety audits of potentially hazardous grade routes by Queensland Transport was published in 1993 (Queensland Transport, 1993).

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5.2.4 Capacity and Level of Service

5.2.4.1 General

Capacity

Capacity is the maximum rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of lane or roadway during a given time period under prevailing roadway, traffic and control conditions:

- The minimum time period used for capacity analysis is 15 minutes, as this is the shortest time over which stable or steady flow can be considered to exist in a traffic system. The flow rate determined from this is expressed in vehicles per hour.
- Roadway conditions refer to the geometric characteristics of the particular facility, including its type and abutting development, the number of traffic lanes in each direction, traffic lane and shoulder widths, lateral clearances, design speed, and horizontal and vertical alignments.
- Traffic conditions refer to the characteristics of the traffic using the facility, including its composition, lane and directional split.
- Control conditions refer to the types of control devices and traffic regulations applicable to the facility.

Level of Service

Level of Service (LOS) relates to the operating conditions encountered by traffic. It is a qualitative measure of such factors as speed, trip time, interruptions, interference, freedom to overtake, ability to manoeuvre, safety, comfort, convenience and vehicle operating costs. However, the usual definitions of LOS for uninterrupted flow are defined in terms of traffic flows. They are:

- LOS A - Free flow with high speeds and low flows (<700veh/h/lane). Drivers can travel at their own free speed with little interference (Figure 5.5).

Figure 5.5 Level of Service A

- LOS B - Appropriate to rural roads with moderate design flows (700 – 1000 veh/h/lane). Drivers have reasonable freedom to select their speed (Figure 5.6).

Figure 5.6 Level of Service B

- LOS C - Appropriate to design flows encountered on urban roads (1000 – 1500 veh/h/lane). Drivers are restricted in their freedom to select speed or manoeuvre, but speeds are still at or above optimum speed (Figure 5.7).

Figure 5.7 Level of Service C

- LOS D - Appropriate to flows near tolerable capacity (1500 – 1800 veh/h/lane). For sections with intersections, this range drops to 1300 – 1500 veh/h/lane (Figure 5.8).

Figure 5.8 Level of Service D

- LOS E - At or near actual capacity (1800 – 2000 veh/h/lane). There may be momentary stoppages. The actual capacity is subject to some debate and may be closer to 2200 veh/h/lane on multi-lane rural highways and 2400 veh/h/lane on motorways. For sections with intersections, the range drops to 1500 – 1600 veh/h/lane (Figure 5.9).

Figure 5.9 Level of Service E

- LOS F - Demand exceeds capacity, with queues and delays (demand exceeds the capacity of a lane but the throughput varies with the extent of interruptions – the volume is zero when the stream is stopped). There is stop-start driving in congested conditions (Figure 5.10).

Figure 5.10 Level of Service F

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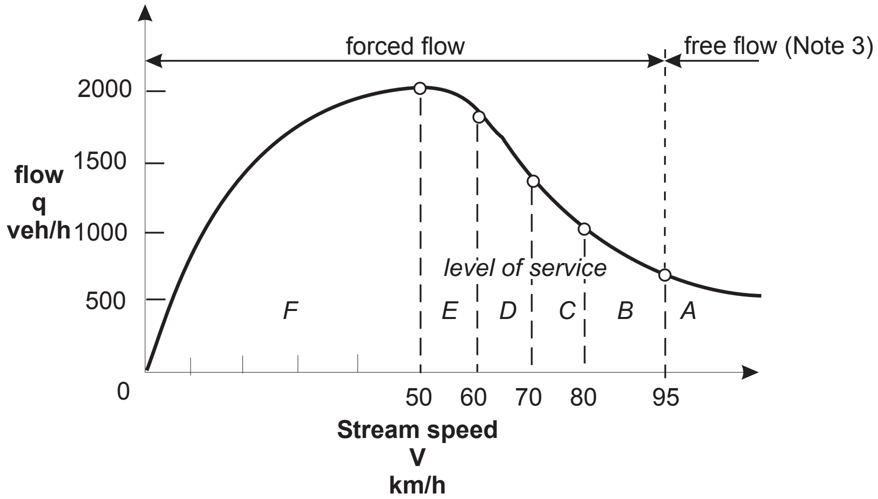

Notes:
1. The speeds used are trip speeds and, on urban roads, would include average delays at signalised intersections.
   The capacities are for the uninterrupted flow of cars on a two-way road in good conditions, but with some sight
   distance restrictions.
2. "Forced" (or "impeded) flow occurs when flows are sufficiently high for a vehicle to be impeded by a slower vehicle
   ahead and forced to adopt its speed and the minimum spacing associated with that speed.
3. "Free" flow occurs when vehicle speeds are not influenced by vehicle spacing.

Figure 5.11 Level of Service Representation (Lay, 1998)

Figure 5.11 illustrates the levels of service on the speed/flow diagram (refer to Figure 5.3(c) for the basic relationship).

These descriptions of level of service are not totally adequate for all circumstances. For urban arterial roads, these descriptions are not appropriate since interrupted flow conditions apply. Further, on rural two-lane roads, drivers will have a different perception of acceptable levels of service for given road and traffic conditions. A Policy on Geometric Design of Highways and Streets (AASHTO) and the Highway Capacity Manual (TRB, 2000) provide more detailed descriptions of LOS for different road types. These are reproduced as Figure 5.12.

For road design purposes, a design volume and LOS must be determined for the road under consideration (refer to Section 5.2.1). The objective of the road design is to produce a facility that will serve the expected traffic without the degree of congestion becoming worse than a pre-selected LOS (i.e. design so that LOS is acceptable at end of design life).

Principles for acceptable levels of congestion suggested by AASHTO are as follows:

- The highway should be so designed that when it is carrying the design volume, the traffic demand will not exceed the capacity of the facility even during short periods of time.
- The design volume per lane should not exceed the rate at which traffic can dissipate from a standing queue. (While the capacity of a lane may be as high as 2400veh/h, a standing queue can start up at only 1500 to1800veh/h and if the approach volume exceeds this value, the queue will not be able to dissipate.)
- Drivers should be afforded some choice of speed. The latitude in choice of speed should be related to the length of trip.

Level of Service	Controlled Access Highways	Multilane Rural without Access Control	Two Lanes	Urban and Suburban Arterials
A	Free flow. Average travel speeds at or greater than 112 km/h. Service flow rate of 700 passenger cars per hour per lane, or **32%** of capacity.	Average travel speed 96 km/h or greater. Under ideal conditions, flow rate is limited to 720 passenger cars per lane per hour or **33%** of capacity.	Average travel speed of 93 km/h or higher. Most passing manoeuvers can be made with little or no delay. Under ideal conditions, a service flow rate of 420 passenger cars per hour, total two-way, can be achieved; about **15%** capacity.	Average travel speed of about **90%** of free flow speed. Stopped delay at signalized intersections is minimal.
B	Reasonably free flow conditions. Average travel speed at or greater than 112 km/h. Service flow rate not greater than 1,120 passenger cars per hour per lane, or **51%** of capacity.	Reasonably free flow. Volume at which actions of preceding vehicle will have some influence on following vehicles. Flow rates will not exceed **55%** of capacity or 1,200 passenger vehicles per lane per hour at 96 km/h average travel speed under ideal conditions.	Average travel speeds of 88 km/h or higher. Flow rates may reach **27%** of capacity with continuous passing sight distance. Flow rates of 750passenger cars per hour, total two-way, can be carried under ideal conditions.	Average travel speeds drop due to intersection delay and inter-vehicular conflicts, but remain at **70%** of free flow speed. Delay is not unreasonable.
C	Operation stable, but becoming more critical. Average travel speed of 110 km/h. Service flow at **75%** of capacity or not more than flow rate of 1,650 passenger cars per hour per lane.	Stable flow to a flow rate not exceeding **75%** of capacity or 1,650 passenger cars per lane per hour, under ideal conditions maintaining at least a 95 km/h average travel speed.	Flow still stable. Average travel speeds of 84 km/h or above with total flow rate under ideal conditions equal to **43%** of capacity with continuous passing sight distance or 1,200 passenger cars per hour total two-way.	Stable operations. Longer queues at signals result in average travel speeds of about **50%** of free flow speeds. Motorists will experience appreciable tension.
D	Lower speed range of stable flow. Operation approaches instability and is susceptible to changing conditions. Average travel speeds approximately 101 km/h. Service flow rates at **92%** of capacity. Flow rate cannot exceed 2,015 passenger cars per hour per lane.	Approaching unstable flow at flow rates up to **88%** of capacity or 1,940 passenger cars per hour at an average travel speed of about 92 km/h under ideal conditions.	Approaching unstable flow. Average travel speeds approximately 80 km/h. Flow rates, two-direction, at **64%** of capacity with continuous passing opportunity, or l,800 passenger cars per hour total two-way under ideal conditions.	Approaching unstable flow. Average travel speeds down to **40%** of free flow speed. Delays at intersections may become Extensive.
E	Unstable flow. Average travel speeds of 96 km/h. Flow rate at capacity or 2,200 passenger cars* per hour per lane. Traffic stream cannot dissipate even minor disruptions. Any incident may produce a serious breakdown.	Flow at **100%** of capacity or 2,200 passenger cars per lane per hour under ideal conditions. Average travel speeds of about 88 km/h.	Average travel speeds in neighbourhood of 72 km/h. Flow rate under ideal conditions, total two-way, equal to 2,800 passenger cars per hour. Level E may never be attained. Operation may go directly from Level D to Level F.	Average travel speeds **33%** of free flow speed. Unstable flow. Continuous backup on approaches to intersections.
F	Forced flow. Freeway acts as a storage for vehicles backed up from downstream bottleneck. Average travel speeds range from near 50 km/h to stop-and-go operation.	Forced flow, congested condition with widely varying volume characteristics. Average travel speeds of less than 50 km/h.	Forced, congested flow with unpredictable characteristics. Operating speeds less than 72 km/h.	Average travel speed between **25** and **33%** of free flow speed. Vehicular backups, and high approach delays at signalized intersections.

Note: * 1997 Revision of Highway Capacity Manual indicates lane capacity of 2400 vph.

Figure 5.12 Level of service characteristics by Road Type (Adapted from HCM, TRB 1997, also refer to AAHSTO, 1994)

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- Operating conditions should be such that they will provide a degree of freedom from driver tension that is related to or consistent with the length and duration of the trip.
- The practical limitations that preclude the design of an ideal road should be recognised.
- The attitude of drivers toward adverse operating conditions is influenced by their awareness of the construction and right-of-way costs necessary to provide a better level of service.

AASHTO provides a more detailed discussion of these principles. Notwithstanding the above, in urban areas, the design volume may be determined from a holistic study that seeks to manage demand on various parts of the system.

5.2.4.2 Capacity Reduction Factors

Practical capacity of a section of road is less than the theoretical values given above as the result of the effect of a number of factors listed below (Austroads, 1988b):

- *Surface conditions* – an unsealed gravel surface reduces the capacity by about 50% and a natural earth surface by about 60%;
- *Lateral clearances* – refer to Chapter 7 of this manual;
- *Shoulders* – refer to Chapter 7 of this manual;
- *Lane widths* – refer to Chapter 7 of this manual;
- *Lane distribution* – lane arrangements may cause turbulence in the flow, reducing capacity as a result (e.g. dropping a through lane, merging);
- *Horizontal alignment* – reducing the horizontal curvature lowers the free speed and this can cause flow instabilities;
- *Vertical alignment* – for example each 1% increase in grade decreases capacity by about 0.5%. Grade has an effect on the equivalent passenger car units for trucks (may double in mountainous areas);
- *Overtaking provisions* – lack of overtaking provisions has a marked effect on two-lane, two-way road capacity (refer Chapter 15 of this manual);
- *Traffic composition* – the traffic stream is made up of a mix of vehicles with different capacity flows (e.g. truck maximum capacity flows are about 400 trucks/h). The capacity effect of the various vehicles is accommodated by using passenger car equivalents for the various vehicles;
- *Traffic flow variations* – instability can arise with variations in flow;
- *On coming traffic* – affects two-lane, two-way roads;
- *Traffic interruptions*;
- *Adjacent land use* – the friction created by the traffic activities associated with adjacent land use has a significant effect on capacity (e.g. entering and leaving the traffic stream);
- *Parked vehicles* or vehicles in the process of parking in a kerbside lane;
- *Intersections* and turning vehicles;
- *Pedestrian movements* (particularly at intersections);
- *Bus operations;*
- *Absorption of traffic into other traffic;*
- *Traffic management measures;*
- *Driver behaviour; and*
- *Weather.*

Capacity of a road can only be described in terms that are well defined, probabilistic and specific to a particular locality for specific conditions.

For detailed discussion of the factors affecting capacity and level of service, refer to the Highway Capacity Manual (TRB, 2000) and the GTEP – Part 2 (Austroads, 1988b).

5.2.4.3 Other Elements of Level of Service

LOS of a road is judged by factors other than the speed – flow relationship discussed above. These are discussed further below.

Efficiency of Access

This measure of LOS is related to the overall road network and the efficiency with which it provides accessibility to industry and property. It refers to the extent to which the road system serves a particular area, not to the question of individual access from a specific property to a particular road. Direct access from the road system to these entities is clearly the most efficient although direct access to a major road for individual properties will not be appropriate in many cases. However, it is necessary to provide reasonable access to the system by way of intersecting roads, service roads and the like for the overall road system to properly perform its function.

Where a long indirect route is required to service an area, the efficiency of access is diminished. The extent of the population affected by this is a major determinant of the need to address the problem.

The LOS is also significantly affected by the standard of the road supplying the access. For example, an unsealed road provides a significantly lower LOS than a properly maintained sealed road. These considerations should be addressed in the pre-project and concept phases, reflected in Roads Connecting Queenslanders (Main Roads, 2000) and the Investment Strategies, and applied through the specific road project's concept and development phases.

Road Closures

Road closures of a temporary nature that can be controlled by Main Roads include stock crossings, at-grade rail level crossings, special events and roadwork.

The principal reason for long-term road closures in rural areas is flooding. The acceptable time of closure due to flooding will depend on the importance of the road, the impact on industry that closure will have and the practicality of alternative routes. It is desirable that the state strategic road system is relatively free of flooding closures but this would not be practical or affordable in many locations. While greater times of closure will be acceptable on the regional and district networks, the times of closure need to be limited.

Average annual closure (in hours) is the sum of the durations (in hours) of all expected closures of the road each multiplied by the expected annual exceedance probability applicable to that duration of closure (Commonwealth Department of Transport).

Careful analysis of the whole link is required to establish a reasonable approach to the question of acceptable time of closure. For example, if a link is generally free of this type of interruption except for a single location, it will be reasonable for a greater expenditure to be made to remove that impediment and provide a consistent standard throughout. On the other hand, there is no point in expending large sums on removing a flood impediment at one location if other sections of the link cannot be brought up to the same standard.

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That is, the standard to be applied will depend on a thorough examination of the whole link, the patterns of flooding likely, the importance of the link, the availability of alternative routes and the consequences of various times of closure on the route. Main Roads' Road Drainage Design Manual provides guidance on this issue.

Whether the level of flood immunity is sufficient reason in itself to upgrade the road will have to be decided on a case-by-case basis. There may be other priorities in terms of seal width and roughness that override the flood immunity issue. However, careful analysis of the economic impacts of very low flood immunity should be undertaken to ensure that the best overall result for the State is achieved.

Degree of Saturation

The degree of saturation of a signalised intersection approach may be defined as the ratio of the arrival flow (traffic demand) to the capacity of the approach during the same period. This ratio ranges from close to zero for very low traffic flows up to 1 for saturated flow or capacity.

The degree of saturation can be calculated using computer programs such as aaSIDRA (Signalised and unsignalised Intersection Design and Research Aid).

Other traffic measures of effectiveness used by aaSIDRA are delay, level of service, and queue length. It also provides suggested acceptable limits of measures of effectiveness for traffic analysis in an intersection environment (refer also to Chapter 13 of this manual).

5.2.4.4 Applications

Rural Two-lane, Two-way Roads

On two-lane, two-way rural arterials and highways, drivers expect to travel on an uninterrupted flow basis with little interference from other traffic users.

In this situation, the measures of LOS should be determined by:

- Percent time delayed;
- Average speed; and
- Volume/capacity ratios for various percentages of the length of road with sight distance less than 450m.

The percent time delayed is defined as the average percent time that all vehicles are delayed while travelling in platoons due to their inability to overtake. A surrogate measure of this is the percentage of vehicles travelling at headways closer than 4 or 5 seconds. This measure is expressed as "percent following".

Table 5.3 illustrates the relationship between the percent time following and level of service as defined in the GTEP - Part 3 (Austroads, 1998c) and as adopted in TRARR studies in Queensland. It is considered that the TRARR model figures (Table 5.3) better reflect Queensland conditions.

For details of the methodology and standards to be adopted for the design of overtaking lanes, reference should be made to Chapter 15 of this manual.

Table 5.3 Relationship between LOS and Percent Time Delayed, and LOS and Percent Time Following.

Level of Service	% Time Delayed (Austroads 1998c)	% Time Following (TRARR)
A	<30	<30
B	<45	<55
C	<60	<70
D	<75	<80
E	>75	>80
F	100	100

Two possible strategies for improvements are:

- Overtaking lane strategy; or
- Future duplication strategy.

Upgrading strategies for two-lane, two-way roads must consider the possibilities of using overtaking lanes to improve LOS. A considerable improvement in the LOS can be achieved through the judicious use of overtaking lanes with considerably less expenditure than full duplication.

The following overtaking lane strategy has been developed for this purpose.

In order to maintain a desired LOS (also refer to Multi-lane Roads below) on a typical two-way, two-lane rural road section, overtaking lanes or even short sections of duplication will be required. A requirement for full road duplication would then not be expected for the duration of the design life of the constructed auxiliary lanes. A design period of more than 10 years, and more typically 20 years, is then used to recover the cost of the improvements made. This strategy will commonly apply where there are no existing overtaking lanes and the initial application of the lanes will be at 10 to 15 km intervals (Refer Chapter 15 of this manual).

This type of strategy will only be appropriate up to some limiting traffic volume depending on the desired level of service for the road. This limit can be calculated specific to a road section on the basis of using lengths and spacing of lanes as described in Chapter 15 of this manual. Table 5.4 shows generic limits for LOS B and LOS C.

Table 5.4 LOS and corresponding Generic Limits for Overtaking Lane Strategy.

Desired Level of Service	Upper Traffic Volume Limit (veh/hr)
B	500
C	800

Where the volumes exceed these limits, a future duplication strategy should be pursued if the route is suitable.

Multi-lane Roads

Austroads (1988b) provides a detailed methodology for assessing the capacity and LOS of multi-lane roads for uninterrupted flow conditions. For most rural cases, drivers will expect these conditions.

While LOS B is desirable in these cases, it may be impractical to provide for this level over the life of the facility and for all times of the day. LOS C will generally represent acceptable operating conditions on heavily trafficked roads for the design hour, with LOS B for the remainder of the day. In addition, drivers will accept deterioration in LOS C at known peak demand times.

Mature judgment should be exercised in setting the design LOS and the various elements of the design should be kept in balance to cater for a range of conditions over time.

Cox (1999) discusses these concepts in a specific application.

5.3 Driver Characteristics

The information in this section is specific to drivers of four wheeled vehicles. However most is applicable to other drivers/riders Planners and designers should also refer to Sections 5.4, 5.5, and 5.6 for addition information on road user characteristics.

5.3.1 General

Driver behaviour is central to almost all of the decisions required in the design task. The efficient operation of the road system depends on the interaction of the driver, the vehicle, other drivers and vehicles and the road itself. Crashes occur when some part or parts of the system fail. The road system is a complex, dynamic and fundamentally unstable system, the use of which has devastating consequences for many (Fuller et al 2002). Understanding the road user, and the psychological factors that make them vulnerable in roadway use, should allow designers to be responsive to those characteristics thus creating a safer road environment (refer to Chapter 2 of this manual).

Further, consideration of the common aspects of driver behaviour is necessary to provide the basis for many of the details included in later chapters of this manual (e.g. speed selection, operation on curves, driving through intersections).

A driver's information system has to cater for the following tasks:

- *Strategy selection* – departure time, route, transport mode;
- *Navigation* – which roads to use, maintenance of the route choice;
- *Vehicle guidance* – placing the vehicle on the road in a specific lane and the location in that lane;
- *Vehicle manoeuvring* – how to move from one place on the road to another;
- *Vehicle control;*
- *Compliance with traffic rules and laws;*
- *Interacting with traffic;*
- *Using peripheral communications;* and
- *Responding* – to unexpected emergencies.

Planners and designers should note that the load on some road uses varies (e.g. refer to Sections 5.6.3 and 5.5).

The way these tasks are performed depends on the behaviour of the drivers and this can be considered under four major headings:

- *Psychological traits* – intelligence, learning ability, motivation, desires, temperament, emotional stability and attitudes;
- *Sensory abilities* – vision and hearing;
- *Physical abilities* – response time and physical limitations of the body; and
- *Medical factors* – influence of drugs and alcohol, disease, fatigue and physical impairment.

5.3.2 Psychological Traits

The driver's values and attitudes have a significant effect on the way the driver behaves in the traffic stream. A large range of short-term and long-term needs and motives are brought into play in the driving task (Lay, 1998). These include emotions, goal fulfilment, peer group pressure, driving satisfaction, exhibitionism and risk taking.

Much driving, particularly in rural areas, depends on self-paced tasks and the level of task demand is under the control of the driver. Speed, headway and lateral position are in this category. The driver is therefore an active part of the traffic system and not merely responding to external events. Many of the stresses on a driver in these circumstances are self-imposed. However, the performance of the driver is directly related to the workload placed on the driver. Poor performance can be expected with both over-work and under-work.

If the driver is over stimulated (over-work), then he/she will make mistakes because of information shedding to make the task tractable. On the other hand, under-stimulation (under work) leads to monotony and boredom and insufficient attention to the task often leading to error.

In addition, people do not perform at an optimum level at all times. Drivers do not always perform according to their capability and are influenced by a range of external and internal factors that reduce their capability. Error often comes about because of human frailty and the failure to build error tolerance into the road system (refer to Chapter 2 for a more comprehensive discussion of these factors).

Drivers do not use all of the information made available to them – they frequently do not see a sign. Their awareness of a sign often depends on the relevance assigned to the sign by the driver.

These traits indicate the need for a designer to provide cues and signs that stand out from the surrounds and are very relevant to the driving population in the area. It also indicates that some repetition in the signing and other cues may provide some confidence that drivers will become aware of at least some of the information made available.

Social factors also play a part in determining the behaviour of drivers in the traffic stream. People like to conform and this may lead to behaviour that is contrary to the safe operation of the road system. These forces can be used constructively to influence the behaviour of drivers (e.g. providing feedback on the number of vehicles maintaining speed within designated limits has been shown to reduce high speeds).

There are many human factors that influence performance of drivers that are beyond the ability of road designers to overcome. However, there are some principles that assist the road designer in responding to human factor problems:

- Arousal:
  - Avoid low arousal inducing road alignments;
  - Consider the needs of fatigued and drowsy drivers; and
  - Avoid stimulus driven high arousal states.
- Information Processing:
  - Avoid conflict in attention when critical information is being processed;
  - Avoid informational overload;
  - Avoid memory related errors by placing the necessary information close to the vulnerable phases of the task (do not rely on the information being stored in the driver's head);
  - Design road features to accord with driver expectations;
  - Use speed guidance at critical road segments; and
  - Allow for the effects of speed adaptation (velocitisation) – drivers will approach the first curves after leaving a motorway at a higher speed than they think.
- Error Management:
  - Employ practices of error management (refer to Chapter 2,of this manual); and
  - Increase feedback to drivers regarding the quality of their performance.

For a comprehensive treatment of human factors in road design, refer to Fuller et al (2002).

5.3.3 Sensory Abilities

This discussion is based on the Handbook of Road Technology (Lay, 1998).

Vision provides about 90% of the information received by a driver. Touch provides some feedback in acceleration and deceleration and hearing can be important in judging speed and becoming aware of other vehicles but these senses have little effect on design decisions. However, the importance of vision to the driving task warrants further attention.

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Visual acuity and colour sensitivity are at their peak in the central region of the retina with an angular radius of 1°. These factors are still good within 3°, reasonable within 10° and have some value within 35° of the line of sight. Using peripheral vision, the eye can detect objects within 95° of the line of sight (the peripheral field). However, peripheral vision does not provide detail discrimination and is influenced by a range of factors:

- *Gender* – women have a larger peripheral field than men;
- *Age* – not well developed in children and declines with age (in old age, the peripheral vision moves 10° closer to the line of sight);
- *Alcohol* – impairment begins at a Blood Alcohol Content (BAC) of 0.02mg/100ml;
- *Speed* – the peripheral field drops with increasing speed as shown in Table 5.5:
- *Vehicle design* – features such as window columns can restrict peripheral vision;
- *Object being detected* – response to movement in the peripheral field is enhanced when the objects are large and/or highly contrasted;
- *Light level* – peripheral vision disappears at low light levels;
- *Observer* – response to movement in the peripheral field is reduced when complex visual decisions are being made in the central visual field.

Table 5.5 Speed versus field of Peripheral Vision.

Speed (km/h)	Peripheral Field (°)
0	95
30	50
60	40
100	20

The driver uses central vision for the tasks of steering, braking, accelerating and navigating. Peripheral vision is used for detecting potential hazards outside the normal central visual field (e.g. pedestrians and vehicles from cross streets).

Eye movements are used to gather information outside the central visual field to cover a region within ±15° of the central visual field and these take about 50ms in time. Larger movements are accommodated by head movements, which are much slower (typically 700ms). These times are important factors in the total response time taken by drivers in reacting to roadway conditions.

Visual sensitivity is the ability of the eye to detect differences in light levels measured in terms of their luminance. The threshold luminance contrast is the minimum difference that the eye can detect in the luminance of an object and its background. This determines the eye's ability to draw useful messages from the light signals received.

Table 5.6 Driver Response Time (Lay, 1998)

Driving Actions	Response Times (milliseconds) Mean	Variation[a]
1. *Detect*		
1.1 Basic Perceptual Response to an intellectual or visual stimulus	250[b]	
1.2 Eye movement locates the object in one look	50[c]	+50/-0
1.3 Eye dwells on the detected object	200	+300/-0
Total (1) detection time	**500**	**+300/-0**
2. *Identify* the detected object by recognising and interpreting it	600	+300/-400
3. *Decide* on a response to this identification (see also 6 and 7 below)	500	+500/-250
4. *Respond*		
4.1 Driver responds (e.g. lifting foot from or applying it to accelerator)	200	+350[d]/-100-
4.2 Vehicle begins to respond	100	+1000[e]/-0
TOTAL (1 - 4) Vehicle begins to respond	**1800**	**+1800/-800**
5. Vehicle manoeuvre time		
5.1 *Brake*		
• Move foot from accelerator to brake	200	+1000/-100
• Braking system completes operation	Braking distance calculation (refer to Chapter 9)	
5.2 *Steer*	100	
TOTAL (1 - 5) driver and vehicle response time	**1900+**	**+?/-900**
6. Additional time if two responses required	600[f]	+/-200
7. Additional time if three responses required	1200[f]	+/-300

a The +/- values are indicative variations and define a range that covers about 90% of the population.
b Can increase for complex tasks.
c If the object is outside the desired visual field (typically, ± 15%) and a head movement is needed, this will add another 700ms.
d Occurs if driver is not watching the rear light of lead car. Thus, in close traffic, the time for a following car's rear light to illuminate after the lead vehicle's rear light illuminates is 250 (from 1.1) + 200 (from 1.3) + 200 (from 4.1) + 50 (light latence) = 700, +350/-100 ms.
e This may extend to 4000ms for some large vehicles.
f Add 200 for older drivers.

In conditions of low luminance, such as at night, the eye becomes more sensitive to light but suffers a compensating loss of resolving ability. About 5% of the population is deficient in detecting low luminance contrasts. This ability declines with age, particularly for people over 40years, and deteriorates with alcohol intake making the reading of signs difficult for old or alcohol-affected drivers. For elderly drivers, the threshold luminance contrast ratio (luminance difference divided by the background luminance) is about double that of “normal” drivers (Lay, 1998).

Visual recognition takes a finite time. The basic response time to a stimulus is about 250ms and this increases with the number of possible responses. Then a visual search for an object following the stimulus takes about 50–100ms to complete. (If a head movement is required, a further 700ms is required.) Thus a driver will take 250 + 50 = 300ms to have one look at the scene within the centrally located field. After the visual field is scanned, the brain takes a further 60ms to perceive what the eye has seen. Drivers will fixate on the object for at least 200ms so the total time to visually locate one object is 300 + 200 = 500ms. The driver then needs to recognise the object and this can take a further 600ms.

Table 5.6 sets out response times for drivers. This table cannot be precise because of the variations from driver to driver. It is intended to be an indication of driver performance and an affirmation of the values of this parameter adopted for design.

These factors have significant effects on a range of design elements including sight distance requirements and sign design.

5.3.4 Physical Skills

Visual ability was discussed above. The other physical abilities relevant to the driving task relate to the driver-vehicle interaction part of the road system. Vehicle control, tracking, curve negotiation and response time are discussed under this heading.

Vehicle control refers to the actions of steering, accelerating, decelerating and braking and their management. These are not significant issues with modern vehicles and are not further discussed. The design parameters relating to these factors are dealt with in relevant chapters in the manual.

Tracking refers to the maintenance of the vehicle position on the roadway and is a continuous activity for all drivers. The driver's skill in this area determines the need for the width of lanes and necessary clearances to lateral objects. Studies have shown that drivers have difficulties with lane widths under 2.5m, and that the optimum width for a 1.9m wide car is 3.1m. Allowances for conditions in adjacent lanes often raise this to 3.5m. Trucks require wider lanes than cars and physically take up at least 2.9m of width (2.5m plus wing mirrors). 3.5m lanes are desirable for this reason.

It has also been shown that drivers travel about 150mm closer to the pavement edge as the lane width increases from 3.2 to 3.7m. This demonstrates that there is danger in making lanes too wide since it may lead to poor discipline and attempts to make multiple use of a single lane. In addition, it will be wasteful of road space since the driver does not need to use the additional width.

Lanes that are too narrow result in difficult driving conditions and contribute to driver tension and fatigue. The decline in driver performance is shown by a loss in safety on narrow lanes. Crash rates for run-off-the-road and on-coming traffic crashes reduce as the lane width increases from 2.5 to 3.5m.

Pavement marking improves a driver's lateral position keeping regardless of lane width. Drivers also are prepared to travel closer to a wide shoulder and to a sealed shoulder than they do to unsealed and/or narrow ones.

Curve negotiation is a major function of the driving task. The driver's perception of the curve has a marked effect on the speed adopted and the behaviour on the curve. Chapter 11 of this manual deals with these issues in detail.

Response or reaction time is a major component of the determination of a range of design parameters. This time represents the period taken by the driver to convert perceived information into action. Table 5.6 shows the components of response time for the average (50th percentile) driver. These components are:

- Visual detection (refer above);
- Identification;
- Decision making;
- Driver response (or volition); and
- Vehicle response.

For more detail, refer to the Handbook of Road Technology (Lay, 1998). Table 5.6 suggests that the range of response times for unexpected events is from 1.0 to 3.6s with 1.8s as a median value. The commonly used 2.5s appears to be a reasonably “safe” one to respond to an event. However the variance between drivers is very large and values up to 7s have been recorded at one extreme with 1s being recorded for some forced stops.

5.3.5 Medical Factors

Alcohol, drugs and fatigue all effect driver performance/capability.

5.3.5.1 Alcohol and Drugs

Alcohol consumption by drivers has a degrading effect on their driving abilities. Of particular note for designers is the effect on visual acuity, the reduction in peripheral visual field and the increase in response times of alcohol affected drivers.

Drugs can have an effect similar to that of alcohol and contribute to at least 10% of road fatalities (Lay, 1998). Both prescription drugs and “recreational” drugs are included in this category.

While it is not possible to adopt specific parameters to account for these types of drivers, it must be recognised that they do exist and that the road should be as forgiving as possible to minimise the consequences of alcohol and drug affected drivers. Longer reaction times, simple decision sequences, less reliance on peripheral visual cues, lighting and clear roadsides are some of the factors that will assist. These are also good design practices for other reasons.

5.3.5.2 Fatigue

Fatigue has become a major factor in road crashes. It can be defined as a diminished capacity or inclination to perform and can be both psychological and physical (Lay, 1998). Fatigue can result from emotional stress, medical condition and from physical factors such as over-extensions of the driver’s physical capability, monotony, adverse environment and physiological factors such as over-eating.

The only way to properly overcome fatigue is by resting. It is therefore necessary for appropriate rest facilities to be provided for drivers on the road system to encourage regular rest periods (refer to Chapter 20 of this manual).

However, some improvement may be possible if monotony can be reduced and a more interesting driving experience created. Designers should be aware of the possibility of creating this interest in their designs (e.g. designing the alignment to bring a feature such as a landmark or mountain into view). This will not be possible in all cases. Providing a longer reaction time for drivers who have been subjected to monotonous driving conditions is desirable. Surprises should be avoided – a desirable feature in any case.

5.3.6 Effects of Age

Age effects occur at both ends of the spectrum. For young people, the issues involve psychological and attitudinal factors as well as inexperience. The elderly suffer from declining physical abilities and slowing of performance.

Some young drivers exhibit the traits of impulsive driving with poor risk management and display a lack of strategic driving skills. These drivers tend to be focussed on the immediate tasks at hand, do not scan the visual field efficiently and make poor use of peripheral vision. Many eighteen-year olds have under-developed cognitive and perceptual skills. All of these factors lead to longer response times at this stage of their driving career but they improve with age and experience. (Refer to Section 5.3.6.2 for more detail.)

At the other end of the spectrum, driving skills tend to start declining from the age of 55 and tend to decline rapidly from the age of after 75 (Lay, 1998). Older drivers tend to compensate by driving more slowly and limiting the times and places of their driving. Eyesight also begins to decline for most people after the age of 45 and loss of light transmission makes night driving more difficult after the age of 40. For such people illumination levels must be doubled for each 13 years of age to maintain equivalent performance. (Refer to Section 5.3.6.3 for more detail).

For both ends of the age spectrum, the overall effect is to increase the response times and design should recognise this. The need for greater illumination for older drivers should be considered for situations where more complex decisions are required. Further, the design should be tailored to these needs where it is known that concentrations of younger and/or older people occur.

5.3.6.1 Designing for the Young Driver

Background

This discussion is based on Fuller et al 2002, Human Factors for Highway Engineering.

Some young drivers (18 to 24 years) are significantly over-represented in the crash statistics in Australia. They comprise about 20% of the driving population but account for about 50% of injury crashes and about 35% of fatal crashes (Fuller et al 2002). Similar statistics are experienced in other countries. The "just trained" are the most dangerous.

The conclusion is that the driving experience has to be learned on the road and drivers require considerable experience to be able to cope with the range of circumstances that confront them in practice.

Young Driver Characteristics

Factors that influence the characteristics of young drivers include:

- *Risk Life Style* - a proportion of young drivers (e.g. 15 - 20% of young male drivers) deliberately take risks, a factor in the lifestyle they have been conditioned to or have adopted. They may be considered "sensation seekers" and they are more likely to be involved in traffic violations and to crash.
- *Risk Exposure* - young drivers operate in an environment that creates greater exposure to risk - older cars (less protection), more passengers (more casualties in a crash), night driving.
- *Risk Seeking* - attitudes play an important part in this as well as peer pressure. High risk driving is often seen as a demonstration of superior skills.
- *Overestimating Competence* - young male drivers often overestimate their ability and therefore their ability to correct a situation.
- *Deficiencies in competence* - they may:
    - be poor at identifying distant hazards;
    - see less risk in various driving scenarios;
    - put themselves in driving situations where they come in conflict with other drivers (e.g. accepting shorter gaps);
    - find it difficult to manage and control their speed; and
    - be prone to drive too fast for the conditions.

Design Recommendations

The young driver has less well developed driving skills and does not find it easy to select the appropriate behaviour when confronted by various situations. The appropriate speed to adopt often escapes the young driver. The array of information may be too much and the young driver can suffer from information overload, leading to some information being ignored. Design must consider the approach of the young driver and their performance can be improved by:

- ensuring that the driver's attention is directed to hazards ahead so that warning information is picked up by the driver (e.g. adequate well located signage);
- signing hazards clearly with high contrast and dynamic warning signs;
- providing clear guidance on what to do to cope with a particular hazard (i.e. where to go and what speed to adopt, e.g. through signs, reduced speed limits);
- providing information well in advance of a possible conflict, hazard, etc;
- allowing higher perception/reaction times where complex situations occur;
- using high skid resistance surfaces where drivers are likely to respond late (e.g. approach to isolated traffic signals);
- using traffic calming devices in urban areas to control driver behaviour; and
- modifying perceptions of the roadway to give drivers heightened awareness and induce greater vigilance (e.g. devices to give an illusion of higher speed such as rumble strips at decreasing spacing longitudinally).

Providing for the expected performance of younger drivers will also assist all other drivers, and in particular, the elderly. Even though the basis for the reduced performance represents conditions at different ends of the scale, the methods used will usually benefit both groups and provide a more comfortable experience for others.

In both cases, the designer needs to be creative, as there are no robust certainties about the best solution. A good understanding of the attitudes and limitations of both groups is a necessity.

5.3.6.2 Designing for the Older Driver

Background

The numbers of older drivers involved in fatal and serious injury crashes can be expected to increase as the proportion of elderly people in the population increases (Oxley et al, 2001). The challenge of driving in the modern traffic environment increases exponentially with age.

Aging brings with it a gradual deterioration in physical and cognitive performance. For example, older drivers can require signs three times brighter at night and two to three times the colour contrast during daytime, than signs meeting the detectability and legibility needs of younger (20 to 35 years old) drivers (Dunne 2001).

The aging process is associated with increases in functional disabilities that can lead to decreases in safe driving and mobility. Road design should take account of these factors in making decisions on the elements of a road design.

Aging and Functional Capacities

The main feature of aging is the progressive slowness of behaviour but the following characteristics have also been identified (Fuller et al 2002):

- The neuromuscular system changes in ways that influence both cognitive and motor behaviour - loss in ability to perform complex tasks and coordination;
- Loss of muscle strength, endurance and tone - decrease in joint movements and reaching distances are the main factor in motor limitations;

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- Step length, step height and walking speed decrease - difficulty in performing daily tasks (pushing buttons, opening doors, using stairs, using public transport);
- Loss in the ability to detect, interpret and react to visual and auditory information - response to illumination and colour discrimination declines, sensitivity to glare increases;
- Memory loss and decrease in ability to learn are the main cognitive age-related changes - semantic memory and procedural memory remain quite stable so these deficits can be compensated by appropriate strategies based on previous knowledge and/or experience.

The effects of aging may be due to a reduction in mental energy or processing resources, reduction in information processing speed, or inefficient inhibitory mechanisms in working memory leading to attention to irrelevant details (reduction in focus on the task). These mechanisms tend to lead to a requirement for increased response time for decision making.

Reduced information processing speed has a major effect on performance in several areas. It emphasizes the importance of the time available in areas requiring decision-making and particularly where an unexpected change in road environment occurs. Additional response time is required to cater for older people.

The inefficient inhibitory mechanism leads to the need to assume that the elderly are easily distracted and may be confused by competing information. Therefore, clarity and simplicity of information being provided is necessary.

Travel Needs of the Elderly

Identified needs and corresponding areas of difficulty for elderly drivers include (Fuller et al, 2002):

- Vehicle control:
  - Road-related tasks (difficulty in various manoeuvres);
  - Traffic-related tasks (car following, overtaking, etc); and
  - Roadside service (difficulty in contacting breakdown service, changing a wheel).
- Trip Information:
  - Determining whereabouts (difficulty in map reading, identifying visual displays, understanding announcements); and
  - Information on route changes (road works, traffic jams).
- Environmental conditions:
  - Weather (difficulties in seeing, reading and understanding signs and audible information); and
  - Night driving (difficulties resulting from visual deficits and sensitivity to glare).
- Parking (identifying parking areas, manoeuvres required may be difficult for the elderly).

Improving the Road Environment for the Elderly

Enhancing the road environment can be achieved by meeting the needs of the elderly driver as follows (Fuller et al, 2002; Jennie Oxley et al, 2000):

- Intersections:
  - Signal controlled intersections are better than those without signals;
  - Adequate roadside information is required;

    - Clearly defined permissible vehicle paths are required;
    - Separate right turn movements are desirable.
    - Greater prominence of traffic signals is necessary; and
    - Sight distances to intersections controlled by “Stop” and “Give Way” signs should be improved (longer perception/reaction times - 3 seconds is desirable).
- Motorways:
    - Provide adequate information with adequate size, lighting and glare protection; and
    - Allow increased distances to enter the required traffic lane where lane changes are required.
- Road works - advance and clear information is required (fluorescent signs have been claimed to improve the legibility and recognition distance for older drivers by a significant margin - 3.2s earlier at 100km/h (Dunne, 2001)).
- Railway crossings clear and early warnings are required for at grade crossings.
- Traffic manoeuvres - car following, overtaking, entering and leaving a traffic stream, lane changing require:
    - Good visibility;
    - Extended use of overtaking lanes on two-lane roads; and
    - Clear information.
- Traffic-related tasks - elderly drivers require information in due time, correctly located, with adequate dimensions and contrast and designed to accommodate environmental conditions.

Design Recommendations

The roadway can be designed to improve the performance of older drivers and provide for their needs and abilities. Studies (Oxley et al 2000) indicate that the following changes in design practice have the potential to reduce crash risk for older drivers:

- Improve (i.e. increase) sight distances at intersections controlled by “Stop” and “Give Way” signs;
- Separate right-turn movements from opposing through movements at intersections;
- Enhance the prominence of traffic signal displays at signalised intersections; and
- Define clearly permissible vehicle paths and prevent wrong choices or use of traffic lanes at intersections.

Gap selection is a significant problem for older drivers involved in crashes. It is therefore possible to reduce the risk for older drivers by appropriate decisions in the design process. Some counter-measures to address the problem for older drivers include:

- Replacing “Stop” and “Give Way” signs with fully controlled traffic signals where appropriate (lessens the decision making task for older drivers);
- Providing a roundabout - drivers need only select a gap in one direction of traffic at a time; and
- Providing fully controlled right-turn phases - simplifies gap selection and addresses site-specific problems with limited sight distance, high traffic volumes and high speeds.

Most measures designed specifically for the older driver also improve the environment for all drivers. Some additional thought at the design stage can provide an enhanced

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driving environment at minimal cost with potentially large benefits.

5.4 Pedestrians

5.4.1 General

Pedestrians are a diverse group of people representing all parts of society with a wide range of abilities. All age groups are represented and all road users are at one time or another, pedestrians. Almost all trips start and end with a walking component, at which times the driver or public transport user becomes a pedestrian.

Pedestrians are also vulnerable road users and they form a large proportion of road fatalities and injuries. Simple safety measures can often provide significant improvements in pedestrian safety. The following safety principles for pedestrian facilities show how this can be achieved:

- warn road users and pedestrians of each other's presence at potential points of conflict;
- inform drivers of areas where pedestrian activity is likely to be heavy;
- guide drivers and pedestrians to minimise points of conflict;
- control driver and pedestrian movements by use of special facilities;
- provide no surprises to drivers (i.e. avoid isolated and unexpected pedestrian facilities);
- do not lead pedestrians into direct conflict with other road users; and
- define clear paths for all users.

Road users with a disability also are usually pedestrians and no pedestrian facility can be designed without consideration of their needs. The objectives of the Commonwealth Disability Discrimination Act 1992 (DDA) are:

- to eliminate, as far as possible, discrimination against persons on the ground of disability in the areas of:
  - work, accommodation, education, access to premises, clubs and sports;
  - the provision of goods, facilities, services and land;
  - existing laws; and
  - the administration of Commonwealth laws and programs; and
- to ensure, as far as practicable, that persons with disabilities have the same rights to equality before the law as the rest of the community; and
- to promote recognition and acceptance within the community of the principle that people with disabilities have the same fundamental rights as the rest of the community.

Disabilities may be physical, intellectual, psychiatric, emotional or sensory in nature and include:

- partial or total loss of sight;
- partial or total loss of hearing;
- partial or total loss of speech;
- disfigurements or deformities;
- difficulties in walking (including partial or total loss of legs);
- difficulties in fully using arms (including gripping);
- learning and orientation difficulties;
- sensitivity to chemicals causing malfunctions of a person's body; and

- emotional or behavioural conditions.

The 1993 Australian Census indicated that 18% of the total population has a disability according to the above definitions. By age group, 36.4% in the 60 - 64 years old range, and 66.7% of those over 75 have a handicap. As Australia has an aging population, it could be predicted that each year, the percentage of the total population with a disability would increase. It should also be noted that many people have a temporary disability from time to time (e.g. injury, pushing a pram).

For road designers, considering people with a disability as pedestrians, in vehicles or in wheelchairs, key issues include:

- How accessible is the use of the road or nearby facilities to people with a disability?
- Can they use the facilities safely with or without minimum assistance from other people? This includes getting in and out of parked cars.
- Is the riding surface smooth enough for the use of wheelchairs without giving discomfort?
- Is it safe so that those with a disability will not slip on the pavement or trip over an obstacle of street furniture?
- Can those with a disability see, hear, identify and/or interpret the meaning of the road signs?

Specific requirements for providing for people with a disability on road infrastructure are given in AS1428.1 to AS1428.4 and the GTEP Part 13 (Austroads, 1995). Other publications also deal with the subject.

It is important that designers integrate the requirements of all pedestrians with the overall design from the earliest stages of design so that the facilities for pedestrians are not after-thoughts.

To do this effectively, designers need to appreciate the characteristics and behaviour of all users of the facilities and their relationship to the various road design elements. The remaining parts of this section address these issues and develop the approach to providing a range of pedestrian facilities also catering to the needs of the users with a disability. For a more detailed treatment of these issues, reference should be made to the GTEP - Part 13 (Austroads, 1995).

5.4.2 Characteristics

5.4.2.1 Body Dimensions

Body depth and shoulder width are the most important dimensions used in the design of facilities. Shoulder width is the factor affecting capacity. The plan view of the average male human being has an area of about 0.14m² but the design envelope adopted is an ellipse, 460mm x 610mm, of area 0.21m² (Figure 5.13). This space is used to determine practical standing capacity.

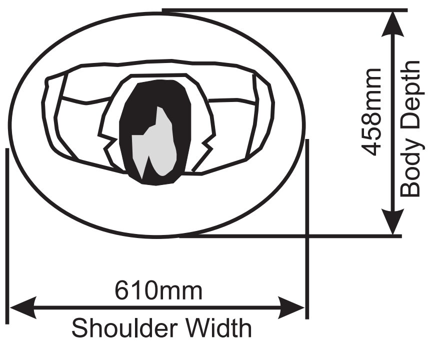

Figure 5.13 Body Ellipse (Austroads, 1995)

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5.4.2.2 Road Users with a Disability – Dimensions

Basic reach and geometric parameters have been established to assist in the design of components of the street system to accommodate people with disabilities (Austroads, 1999a). Figures 5.14, 5.15 and 5.16 provide details of these dimensions.

The factors to be considered are reach, visual limits, wheelchair dimensions and general spatial requirements. These can be used to determine the requirements for paths, sign location and clearances.

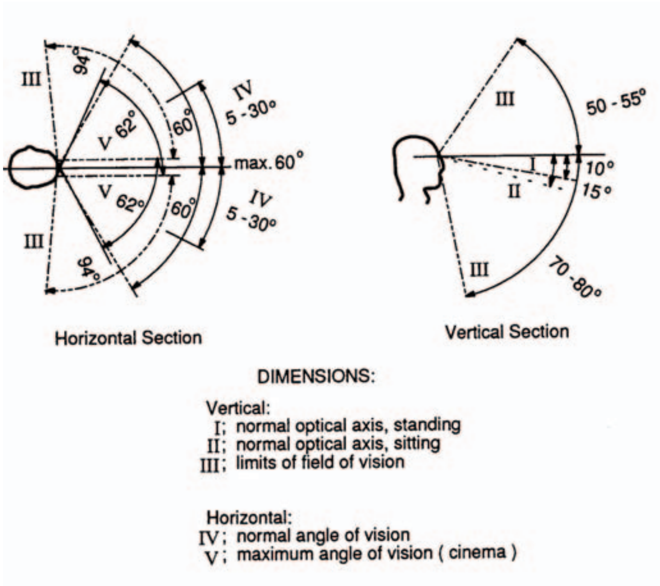


Figure 5.15 Limits to Field of vision (Austroads, 1995)

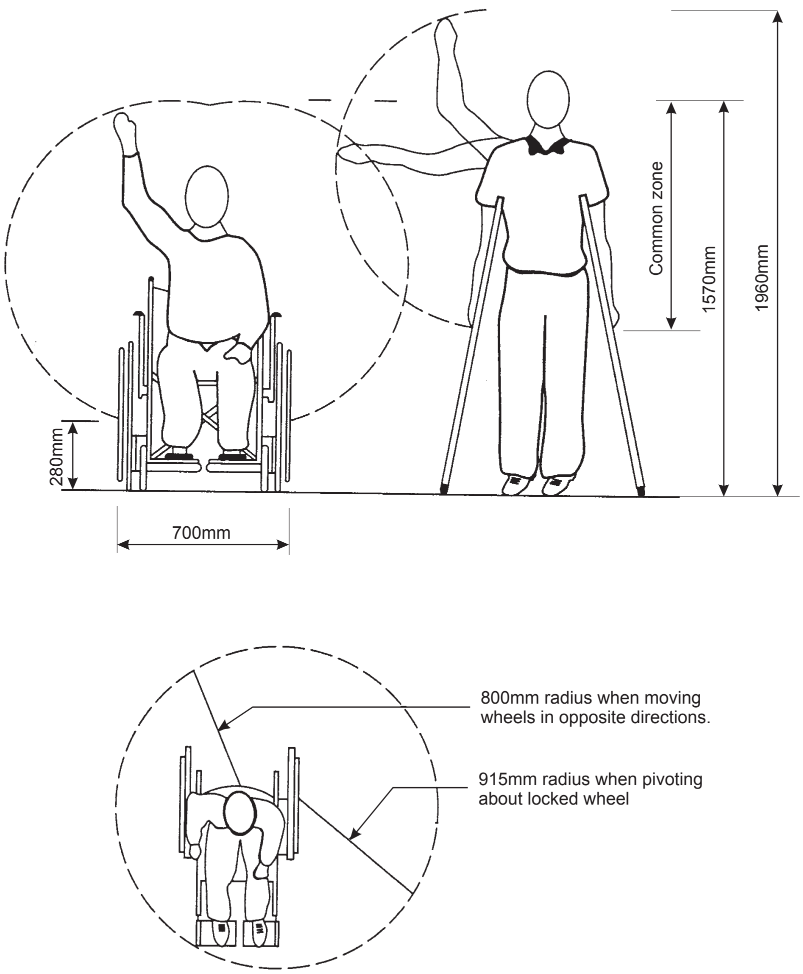
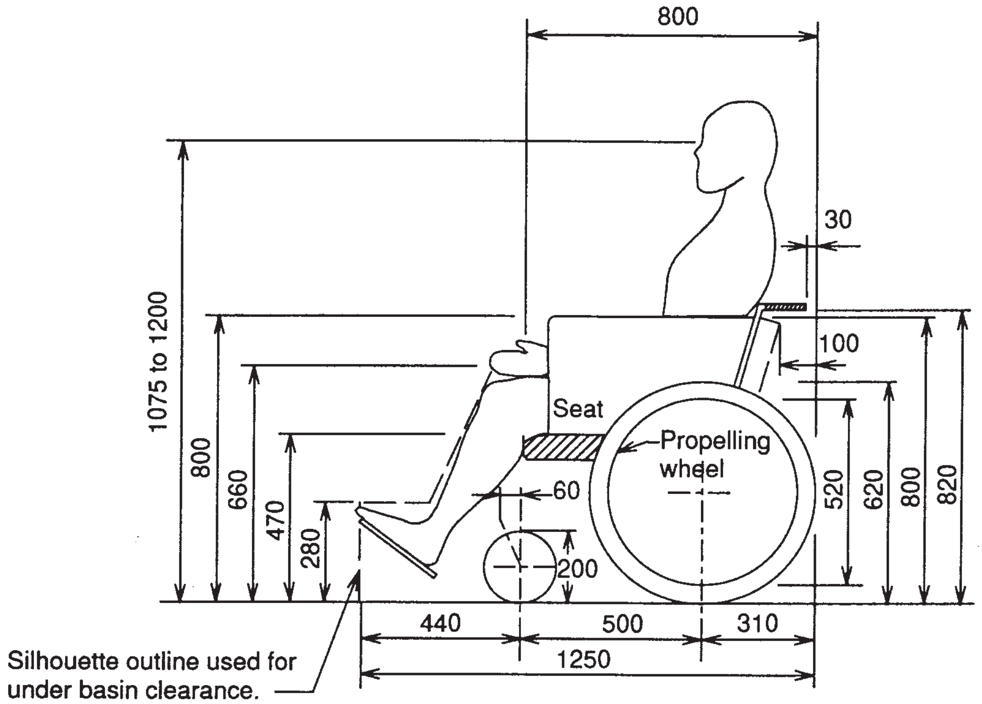
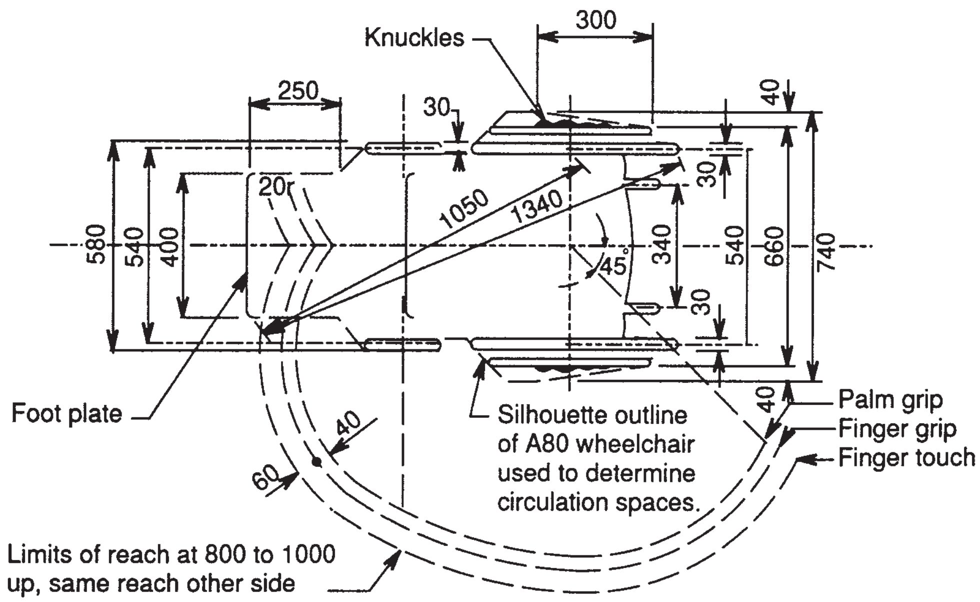


Figure 5.14 Reach dimensions for design for uses with a disability (Austroads, 1995)



Side View of A80 Wheelchair



Side View of A80 Wheelchair and Reach Limits

DIMENSIONS IN MILLIMETRES

Figure 5.16 Wheelchair Details (AS 1428.1 Supplement, 1990)

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5.4.2.3 Walking Speed

There is a great variation in walking speeds in the pedestrian population; the speed adopted being affected by age, sex, motivation, presence of other pedestrians and other traffic impediments. The distribution of free flow walking speeds varies as follows:

- Minimum walking speed - 0.74m/s.
- Maximum walking speed - 2.39m/s.
- Maximum speed of wheelchairs -10km/h = 2.78 m/s (wheelchairs are classified as pedestrians in legislation).
- Average unimpeded free-flow - 1.35m/s walking speed.

Calculation of green time at traffic signals is based on an average design walking speed of 1.2m/s but this is still faster than some pedestrians can manage. In particular, elderly pedestrians often adopt significantly lower speeds than the younger part of the population. Table 5.7 shows the range of speeds for senior pedestrians (Austroads, 1995).

Table 5.7 Walking Speeds for Senior Pedestrians

Walking Pace	Mean Speed	10 th Percentile Speed
Normal	1.13m/s	0.8m/s
Hurried	1.41m/s	1.0m/s
Rushing to catch a bus	1.71m/s	1.0m/s

At busy intersections where crowding will reduce walking speeds and where elderly people or people with a physical disability cross, the design walking speed should be reduced to 1.0m/s.

5.4.2.4 Walking Distances

People often try to minimise their walking distances and the acceptable distance for walking varies widely. The practical limit for most non-recreational walking is about 1.5km (approximately 15 minutes) for the average person with no disabilities; 800 m is the accepted maximum that most people will walk to public transport; 400m is the desirable maximum distance for people to walk to a bus stop. However, people are not likely to go out of their way to accommodate a design requirement by more than about 50m depending on the opposing traffic volumes. When people want to cross a road, they attempt to do it by the most direct path and will resist using facilities remote from where they are at the time.

5.4.2.5 Children

Research into the crashes involving child pedestrians has isolated a cluster of common factors. The cognitive and perceptual skills of children take time to develop. For example, until children are approximately nine years of age they have limited peripheral vision. Similarly, young children lack the cognitive skills to cope with complex traffic environments, particularly in terms of gap selection. Young children also tend to be impulsive and, being small, can be difficult for drivers to see.

Therefore, in areas where there are high levels of child pedestrian activity, designers must consider issues such as:

- hazards impeding the vision of drivers, particularly parked cars;
- the adequacy of traffic control;
- measures in place to control and channel pedestrian movement; and
- the speed of the traffic and related regulatory and warning signs.

5.4.2.6 Alcohol Impaired Pedestrians

"Drink walking" is an issue that has attracted increasing attention. To some degree, this problem may have been exacerbated by the success of drink driving countermeasures like Random Breath Testing (RBT), which have deterred drinkers from driving. As with driving, alcohol seriously impairs the judgment of pedestrians, increasing their risk of being involved in a crash. From a design perspective, there is a need to consider physical devices in the vicinity of public drinking venues that control or channel the movement of pedestrians (refer to Section 5.4.5), or devices to control the speed of traffic.

5.4.3 Pedestrian Capacity

5.4.3.1 Pedestrian Demand

The volume of pedestrians expected to use a footpath or other facility can be estimated from existing data and growth factors, or by assessment of the pedestrian generating characteristics of the land use in the area under consideration. The 15-minute peak is often used as the basis for evaluation but shorter times may be required where there is a low tolerance to delay and crowding. Surges of up to two times the average can occur within the peak period creating short term crowding.

Typical factors to consider in determining likely pedestrian requirements are:

- Office activity;
- Retail activity;
- Industrial activity;
- Residential; and
- Cultural and recreational activities.

Generation rates are given in Austroads GTEP - Part 13 (Austroads, 1995).

5.4.3.2 Capacity

The capacity of the various pedestrian facilities can be determined to allow a decision to be made on the size of facility to meet the demand. It is not likely that the design will be done on the basis of the capacity of the facility but the level of service will be the measure to assess the adequacy of the design.

One way of assessing level of service is to use the concept of pedestrian module size, which relates to the pedestrian's buffer zone or personal space. Encroachments into this personal space indicate a lowering of level of service. An expression of flow rate is:

$$P = S/M$$

where:

P = flow rate in pedestrians per metre width per minute (ped/m/min)

S = mean horizontal space speed (m/min)

M = pedestrian area module (m^2)

Pedestrian levels of service have been determined on a basis similar to traffic flow. They are based on the freedom to select walking speed, ability to pass slow moving people and the ease of cross and reverse flow movements at traffic concentrations. Figure 5.17 illustrates the six levels of service defined and Table 5.8 describes the conditions applying to these six levels.

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Table 5.8 Levels of Service for Horizontal Pedestrian Movement (Austroads, 1995)

Level of Service	Module Size M (m^2/ped)	Flow Rate (ped/m/min)	Sample Applications
A	>3.3	23	Public Buildings or plazas without severe peaking fit this level.
B	2.3 -3.3	23 - 33	Suitable for transport terminals or buildings with recurrent but not severe peaks.
C	1.4 - 2.3	33 - 49	Recommended design levels for heavily used transport terminals, public buildings or open space where severe peaking and space restrictions limit design feasibility.
D	0.9 - 1.4	49 - 66	Found in crowded public spaces where continual alteration of walking speed and direction is required to maintain reasonable forward progress.
E	0.5 - 0.9	66 - 82	To be used where peaks are very short (e.g. sports stadia or on a railway platform as passengers disembark). A need exists for holding areas for pedestrians to seek refuge from the flow.
F	0.5	Variable, up to 82	The flow becomes a moving queue, and this is not suitable for design purposes.

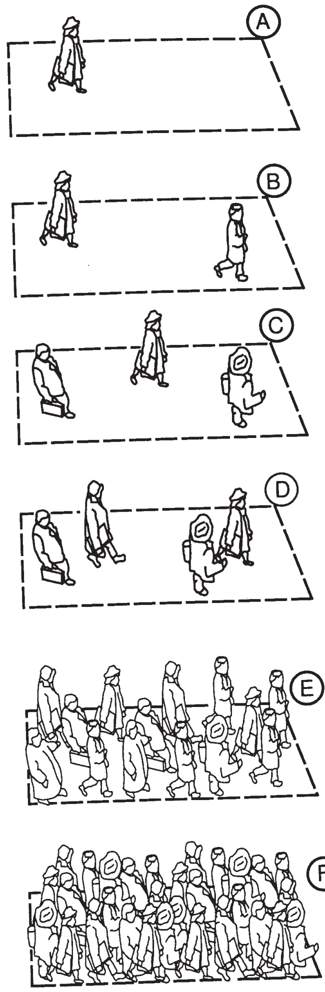

Figure 5.17 Illustration of Walkway Levels of Service (Austroads, 1995)

5.4.4 Planning Implications

Much can be done in the planning of the transport network to provide for the integration of pedestrian facilities into the overall system. Town planning can locate land uses to minimise the conflict between road traffic and pedestrians but existing development has often been done without taking these factors into account.

The pedestrian is an essential part of the transport system but is a vulnerable road user and should have direct, safe and easy access to the transport system. Desirably, the pedestrian network should be separate from, but integrated with the main road and public transport system. Security is an important issue and appropriate lighting, overall visibility, telephones and surfacing of paths must be used.

Classes of road users that are particularly vulnerable are:

- older pedestrians;
- those with a disability;
- children; and
- alcohol impaired pedestrians.

Planning and design should take account of the characteristics of these road users.

In general, as the intensity of land use increases, the requirement for pedestrian facilities becomes greater and the density of pedestrian facilities increases. Thus, as a driver approaches an urban area, the expectation should be that of increasing pedestrian activity, increasing frequency of pedestrian crossings and a consequent need for greater care and lower speed. Design should encourage this expectation.

The actual measures to be adopted to integrate the pedestrian into the transport system are heavily influenced by the functional road hierarchy. This hierarchy can be conveniently considered as comprising Local Streets, Collector Streets and Arterial Roads as far as pedestrians are concerned.

The Australian Model Code for Residential Development (AMCORD, 1995), specifies pedestrian and cyclist needs as an integral part of the local transportation network. It defines local streets as having traffic volumes up to 2,000vpd. On these streets, providing separate pathways, open spaces for pedestrians and play areas for children free from vehicular traffic, and minimising through traffic may achieve reduction of pedestrian/vehicular conflict.

Collector roads are defined as having traffic volumes up to 6,000vpd. Footpaths removed from the general path of vehicles, kerb extensions, pedestrian refuges, signing, speed deterrent devices, parking restrictions, and speed restrictions may be appropriate in sections of these streets. Formal pedestrian crossing devices may be necessary at schools, near recreational facilities, shopping areas, hospitals or other areas where high use by vulnerable groups could be expected.

Arterial roads have the principal function of moving traffic, and physically separated facilities for pedestrians are desirable.

The next level of facilities includes zebra crossings, pedestrian operated signals, pelican crossings, kerb extensions and central refuge islands.

Guidelines for selection of appropriate mid-block pedestrian facilities according to road classification are given in Table 5.9. The Traffic and Road Use Management Manual (Main Roads 2002) also includes some guidelines.

Table 5.10 provides a useful classification system for pedestrian facilities.

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Table 5.9 Guidelines for the Selection of Mid-Block Pedestrian Facilities (Austroads, 1995 and Queensland Transport, 2000)

	Pedestrian Operated Signals	Pedestrian Operated School Signals	Pedestrian (Zebra) Crossing	Children's Crossing	Pedestrian Refuge	Footpath Extension (Kerb)	Road narrowing indented parking kerb extension, line marking
Primary Arterial*	A	A	C	C	B	C**	C
Secondary/ Sub-Arterial	A	A	B	B	B	B	C
Collector/Local Crossing Road	C	B	B	A	A	A	A
Local Street	Pedestrian device should not be used					A	A

* Non-Motorway -on motorways grade separation must be used.

** Footpath extension may be appropriate on primary arterial in rural town

A - most likely to be the appropriate treatment

B - may be an appropriate treatment

C - inappropriate treatment

Notes:

1. The installation of any of these devices is to be in accordance with the Queensland Manual of Uniform Traffic Control Devices. It is important that they be installed only when warranted as their indiscriminate use leads to both drivers and pedestrians ignoring them with consequent safety problems. On the other hand, too many interruptions to a dense traffic stream may cause congestion and increase traffic crashes.
2. Where installed, these facilities are most useful where they are placed on, or as close as practicable to, the desire line, with minimum possible waiting times for pedestrian crossings.

Table 5.10 Classification of Pedestrian Facilities (Austroads, 1995)

Classification	Objectives	Treatments
Time Separated Facilities	To minimise conflict between pedestrians and vehicles by allotting short time periods for use of a section of road by pedestrians alternating with periods of use by vehicles	Pedestrian crossings (Zebra) Children's crossings Pedestrian actuated traffic signals (mid-block) Pedestrian crosswalks at signalised intersections
Physical Pedestrian Aids	To increase the safety of pedestrians by use of physical aids within the roadway so as to reduce conflict between pedestrians and vehicles and simplify the decisions which both pedestrians and drivers have to make	Pedestrian refuges Traffic islands Medians Kerb extensions Loading islands Safety zones Pedestrian fencing
Physically Separated Facilities	To increase the safety of pedestrians by eliminating conflict between pedestrians and vehicles.	Subways and bridges Pedestrian malls
Integrated Facilities	To provide an environment in which pedestrians and vehicles may share existing road space in a largely unsupervised manner	Pedestrian warning signs Shared zones School zones Local area traffic management schemes Lighting

5.4.5 Design Implications

5.4.5.1 Footpaths / Walkways

The term “footpath” is usually applied to the area adjacent to the road provided for use by pedestrians (refer to Chapter 7 of this manual). The footpath grade follows the grade of the road in most cases. On new roads, the needs of all potential users of the footpath should be considered and appropriate features provided. On existing roads, the space available and property access requirements may make it difficult to make adequate provision for users with a disability and it may be impracticable to add features to cater for them.

A “walkway” (footway) refers to a purpose designed facility for pedestrians and is usually separate from a road. Walkways must be usable by all members of the community and the design must consider the needs of all potential users.

Chapter 7 of this manual provides details of cross section requirements for footpaths beside roads. Austroads (1995) provides a detailed discussion on footpath widths for various circumstances.

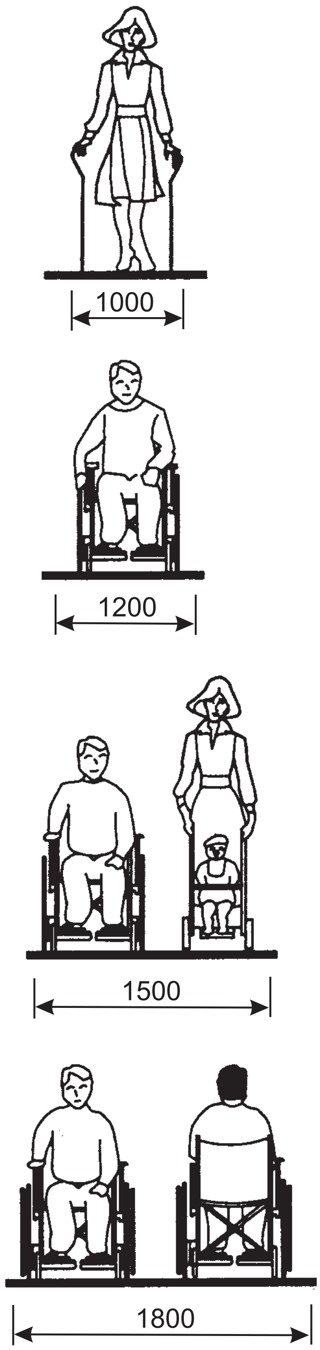
The basic walkway requires a general minimum width of 1.2m. A clear width of 1.5m allows a wheelchair and a pram to pass and 1.8m allows two wheelchairs to pass comfortably (Figure 5.18). To provide for the specific needs of those with a disability (including those in wheelchairs), footways should possess all of the following:

- A width between 1.5m and 1.8m (minimum).
- As level a grade as practicable - appropriate longitudinal grades are defined in AS1428 and summarised in Table 5.11.
- Crossfalls not steeper than 1 in 50 with an absolute maximum 1 in 40.
- Vertical clearance over the full width of the footway not less than 2.4m with 2.7m preferred (refer to Chapter 7 of this manual).
- No manhole covers and grates. If this is not practical, they should be of non-slip surface and flush with the footpath. The openings of drainage grates should be not more than 13mm wide and not more than 150mm long (AS1428) and arranged perpendicular to the direction of pedestrian movement to prevent wheelchair wheels and walking sticks from being trapped in the grating.
- An unobstructed passage free from all obstacles including, trees, signs, posts and bicycles.
- A smooth, obstacle free surface (i.e. maintained in this condition).
- Guidance devices and tactile surfacing as integral parts of the design (refer to AS1428).

The above widths are the minimum and for locations where pedestrians gather such as at the entrance to schools and associated crossings, at recreation facilities and important bus stops, widths up to 5m may be appropriate.

Austroads (1995) also gives other requirements for footpaths such as height (vertical) clearance, avoidance of obstructions, covers and grates, setback distance, changes in level, kerbing and kerb ramps, steps, stairs and ramps, gradients, crossfalls and surface treatments.

WALKWAYS AND FOOTPATHS



(a) A clear width of 1000m is adequate for people with ambulant disabilities, just allows passage for 80 percent of people who use wheelchairs, and is in accordance with AS 1428.1

(b) People who use wheelchairs require a clear width of 1200mm

(c) A clear width of 1500mm allows a wheelchair and a pram to pass

(d) To allow two wheelchairs to pass comfortably, a clear width of 1800mm is required

DIMENSIONS IN MILLIMETRES

Figure 5.18 Path Width Requirements for Various Users (AS 1428.2, 1992)

Table 5.11 Longitudinal Grade Requirements for Walkways.

Aspect	Steep Ramp	Ramp	Walkway	Footpath
Grade	1 on 8	1 on 14 to 1 on 19	1 on 20 to 1 on 33 or flatter	Grade of road[3]
Maximum elevation	190mm	<1.0m preferred	Not relevant	Not relevant
Spacing of Landing's	Not applicable	Grade 1:14 -6m Grade 1:19 - 14m[1]	Grade 1:20 — 14m Grade 1:33 — 25m[2]	Not usually required[3]
Kerb	Not applicable	Required	Not required	Not required
Hand rail	Not applicable	Required	Not required	Not required
Fence	Not applicable	As required	As required	As required
Usage	Kerb crossings	Pedestrian only path	Pedestrians only and shared facilities	Pedestrians (bicycles in some circumstances)

Notes:
1. For grades in between 1 on 14 and 1 on 19, at intervals obtained by linear interpolation.
2. For grades flatter than 1 on 33, no landings are required. For grades between 1 on 20 and 1 on 33, landings should be placed at intervals obtained by linear interpolation
3. Where the grade of the road exceeds 3%, and access by wheelchair bound people is required, consideration should be given to applying the standard for walkways. This is particularly applicable in the vicinity of facilities attracting these users.

5.4.5.2 Surface Treatments Including Tactile Indicators

Because of decreased mobility of some pedestrians, and the sensitivity to jarring and vibration of some people in wheelchairs, the surface of footpath pavements should be smooth and not slippery.

Small ridges and protrusions as low as 6mm can cause some people to stumble and fall. Surfaces should not deviate more than 5mm from a 500mm long straight edge laid anywhere on the surface (Austroads, 1995). For these reasons, the location of tactile indicators for the visually impaired must be chosen with care.

The merits of commonly used surface treatments in relation to those with a disability are considered below (Austroads, 1995).

Concrete and Asphalt

Hard smooth surfaces such as concrete and asphalt are generally quite appropriate. Expansion/contraction joints in concrete should be no wider than 13 mm and concrete surfaces should be brushed perpendicular to the direction of movement to provide increased coefficient of friction.

Pavers and Bricks

Because glazed surfaces can become very slippery when wet, pavers and bricks used on footways in external areas should not be glazed. It is essential that when used as footpaths they be laid on a firm well-compacted base (preferably a concrete base).

Pavers should be uniform in colour as people with slight visual impairment frequently use differences in pavement colour as a means of guidance.

Loose Surface Material

Some physically disabled people find difficulty in walking on loose surface materials such as exposed aggregate, gravel, sand, soil, grass and tanbark. Such surfaces are only appropriate on some recreational routes since they can present severe difficulties to people in wheelchairs.

Tactile Indicators

Tactile ground surface indicators have been designed to give directional guidance and warning of hazards to vision impaired pedestrians. They are detected through contact by foot or cane.

They have been made in synthetic rubber, ceramic and clay tiles and stamped concrete. Obviously some will be more suited to indoor and/or lightly trafficked areas rather than outdoor footpaths. Guidance strips and tactile tiles, commercially produced, are commonly used on footpaths and shopping complexes.

All must conform to the Australian Standard AS1428.4, which provides for warning indicators and directional indicators. AS1428.4 sets out details of their use and provides examples of typical applications.

Note that there is a conflict between the needs of those in wheelchairs and the visually impaired. Care is needed to ensure that this conflict does not create undue difficulties for either group.

Refer also to the appropriate Main Roads' Standard Drawings for details of applications.

5.4.5.3 Other Facilities

The control of pedestrian/vehicle interaction can be achieved by means of one or more of the following strategies:

- Time separated facilities;
- Spatial separation (including physical pedestrian aids);
- Physically separated facilities; and
- Integrated facilities.

Table 5.10 defines the objectives of these classifications and gives examples of the treatments. The appropriate choice of treatment depends on the type of road.

Time Separated Pedestrian Facilities (Traffic Signals)

Traffic signals are installed whenever the degree of hazard or conflict between motorists and pedestrians is sufficient to warrant imposing specific regulatory controls on the driver or, in some circumstances, on the pedestrian.

When considering the use of traffic signals, it is desirable to ensure that they are only provided where sufficient pedestrian demand exists, as drivers who use the route regularly will tend to ignore the presence of a device if they seldom see it used.

Similarly, pedestrians tend to ignore or misuse a device if traffic volumes are so low as to make its use unnecessary on most occasions. Conversely, frequent random interruptions to a dense traffic stream may create congestion and the likelihood of accidents, and a physically separated facility may be warranted. These factors highlight the need for care in the setting and observance of pedestrian volume guidelines for each type of crossing facility.

Minimising the time pedestrians have to wait for traffic signals to change will maximise compliance with crosswalk signals. This needs to be balanced against vehicle waiting time. It is possible to achieve coordination of pedestrian signals along a road in harmony with the signal cycle times. This possibility should be explored.

Refer to the Queensland Manual of Uniform Traffic Control Devices - Part 10 (Main Roads, 1999) for details on guidelines, installations, design and signage of pedestrian crossings. The Traffic and Road Use Management Manual includes guidelines on traffic signal installations.

Pedestrian Crossings

For pedestrian crossings, both the approach sight distance (ASD) and the crossing sight distance (CSD) are to be considered:

- Approach Sight Distance (ASD) is the minimum required for a driver to see the crossing and alert him/her to a possible pedestrian hazard, allowing time to react and brake, stopping the car before the crossing, if necessary. It is the distance from a driver's eye height of 1.15 m to the road surface at the crossing.

- Crossing Sight Distance (CSD) is that required for a pedestrian to see approaching vehicles and decide if he/she has time to cross the road safely. For wide crossings, this distance may be considerably longer than the ASD.

Both ASD and CSD may be calculated from procedures shown in Austroads (1995) and in Chapter 13.

Pedestrian crossings should not be constructed at horizontal curves or immediately past the crest of a vertical curve because of the restricted sight distance available. Pedestrians may have walking disabilities and may also be visually impaired. Pedestrian crossings and signals should be designed to allow for these factors.

Crossings should:

- Be clearly marked as per the Manual of Uniform Traffic Control Devices (MUTCD, Main Roads, 2003).

- Have a clear delineation between road and footpath with at least colour contrasts between the two (e.g. asphalt and concrete) and perhaps, tactile guidance (see pavement design below).

- Be well lit (refer to Chapter 17 of this manual).

- Have kerb cuts or kerb ramps (Austroads, 1995 and Main Roads' Standard Drawings 1446 and 1447) to allow smooth transition from a raised footpath to road level. These ramps should not be located on a kerb radius unless there is no left-hand turn traffic, and should be on the safe side of stop signs.

- Crossings must be clear of parked vehicles and adequate sight distance must be provided to the pedestrian crossing. This may require banning parking for some distance on each side of the crossing, the distance being determined for each case to ensure that parked vehicles will not obscure the required sight lines.

- Include a kerb extension to shorten the travel path across the road where practicable (Austroads, 1995).

- Have a pedestrian refuge island on wide carriageways.

Signals and Signs

Those with a disability will need special consideration. In particular, those with a visual impairment are especially disadvantaged. Visual impairment ranges from the colour blind, to the partially blind and to those who have zero vision.

The most common form of colour blindness is the inability to distinguish red or green although there are those who have less than average perception of one or more colours. Standardisation of traffic signals with the red signal always on top helps to overcome a deficiency in red/green differentiation.

International symbols and different shape signs facilitate sign recognition not only for those visually impaired, but also for those with normal sight. This emphasises the need to use the standard signs defined in the MUTCD.

More specifically for those with a disability, including those other than the visually

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impaired, some general principles for signals and signs include:

- using audible signals - audible pedestrian signals are of particular help to the visually impaired, but also benefit the general public;
- placing signs at a height more easily read by people in wheelchairs (refer to Figure 5.14 and Austroads, 1995);
- ensuring push buttons for pedestrian lights are large enough to facilitate use by manually or visually limited people;
- locating traffic signal posts and buttons at standard positions for the same reason;
- using colours in signs to contrast with the background colours;
- using light coloured letters on a dark background, as the most successful colour combination;
- ensuring lettering on signs is large enough to be compatible with the viewing distance and has the recommended typeface;
- using national and international symbols especially for those who cannot read; and
- providing appropriate signs in Braille for the blind for vital information (e.g. directional signs to public facilities such as toilets, telephones and service information at major public transport stops).

Pedestrian signals assist pedestrians to cross a road in safety. The commonly used minimum walking speed of 1.2m/s covers the majority of cases but special needs of the elderly or infirm pedestrians will also need to be considered at some locations (refer to Section 5.4.2).

Devices such as an electronic pedestrian detector, which scans the crossing and allows longer time for a disabled pedestrian to cross in safety, are available. Conversely the green signal would stay on for a shorter period than average for a crossing that is used only by faster walkers.

Loop detectors at the rear of kerb ramps and similar to those on roadways for vehicles, may be used to detect wheelchairs and steel framed perambulators at pedestrian crossings. If used, detecting a wheelchair or perambulator would override the normal signal phase. Bicycles may also be detected by such loops.

Physical Pedestrian Aids

Physical (or spatial) separation of pedestrians from vehicles within the roadway may be achieved by providing pedestrian refuges, medians, and safety zones within the pedestrians’ path across the traffic stream. Providing street lighting in association with these aids should be considered.

Physical pedestrian aids are used to reduce the exposure of pedestrians to vehicular traffic and may be used in conjunction with traffic signals. They may be used on wide heavily trafficked roads where the number of pedestrians crossing is insufficient to warrant traffic signals. Pedestrians might have walking disabilities and might also be visually impaired. Pedestrian crossings and signals should be designed to allow for these factors.

The MUTCD (Main Roads 2003) and the Traffic and Road Use Management Manual (Main Roads 2003) provide guidelines, and some installation details, drawings and signage details for:

- pedestrian refuges, traffic islands and medians;
- kerb extensions;
- loading islands and safety zones; and

- pedestrian fencing.

Pedestrian refuges, medians and kerb extensions have the effect of narrowing the road, thereby reducing the time pedestrians are exposed to traffic when crossing the road. Providing these devices can also have the added benefit of helping to reduce the speed of passing motorists by giving additional cues of the need to reduce speed.

When designing physical pedestrian aids, it is important to ensure that the device will not create a hazard for other road users. The following issues must be considered:

- The devices must not encroach on the travel routes of other road users, particularly cyclists.
- Devices must be well lit (refer to Chapter 17 of this manual), delineated and appropriately signed to ensure they do not become a hazard at night.
- Crossings should have kerb cuts or kerb ramps (Austroads, 1995 and Main Roads' Standard Drawings Nos 1446 and 1447) to allow smooth transition from a raised footpath to road level. These ramps should not be located on a kerb radius, and should be on the safe side of stop signs. Main Roads Standard Drawing No 1446 provides details of a ramped pedestrian crossing with hazard tactile indicators in accordance with AS 1428.4.
- Bollards, fencing or vegetation installed on these devices must not obscure child pedestrians (fencing should not include rigid horizontal components that could become spears if hit by an errant vehicle).
- Appropriate kerbing must be used (refer Chapter 7of this manual);
- The facilities should be accessible to people in wheel chairs and people with prams.
- A kerb extension to shorten the travel path across the road (Austroads, 1995) is desirable where practicable.
- A pedestrian refuge island on wide carriageways assists all pedestrians (including those with a disability) to cross safely.

Further details and installation requirements are included in the MUTCD.

Physically Separated Facilities

Physically separated facilities are used when the degree of hazard or conflict is so high as to require that vehicles and pedestrians cannot share the same carriageway. Physical separation may be lateral (e.g. separate footways, pedestrian malls), or vertical (e.g. bridges and subways), depending upon particular circumstances.

Subways and bridges provide the highest degree of protection from traffic for pedestrians and minimum disruption to road traffic, but there are practical limitations to their installation and they are usually expensive. In addition they may require pedestrians to travel up to twice the distance they would otherwise have to walk if crossing the road at grade.

People throwing objects from overpass bridges can be an issue and some form of caging may be required to ensure security for, and the safety of, the traffic below. The aesthetics of the caging must be an important consideration in its design. For design requirements and the risk assessment methodology, refer to Main Roads' policy, Reduction of Risk from objects Thrown From Overpass Structures onto Roads, and its accompanying Technical Guidelines for the treatment of overhead structures – objects thrown or dropped. A perceived lack of personal security may result in poor usage of subways notwithstanding the provision of measures to discourage pedestrians crossing at grade (refer to Chapter 3 of this manual). The proposed location of subways should consider this factor. Refer to Chapter 7 of this manual for further discussion and cross section requirements.

When locating and designing subways and bridges for pedestrians, the access to the facility should be attractive to encourage its usage. This may require adjustment of property access points (e.g. gates) and of bus zones. In some cases, fences may be necessary to prevent pedestrians crossing the road at grade or to guide them to the facility.

In assessing the need for subways and bridges, planners and designers should take account of site conditions, accident history, pedestrians and vehicular volumes and delays, as well as likely usage by school children and people with a disability. The principles set out in this section should be applied to the design of the facility.

When comparing the cost with that of possible alternatives, savings attributable to the following should be taken into account:

- reduction of accidents;
- reduction of delay to vehicular and pedestrian traffic; and
- elimination of any existing pedestrian facility, if appropriate.

Appropriate signing will be necessary and must be in accordance with the MUTCD.

Pedestrian malls are reserved for pedestrian traffic to the exclusion of all or most motor vehicles during part or all of a day. Where some motor vehicles are allowed (e.g. vehicles for loading/unloading of goods or for maintenance of buildings in the mall), they are usually controlled by permit. Providing for emergency vehicles is essential.

Integrated Facilities

Integrated facilities are applied to conditions where the presence of pedestrians, or pedestrians with a special characteristic (e.g. school children), may not be obvious but where the degree of potential hazard or general conflict is not such as to call for time or spatial separation of the two traffic elements.

The MUTCD provides details of the design of these facilities and the required signage. Austroads (1995) contains additional data not included in the MUTCD.

Warning signs may be used to warn motorists of the likely presence of pedestrians on or crossing the road other than at a specific pedestrian facility.

Warning signs alone will normally be necessary only where:

- pedestrian volumes are significant but insufficient to justify a pedestrian crossing (zebra) or traffic signals;
- the presence of pedestrians may not be expected; or
- the pedestrian demand extends over a length of road.

Details of signs required and their installation are included in the MUTCD.

Shared zones are generally constructed in areas where the competing demands of pedestrians, moving vehicles and parking require a form of control which allows complete pedestrian mobility whilst at the same time enhancing pedestrian safety. In such zones a speed limit of 10 km/h is usually considered appropriate.

The most important element in a shared zone is to alter the environment to make it obviously different from other streets. This can be achieved by the use of different coloured and textured paving, by the use of full width paving between property lines and by judicious and aesthetic placement of planters and other landscaping.

Shared zones are often provided on roads in commercial or shopping areas. They are appropriate where all of the following conditions exist:

- the road is not a through route;
- pedestrian movement predominates;
- reasonable vehicle movement is required; and
- it is desired to clearly establish the priority of pedestrian movement.

School Zones

A school zone is a time based speed zone, which may be installed to regulate vehicle speeds in the vicinity of schools. Additional engineering treatments (e.g. road width reduction), while not essential to the installation of a school zone, can improve driver compliance with the reduced speed limit.

Queensland school zone speed limits are:

- 60 km/h for zones normally 70 to 80km/h.
- 40 km/h for zones normally 50 to 60km/h.

Where a school zone is required on a road where the speed limit is greater than 80km/h, a permanent 80km/h speed zone must be installed to provide buffer zones for the 60km/h school zones.

Times of operation for school zones are defined in the School Environment Safety Guidelines (Queensland Transport, 2000).

The school zone should extend for the length of the school frontage. Notwithstanding this, the minimum length of a school zone should not be less than 200m and the school zone should not extend more than 100m beyond the limits of the school frontage. Where possible, the school zone on the main school frontage should be installed such that the point where most children cross is centred in the school zone.

Signs and markings are to be in accordance with the MUTCD. If the length of the school zone is longer than one minute's travel time or where there are major intersections within the school zone, repeater signs should be installed at appropriate locations to remind drivers of the school zone speed limit.

School zones are provided on roads adjacent to schools where the presence of the school can be readily perceived by motorists, with the following exceptions:

- on multi-lane roads;
- on roads where no kerb side parking is permitted in the proposed school zone and pedestrian actuated signals, or grade separated facilities have been installed; and
- at pre-schools, kindergartens or day-care centres (an exception is a pre-school next to an eligible school, in which case the school zone may be extended to include the pre-school).

At the excluded locations other traffic engineering treatments are considered more effective in improving safety of school children.

Local area traffic management schemes aim to reduce traffic volumes and speeds to reduce the number and severity of accidents to pedestrians in the area. The GTEP Part 10 (Austroads, 1988d) provides details of a range of local area traffic management schemes.

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5.5 Bicycles

5.5.1 General

Studies have shown that bicycle travel accounts for 2% to 9% of all journeys in various towns and cities in Australia. The Queensland Cycle Strategy aims to increase cycling by 50% by 2011 and 100% by 2021. It aims to achieve this by a range of measures to:

- Improve the network of bicycle routes throughout the State;
- Improve the safety and security of bicycle riders;
- Integrate cycling and public transport;
- Provide convenient and secure end of trip facilities; and
- Promote and encourage cycling.

Convenient and safe bicycle facilities on roads are a prerequisite for this objective to be realised. Main Roads' Policy for Cycling on State Controlled Roads defines the approach to be adopted for providing bicycle facilities on State controlled roads in Queensland.

As bicycles are defined as vehicles in road regulations, they have a right to use the road system unless specifically excluded (e.g. on some motorways and controlled access highways). Bicycles are also allowed to travel on footpaths in Queensland unless specifically prohibited by a local law.

The safety principles for bicycle facilities are similar to those for pedestrians shown in Section 5.4.1. Substituting the word "cyclists" or "bicycles" for "pedestrian(s)" in that Section will give the appropriate principles.

Obviously, the design of facilities will be different, as bicycles travel faster and take up more space than pedestrians do.

The cycle network is only partially developed in most areas in Queensland, and long lengths of cycle facilities are uncommon. However, for safety reasons, cycle paths must not end at locations that could place users at risk. It is poor design practice to terminate a cycle facility because the road narrows and no alternative route is available.

The following sections provide an overview of design practice with respect to bicycles. More details can be found in the GTEP Part 14 (Austroads, 1999a), and MUTCD (Main Roads 2003)

5.5.2 Characteristics

Cyclists may be divided into the following five broad groups:

- Primary school children;
- Secondary school children;
- Recreational cyclists;
- Commuter cyclists (e.g. work, shopping); and
- Sports cyclists in training.

For any specific locality, the needs of all the potential users should be considered.

All will share common needs such as a smooth riding surface, a safe travelling corridor including connectivity of routes to potential destinations and somewhere to park the bicycle at the end of the trip.

Primary school children, particularly the younger ones, do not have developed road skills and awareness of dangerous situations and should preferably be provided with off road facilities.

Secondary school children are more adventurous and may prefer public roads to off-road paths, particularly if the latter requires a longer journey.

Recreational cyclists prefer most of their travelling on the quieter off-road paths and streets and are usually not in any hurry to reach their destination. However, they will use the road system for longer journeys. For example, cycle tourers will travel extremely long distances within and between towns.

Commuter cyclists may have varying needs. Some will want to reach their destination in the shortest time, regardless of traffic conditions, and the others are prepared to take longer on less stressful routes. Secure bicycle parking facilities at the end of the journey are required, especially where stops for long periods occur.

Sporting cyclists travel long distances for training and will be found on arterial roads and highways. Many of these cyclists will also commute to work.

5.5.3 Types of Facilities

In considerations of whether special or separate facilities should be provided for cyclists, the following definitions apply: (refer to Table 5.12 and Austroads, 1999a):

- *Full integration* - motor vehicles and cyclists share the same lane.
- *Partial integration* - the left side lane shared by motor vehicles and cyclists is widened to allow motor vehicles to overtake cyclists without changing lanes.
- *Partial separation* - a separate lane or sealed shoulder is provided for cyclists (and parked vehicles).
- *Full separation* (i.e. off-road facilities) - a separate path away from the carriageway is provided for cyclists. This path may be exclusively for cyclists or shared with pedestrians.

The degree of integration or separation to be adopted depends on:

- Vehicle volumes;
- Bicycle volumes (12 hour two-way);
- Presence of parking; and
- Design speed of the road.

Off-street bicycle paths provide safety and access to local roads away from the high speed and limited access roads, but may also be warranted for other reasons such as:

- recreational value, allowing leisurely trips to parks and scenic areas etc;
- providing for inexperienced cyclists such as primary school children; and
- providing facilities that can also be used by pedestrians.

Appendix 5B discusses facilities associated with motorways.

5.5.4 Road Design Criteria for Cyclists

5.5.4.1 General

Bicycle operating space is defined in Figure 5.19. A desirable lateral clearance between bicycle operating spaces of 1.0m is required on cycleways where speeds may reach 30km/h. The required clearance to rigid obstacles beside the cycleway is 1.0m (refer to Austroads, 1999a).

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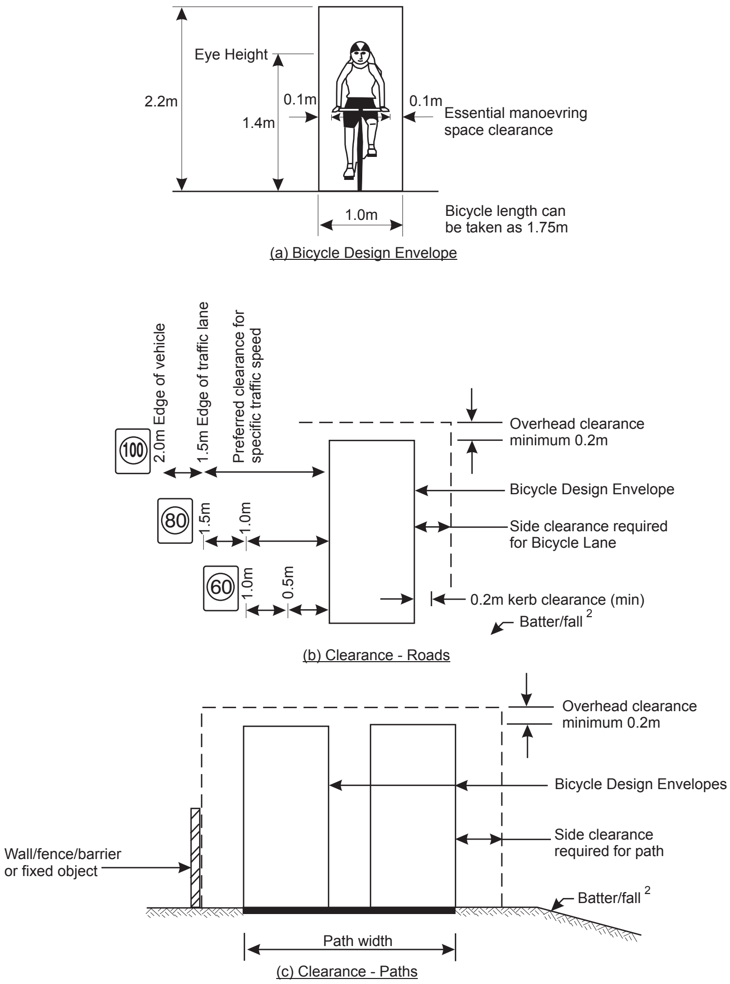
Table 5.12 Relationship of Bicycle Facilities Required and Traffic Volumes

Level of Facility	Vehicle Vol. (AADT)	Bicycle Vol.** (12 hr two-way)	Comments
Level 1: Full Integration	<3000vpd and <300vph	any	
Level 2: Part Integration	> 3000vpd	<50	
Level 3: Part Separation	> 3000vpd	>50 <200	Generally acceptable except for some limited access and/or high design speed roads or where the special benefits of Level 4 facilities are not required.
Level 4: Full Separation	> 3000vpd	>200	Off road facilities required. Consider potential shared use with pedestrians.
* Or where inexperienced riders are prevalent. ** Note that bicycle usage may increase significantly when a facility is provided.			



Note: below refer to Austroads 1999a
1 - See Reference 10, Section 6.3.5. for clearances to trees and other obstructions
2 - See Reference 10, Section 7.6.2. for protection measures where road/path shoulder falls away from road

Figure 5.19 Bicyle Operating Space (Austroads, 1999a)

Passing heavy vehicles exert a side "wind" force on cyclists and it is desirable to provide adequate clearance between the bicycle envelope and these vehicles. At motor vehicle design speeds of 60, 80 and 100 km/h, clearance between the cyclist envelope and a truck of 1.0, 1.5 and 2.0m respectively are desirable for cyclist safety. These clearances are not always achievable and absolute as well as desirable lane widths are shown in other sections of this Manual (refer to Chapter 7 of this manual).

Cyclists typically travel at 20 km/h to 30 km/h and can achieve downhill speeds of 50 km/h. Roads and paths should ideally be designed to allow travel at these speeds; incidences of compulsory stop or give way controls should be minimised (where it is safe, possible and practical to do so).

5.5.4.2 Gradients

Grades should be as flat as possible to avoid the hazard of down hill riding and to accommodate ease of riding up hill. Desirable maximum grades of 3% should be applied with a maximum of 5%. If steeper grades are unavoidable, their length must be limited and flatter sections used at regular intervals. Steep grades must not be combined with sharp horizontal curvature (i.e. curves < 200m radius).

On the steeper grades, experienced cyclists work the bicycle from side to side and inexperienced cyclists tend to wobble. Wider lanes should be used to allow for this operating characteristic.

Austroads (1999a) provides comprehensive guidance on this subject.

5.5.4.3 Horizontal Curvature

If possible, a generous alignment should be used to provide good operating characteristics. There will be constrained situations where smaller radii will be required. Table 5.13 provides data on acceptable curve radii for various design speeds. On the approach to intersections or on "hair-pin" bends in steep terrain, radii as small as 5m may be appropriate. In general, radii of 15m are considered "sharp".

Table 5.13 Minimum Horizontal Curve Radii (Austroads, 1999a)

Speed (km/h)	Superelevation (%)					
	0	2	3	4	5	6
20	10	10	9	9	9	9
30	25	24	23	22	21	21
40	50	47	45	43	41	41
50	94	86	82	76	73	73

5.5.4.4 Sight Distance

Cyclists have similar needs to drivers of vehicles in requiring adequate sight distance to negotiate horizontal and vertical curves safely. Parameters used to calculate stopping distance are:

- Perception/reaction time - 2.5s.
- Eye height - 1.4m.
- Object height - 0m.
- Coefficient of longitudinal deceleration - 0.25.

Stopping distance is required to be used:

- for intersection design;
- in setting out alignment of paths;
- in positioning terminals and handrails;
- at entries to underpasses;
- for landscaping in the field; and
- otherwise to ensure the safety of cyclists.

Figure 5.20 provides information on minimum stopping distances, Figure 5.21 provides the minimum length of crest vertical curves to meet the design requirements and Figure 5.22 sets out the lateral clearances on horizontal curves

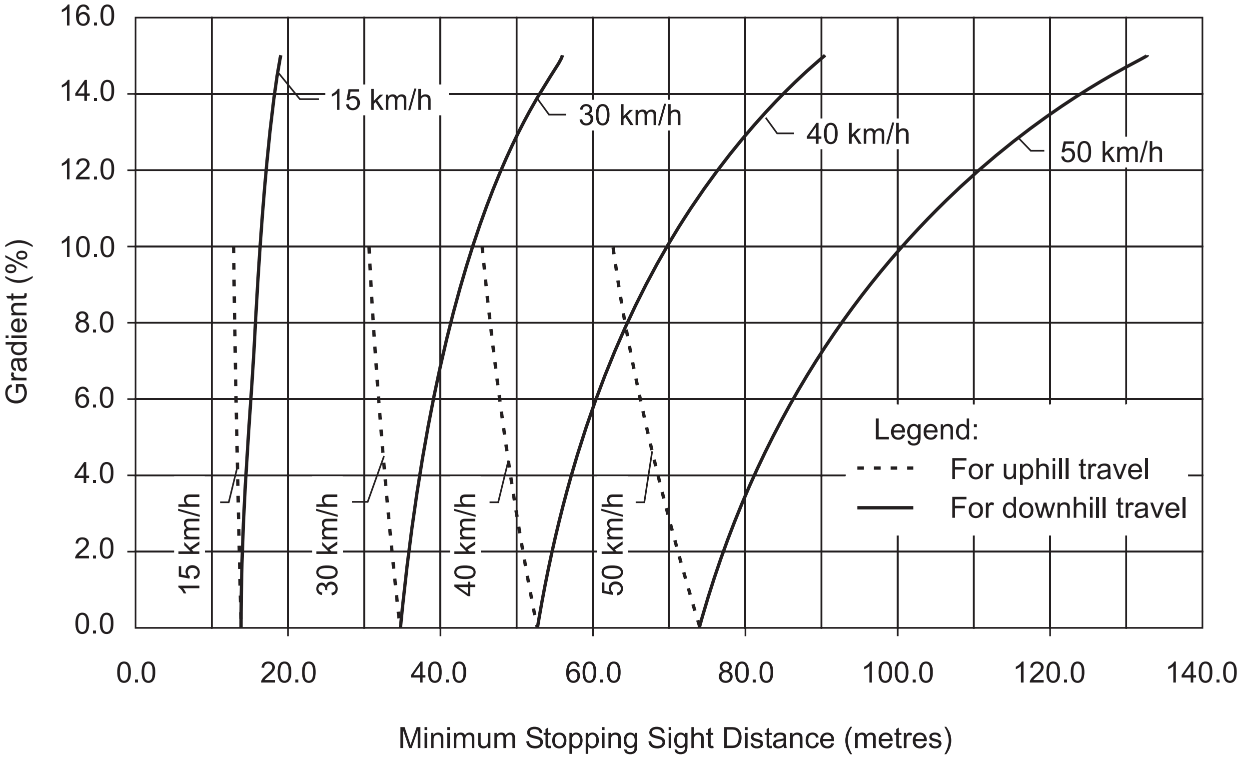


Figure 5.20 Minimum Stopping Sight Distances (Austroads, 1999a)

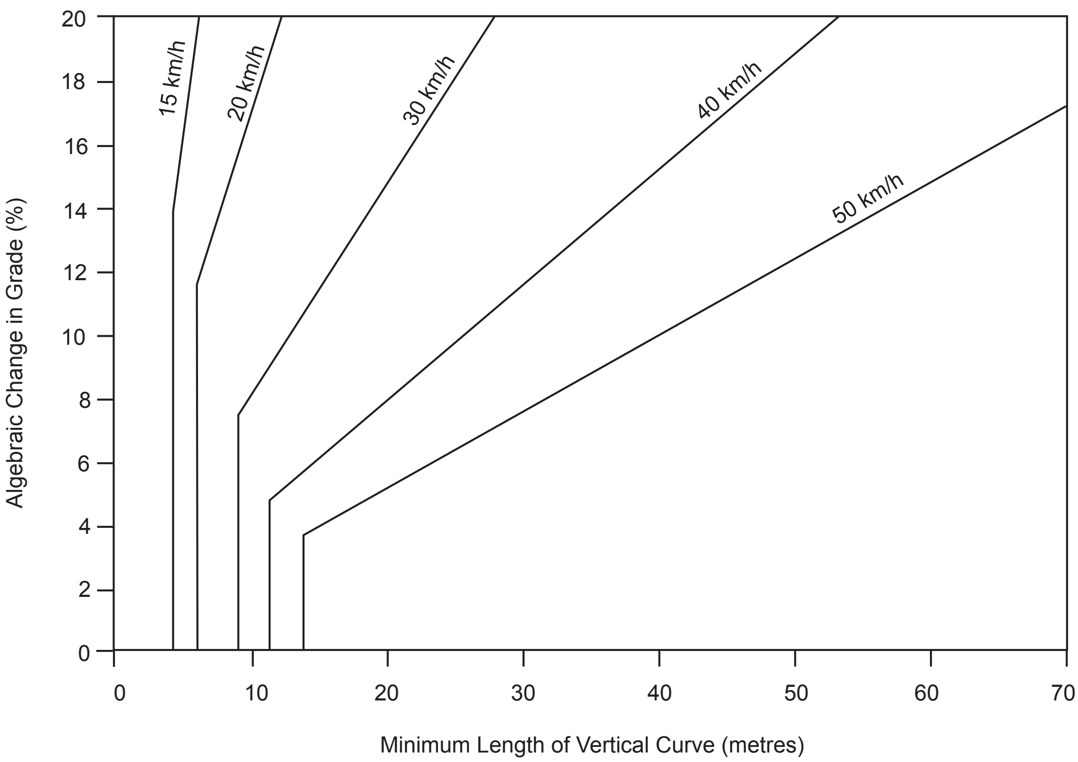
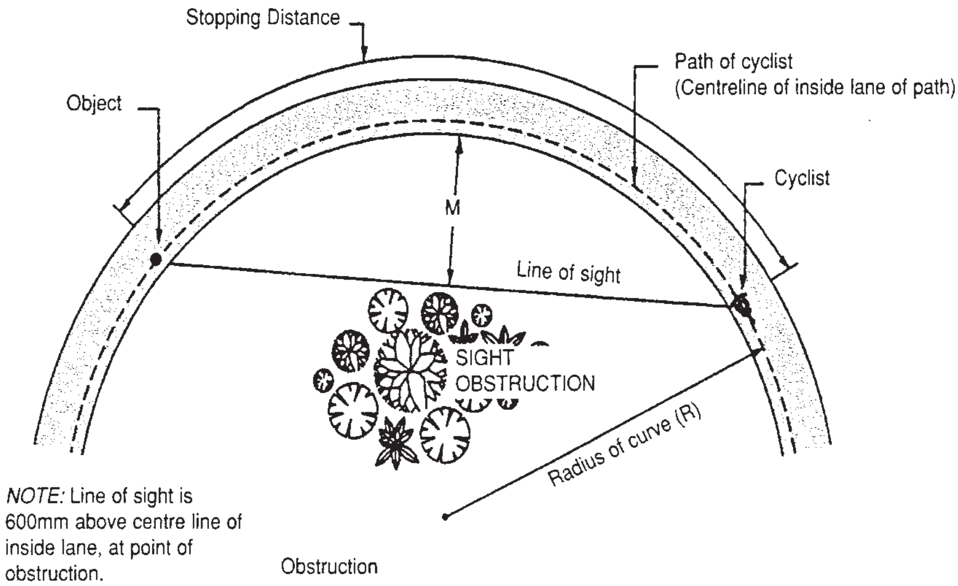
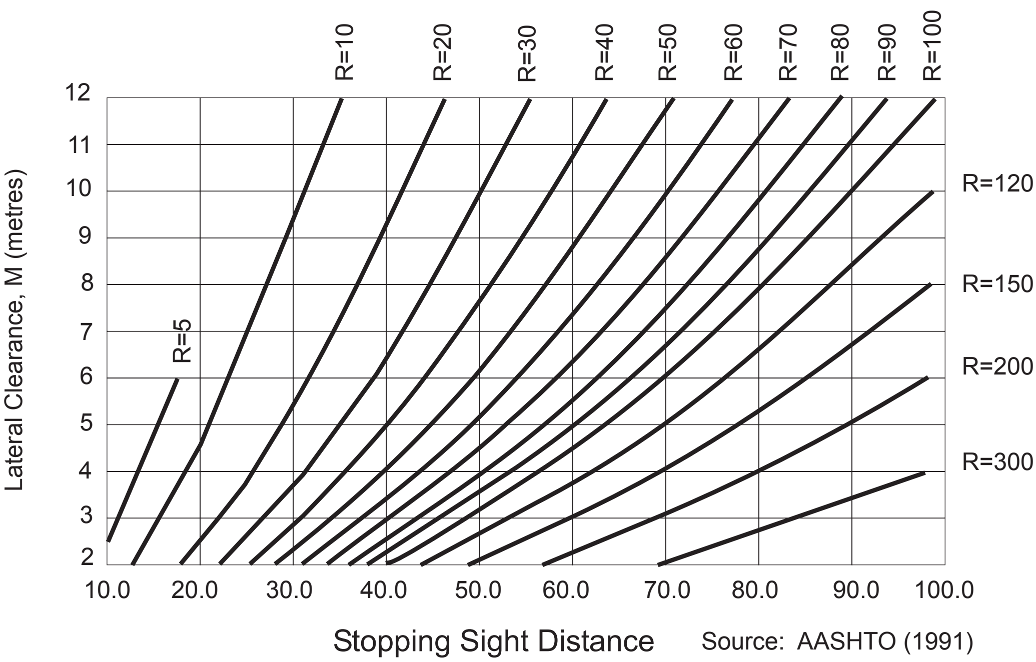


Figure 5.21 Minium Length of Crest Vertical Curves (Austroads, 1999a)





Source: AASHTO (1991)

Figure 5.22 Lateral Clearances required on Horizontal Curves (Austroads, 1999a)

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5.5.4.5 Clearances

Horizontal clearances for safe operation are:

- 1.0m between bicycle operating spaces on other than recreational routes;
- 0.4m between bicycle operating spaces on recreational routes where bicycle speeds are generally no more than 20km/h; and
- 1.0m between the edge of the path and an obstacle, which if struck may result in cyclists losing control or being injured.

The minimum vertical clearance for bicycles is 2.4m measured above the riding surface (3.0m preferred).

5.5.4.6 Cross Section

This section should be read in conjunction with Chapter 7 of this manual.

Wide Kerbside Lanes

In part integration of cyclists and motorists, a wide kerbside lane is provided to give sufficient width to allow vehicles to overtake cyclists without having to effectively change lanes.

Figure 5.23 illustrates vehicle positions for wide kerbside lanes. The width should not be greater than 4.5m to avoid the potential for small vehicles to use the lane to form two queues.

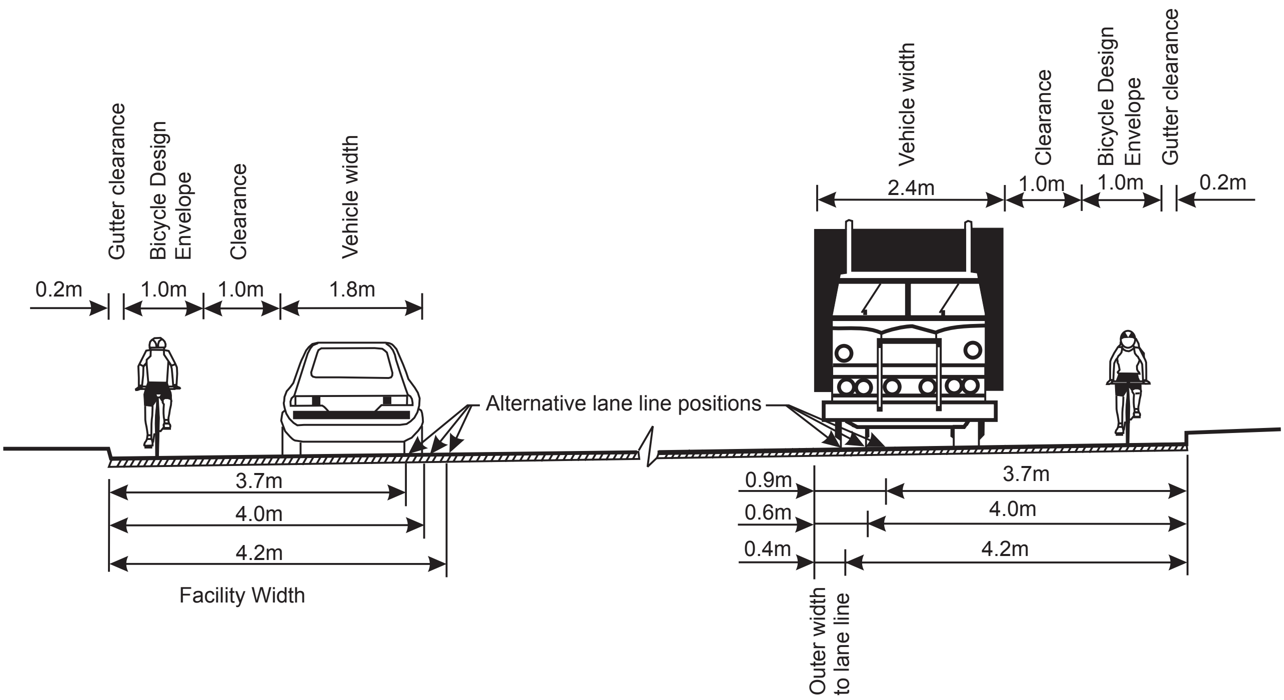

Figure 5.23 Vehicle Positions on Road Carriageway associated with Wide Kerbside Lanes (Speed ≤ 60km/h) (Austroads, 1999a)

Partial Separation

Partial separation may be achieved by:

- sealed shoulders;
- exclusive bicycle lane; or
- shared bicycle / car parking lanes.

Sealed Shoulders

Sealed shoulders are provided to reduce road edge maintenance and repair costs and to improve safety for motorists. In addition they may also effectively provide separate lanes for cyclists provided they meet certain conditions such as:

- an edge line between the shoulder and the traffic lane;
- smooth riding surface, free of debris and obstructions so that cyclists prefer to ride on the shoulders rather than in the traffic lanes;
- the edge of the shoulder being flush with the adjacent ground; and
- lengths of sealed sections to be a desirable minimum of 500m to avoid short sections with narrowing at each end (squeeze points).

Exclusive Bicycle Lane

An exclusive bicycle lane is the preferred option where motor vehicle speeds exceed 80 km/h and/or bicycle traffic is concentrated (e.g. near schools or along major routes near city or town areas). They should:

- be provided on both sides of the road so that use is in the same direction as motor vehicle traffic;
- not be placed between the kerb and parked cars as there is no escape for cyclists should a car door be opened suddenly;
- only be used where there is little demand for parking throughout the day or where parking can be prohibited during certain designated hours to suit the peak travel demand of cyclists and motor vehicles (e.g. clearway times, school journey hours);
- not be delineated with raised markers or raised barriers as these are hazardous to cyclists.

They are:

- of considerable advantage on long uphill grades where there is a higher speed differential between motor vehicles and cyclists and cyclists tend to weave about whilst working their way uphill; and
- advantageous on long downhill grades where extra room to manoeuvre is desirable.

Because debris from the adjacent lanes tends to accumulate in exclusive bicycle lanes (they are not “swept” by motor traffic travelling in them), it is important that they are regularly swept as part of routine road maintenance.

Figure 5.24 gives widths of exclusive bicycle lanes and sealed shoulders.

The absolute maximum width to avoid the lane being attractive to vehicular traffic is 3m. This width is desirable where the adjacent motor traffic is moving at high speed (e.g. 100 km/h) and large vehicles are a significant proportion of the traffic stream. It may be required where demand for cycling is so great that this width is required to provide adequate level of service to the cyclists (3.0m allows cyclists to overtake each other without encroaching into the adjacent traffic lane).

Shared Bicycle/Car Parking Lanes

Shared bicycle/car parking lanes are appropriate in speed zones that are 60 km/h or less. These roads will normally have a significant parking demand and, therefore, bicycle/car parking lanes will generally be required.

These lanes should be wide enough to allow cyclists to pass cars with open doors without crossing into a traffic lane. Cyclists also have to be aware of the possibility of doors opening and the additional space allows them to take this into account.

Although generally used where parallel parking is permitted, these lanes are sometimes installed with angle parking.

Pavement marking and signs give these lanes legal status, and cyclists are required to use these lanes unless it is impractical to do so. Cyclists may use the general traffic lanes to make a right turn or to avoid hazards in the bike lane. Vehicles may only use these lanes for parking, property access or turning. Refer to the MUTCD (Main Roads, 2003) for lane marking and traffic signs.

Figure 5.25 shows vehicle positions and gives widths of bicycle/car parking lanes for parallel parking. Further discussion of appropriate lane widths is provided in Chapter 7 of this manual.

The desirable minimum width of a combined bicycle/parking lane is 4.0 m. The desirable maximum width is 4.5m as a greater width may tempt cars to use it as a vehicle lane. It should be noted that 4.5m provides the cyclist with better capacity to avoid opening car doors when associated with a parking lane. If the lane is a combined bus/bicycle lane, the minimum width should be 4.1m. If the kerbside lane is a combined car/bicycle lane, the minimum width should be 3.7m (see Section 7.2.4)

Austroads (1999a) gives other important aspects of bicycle/car parking lanes as:

- Full integration of bicycles with other traffic may be preferable where parking turnover is high, through traffic speeds are low and the desirable minimum width of 4.0m cannot be achieved.
- A bicycle lane should never be provided between parked cars and the kerb, either in the case of parallel parking or angle parking. A lane in this location creates a hazard with motor vehicle doors opening into the lane or vehicles overhanging the bicycle lane. Parked vehicles also unreasonably restrict cyclists from reaching desired destinations. Further, an additional conflict with pedestrian movement occurs.
- It is preferable to mark the parking bays or a line between parked cars and the edge line of the motor vehicle traffic lane to adequately define the spaces to be occupied by cyclists and opening car doors respectively.
- Additional width is required where heavy vehicles park frequently (nominally 0.6m).
- Angle parking can create hazardous situations for cyclists and requires careful consideration including the option of full integration with other traffic.

Separate Paths

Separate paths may be exclusively for cyclists or may be shared between pedestrians and cyclists. They may be located remote from the road or may be adjacent to the road separate from the vehicle carriageway. Figure 5.26 illustrates the latter case for an urban road.

On high-speed roads, the physical separation of off-road bikeways can be achieved with an appropriate safety barrier, allowing sufficient distance for the expected deflection of the

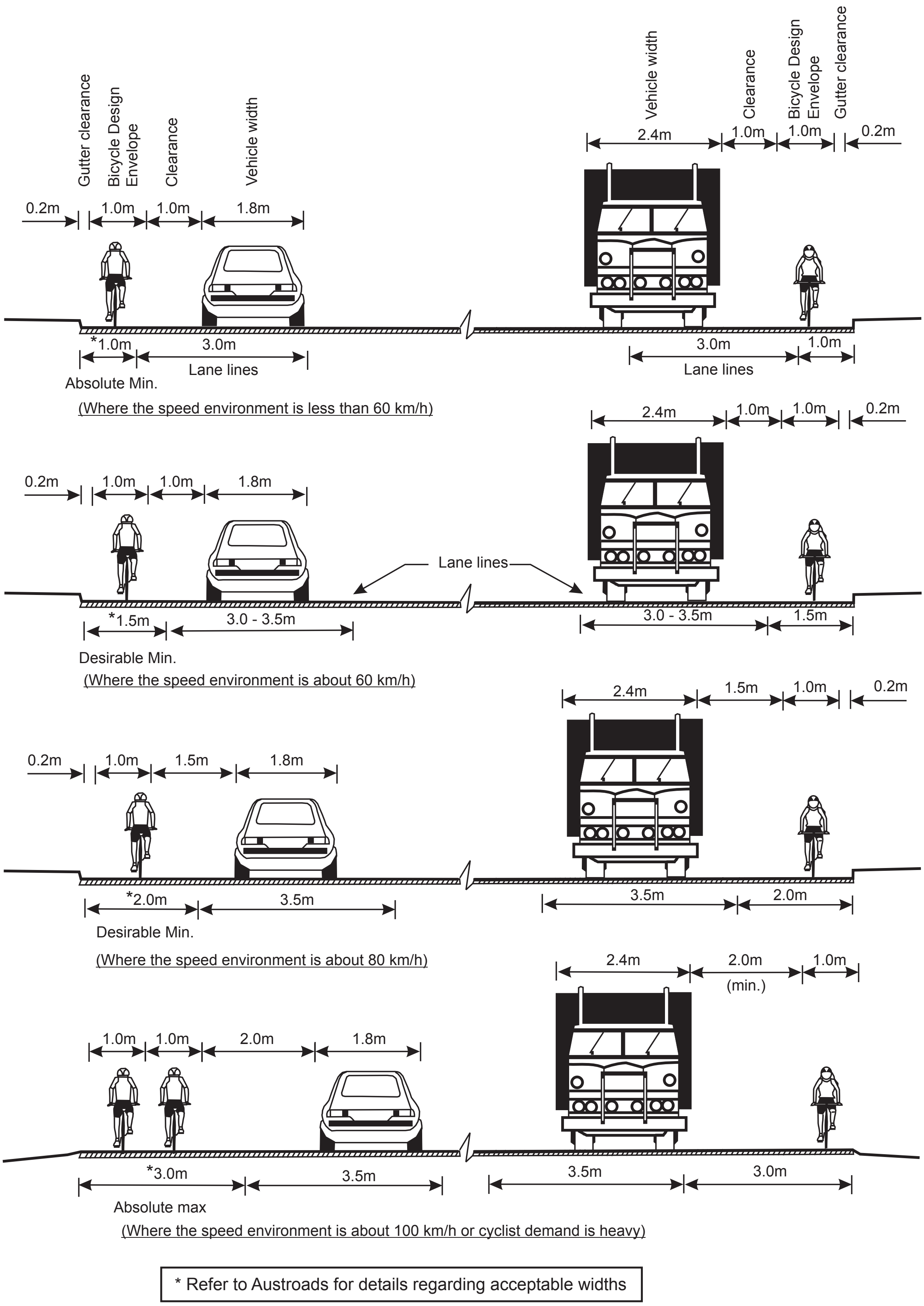

Figure 5.24 Vehicle Positions on Road Carriageway associated with Exclusive Bicycle Lanes (Austroads, 1999a).

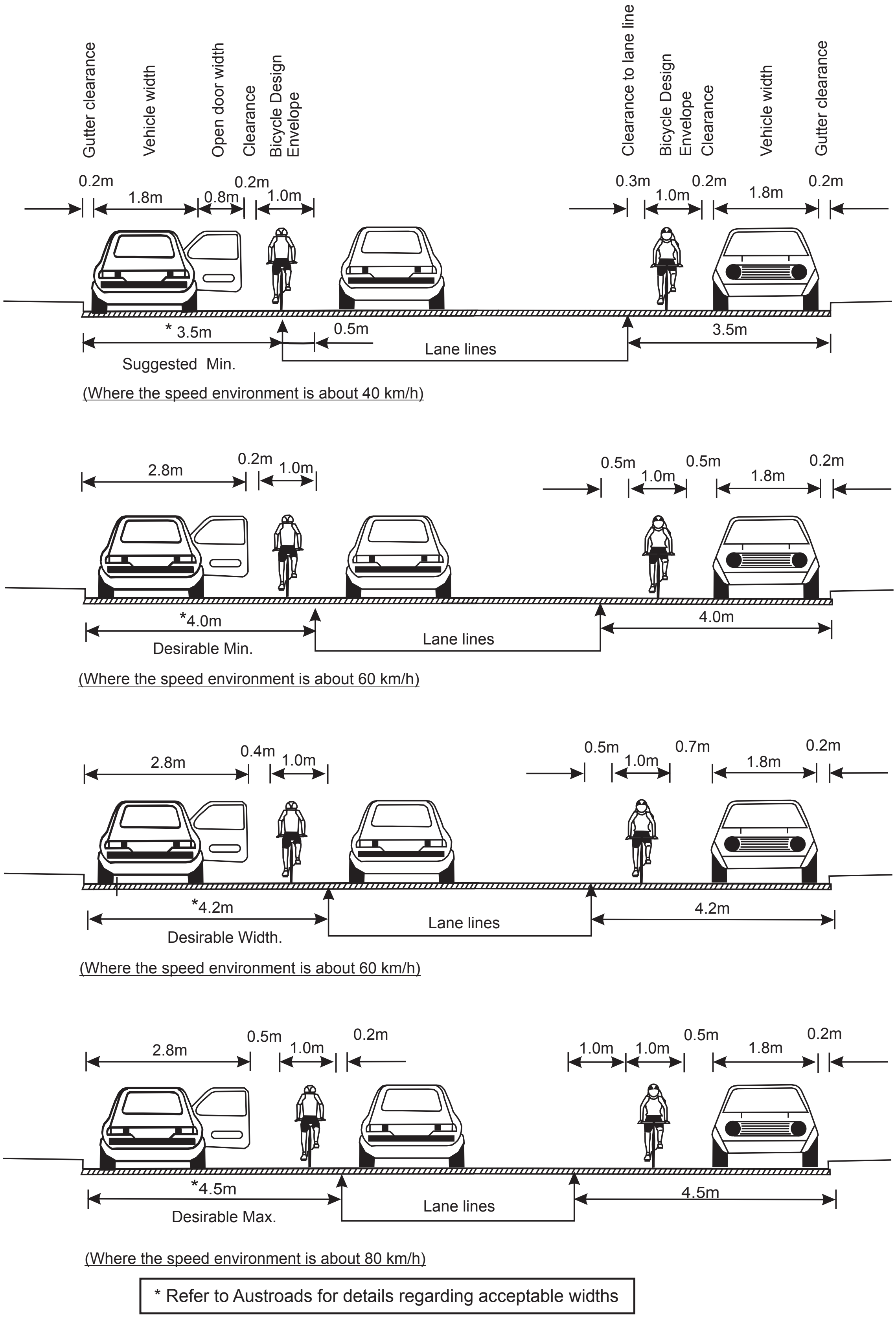

Figure 5.25 Vehicle Positions on Road Carriageway associated with shared Bicycle / Car Lanes for Parallel Parking (Austroads, 1999a)

barrier, or by an adequate separation distance. Desirably, the separation distance should be 10m or more, but not less than the clear zone required for the road (refer to Chapters 7 and 8 of this manual).

Where bicycles have exclusive use of the path, dimensions should be as shown in Figure 5.27.

If one-way bicycle operations are appropriate, Figure 5.28 shows the dimensions required to accommodate shared use.

Shared use path operation for a range of scenarios is shown in Figure 5.29.

For a more comprehensive discussion of these issues, refer to Guide to the GTEP Part 14 (Austroads, 1999a).

5.5.4.7 Other Road Design Issues

Other road design issues for bicycles include:

- bus/bicycle lanes;
- designing intersections for bicycles;
- providing for bicycles at roundabouts;
- maintaining roads for bicycles; and
- local area traffic management schemes.

These issues are dealt with in detail in Austroads (1999a) and some are covered in other Chapters of this manual.

Providing for cyclists on motorways is dealt with in Appendix 5B "Guideline for Motorway Cycling".

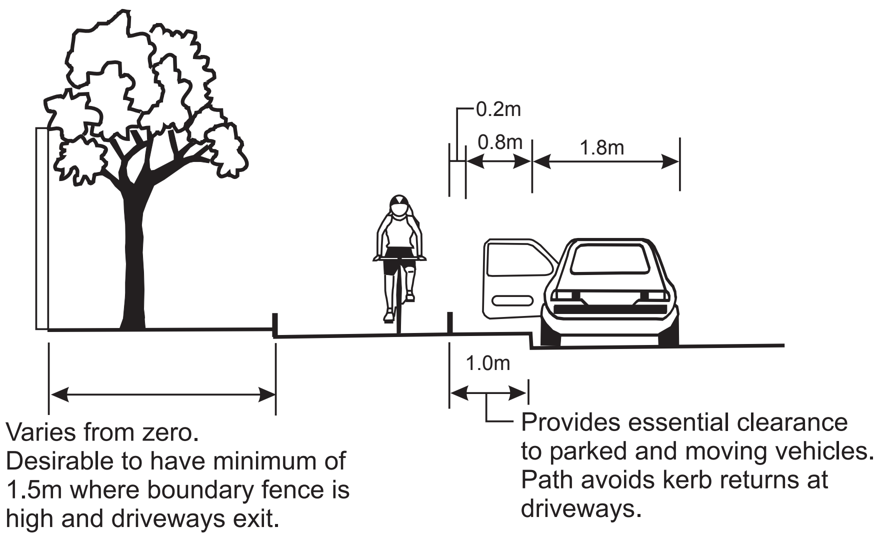

Figure 5.26 Location of Path in Road Reserve (Austroads, 1999a)

Scenario	Overall Width of Path	Predominant Path Purpose • Typical circumstances of use
A	2.0m	Commuting and Local Access • Constrained conditions • 'Tidal flow' • Low use
B	2.5m	Commuting and Local Access • Regular use • 20 km/h
C	3.0m	Commuting • Frequent & concurrent use in both directions • 30 km/h+

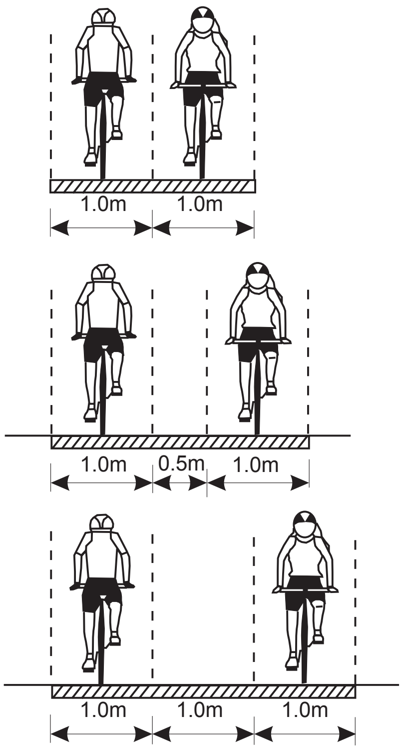

Figure 5.27 Exclusive Use Path Operation (Austroads 1999a)

Scenario	Overall Width of Path	Predominant Path Purpose • Typical circumstances of use
A	2.5m	Commuting and Local Access • Constrained conditions • 20 km/h
B	3.0m	Commuting • Frequent & concurrent use of both path sections • 30 km/h

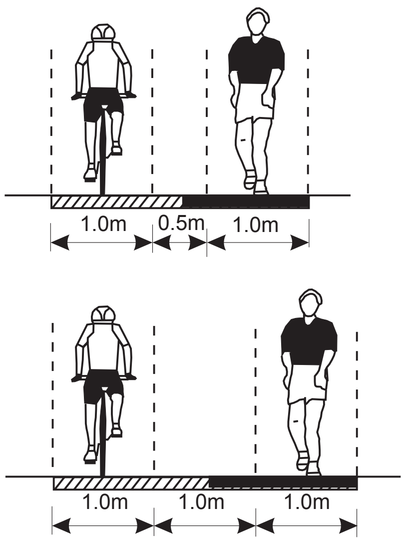

Figure 5.28 Separated One-Way Path Operation (Austroads, 1999a)

Scenario	Overall Width of Path	Predominant Path Purpose • Typical circumstances of use
A	2.0m	Commuting and Local Access • Constrained conditions • 'Tidal flow' • Low use
B	2.5m	Commuting and Local Access • Regular use • 20 km/h
C	3.0m	Commuting • Frequent & concurrent use in both directions • 30 km/h+
D	3.0m	Recreation • Regular use • 20 km/h
E	3.5m	Commuting and Recreation (concurrent) • Frequent & Concurrent use in both directions • 30 km/h+
F	4.0m	Major Recreation Path • 20 km/h • Heavy & concurrent use in both directions
G	4.0m	Major Recreational Path • Regular group rides • Heavy & concurrent use in both directions • Generally low speed due to congestion

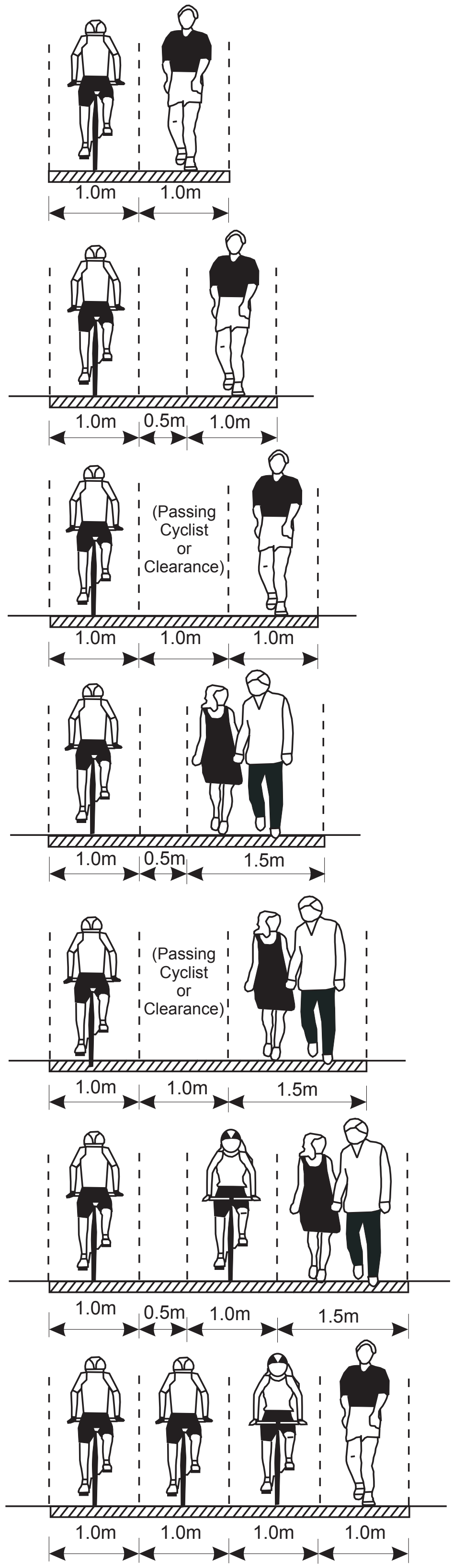

Figure 5.29 Shared Use Path Operation (Austroads, 1999a)

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5.5.5 Providing for Bicycles at Structures

If an exclusive bicycle lane exists on the approaches to a structure, then the same width facility should be carried across the structure. This will be possible for new structures, but may not be possible at existing structures.

The width between kerbs on bridges is often less than the formation width. Where no marked cycle facilities are provided on the adjacent road, a cycle / pedestrian facility across a new structure may still be appropriate to reduce risk to these road users.

Bridges generally have a design life of over 50 years. Even though no dedicated pedestrian / cycle facility may be planned in the initial construction of the adjacent roadway, providing a cycle / pedestrian facility or the substructure for a future cycle / pedestrian facility with the initial construction could be cost effective.

5.5.5.1 Bridges including Overpasses

The Bridge Design Code (Austroads), specifies the following for the required clear width:

- Bikeway on carriageway (one way cycling):
  - 2.0m preferred; and
  - 1.5m minimum.
- Separate bikeway (two-way cycling):
  - 3.0m preferred; and
  - 2.0m minimum.
- Dual use (two-way cycling and pedestrians):
  - 3.0m preferred; and
  - 2.5m minimum.

The vertical clearance above a roadway for overpass bridges for cyclists must be at least 5.5m since they are lighter than road bridges and considerably more damage might occur if hit by a high load. (Note this also applies to pedestrian bridges.). Where there are adjacent bridges, the clearance of the bridge for cyclists must be at least 0.2m greater than that of the adjacent bridges.

The vertical clearance above bikeways specified is:

- 3.0m preferred; and
- 2.5m minimum.

Ramp gradients specified are:

- 10% (1 in 10) for a desirable maximum length of 20m; and
- 7% (1 in 14 maximum) for a desirable maximum length, except for wheelchairs, of 50m. For wheelchairs, the maximum length of a 7% (1 in 14) grade is 9m. This will have to be accommodated on approaches to overpass bridges for pedestrians and bicycles.

5.5.5.2 Underpasses

As for pedestrian underpasses, actual and perceived safety of users is a factor. Sight distance approaching and leaving an underpass and light levels in the underpass must also be sufficient to engender confidence in the users.

A minimum width of 3.0m and a minimum vertical clearance of 2.4m (3.0m preferred) are desired. The best use of resources will mean that most if not all underpasses will be shared use facilities.

Large culverts may be used for bicycle underpasses provided the path is above long standing water levels.

5.5.5.3 Handrails

At bicycle bridges, the height of handrails should be between 1.1 and 1.35m. Railings should be designed to minimise the possibility of cyclists snagging their handlebars or pedals on the barrier.

Where bicycle safety railings are terminated, they should be flared away from the line of the rail to produce an offset of about 0.5m over a length of 5m (Figure 5.30). The end of the rails at all terminals should be joined smoothly to form a semi-circular face; this face forms the terminal presented oncoming cyclists, as illustrated in Figure 5.29.

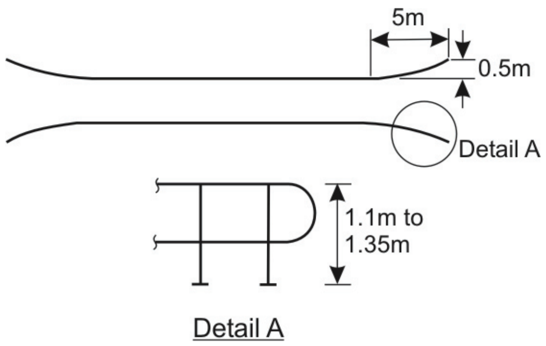

Figure 5.30 Bicycle Safety Railing.

If handrails are used, designers should ensure that any rigid horizontal components are located to prevent them from becoming spears if hit by an errant vehicle.

5.5.6 Bicycle Parking

At common destinations of bicycle trips, it is important that adequate facilities are provided. These facilities include:

- showers, lockers and secure long term parking for staff at workplaces;
- secure short term parking at public transport stations, interchanges and termini; and
- secure short term parking facilities in commercial and retail areas.

Brief comments only are given in this Manual. Detailed information is available in the GTEP - Part 14 (Austroads, 1999a).

Table 5.14 gives the required number of bicycle spaces to be provided for different land uses for planning purposes and as a guide for design.

Refer to Table 5.15 for details of the three classes of bicycle parking facilities offering different degrees of security.

Bicycle Lockers give the highest level of security. They are completely enclosed individual containers into which helmets and other gear can be placed with the bicycle and locked in. Bicycle lockers are most appropriate for all day parking at such places as bus and rail terminals.

Bicycle Enclosures provide a medium level of security. Although bicycles can be locked in, an enclosure is shared with the bicycles of several owners.

Bicycle Parking Rails are facilities to which both the bicycle frames and wheels can be locked if desired. They offer low level of security and are suited to short and medium term parking.

Bicycle Racks and Stands provide very little security and are generally unsuitable for public use in otherwise unsecured areas. Note that there are many existing bicycle racks and stands, which offer either support for only the front wheel of a bicycle or allow only one wheel to be locked with a device. These bicycle racks do not conform with the AS2890 for bicycle parking which requires the frame and at least one wheel to be able to be secured to the rack.

More comprehensive discussion and further details are contained in Austroads (1999a). Also, refer to local government planning scheme requirements for bicycle parking and end of trip facilities.

Table 5.14 Provision of Bicycle Parking for Planning Purposes (Austroads, 1999a).

Land Use	Employee/Resident Parking Spaces	Class	Visitor / Shopper Parking Spaces	Class
Amusement Parlour	-	1 or 2	2 plus 1 per 50m^2 gfa	3
Apartment House	1 per 4 habitable rooms	1	1 per 16 habitable rooms	3
Art Gallery	1 per 1500m^2 gfa	2	2 plus 1 per 1500m^2 gfa	3
Bank	1 per 200m^2 gfa	2	2	3
Cafe	1 per 25m^2 public area	2	2	3
Community Centre	1 per 1500m^2 gfa	2	2 plus 1 per 1500m^2 gfa	3
Consulting Rooms	1 per 8 practitioners	2	1 per 4 practitioners	3
Drive-in Shopping Centre	1 per 300m^2 sales floor	1	1 per 500m^2 sales floor	3
Flat	1 per 3 flats	1	1 per 12 flats	3
General Hospital	1 per 15 beds	1	1 per 30 beds	3
General Industry	1 per 150m^2 gfa	1 or 2	-	3
Health Centre	per 400m^2 gfa	1 or 2	1 per 200m^2 gfa	3
Hotel	1 per 25m^2 bar floor area & 1 per 100m^2 lounge, beer garden	1	1 per 25m^2 bar floor area & 1 per 100m^2 lounge, beer garden	3
Indoor Recreation Facility	1 per 4 employees	1 or 2	1 per 200m^2 gfa	3
Library	1 per 500m^2 gfa	1 or 2	4 plus 2 per 200m^2 gfa	3
Light Industry	1 per 1000m^2 gfa	1 or 2	-	3
Major Sports Ground	1 per 1500 spectators	1	1 per 250 spectator places	3
Market	-	2	1 per 10 stalls	3
Motel	1 per 40 rooms	1	-	3
Museum	1 per 1500m^2 gfa	1	2 plus 1 per 1500m^2 gfa	3
Nursing Home	1 per 7 beds	1	1 per 60 beds	3
Office	1 per 200m^2 gfa	1 or 2	1 per 750m^2 over 1000m^2	3
Place of Assembly	-	2	-	3
Public Hall	-	1 or 2	-	3
Residential Building	1 per 4 lodging rooms	1	1 per 16 lodging rooms	3
Restaurant	1 per 100m^2 public area	1 or 2	2	3
Retail Show Room	1 per 750m^2 sales floor	1	1 per 1000m^2 sales floor	3
School	1 per 5 pupils over year 4	2	-	3
Service Industry	1 per 800m^2 gfa	1	-	3
Service Premises	1 per 200m^2 gfa	1	-	3
Shop	1 per 300m^2 gfa	1	1 per 500m^2 over 1000m^2	3
Swimming Pool	-	1 or 2	2 per 20m^2 of pool area	3
Take-away	1 per 100m^2 gfa	1	1 per 50m^2 gfa	3
University/Institute of Technology.	1 per 100 f/t students[5] 2 per 100 f/t students[5]	1 or 2 2	- -	3 3

Notes:
1. A – indicates that no parking demand information is available, and therefore planners should make their own assessment of the required bicycle parking provisions, on an individual project basis.
2. gfa - gross floor area.
3. It is sometimes appropriate to make available 50% of the level of provision recommended in the table at the initial installation stage, however space should be set aside to allow 100% provision in the event that the full demand for bicycle parking is realised.
4. "Class" of parking is defined in Table 5.15 of this manual
5. f/t full time

Table 5.15 Classification of Bicycle Parking Facilities (Austroads, 1999a)

Class	Security Level	Description	Main User Type
1	High	Fully enclosed individual lockers	Bike and ride commuters at railways and bus stations
2	Medium	Locked compounds fitted with Class 3 facilities. Communal access using duplicate keys or electronic swipe cards.	Regular employees, students, regular bike and ride commuters.
3	Low	Facilities to which the bicycle frame and wheels can be locked.	Shoppers, visitors to Public offices, Places of employment where there ia security supervision of the parking facilities.

5.6 Motorcycles

5.6.1 General

The GTEP Part 15 (Austroads, 1999b) provides a detailed discussion of the requirements for motorcycles. Designers should consult this reference to canvass the range of good practice alternatives available. This section provides a summary of the relevant design features of GTEP Part 15 (Austroads 1999b).

Motorcycles are a significant part of the traffic stream, albeit a small proportion (1%), and require specific attention because of the differences in operating characteristics between motorcycles and other vehicles. What makes special consideration of motorcycles even more important is the over-representation of motorcycle casualties in road crashes in Australia (12% of deaths and hospitalisations with 1% of the road travel).

Design is a complex process in which the competing demands of various road users have to be provided for and compromises made to obtain the best result for the road users as a whole. Designers will have to make judgments on the proper mix of treatments to achieve this end. Providing for motorcycles has to be undertaken in this context and this section is intended to provide guidance on good practice.

5.6.2 Characteristics

Motorcycles are not just “smaller cars” (Austroads, 1999b):

- Motorcycle handling characteristics are different from cars;
- With only two tyres, motorcycles are far more dependent on good, consistent traction on the road surface;
- Motorcycles are more manoeuvrable than cars and will use different parts of the carriageway (e.g. on curves);
- Motorcycles provide no protection to riders in the event of an accident.

They are also not “fast bicycles” (Austroads, 1999b):

- Motorcycle handling characteristics are different from those of bicycles;
- Motorcycles have their own power source, resulting not only in greater speed, but also in greater opportunities to negotiate differing traffic conditions;
- Motorcycle riders are licensed;
- Motorcycles are motor vehicles, registered for on-road use.

The unique characteristics of motorcycles are:

- Vehicle stability – they are less stable than vehicles with four wheels and anything leading to skidding is potentially hazardous.
- Vehicle performance and capability:
    - Faster acceleration;
    - Ability to move between lines of other stationary vehicles; and
    - Brakes are designed to operate independently for the front and rear wheels and require experience to use them effectively – leads to longer stopping distances for inexperienced riders.
- How conspicuouis they are in traffic – smaller than other vehicles (and therefore can be difficult to see); narrow with one headlight so other drivers have difficulty in judging the approach speed of the motorcycle particularly at night.
- Vehicle alignment in traffic lanes:
    - The motorcycle envelope can extend beyond the edge of the traffic lane (e.g. leaning into a curve – road furniture must be outside the potential line of this encroachment);
    - The wheel track of the motorcycle through the curve will not necessarily follow the wheel track of a car or be parallel to them (may traverse the width of the lane); and
    - Since the motorcyclist must lean into the curve, or into the wind on a straight, any change in traction with the road due to a change in surface conditions can have serious consequences.
- Rider vision – headlight spread as the rider leans into a curve means that objects and delineation are not as visible to motorcyclists. This is compounded by the fact that riders wear helmets and the visors become covered in grime thereby reducing the visibility of important road elements, retro-reflective materials and other road users.
- Rider characteristics – eye height varies from 1.3 to 1.6m (cf. the design eye height for car drivers of 1.15m). Riders need a clear view above or below signs and other objects.
- Exposure to injury – riders have no protective envelope surrounding them and are therefore exposed to contact with the road surface or objects. Protective clothing will allow a rider to survive a long slide along the road surface provided no object is in the line of the slide.

5.6.3 Implications for Design

Designers should take account of the motorcycle rider's perspective, providing designs that cater for the special needs of motorcycles as well as meeting the needs of the other road users. Many principles of good design for motorcycles are equally valid for the other road users.

Motorcycle riders require constant attention to the road and its environment and are more likely to be subject to information overload than car drivers. Motorcycle riders have to attend to:

- keeping the vehicle upright (road surface, road alignment, wind conditions, stability when braking);
- anticipating the actions of other road users who may not expect a motorcycle;
- navigating without the assistance of a map or passenger; and
- withstanding direct exposure to the elements.

The additional tasks are more likely to lead to stress and overload and the consequences of a mistake are more severe than for other motorists. Motorcyclists are more likely to benefit from roads that will provide:

- uniformity – familiar and standard treatment, so there are no surprises;
- optimum values of design parameters rather than minimum;
- high standard of workmanship and maintenance practices;
- advance information, warning and good delineation of the road;
- controlled and timely release of relevant information and the avoidance of irrelevant information; and
- repeated information, consistent with the need for action.

5.6.4 Guidelines for Good Practice

5.6.4.1 Safety Needs of Motorcyclists

Motorcyclists have their own safety needs in the physical layout and construction of a road. The characteristics of the motorcyclist set out in previous sections provide the reasons for these particular needs.

The fact that motorcycles have only two wheels highlights the importance of traction on the road surface. The entire operation of the motorcycle depends on adequate continuous traction and on consistency in the available friction between the tyre and road surface.

As a motorcycle has only two wheels, which provide challenges for stability of the vehicle, the rider has to provide continuous attention to the riding task to maintain stability. It is the case that the inherent instability of the vehicle can lead to loss of control at points of sudden change, particularly where surface irregularities occur, with hazardous consequences for the rider.

These consequences can be serious if solid objects are located in the path of the motorcycle as it slides out of control. Care is therefore required when providing roadside and road surface furniture, which may be a positive safety feature for other road users (e.g. pavement bars or “jiggle bars”).

The complexity of the riding task means that the rider is capable of absorbing limited amounts of information in addition to the needs of traffic monitoring and vehicle control. Designs must therefore provide appropriate information; at the same time limiting it to that which is necessary for the particular situation.

5.6.4.2 Good Practice in Design

Two general ways to improve the practice with respect to providing for motorcyclists are:

- Apply established good practices that benefit all road users; and
- Apply practices that are directed to the particular needs of motorcyclists.

General good practice will often meet the needs of motorcyclists:

- Ensure no surprises in alignment or layout;
- Avoid unusual treatments and traffic arrangements;
- Avoid complex decision making tasks imposed by layouts;
- Provide adequate warning;
- Ensure no misleading or conflicting information;
- Provide adequate delineation and guidance;

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- Provide good visibility; and
- Provide a forgiving roadside environment.

Motorcyclists are more vulnerable to breaches of these practices than drivers of cars and trucks, particularly because they have no protection against injury. However, application of these practices benefits all road users.

The particular needs of motorcyclists are alluded to in earlier parts of this section and are dealt with in the following sections under the headings of the features with the greatest impact on the safety of motorcyclists. Current practice is not always able to meet the needs of motorcyclists and this means that there are unresolved safety issues in several areas. These may be dealt with as follows:

- Avoid the use of the unsafe practice (for motorcyclists) if possible;
- Provide appropriate warning where feasible; and
- Educate motorcyclists to recognise these features and take care when confronting them.

Austroads (1999b) provides a detailed discussion on all of these issues.

The Road Surface

The road surface is critical to the motorcyclist staying upright and in control of the vehicle. It should therefore have a uniform and predictable surface friction.

Wet weather will change the skid resistance of various materials (including pavement markings). These become slippery and can lead to inconsistent surface friction and unexpected loss of control. Motorcycles require more distance to stop in wet weather.

Aquaplaning is also critical for motorcyclists and designers should check for this problem and design to mitigate or avoid it (refer to Main Roads' Road Drainage Design Manual). (Note that the transverse position of a motorcycle may be different to that of a car, truck, etc).

Gravel or debris on the road surface is a major hazard. It results in loss of traction and cannot be seen in time to take action.

While this is a maintenance issue, design should be carried out to ensure, as far as practicable, that debris will not accumulate on the road surface (e.g. avoid overland flow paths spreading onto/across the road).

Grooving on the surface, parallel to the direction of travel, can create difficulties for motorcyclists as some tyres can be trapped along it (i.e. forced to track in a groove). Since a motorcyclist may not track around a curve parallel to the lane lines, loss of control can result when the tyres become trapped in the grooves. This practice should be avoided.

Unresolved issues are:

- Lack of adequate skid resistance of most pavement marking materials;
- Slipperiness of rubberised crack sealant without a friction additive; and
- Inability to provide warning about adverse superelevation.

Road Surface Furniture

Road surface furniture interrupts consistent surface friction if struck by a motorcycle and includes:

- Temporary steel plates over trenches (major hazard to motorcyclists – avoid);
- Rail level crossings – curvature on approaches and evenness of surface are important;

- Tactile or profiled edge lines – useful for motorcyclists when used with sealed shoulders;
- Tram tracks – warning required in unexpected locations;
- Services access covers – avoid locating them in carriageways;
- Temporary kerbing – do not use in high-speed areas and it must be properly secured when it is used in low speed areas;
- Low kerbing to separate traffic streams – avoid as a motorcycle's foot peg may hit the kerb while cornering;
- Road humps – visibility, particularly at night;
- Rumble strips on approach to intersections – cause uneven braking ability and should be located away from the final braking area;
- Lateral rumble strips on sealed shoulders – do not use these since they look like paint, give a considerable jolt and can cause loss of control; and
- Pavement bars – do not use where over-running can be expected (stability, danger from dislodged bars).

If a motorcycle strikes these items, loss of control can lead to toppling over of the vehicle. They should be kept away from likely travel paths, including those that may be taken in error.

Some raised devices can snag the foot pegs when the motorcycle is cornering, as the motorcyclist needs to lean into the turn. This destabilises the vehicle.

Road Layout and Alignment

Visibility is a critical issue for all road users but it must be recognised that motorcyclists may not be as conspicuous as other vehicles

Adverse superelevation is particularly hazardous to motorcyclists. The stability of a motorcycle relies entirely on the friction between the tyre and surface and this is minimised when the motorcycle is leaning over in the curve. Any uneven road surface or localized low friction areas can be catastrophic.

On any alignment where the curvature changes part way around the curve a motorcyclist will have similar problems to those described above. **Compound curves should therefore be avoided.**

The alignment of the road should not contain any surprises.

Intersection layouts should be kept obvious and simple and particular attention given to the following:

- Visibility between vehicles – note that motorcycles may be difficult to detect and motorcycles may take longer to stop in some situations;
- Recognition of the layout – night time visibility is critical for motorcyclists and it is best to keep it simple;
- Right turn visibility – right turning vehicles may find it difficult to see oncoming motorcycles; and
- Parked vehicles – may obscure a motorcycle;
- Gravel build up;
- Surface treatments must have adequate skid resistance;
- Islands – need to be lit because of the limited effectiveness of the motorcycle headlights;
- Signal detector loops should be tuned to detect motorcycles; and

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- Zebra crossing markings at left turn slip lanes must have adequate skid resistance as motorcycles lean into the corner.

Additional issues to be considered for roundabouts include:

- Visibility of the central island, particularly at night;
- Visibility of splitter islands;
- Crossfall on the roundabout must be predictable and consistent on the approach and within the roundabout. Adverse crossfall is not preferred, (refer to Chapter 14 of this manual);
- Recognition of the roundabout – design should ensure an early appreciation of the situation;
- Line marking – materials should have a skid resistance similar to that of the road surface; and
- Sight lines to motorcycles and sight lines of motorcyclists should not be blocked by landscaping and island treatments.

Delineation, Signing and Lighting

Good delineation, signing and lighting is required for all road users. These features may be more critical for motorcyclists as they cannot consult a map or street directory while riding. Delineation is also critical for motorcyclists as the headlights of the motorcycle have limited effectiveness and there is considerable potential for the visors to be obscured (no wipers or cleaning available while riding).

The following issues must be addressed:

- Clear delineation of vehicle paths;
- Low standard curves - must have consistent and credible advisory speed signs;
- Adequacy of direction information - critical for motorcyclists;
- Effectiveness of street lighting - align lanterns with the road layout and provide lighting in areas of complex decision making;
- Glare from street lighting - can be a problem for riders wearing closed face helmets.

Roadside Layout

Issues for motorcyclists include:

- Clear zone – is most important for motorcyclists since it provides an area clear of obstructions in the event of a rider falling from the vehicle;
- Sealed shoulders provide significant benefits to motorcyclists in the event of veering to the left or being forced from the traffic lane;
- Barrier kerbing is particularly hazardous to motorcyclists in the event of their falling from the vehicle;
- Kerbs can snag the foot pegs of a motorcycle and create instability and possibly cause an accident;
- Kerb colouring can blend in with the road surface – a contrasting colour is beneficial; and
- Landscaping should use frangible species if located in areas where the risk of running off the road is high.

Roadside Furniture

Safety devices designed to minimise the consequences of crashes by vehicles are often major obstacles for motorcyclists. Most safety barriers pose a significant hazard to motorcyclists when they fall from their vehicles. Any solid object in the path of the rider will cause considerable damage to the motorcyclist if struck. It is therefore better to keep the roadside clear of all such objects if possible. However, the greater good must be addressed in all situations and a compromise will often be required. Some issues to address are:

- Poles on the roadside are a hazard to all users – for motorcyclists, the best solution is to remove them as the installation of guard rail may be worse for them;
- Watering systems should not be allowed to spray water onto the road surface as it alters the friction characteristics and introduces sudden variability in the friction value;
- The number of roadside posts should be reduced to a minimum;
- Posts or poles on the inside of curves must be located sufficiently far from the edge of the lane to ensure that the rider will not impact them when leaning into the curve – it is preferable for poles to be removed from this location altogether;
- Signs must not obstruct visibility at the rider eye height (which can vary between 1.3m and 1.6m);
- Road edge guide posts should be frangible or flexible – brittle posts can spear a motorcyclist and rigid sharp posts can cause loss of limbs if struck;
- Safety barriers should only be used where the likely damage or injury from hitting the barrier is less than that of hitting the hazard it shields;
- Since motorcyclist crashes involving guard rail are only a small part of the motorcycle accident problem, care is required in allocating funds to provide solutions that are expensive and therefore diverting resources from more urgent situations;
- It is usually the posts on safety barrier systems that cause the problems for the motorcyclist so means of protecting the sliding rider from the posts would be desirable – very few solutions are available (refer to Chapter 8 of this manual);
- Protrusions on the surface of the barrier can cause unnecessary damage so the surfaces of the barrier should be as smooth as possible – added devices or entrapment areas should be avoided;
- Reflectors on a barrier should be frangible, not sharp and should not be located in the W shape of steel beams; and
- Kerbing should not be placed in front of barrier systems.

There are many unresolved safety issues with respect to providing for motorcyclists. Adopting good practice will go a long way to minimising the incidence of crashes and the consequences of them. Attention to detail in design can remove unnecessary hazards and/or the need for barrier systems and make the road environment safer for motorcyclists and other road users.

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5.7 Design Vehicles

5.7.1 General

Austroads/SAA (1995) defines Design Vehicle as *"a hypothetical vehicle whose dimensions and operating characteristics are used to establish certain aspects of road and intersection layout and geometry".*

The design vehicle is not necessarily the largest of the vehicles but is intended to represent an economical level of design catering for at least 85% of vehicles operating in accordance with the relevant regulations. Larger vehicles will not be precluded from the road but they will need to encroach on adjacent lanes (or mount kerbs) in some circumstances. While this may inconvenience some other road users, the low frequency of the occurrence of these vehicles and the additional cost and other impacts of providing for these infrequent occurrences makes this acceptable.

Three design vehicles are used for most purposes:

- Design Car;
- Design Single-Unit Truck/Bus; and
- Design Semi-trailer

The design vehicle to be used in various circumstances is identified as appropriate in Sections 5.7.3 to 5.7.7.

In addition, other "Restricted Access Vehicle" types are included. These are often used as check vehicles in the circumstances described above.

The full range of vehicle types operating on the Queensland road system is shown in Table 5.16 .

Table 5.16 (a) Austroads Vehicle Types (Main Roads, 2000)

Austroads Class	Vehicle Type	Maximum Length (m)	Maximum GCM (Tonnes)	GCM (Tonnes) MLR	No. of ESA's Per Commercial Vehicle When Fully Loaded (Without MLR)	No. of ESA's Per Commercial When Fully Loaded (With MLR)	Permit Required
Class 1	Short Vehicle 	5m	NA	NA	NA	NA	NO
Class 2	Short Vehicle Towing 		NA	NA	NA	NA	NO
Class 3	General Access Vehicles Rigid Trucks 	12.5m	15t	NA	3.0	NA	NO
Class 4	Three Axle Truck 	12.5m	22.5t	23t	3.7	3.97	NO
Class 5	Four Axle Truck 	12.5m	27.5t	28t	4.4	4.4	NO
Class 6	Three Axle Articulated Vehicle 	19m	24t	NA	4.4	NA	NO
Class 7	Four Axle Articulated Vehicle 	19m	31.5t	32t	5.1	5.42	NO

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Table 5.16 (b) Austroads Vehicle Types (Main Roads, 2000)

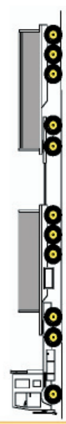
Austroads Class	Vehicle Type	Maximum Length (m)	Maximum GCM (Tonnes)	GCM (Tonnes) MLR	No. of ESA's Per Commercial Vehicle When Fully Loaded (Without MLR)	No. of ESA's Per Commercial When Fully Loaded (With MLR)	Permit Required
Class 8	Five Axle Articulated Vehicle 	19m	39t	40t	5.9	6.41	NO
Class 9	Truck-trailers 	19m	45t	NA	7.3	NA	NO
	Prime-mover semi-trailers 	19m	42.5t	45t	5.1	6.15	NO
Class 10	19m B-Doubles 	19m	50t	NA	7.2	NA	NO
	Truck and 4-axle dog 	19m	50t	NA	8.0	NA	NO
	25m B-Doubles 	25m	62.5t	68t	6.4	8.32	NO
Class 11	Conventional Type I Road Train 	36.5m	79t	85t	8.60	10.78	NO

Table 5.16 (c) Austroads Vehicle Types (Main Roads, 2000)

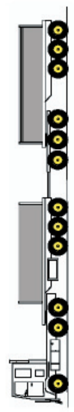
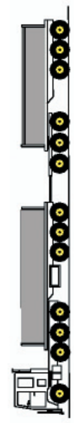
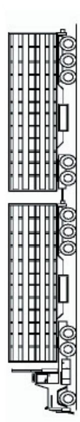
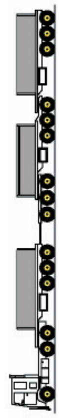
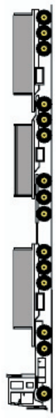
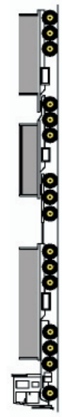
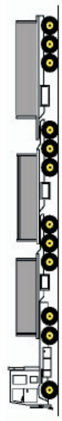
Austroads Class	Vehicle Type	Maximum Length (m)	Maximum GCM (Tonnes)	GCM (Tonnes) MLR	No. of ESA's Per Commercial Vehicle When Fully Loaded (Without MLR)	No. of ESA's Per Commercial When Fully Loaded (With MLR)	Permit Required
	Type I Road Train with a tri-axle dolly 	36.5m	82.5t	90.5t	7.80	10.53	NO
	Type I Road Train with a tri-drive pri-mover and tri-axle dolly 	36.5m	86t	NAP (96)	7.0	10.28	YES
	Type I Road Train under Livestock loading 	36.5m	79t to 106t*	NA	8.6	24.71	NO
	AB-Triple 	36.5m	99t	107.5t	9.97	12.97	NO
	AB-Triple with tri-axle dolly 	36.5m	102.5t	113t	9.17	12.72	NO
	AB-Triple with a tri-drive prime-mover and a tri-axle dolly 	36.5m	106t	NAP (118.5)	8.37	12.46	YES
	B-Triple 	36.5m	82.5t	NAP (90.5)	7.80	10.53	YES

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Table 5.16 (d) Austroads Vehicle Types (Main Roads, 2000)

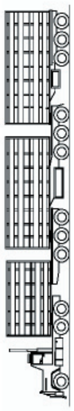
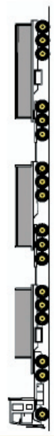
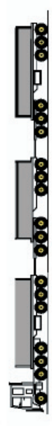
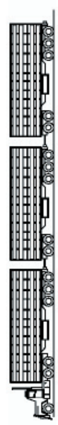
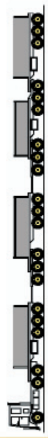
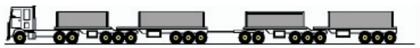
Austroads Class	Vehicle Type	Maximum Length (m)	Maximum GCM (Tonnes)	GCM (Tonnes) MLR	No. of ESA's Per Commercial Vehicle When Fully Loaded (Without MLR)	No. of ESA's Per Commercial When Fully Loaded (With MLR)	Permit Required
	B-Triple under livestock loading 	36.5m	82.5t to 116t*	NA	7.8	26.95	YES
Class 12	Conventional Type II Road Train 	53.5m	115.5t	124.5t	12.14	15.41	NO
	Type II Road Train with tri-axle dollies 	53.5m	122.5t	135.5t	10.54	14.91	NO
	Type II Road Train with tri-drive prime-mover and tri-axle dollies 	53.5m	126t	141t	9.74	14.65	YES
	Type II Road Train operated under Livestock Loading 	53.5m	115.5t to 156t*	NA	12.1	36.3	NO
	AAB-Quad 	53.5m	135.5t	NAP (147)	13.51	17.60	YES
	AAB-Quad with tri-axle dollies 	53.5m	142.5t	NAP (158)	11.91	17.09	YES

Table 5.16 (e) Austroads Vehicle Types (Main Roads, 2000)

Austroads Class	Vehicle Type	Maximum Length (m)	Maximum GCM (Tonnes)	GCM (Tonnes) MLR	No. of ESA's Per Commercial Vehicle When Fully Loaded (Without MLR)	No. of ESA's Per Commercial When Fully Loaded (With MLR)	Permit Required
	AAB-Quad with tri-drive prime-mover and tri-axle dollies 	53.5m	146t	NAP (163.5)	11.11	16.84	YES
	2B2 (B-Double hauling B-Double) 	53.5m	119t	NAP (130)	11.34	15.16	YES
	2B2 with a tri-axle dolly 	53.5m	122.5t	NAP (135.5)	10.54	14.91	YES
	2B2 with a tri-drive prime-mover and a tri-axle dolly 	53.5m	126t	NAP (141)	9.74	14.65	YES
	2B3 (ICON) 	53.5m	166t	NAP (186)	12.48	19.03	YES

Notes:

MLR = Gross Combination Mass allowed under the Mass Limits Review concession for vehicles fitted with Road Friendly Suspensions (RFS).

NA = Not Applicable

NAP = Not Available at Present

* = Assumed Axle Group Loadings: Steer axle 6t, Tandem axle20t, Triaxle 30t.

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5.7.2 Check Vehicle

In some cases (e.g. intersections), the design is undertaken in accordance with the design vehicle characteristics but is checked with a larger vehicle to ensure that it will be able to navigate the intersection. The larger "check vehicle" will be chosen according to the potential for such vehicles to use the facility and will be at least the next larger vehicle to the design vehicle. At an intersection with a residential street where the design vehicle may be a single unit truck (e.g. rubbish truck), the check vehicle could be a semi trailer (e.g. removal van). At the intersection of two state controlled roads, the design vehicle may be a semi trailer or a B-double, and the check vehicle may be a low loader. The appropriate check vehicle should be determined using a risk assessment process.

The check vehicle may encroach onto kerbed areas, which should be mountable or semi-mountable kerbing placed on a designed pavement (Figure 5.37). Avoid locating any road furniture within the swept path of a check vehicle where practical. Any signs within the swept path of a check vehicle should include devices that support their quick removal and reinstallation.

5.7.2.1 Worked example

In this section we examine an intersection serving a heavy industrial area on a B-double route. Through consultation and a risk assessment process, the following check vehicles were determined:

- A small low loader may require infrequent access (<12 times per annum) operating under escort and under permit – high probability of vehicle accessing the area during high traffic times.

- A large low loader could reasonably be expected to access the area under permit and under police escort. However, such vehicles are seldom required to enter the area (< once per annum) – lower likelihood of vehicle needing to access the area during peak traffic times.

The design should allow semi trailers and B-doubles to access the industrial area via the turning lanes.

The small low loader should be able to access the industrial area without running over kerbs. It may need to use the pavement lanes adjacent to the turning lanes, which is legal as provided for in the Transport Operations (Road Use Management - Road Rules) Regulation 1999.

The large low loader is a very low frequency vehicle, operating under permit (access should be restricted to when traffic volumes are low) with police escort. Being a "low frequency or low risk manoeuvre" it is reasonable to allow the large low loader to use the entire available pavement, which may include a "wrong way" manoeuvre (e.g. travelling in the opposing traffic lane as part of the manoeuvre). It may also need to encroach onto kerbed areas. The design should ensure that significant road furniture (e.g. traffic signals, large signs, lighting) is not placed within the swept path.

Minor road furniture (e.g. minor signage such as keep left signs) should not be placed within the swept path, where practicable. Any minor road furniture that must be within the swept path should be installed with devices that allow quick removal and replacement.

The need for kerbed traffic islands rather than painted islands should be assessed.

5.7.3 Design Car

The standard passenger car dimensions take account of the relevant dimensions in the Australian Standard for Parking Facilities (AS 2890.1) and are shown in Figure 5.31. Chapter 7, Appendix 7A provides details of cars to allow checking of underbody clearances at property accesses.

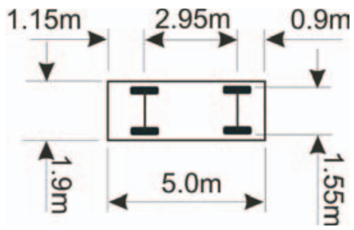

Figure 5.31 Design Motor Vehicle (5.0m).

The design car is used for access into residential driveways (unless access for a larger vehicle such as a refuse truck is required) and for checking manoeuvres on a property that are dependent on the location of the access. In other cases, a car will be able to operate with ease on elements designed for the larger vehicles. The design of parking facilities is covered by a series of Australian Standards (i.e. AS 2890 Series).

5.7.4 Design Single-Unit Truck/ Bus

Figure 5.32 shows the dimensions of the design single unit truck/bus. This vehicle is often used as the design vehicle for minor road intersections on arterial roads and for intersections between secondary arterials, particularly in urban areas.

This unit is also used as the design vehicle for "collector" type local roads. For minor residential streets, the "Design Service Vehicle" (Figure 5.33) will often be adequate. In all cases, the layout should be checked with the next larger design vehicle to ensure that occasional use by these vehicles will be possible.

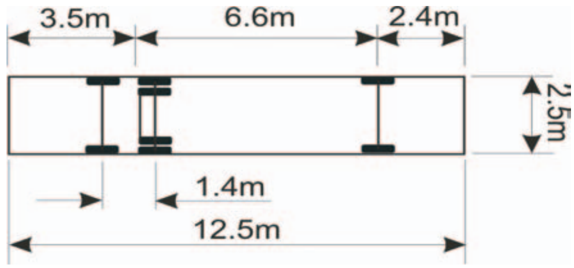

Figure 5.32 Design Single Unit Truck/Bus (12.5m)

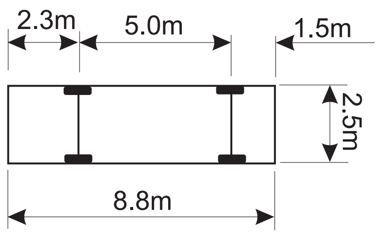

Figure 5.33 Design Service Vehicle (8.8m)

5.7.5 Design Prime Mover and Semi-trailer

Figure 5.34 shows the dimensions of the Design prime mover and semi-trailer. These vehicles should be used as the minimum for all intersections involving two or more arterial roads. (Note that these intersections should also be able to accommodate the 23m B-Double, which can operate on any road.) They are also the "check" vehicles for those designs where a single-unit truck or bus has been the design vehicle.

5.7.6 Higher Order Vehicles

Higher order check vehicles may be required to check for occasional use of larger vehicles at intersections. For many roads, the B-Double may be more appropriate as the design vehicle. In western areas where road trains are common, the design vehicle may be one of the road train configurations. In industrial areas, the check vehicle should be a large low-loader or prime mover and long semi-trailer. For oversize vehicle routes, the design vehicle should be the design low-loader.

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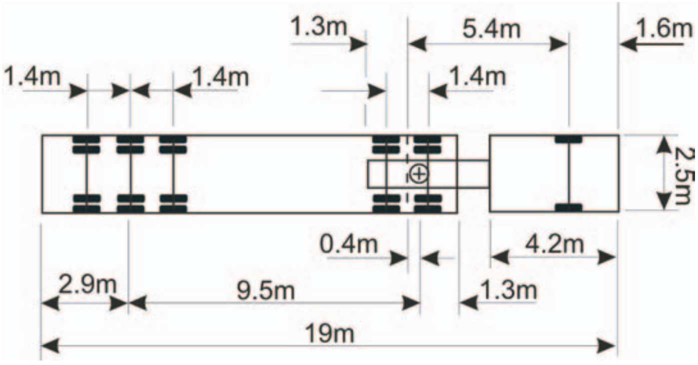

Figure 5.34 Design Prime Mover & Semi - Trailer (19.0m)

5.7.7 Restricted Access Vehicles

Restricted Access vehicles are those that are restricted to defined routes and may require a permit to operate. Routes that are designated for the use of these vehicles are to be designed to cater for them within the normal geometry. The various Restricted Access Vehicles are:

- Long Rigid Bus (14.5m);
- Articulated Bus (19.0m);
- Prime Mover and Long Semi-Trailer (25.0m);
- B-Double (25.0m);
- Type 1 (Double) Road Train (36.0m);
- Type 2 (Triple) Road Train (53.0m).

These are illustrated in Figures 5.35 and 5.36.

These vehicles will be the design vehicles as appropriate for specific routes where they are permitted to operate. The "check" vehicle will be the next larger vehicle type or the specific type of vehicle known to operate occasionally on the road. (Note that the Austroads design road trains are 0.5m shorter than the maximum permitted - see Table 5.16.)

5.7.8 Multi-Combination Vehicles

Development of freight efficient vehicles with innovative axle configurations has resulted in a wide range of vehicles now operating on the road system. Their design is intended to produce good tracking characteristics and swept paths not markedly different from the normally accepted vehicle types. The swept paths of these vehicles can be assessed with the VPATH program. It will be necessary to use this program to check designs for their adequacy in accommodating these vehicles (refer to Section 5.7.8)

These vehicles are allowed to operate on a limited number of routes, or in defined areas of the State under permit, and designers must be aware of the roads where this occurs.

Table 5.16 provides details of all of the current vehicle types from cars to the longest multi-combination vehicles. The table illustrates the range of possible vehicles that may require access to particular roads. However, it should be noted that the swept path performance of many multi-combination vehicles (e.g. AB-Triple, AAB-Quad) would be better than the equivalent length road trains that will operate on the same routes. This is due to the extra points of articulation and/or more uniform component wheelbases.

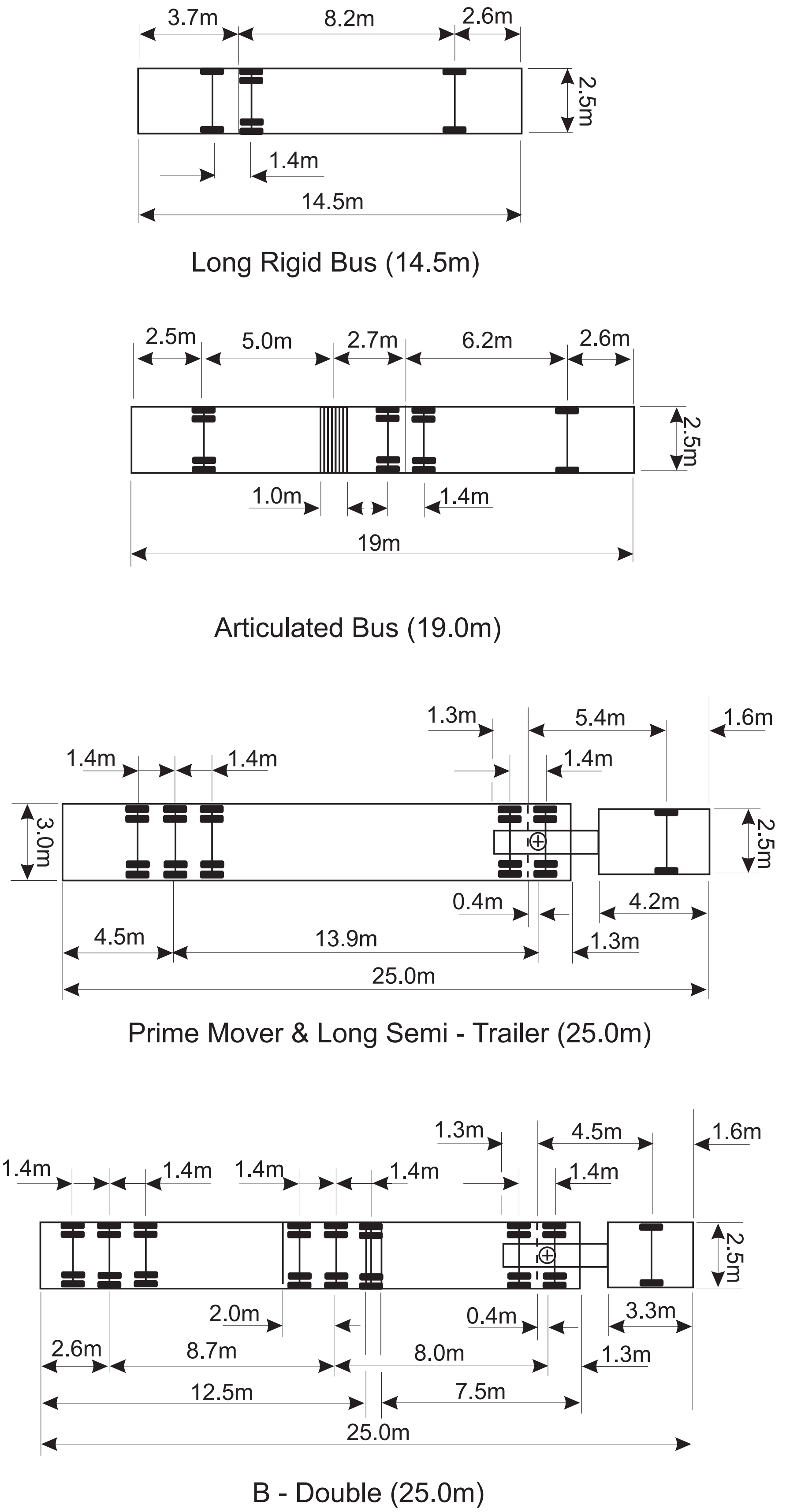

Figure 5.35 Restricted Access Vehicles

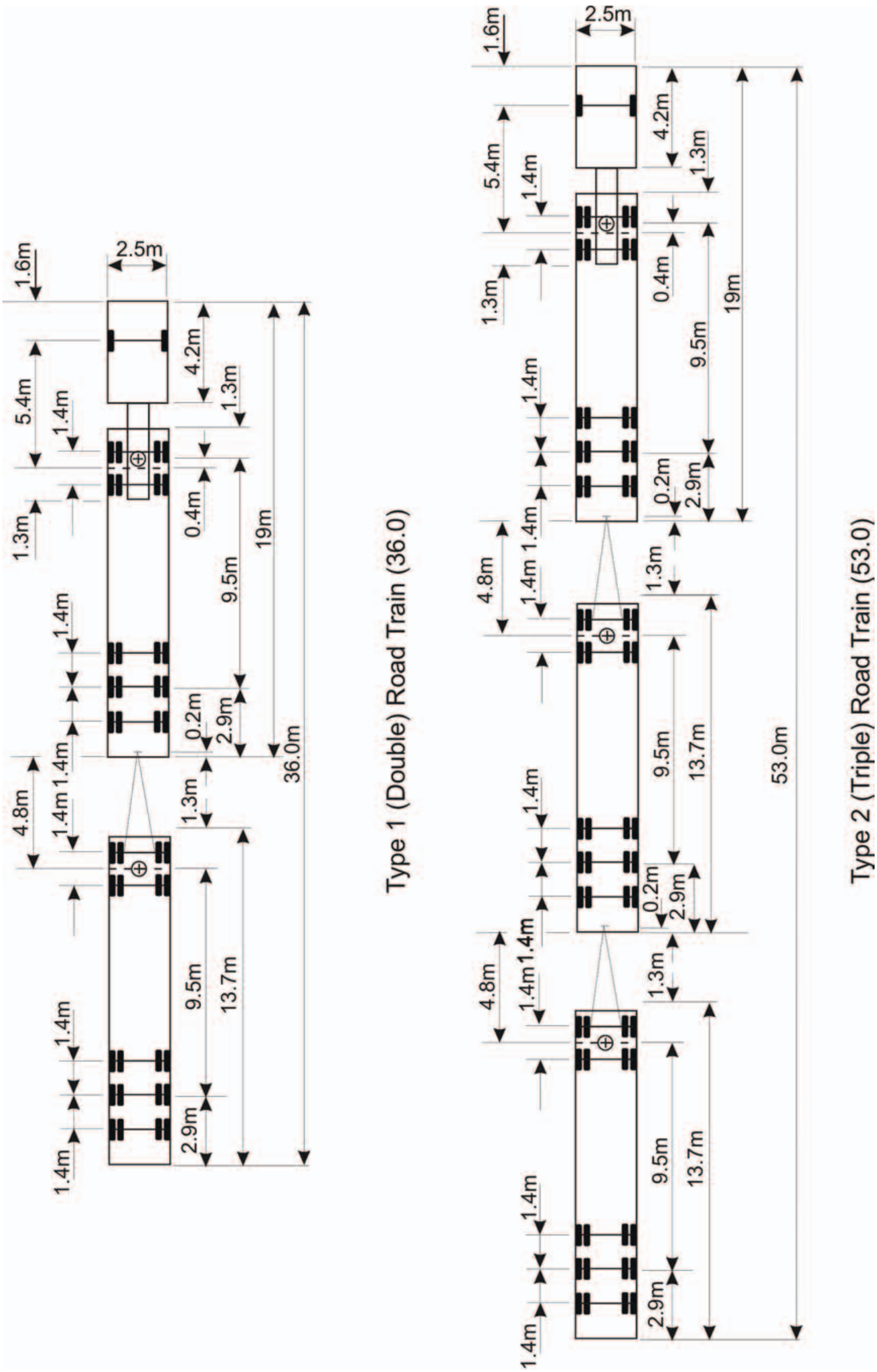

Figure 5.36 Restricted Access Vehicles

5.7.9 Vehicle Swept Paths

The best way to determine the swept path of a vehicle is to use the VPATH program. This program supports a wide range of standard vehicles and can be applied to a design as required. If required, turning templates for any combination of vehicle and turning radius can be readily generated by VPATH. Further, VPATH can generate the swept path of a vehicle following any steering path (simple or complex). Table 5.17 provides details of the standard vehicles supported by VPATH. Users may also define “non-standard” vehicles.

The remarks in Table 5.17 may assist in determining the extent of investigations into the turning paths likely to be encountered.

In addition to the VPATH program, Austroads has produced a suite of turning path templates for use in design. They show the swept path envelope resulting from various angles of turn at a particular radius measured to the outside of the front wheel. They include the swept paths of both the front and rear overhang.

These templates may be used to:

- Establish the width of pavement required at points where the vehicles execute significant turns (i.e. large angles of turn at small radius);
- Define the shape of the edge of the roadway, traffic islands, median ends, turning roadways and the alignment of traffic lanes at intersections, median and separator openings, channelisation and entrances;
- Establish the areas adjacent to turning roadways, traffic lanes and in traffic islands, which are likely to be encroached upon by the swept path of turning vehicles, including the area outside the vehicle’s wheel path that needs to be kept clear of road furniture and fixed objects (Figure 5.37); and
- Define areas within traffic islands or on the roadside that may need to be strengthened or otherwise designed to carry the occasional heavy wheel load when Restricted Access Vehicles or the like turn and are permitted to encroach outside the normal roadway limits.

The VPATH program will give more precise results and should be used to finalise the detail of designs.

The turns which are normally modelled by VPATH and which are shown in the Austroads turning path templates are called tangential turns.

This is because the vehicle is aligned with the entrance tangent for the circular turn with the front (steered) wheels pointing straight ahead. Due to the characteristics of vehicle steering geometry, there is a transient state (or distance) where it is possible for the front wheels of a vehicle travelling at slow speed to follow a circular path while the steering angle is changed from straight ahead to the maximum angle that is needed to describe the turn.

Tangential turns should always be used for the design of intersection turns and turns from the roadway into a property access. In practice, drivers may sometimes execute turns after applying some initial lock while the vehicle is stopped. This is due to factors such as driver error or constraints imposed by low standard geometry, disabled vehicles or obstacles on the road.

Initial lock turns require shorter arcs of turn but involve maximum off-tracking for more of the turn and greater out swing of the rear of the vehicle at the start of the turn (Figure 5.36). Initial lock turns are relevant for off-street manoeuvres (including roadside parking manoeuvres) and, in constrained situations, for entering and leaving parking spaces but not for circulating roadways within a parking facility.

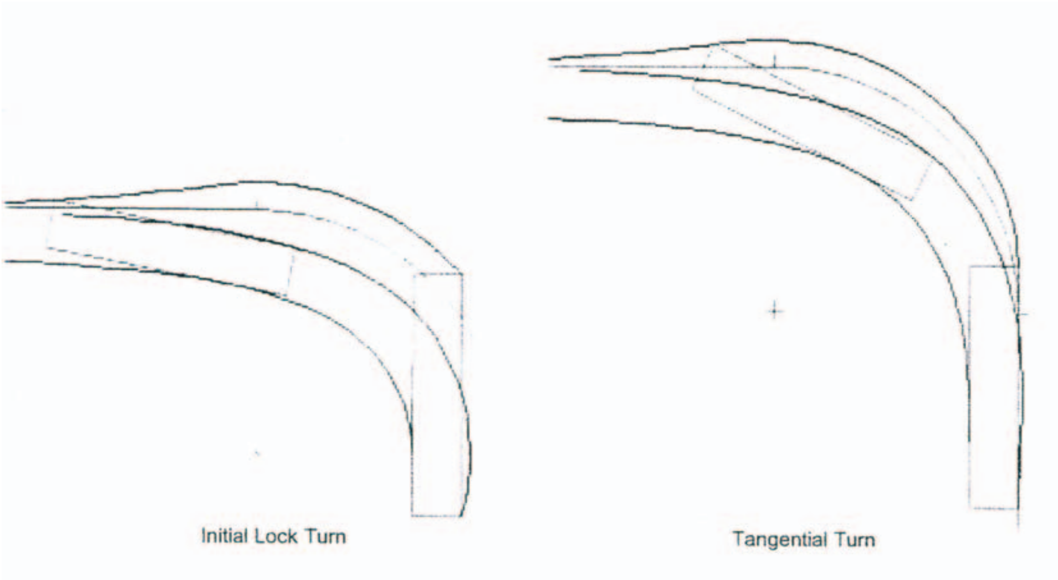

Figure 5.37 Comparison of Initial Lock and Tangential Turns

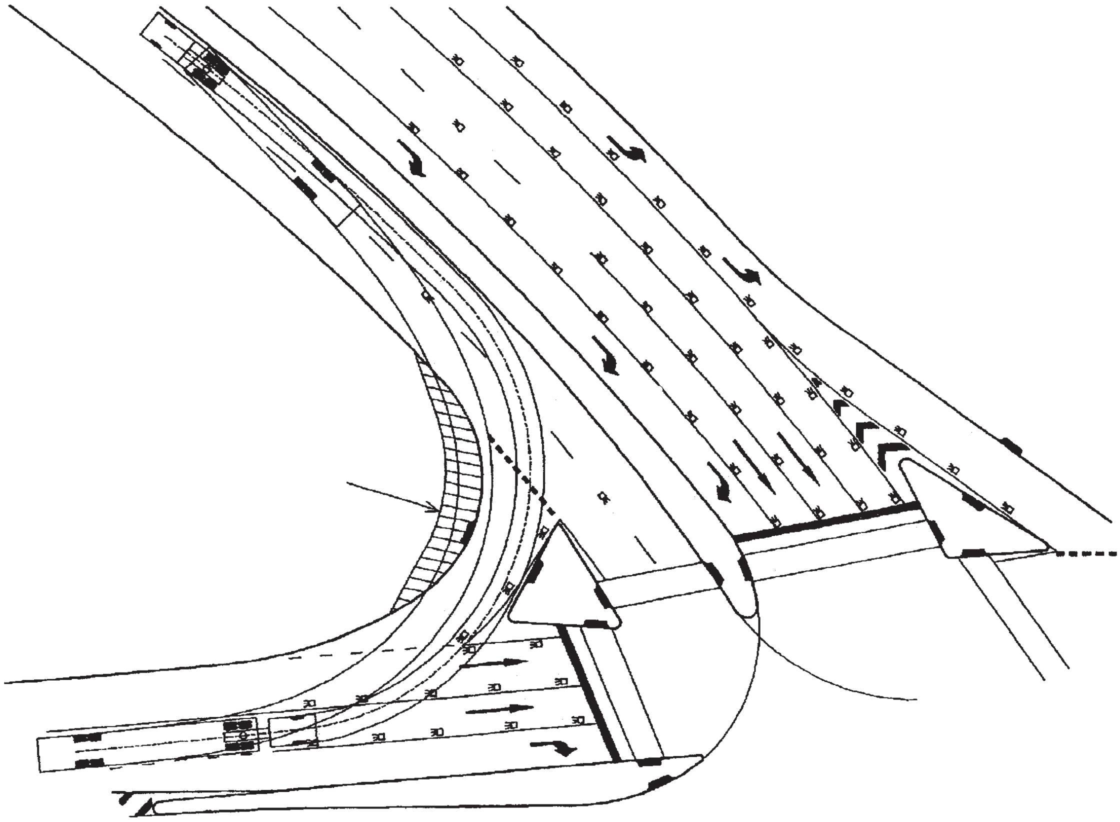

Figure 5.38 Provision for a Check Vehicle

Off-street manoeuvres may involve the reversing of vehicles. Reversing templates for the Design Service Vehicle, the Design Single Unit Truck/Bus and the Design Prime Mover and Semi-Trailer are provided in Appendix 5A.

5.7.9 Clearances

Austroads turning path templates and swept paths generated by VPATH show actual swept path limits; that is, there are no inbuilt margins to ensure that they cover variations in steering path which are likely in operation. These variations are covered by providing clearances beyond the swept path limits. Clearances of 0.6m each side of the swept path should be used when the steering path radius is less than about 50m. For short lengths of straight between curves (less than about 10m), the clearances that are applied to the circular sections should be carried through. For longer lengths of straight and curves with a radius greater than 50m, smaller clearances may be used, with the lower bound being the same as that used on normal straight sections of the road (Cox 1987).

Besides accommodating variations in steering path, clearances also help accommodate larger vehicles than the vehicle used for the design of a road layout. This can occur because the legal maximum sized vehicle is larger than the design vehicle (e.g. 12.5m Design Single Unit Truck/Bus used when a 19m Design Prime Mover & Semi-trailer is still allowed to operate) or the section of road is used for occasional oversized vehicles travelling under permit. Also, the clearances provide some scope for future increases in vehicle size.

When a check vehicle is used to check a layout, or where a design vehicle has to make a turn at an existing intersection that has not been designed for that vehicle, the following compromises might need to be considered:

- The vehicle may have to encroach into an adjacent lane for part or all of the turn. However, Australian road rules, which allow a large vehicle to make use of an adjacent inner lane apply only to the use of the inner two lanes.
- The vehicle will normally encroach into the clearances provided for the design vehicle and may encroach onto islands or verge areas where this is acceptable and appropriate provision has been made.
- The vehicle might have to execute a more complex steering manoeuvre than that needed for the design vehicle.

Figure 5.38 shows a typical case of providing for a check vehicle.

5.7.10 Representative Steering Path

When any turning movement is assessed in VPATH, it is first necessary to determine a representative steering path for the turn. Underlying this task is the fact that even in the case of a simple circular turn, there are essentially an infinite number of steering radii that are possible. However there is always some lower bound and some upper bound with the range decreasing with increase in vehicle size. Variations in steering radius are accommodated by the clearances that must be provided when a swept path is used to check a vehicle movement (Section 5.7.9).

In the case of complex turning manoeuvres, the scope for variations in steering path is greater than for simple circular turns. Besides there being variations in the actual radii which are steered by drivers, there will be variations in the way drivers make the transition from one segment of the steering path to another. Furthermore, it is essential that designers provide some latitude for the

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Table 5.17 Standard Vehicles Supported by VPATH

Name	Description	Min. Radius (m) Abs	Min. Radius (m) Gen	Remarks
DESIGN-SEMI	Austroads 19m long prime mover and semi-trailer.	12.5	15	Design Vehicle. Has as-of-right access to any road unless specifically excluded. Able to make 90 deg R15 turn in same space as R12.5 turn.
DESIGN-TRUCK	Austroads 12.5m long single unit truck / bus.	12.5	15	Design Vehicle. Has as-of-right access to any road unless specifically excluded. Greater difficulty in making R12.5 turn than design-semi
DESIGN-SERVICE-TRUCK	Austroads 8.8m long single unit service truck.	11	12.5	Design Vehicle representing refuse trucks and fire tenders that must be able to operate on any suburban street.
DESIGN-CAR	Austroads 5.0m long design car.	7.5	10	Design Vehicle representing cars, 4WD wagons, small delivery trucks and vans. Minimum turning radius based on 4WD wagon.
ARTICULATED-BUS	Austroads 19m long	10.6	15	Use in special cases. Has better swept articulated bus without rear wheel steering. path performance than design-semi.
LONG-RIGID-BUS	14.5m long rigid bus for controlled access routes.	12.5	15	Used on designated urban routes and as inter-city tourist coach. Designed to minimise swept path width but outswing of rear can be a problem on an initial lock turn.
B-DOUBLE	Austroads 25m long B-Double.	15	20	Design Vehicle for B-Double routes and access roads to B-double routes. Check vehicle for design-semi. Able to turn at R12.5 for turns up to 150 deg deflection.
B-TRIPLE	36.5m long B-triple	15	20	Use in special cases, e.g. assessment of possible B-triple routes. Has poorer swept path performance than road-train-1 due to wheelbase configuration.
13.0M-RIGID-BUS	BCC 13m long rigid bus	15	20	Use in special cases.
ROAD-TRAIN-1	Austroads 36m Type 1 (double) road train.	15	20	Design Vehicle for Type 1 road train routes
ROAD-TRAIN-2	Austroads 53m Type (triple) road train.	15	20	Design Vehicle for Type 2 road train routes.
25M-LONG-SEMI	Austroads 25m long prime mover & semi-trailer.	15	20	Check vehicle for industrial areas where design-semi or B-double used as the design vehicle.
DESIGN-LOWLOADER	26.8m long lowloader with trailer set to 4.27m width.	15	20	DMR Design Vehicle for over dimension vehicle routes. Check vehicle for industrial areas.
CAR-AND-CARAVAN	13.24m overall length car and caravan combination	7.5	10	Use in special cases.
12.5M-RIGID-TRUCK	12.5m long SU truck; twin steer, cab forward type.	14	15	Use in special cases. Has poorer turning radius and swept path performance than the design-truck which is more representative of buses.
TRUCK-AND-TRAILER	19m long SU truck with dog trailer.	12.5	15	Use in special cases. Has better swept path performance than design-semi but has poorer tracking fidelity. Second articulation point gets locked for reversing.
CAR-CARRIER	23m long car and boat trailer.	15	20	Use in special cases. Able to turn at R12.5 for turns up to 150 deg deflection. Has slightly worse swept path performance than design-semi.

drivers of large commercial vehicles to change lock when making the transition from one curve to another in the case of a reverse curve.

If transition curves are not being used, this can be achieved by allowing a sufficient length of straight between the curves. A minimum length of straight of about 3m should be provided, if both of the curves are less than about 40m in radius. If both of the curves are less than about 20m in radius, it is desirable that the minimum length of straight be increased to about 5m (Cox 1987).

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7 Relationship to Other Chapters

- This chapter introduces concepts useful in explaining the background to details in several other chapters;
- Roadway capacity and level of service play a part in the details of Chapter 4;
- Cross section details (Chapter 7) must consider the requirements described in Chapter 5;
- Driver characteristics and their influence on speed selection - Chapter 6;
- Design of safety barriers must consider the needs of all users (including motorcyclists) – Chapter 8;
- Sight distance parameters are derived from driver characteristics in terms of response times – Chapter 9;
- Alignment is affected by the needs of all road users including motorcyclists, bicycle riders and pedestrians – Chapters 10, 11, 12;
- Intersections and Interchanges must take account of the needs of all road users, and the needs of pedestrians and bicycle riders must be accommodated (Chapters 13, 14 and 16);
- Design vehicle dimensions affect many parameters throughout the manual – wherever widths and turning paths are an issue.

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Appendix 5A Service Area Templates

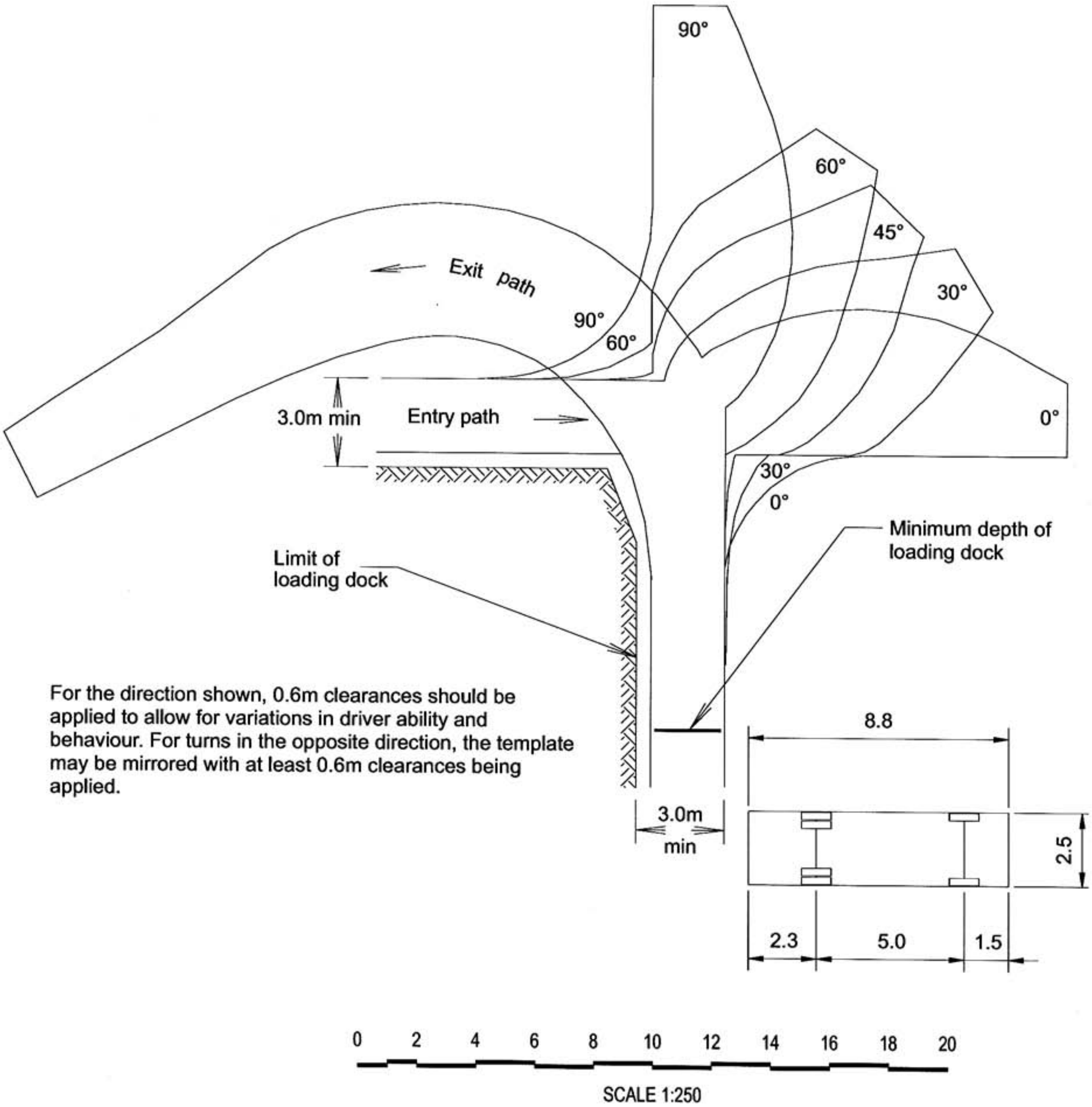

Figure 5.39 Service Area Template 8.8m Design Service Truck

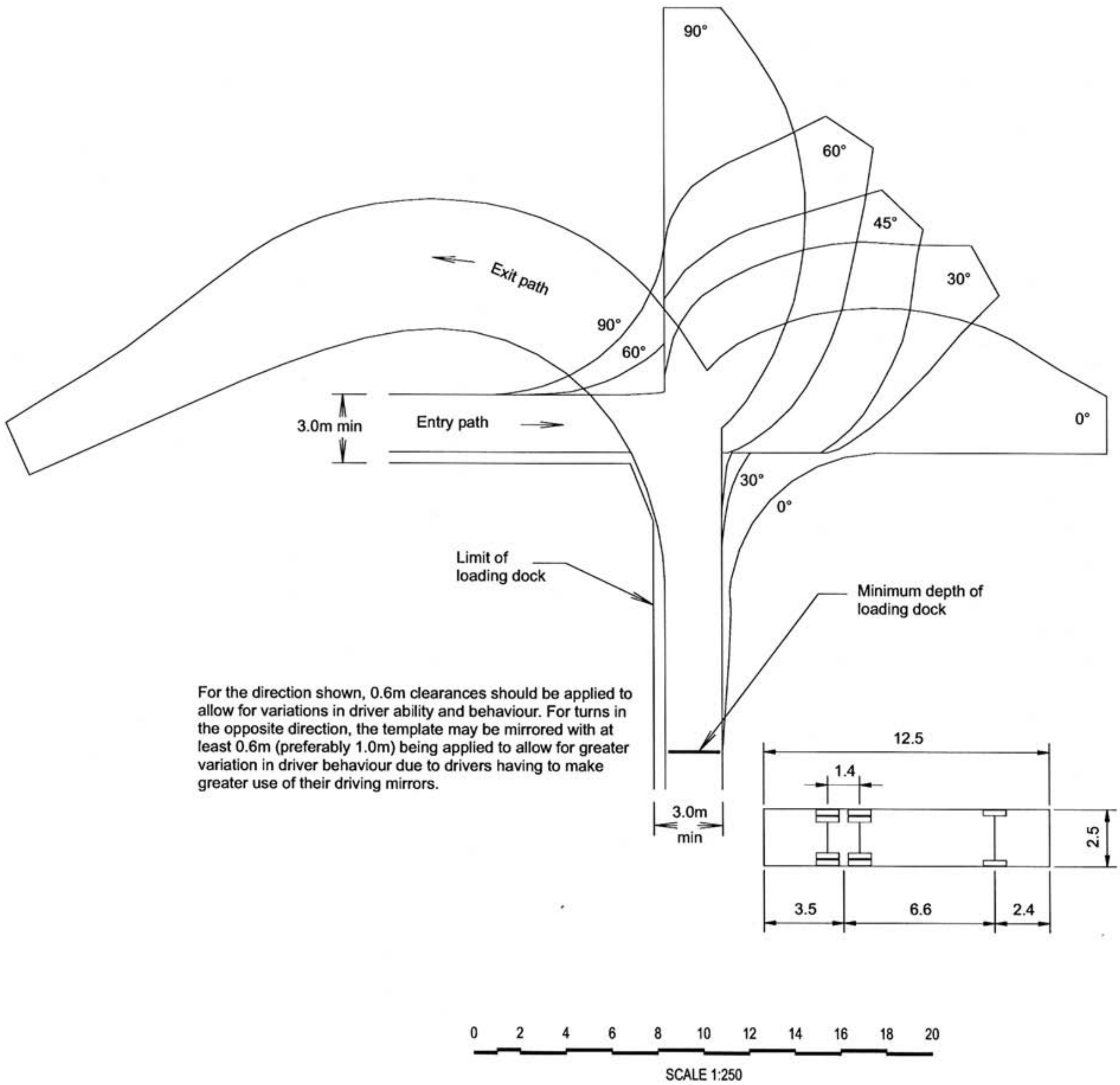

Figure 5.40 Service Area Template 12.5m Design Single Unit Truck

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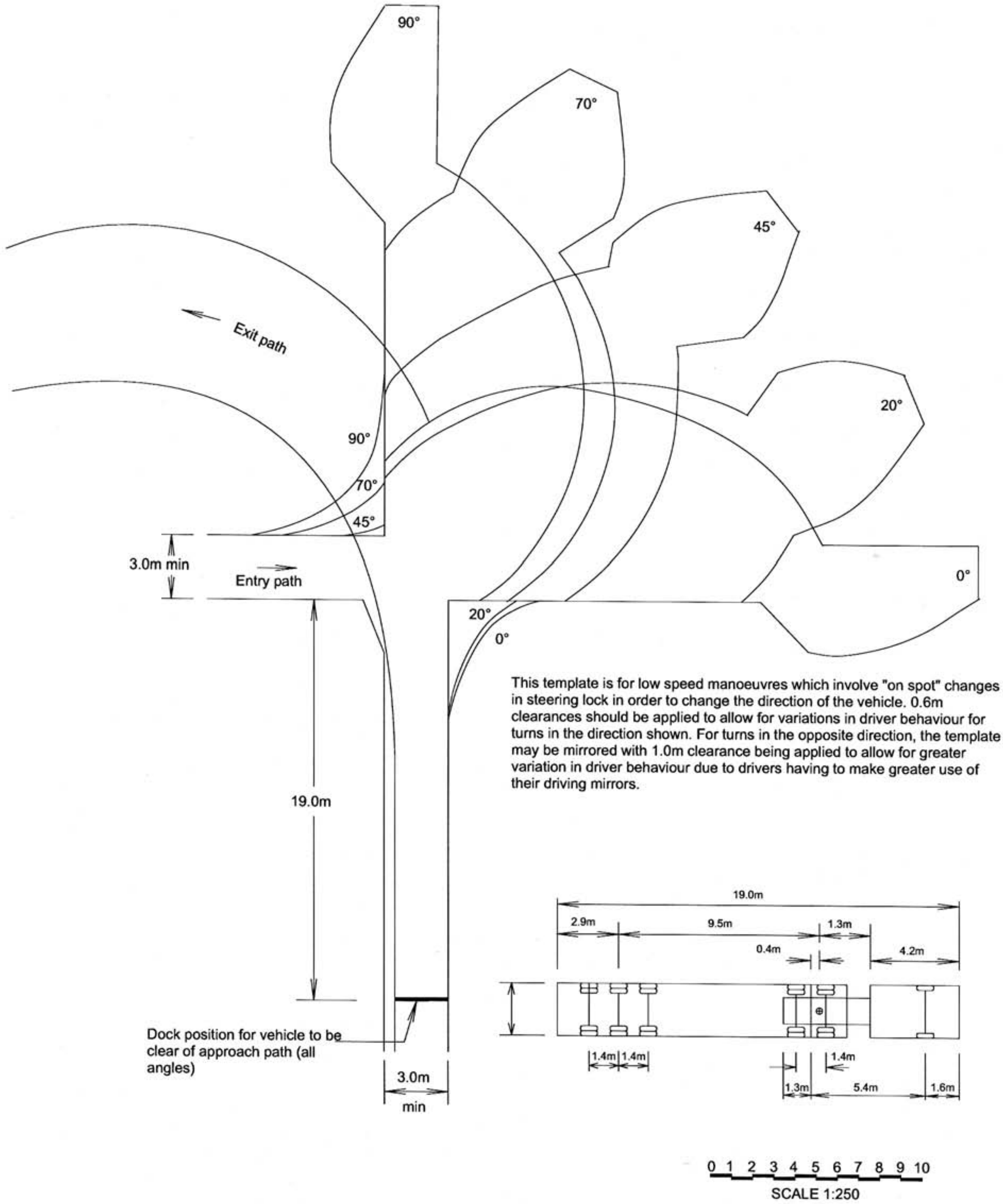

Figure 5.41 Service Area Template 19m Design Prime Mover and Semi-trailer

Appendix 5B: Guideline for Motorway Cycling

5B.1 Introduction

In assessing the feasibility of motorway cycling, detailed consideration should be given to the following design issues:

- Main Roads' Cycling Policy;
- Shoulder width;
- Surface quality of the shoulder;
- Volume of motor vehicles using the ramps;
- Sight distances to cyclists crossing the ramps;
- Existence of multi-lane ramps; and
- Existence of a practical alternative route.

This guideline focuses on only one of the two options available for cycling within the motorway reserve, the use of the motorway shoulders. The option of using a cycle path within the motorway reserve or the construction of a high standard off-motorway facility should be considered if it is determined that the shoulder use does not meet the criteria. The design criteria for alternative facilities should accord with the requirements set out in this Chapter.

5B.2 Single Lane Ramp Volumes

Cyclists can cross motorway ramps if there are sufficient gaps in the traffic flow. Cyclists require a minimum time of 7 seconds to cross a single lane ramp. The GTEP Part 14 (Austroads, 1999a) refers to a 1989 study on "Urban Freeway Cycling" which established a relationship between how long cyclists needed to wait for a 7-second gap to occur, in a range of traffic conditions. It states that a maximum average delay of 15 seconds for cyclists is appropriate, and this corresponds to a random traffic flow of 1000 vehicle per hour.

However, traffic counts for peak hours are an average, and volumes are higher at various times during the middle of this peak period. Consequently, an average traffic flow of 800 vehicles per hour is more appropriate, to allow for peak flows of 1000 vehicles per hour in any part of the hour.

Reasonable expectations for use of the ramp include:

- Cyclists understand that they must cross high speed motor vehicle traffic; and
- Motorists are expecting to merge or diverge smoothly without crossing facilities

Therefore, cyclists may be permitted to cross single lane freeway ramps if motor vehicle volumes do not exceed 800 vehicles per hour at any time during the day. The crossing method should be as shown in GTEP Part 14.

5B.3 Sight Distances

Both the on and off ramps should have adequate stopping sight distances between the approaching motor vehicles and the point where cyclists cross the ramps to allow motorists to stop should there be a need.

The desirable sight distance between a motor vehicle on the ramp, and the point where cyclists cross the ramp, is 210m based on a design speed of 110km/h and 0% grade in accordance with Chapter 9. Similarly the distance is 250m for a design speed of 120km/h. Sight distances should be adjusted for the grades.

These sight distances should be adopted on motorways where cyclists are permitted to ride and are directed to cross the motorway interchange ramps.

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5B.4 Multi-lane Ramps

Multi lane ramps are difficult for cyclists to cross, as they need to judge an appropriate gap in both lanes of traffic. Cyclists should not be permitted to cross ramps with more than one lane. Where there are multilane ramps, cyclists should either be prohibited from using the motorway, or if the motorway is otherwise suitable, they should be provided with an alternative route that avoids the ramps (or a grade separated crossing should be provided).

5B.5 Avoiding Ramp Crossings at Interchanges

There may be some situations where a motorway is suitable for allowing cycling on the sealed shoulder/emergency-stopping lane, with the exception of a particular interchange. The interchange may have multiple lanes on the ramp, or it may have traffic volumes greater than the acceptable maximum.

Rather than prohibiting cyclists this from section of the motorway and needing to provide an alternative route, it may be appropriate to direct cyclists onto the off-ramp and then via the on-ramp back onto the motorway as shown in the GTEP Part 14 (Austroads 1999a).

Where it is necessary to avoid multiple ramps, a high standard alternative route shall be provided.

Where the interchange is not a full diamond, off road paths could be provided to create a full diamond interchange for cyclists.

Another alternative for avoiding crossings is to provide cyclists with a grade separated crossing. This is an expensive option however, whether the benefits outweigh the costs requires careful consideration.

5B.6 Sealed Shoulder Width

Sealed shoulders should be wide enough to provide adequate separation between cyclists and the adjacent motor vehicles. Refer to Sections 5.5.4 and Chapter 7 of this manual for further detail.

5B.7 Sealed Shoulder Surface Quality

The shoulder/emergency-stopping lane on a motorway should be as smooth as the adjacent road surface. Where bicycles are to use the motorway shoulders the motorway shoulders should be sealed with a maximum stone size of 10 mm to ensure a smooth, high quality riding surface.

5B.8 Signage

Signage is only necessary if the cycle route is marked. Cycles may not be banned from using a Motorway, but the department may choose not to mark the cycle route.

Where cyclists are permitted to ride on the motorway shoulder on a marked cycle route, additional signs in accordance with the MUTCD (Main Roads, 2003) are required:

- At entry and exit ramps, warning motorists that they might encounter cyclists crossing ramps;
- At all interchanges to guide cyclists safely across the ramps or via an alternative route;
- To advise cyclists of a requirement to leave the motorway (e.g. at 'squeeze points' such as narrow shoulder on bridges) or to cross a ramp;
- When an alternative route is provided due to roadworks or future closure of a section of motorway.

5B.9 Alternative Routes

Motorways tend to be used by training cyclists, commuter cyclists and some experienced recreational cyclists. They have usually chosen the motorway route due to its directness and the lack of alternative routes.

If a motorway, or motorway section, does not meet the design requirements outlined above the cycle route should not be marked and forward planning should be undertaken to develop an appropriate alternative route before cyclists are prohibited on the motorway. The alternative route could be a separated facility or a continuous and direct route using adjacent lower volume and lower speed roads. The alternative route should aim to provide cyclists with a facility of a similar standard to that of the motorway, and with minimum deviation or added distance.

When developing alternative cycling routes, the following factors need to be considered:

- clear directional signage of the route;
- sufficient or continuous shoulders or bike lanes;
- lower speed limits; and
- intersection and roundabout treatments.

When designing the alternative route, the bicycle facilities should be designed in accordance with this Chapter the GTEP Part 14 (Austroads, 1999a).