ASIAN HIGHWAY DESIGN STANDARD
FOR ROAD SAFETY

DESIGN GUIDELINES

October 2017

This document consists of recommended guidelines related to the “Asian Highway Design Standard for Road Safety” to the Intergovernmental Agreement on the Asian Highway Network.

While the guidelines are not mandatory in nature, the member countries of the Asian Highway network are encouraged to refer to the principles and recommendations given in the document for new road projects and improvements of existing sections of Asian Highway routes under their jurisdiction.

Due to the diverse circumstances of the Asian Highway Network, the adoption of particular recommendations would need to take into account prevailing social, economic and technical considerations.

In all cases, sound engineering skills are required to formulate specific solutions to address project issues which could be complex in reality. Flexibility and innovations are desirable as far as safety performance is not undermined and consistency is reasonably maintained.

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- Bangladesh (Mr. Noor-E-Alam)
- China (Prof. Xiaojing Wang)
- India (Mr. Tony Mathew)
- Republic of Korea (Dr. Sung-min Cho)
- Thailand (Mr. Sujin Mungnimit)

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PART 1 ROAD NETWORK

1 GENERAL CONSIDERATIONS

1.1 Network Development

The Asian Highway Network consists of a diversity of road types and facilities serving a variety of destinations of importance in terms of population, industrial activities, tourism, logistics and international cross-border transport.

A high level of road safety design on this network is a prime objective. Harmonisation of road safety infrastructure facilities is also highly desirable for the network to function as international corridors. This would enable drivers of cross-border traffic as well as foreign rental car drivers to better adapt to the road network in different countries.

The general characteristics of the network are illustrated in ***Figures 1.1.1.1, 1.1.1.2 and 1.1.1.3***. These road network and usage perspectives are fundamental considerations for road safety.

FIGURE 1.1.1.1 GENERAL COMPONENTS OF THE ROAD NETWORK

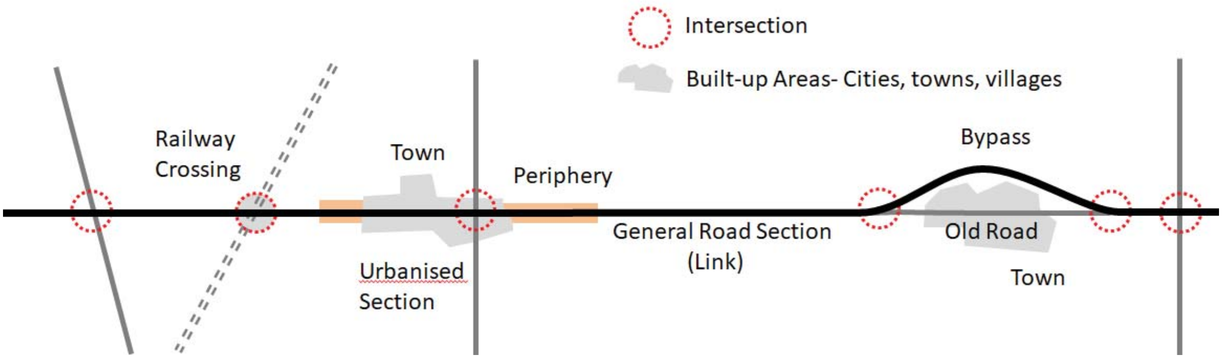


FIGURE 1.1.1.2 MAJOR BYPASSES

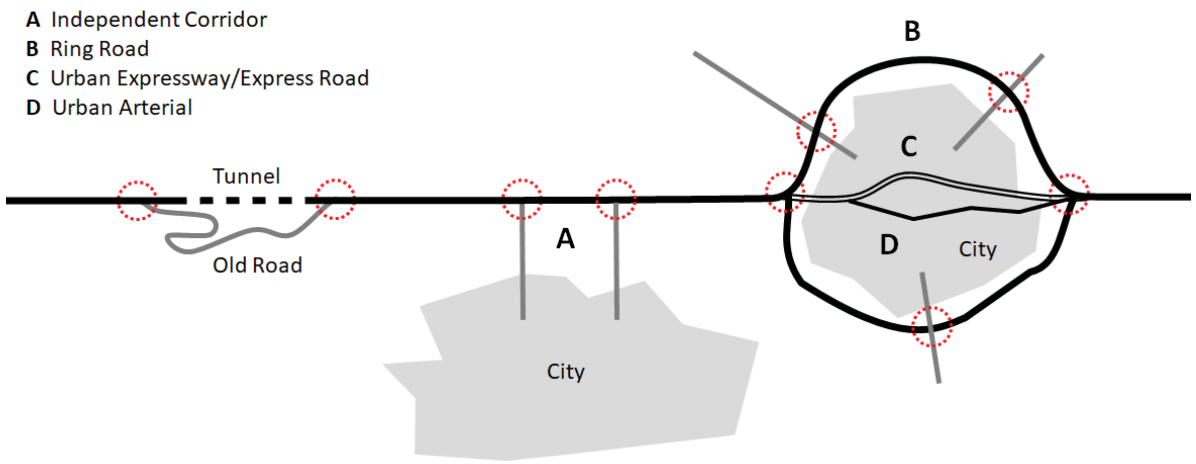
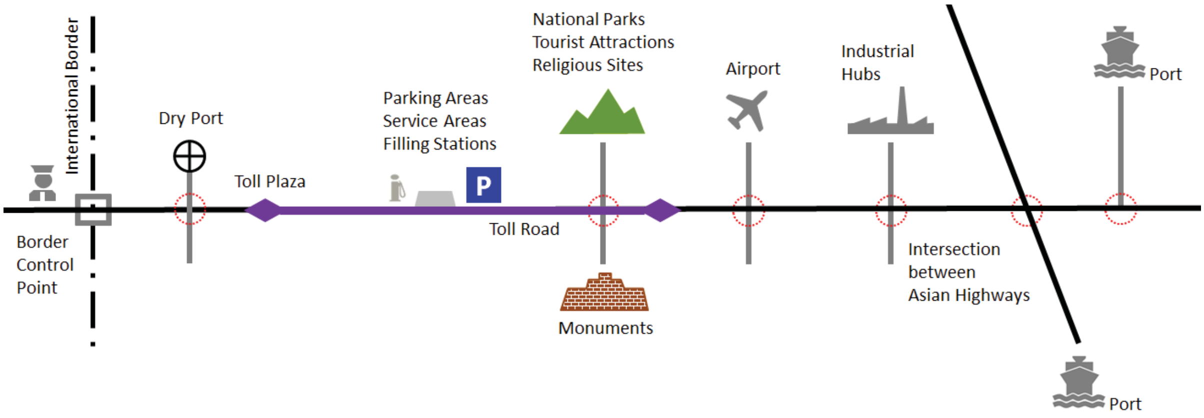


FIGURE 1.1.1.3 KEY FACILITIES AND CONNECTIONS



Signing of Expressways and Express Roads

Where justified by traffic volume and economics, access-controlled roads are desirable for Asian Highway routes. They should be signed as expressways or express roads which are defined in national law for the exclusive use of motor vehicles. Expressways are appropriate for high standard Primary class roads with design speed not less than 80km/h. Express roads are appropriate for other access-controlled roads with design speed not less than 60km/h. The entrance and termination of expressways and express roads should be demarcated by traffic signs as shown in ***Figure 1.1.1.4***.

FIGURE 1.1.1.4 EXPRESSWAY AND EXPRESS ROAD SYMBOLS

Bypass of Population Centres

Bypasses are diversion routes which bring main road traffic away from built-up areas. They are often beneficial around cities from the safety, environmental and urban design perspectives. Bypasses are also highly desirable around smaller built-up areas with thriving activities or narrow cross-sections of the road.

City bypasses are preferably ring road systems, but they may also directly traverse urban areas in the form of expressways or express roads in tunnels, viaducts or flyovers. On the other hand, high priority routes may follow entirely independent corridors away from cities.

Bypasses are preferably in the form of access-controlled roads, otherwise the number of intersections and direct frontage accesses should be restricted. Adequate right-of-way will be needed for future widening and provision of service roads, grade-separated intersections or crossing facilities.

Allowance for Future Widening

In the design of new Primary class roads, adequate consideration should be given to the need for future widening. There are two possibilities:

- Acquiring right-of-way to accommodate additional traffic lanes
- Initial construction of one carriageway for two-way traffic

For Option 1, symmetrical widening is preferred as asymmetrical widening is generally more prone to safety problems during construction.

Option 2 should not be adopted unless a high level of safety design and management is ensured. Special treatments are required to reduce the risk of indiscriminate overtaking and drivers' misinterpretation as a unidirectional road.

It is generally not recommended to construct only one tunnel tube of a planned twin tube tunnel for bidirectional traffic in the interim period. If this option is chosen, special measures will be required to minimise any safety risks.

Network for Pedestrians and Slow Vehicles

Safety improvements on Asian Highway routes should, as far as possible, involve a wider optimisation of the road network by diverting pedestrians and slow vehicles to local roads and minor corridors away from the main highway. Outside built-up areas, a network strategy comprising one or more of the following measures is recommended:

- Restricting the number of at-grade intersections and direct frontage accesses
- Providing alternative or parallel routes, or service roads
- Grade-separation with or without intersection

Re-use of Old Roads

Where improvements of existing Asian Highway routes involve realignment, consideration should be given to the beneficial re-use of abandoned sections of the existing roads.

Such re-use is preferably part of a network strategy to improve safety for pedestrians and slow vehicles. Possible initiatives include:

- Existing road promoted as a local access road
- Existing sections of roads and bridges converted for the use of pedestrians, slow vehicles or tourist traffic
- New usage such as public parks, viewpoints, roadside parking areas, rest areas, emergency parking areas or bus stops

Re-use of old bridges should be encouraged provided that they are well maintained. An individual old bridge only benefits one direction of travel, in which case pedestrian and slow vehicle facilities are still required for the other direction of travel.

For successful re-use of existing roads, attention should be given to the details so that they are attractive to users. It is generally desirable for users to be within the visibility of the new road for reasons of personal security.

Intersections between the existing road and the new road should be minimised and treated with appropriate safety measures, particularly where crossing movements are involved. Side roads should intersect the main road at right angle with adequate visibility.

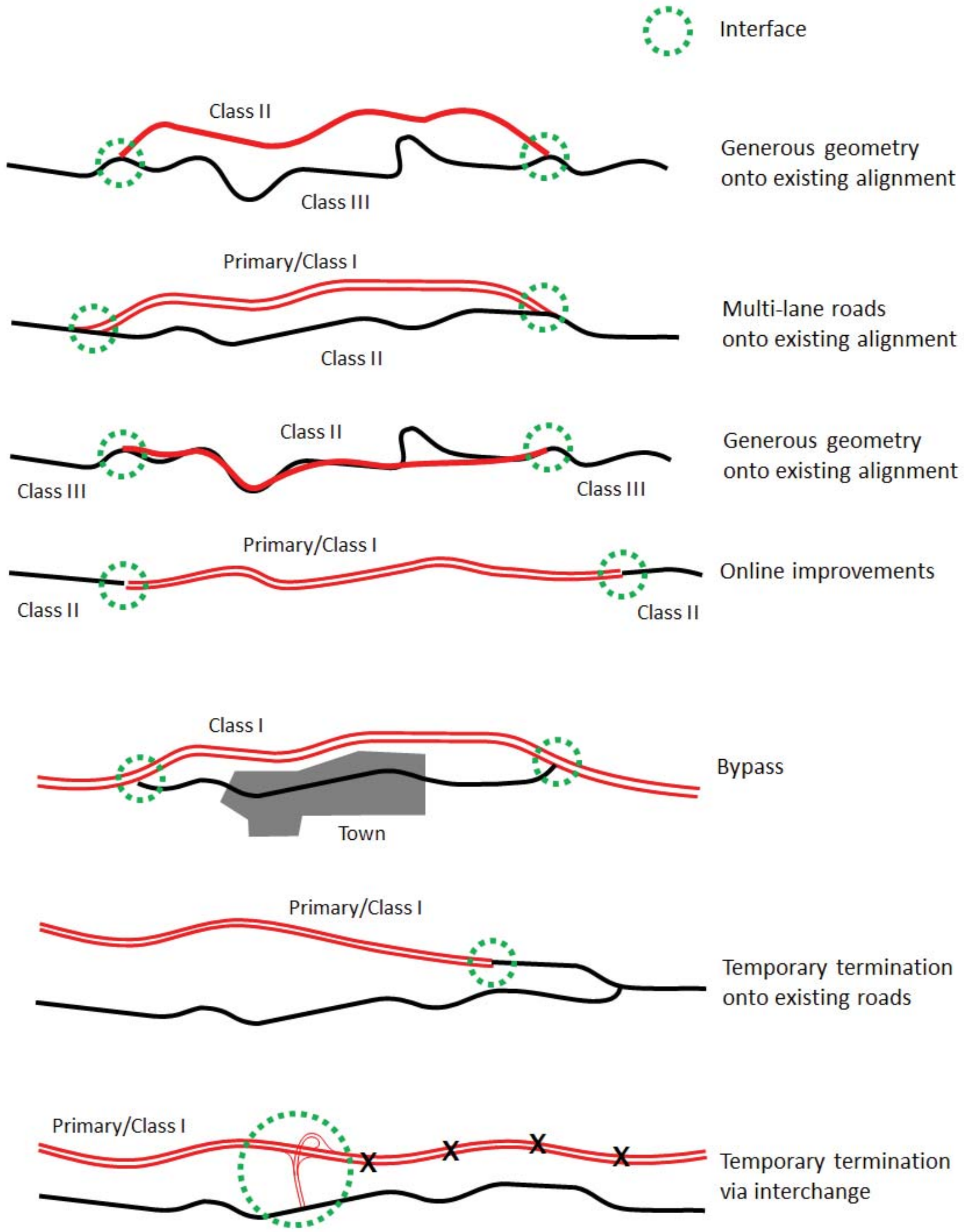
Where a bypass is available, the original urbanised section is preferably converted as a multi-purpose urban street with traffic calming and pleasant streetscape in favour of pedestrians, slow vehicles and local activities. Intersections between the bypass and the existing road should be designed to clearly distinguish the two directions.

1.2 Interfaces

General Requirements

Phased improvements of Asian Highway routes will constantly result in interfaces between road sections of different characteristics. Typical interfaces are illustrated in ***Figure 1.1.2.1***.

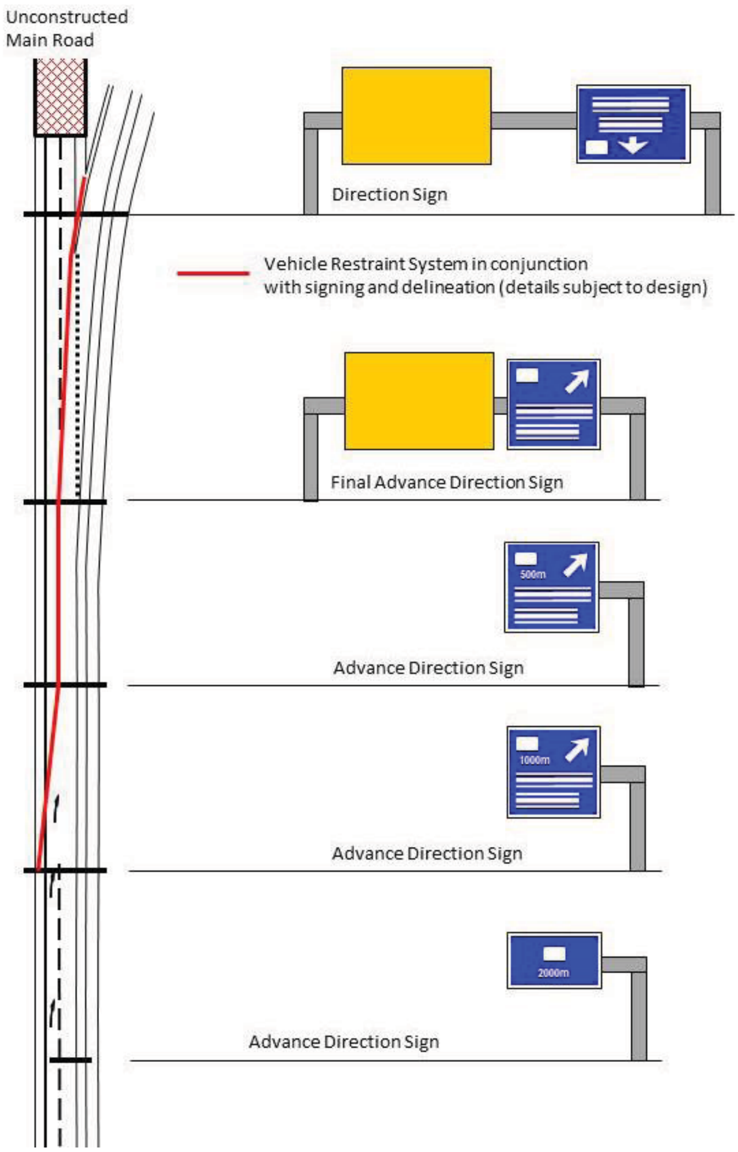
FIGURE 1.1.2.1 TYPICAL INTERFACES



At the interface between road improvement projects and existing roads, particular attention should be given to road safety in the direction from the new road to the existing road. The following treatments are desirable to incite drivers adapting their speeds and behaviour:

- Cross-section change together with changes in the surrounding environment and landscape
- Usage of roundabouts
- Mandatory exit at grade-separated intersections (***Figure 1.1.2.2***)

FIGURE 1.1.2.2 EXPLICIT MANDATORY EXIT LAYOUT



Interfaces should not be located where the existing road geometry is significantly inferior to the new road. Unfavourable situations include the presence of sharp curves, significant crest profiles, complex road environment, constrained visibility etc. Particular attention is also needed in the design of delineation and roadside safety at interfaces.

1.3 Transition Zones

Transition zones are road sections at the interface between different road classes, road types or road sections with different design speeds. These zones should be accompanied by physical changes of the road which are obvious and explicit, but not to the extent of causing abrupt braking.

A change of speed limit at transition zones should accord with:

- changes in horizontal and vertical alignment, cross-sections etc.
- interchanges, roundabouts, intersections etc. which create a gateway effect
- changes between urban and rural settings
- difference in streetscape, plantings or landscape, safety barriers etc.

The length of transition zones may be based on a deceleration rate of $0.8m/s^2$ and is generally in the order of 100m to 200m for each stepwise speed limit reduction of 20km/h.

Termination of Primary Class Roads

Special treatments are required at transition zones to alert drivers and to assist them adapting to the change where a Primary class road or access-controlled Class I road terminates in one of the following arrangements:

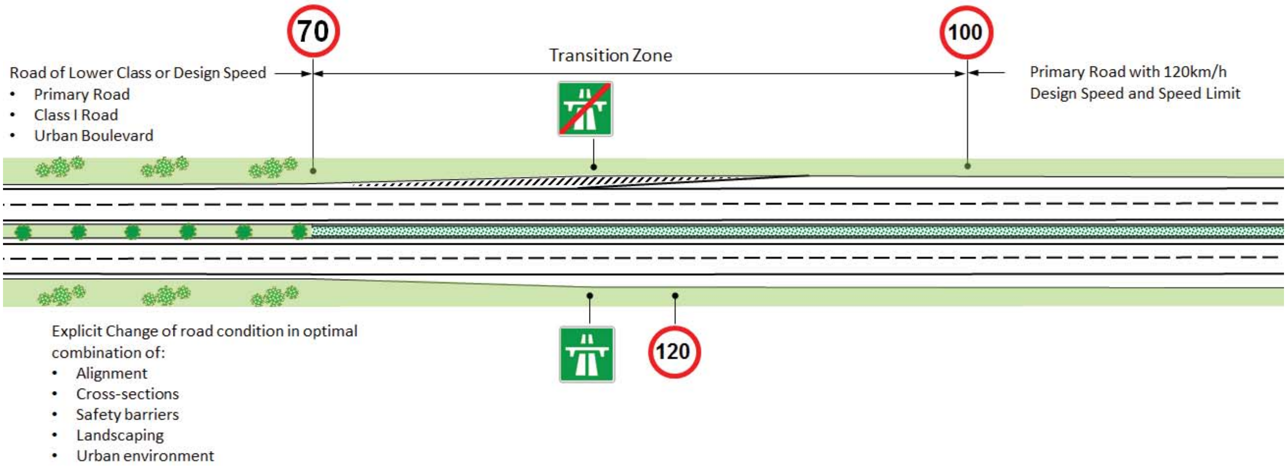
- A lower design speed is adopted on the road
- The Primary class road becomes a Class I road
- The road becomes a Class II or Class III road
- The road terminates directly onto an at-grade intersection
- The road terminates at a partially constructed grade-separated intersection

“End of Expressway” signs should be erected on the approach, commencing not less than 1500m ahead of an intersection or the point where the design speed or road class changes. In addition, these should be accompanied by appropriate traffic signs, road markings and speed reduction measures. Lower speed limits should be posted with stepwise reduction of 20km/h or 30km/h if there is a large reduction of design speed. A typical transition zone is illustrated in ***Figure 1.3.1.1***.

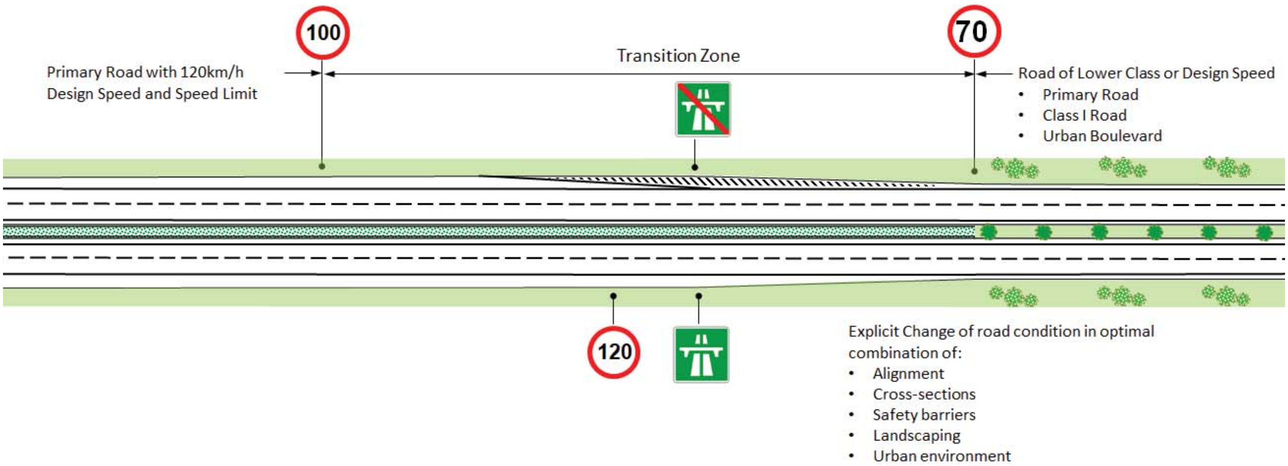
Reduced speed limits may be preceded by advance signs 100m to 200m upstream. Advance signs could be beneficial if the need to slow down is not immediately clear or the change in speed limit is located after a curve.

FIGURE 1.1.3.1 CONCEPTUAL LAYOUT OF TRANSITION ZONE

(for driving on the right side of the road)



(for driving on the left side of the road)



2 SPEED LIMITS

2.1 General Considerations

Speed limits define the maximum legal speed of travel on a road and are part of the overall strategy to enhance road safety. The objective is to foster a safer speed distribution to benefit all users on the road. They should be set according to design speed and alignment characteristics in conjunction with the following considerations:

- Road function
- Roadside land-use
- Existing speed distribution (average and 85 percentile)
- Historic crash data
- Type and density of intersections
- Presence of pedestrians, slow vehicles and tourists
- Roadside risks and conditions of safety barriers

Speed limits may be reduced to reduce environmental impacts and noise through scenic areas, tourist areas and ecologically sensitive zones.

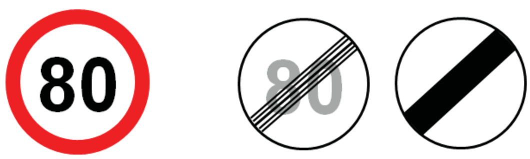
Speed limits should be credible, reasonable and self-enforcing. Their rationale should be obvious and commensurate with the prevailing road design and roadside characteristics. Speed limits should be consistently applied for similar road conditions and frequent changes should be avoided. Isolated hazards such as curves may be treated with warning signs and delineation without reducing the speed limit.

For road sections with difficult alignments, poor roadside conditions and inadequate visibility, it is generally appropriate to lower the speed limit but this should not substitute essential safety improvements such as installation of safety barriers over sheer drops.

Speed Limit Signs

Speed limit signs are circular regulatory signs with a red border containing numerals of the speed limit in "km/h". Speed limit termination signs are used if the route-wide or national speed limit is resumed after a short section of reduced speed limit. These signs are shown in ***Figure 1.2.1.1***.

FIGURE 1.2.1.1 SPEED LIMIT AND TERMINATION SIGNS



Speed Limit Repeater Signs

Speed limits other than national speed limits should be repeatedly signed. Repetition is also desirable on urbanised sections, notably along ribbon developments. Repeater signs are generally smaller versions of speed limit signs. The intervals for their placement may be based on the following values:

- Not more than 2km outside built-up areas
- Urbanised sections <300m
- Peripheries of urbanised sections <600m

Other Uses of Speed Limit Signs

It is generally desirable for heavy vehicles to travel at lower speeds than lighter vehicles. The maximum speed limit for heavy vehicles on different roads is often defined in national laws. These may be displayed on informatory signs at the entrance to Primary class roads.

On road sections with constrained alignment such as hairpins and long steep grades, it could be desirable to impose lower speed limits for heavy vehicles.

Consideration may be given to advisory speed limits on Primary class roads for adverse weather conditions such as rain and fog. A typical informatory sign is illustrated in ***Figure 1.2.1.2***.

FIGURE 1.2.1.2 INFORMATORY SIGNS FOR ADVISORY SPEED LIMIT DURING ADVERSE WEATHER

Positioning Speed Limit Signs

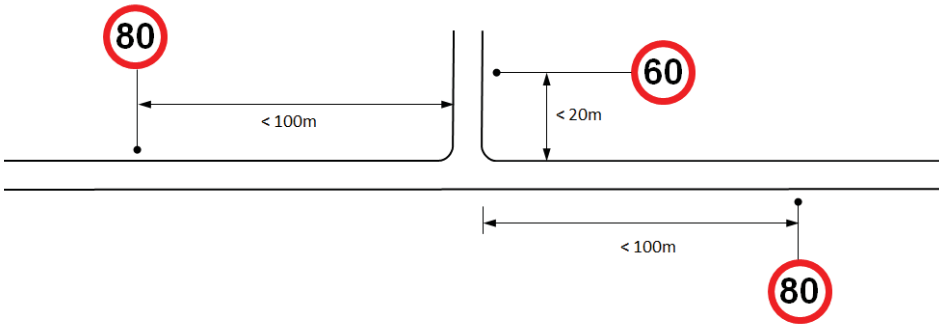
Suitable locations of speed limit signs or speed limit termination signs are:

- Entrance and exit of Urbanised Sections
- Downstream of toll plazas
- Downstream of grade-separated intersections
- Entrance and exit of tunnels
- Exit of border control points

At the exit of tunnels or urbanised sections, signing of a higher speed limit may need to be deferred if the immediate road alignment or road condition is not yet suitable for high speed travel.

Speed limit signs should be provided where there is a change of speed limit at intersections. The recommended locations are illustrated in ***Figures 1.2.1.3*** and ***1.2.1.4***.

FIGURE 1.2.1.3 SIGNING SCHEME WHERE SPEED LIMIT IS LOWER ON THE SIDE ROAD [1]
(for driving on the right side of the road)



(for driving on the left side of the road)

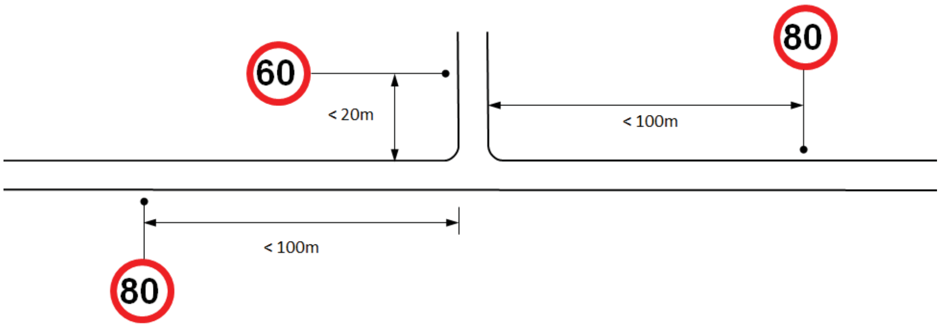
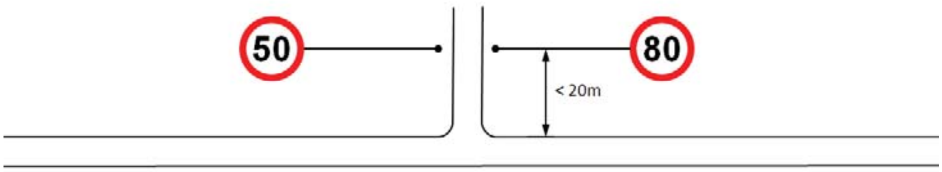


FIGURE 1.2.1.4 SIGNING SCHEME WHERE SPEED LIMIT IS HIGHER ON THE SIDE ROAD [1]
(for driving on the right side of the road)



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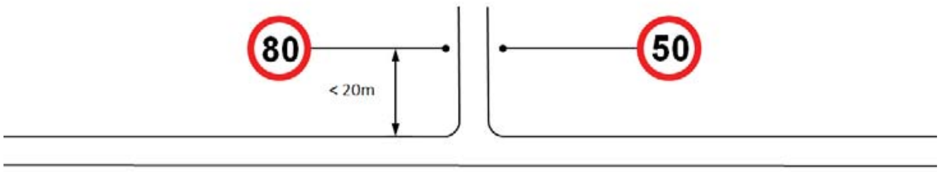


2.2 Setting Speed Limits

National Speed Limits

Default speed limits outside built-up areas are preferably set at the national level. A typical system consists of the following categories:

- Expressways: 120km/h
- Access-controlled Divided Roads: 100km/h
- Outside Built-up Areas: 80km/h
- Built-up Areas: 50km/h

Speed Limits outside Built-up Areas

Default speed limits may be adjusted to match the particular circumstances of a road (***Figure 1.2.2.1***). ***Table 1.2.2.1*** provides some general guidance on setting speed limits.

TABLE 1.2.2.1 SPEED LIMITS OUTSIDE BUILT-UP AREAS

Road Class	Speed Limit km/h*	Road Conditions
Primary class	120 (110)	- Rural or urban sections with very high alignment standard
	100 (90)	- Rural or urban sections with high alignment standard
	80 (70)	- Rural sections constrained by alignment or safety provisions - Urban sections with frequent grade-separated intersections
Class I	100 (110)	- Rural access-controlled sections with high alignment standard
	80 (90)	- Rural access-controlled sections constrained by alignment or safety provisions - Rural or Suburban sections with well separated intersections
	70 (80)	- Rural access-controlled sections constrained by alignment or safety provisions - Suburban sections with frequent at-grade intersections
	60 (50)	- Rural sections heavily constrained by alignment or safety provisions - Suburban sections with or without access-control - Suburban sections with very frequent at-grade intersections
Class II	80 (90)	- Sections with well separated intersections - Rural sections with high standard alignment
Classes II， III	70	- Rural sections constrained by alignment or safety provisions - Rural Sections with frequent intersections
	60 (50)	- Rural sections constrained by alignment or safety provisions - Rural or suburban sections with very frequent intersections
Class III	50 (40)	- Rural sections constrained by mountainous terrains or safety provisions - Narrow sections with fair alignment
	40 (30)	- Rural sections heavily constrained by mountainous terrains or safety provisions - Narrow sections with poor alignment

* For guidance only, categories and changes in speed limit should be minimised
( ) Alternative depending on national and local circumstances

FIGURE 1.2.2.1 ROAD WITH 70KM/H SPEED LIMIT *(driving is on the right side of the road)*

Speed Limits on Urbanised Sections

Speed limits within urbanised sections and their peripheries are set to limit the probability and severity of conflicts between vehicles and pedestrians or slow traffic. Recommended speed limits are given in Table 1.2.2.2.

TABLE 1.2.2.2 RECOMMENDED SPEED LIMITS ON URBANISED SECTIONS

Scenario	Default Speed Limit (km/h)	Possible Alternatives*(km/h)	Maximum Acceptable* (km/h)
Built-up areas/major villages	50	30**, 40**	50
Scattered houses	No reduction	50, 60, 70	No reduction
Peripheries of built-up areas	60	50	70
Peripheries of cities	60	50	70

* Retain or adopt lower speed limits if speed limit on the approach is already at or lower than the default value

** Desirable in very busy core zones of built-up areas and narrow roads with thriving activities

Drivers are more likely to comply with speed limits if the reasons are obvious e.g. visible presence of houses in a village. This is illustrated in ***Figure 1.2.1.2***,

FIGURE 1.2.1.2 VILLAGES WITH 40KM/H SPEED LIMIT *(driving is on the right side of the road)*

Other Usage of Speed Limits

Beside the above general usage, speed limit signs may be desirable or necessary with the following applications:

- Reduced speed limit for toll plazas and free-flow toll lanes
- Reduced speed limit for roundabouts
- Reduced speed limit for heavy vehicles on long steep downhill gradients, narrow roads and hairpins
- Reduced speed limit for slip roads
- Stepwise reduction of speed limit for diverging areas (***Figure 1.2.1.3***)
- Reduced speed limit or advisory speed limit for isolated hazards
- Advance informatory signs for reduced speed limit ahead

FIGURE 1.2.1.3 SEQUENTIAL SPEED LIMIT REDUCTION AT DIVERGING AREA
(driving is on the right side of the road)

PART 2 ROAD INFRASTRUCTURE

1 OVERVIEW

The fundamental safety aspects of road infrastructure are primarily the domain of highway engineering design covering alignment, cross-sections, forward visibility and overtaking sections. Provision of adequate facilities for road-users to stop and rest is also crucial to road safety in the highway network.

Adoption of appropriate design parameters is an important starting point. As road design elements are interdependent, consistency and coordination of elements are equally important. Planning on a route-wide basis is therefore encouraged.

It is necessary to ensure that drivers adopt appropriate speeds and behaviour commensurate with the road design. Self-explaining design is therefore also an integral component of the road design.

Self-explaining Road Characteristics

Self-explaining roads have consistent design and visual appearance which match the expectation of all road-users. They foster appropriate speeds and behaviour naturally without resorting to excessive use of signs and deterrence measures. Self-explaining roads are therefore more sustainable in safety performance and often are more compatible with urban design objectives.

The following road types of different nature or operational characteristics should be distinctly different in their visual appearance and reinforced by signing:

- Access-controlled divided roads: Primary class roads and Class I roads
- Non access-controlled divided roads: Class I roads
- Two lane undivided roads: Classes II, III roads
- Urbanised road sections

Drivers may fail to react and behave correctly on roads which are confusing, misleading or distractive. They tend to perceive the straight ahead direction as the continuation of the main road. Layouts contradicting this perception will then require explicit treatments. On the other hand, pedestrians are accustomed to interpret central refuge islands as separator of opposing traffic. A central refuge island on a one way road could then risk pedestrians looking into the wrong direction.

Self-explaining design is a vast concept which should be embedded into all aspects of the design of the road and traffic environment. In general, self-explaining designs are associated with clarity, consistency and simplicity of the road environment. Additionally, any potential hazards or conflicts should be obvious to road-users and within their direct vision.

2 ALIGNMENT AND CROSS-SECTIONS

2.1 Visibility

Visibility is required to ensure that drivers are able to predict, react to and negotiate through road features, pavement conditions and the movements of other vehicles or road-users.

Visibility requirements are based on Stopping Sight Distance (SSD) which consists of two components, namely distance for perception-reaction and distance for braking. The basic formula is given by:

$$\mathrm{SSD} = 0.278\mathrm{vt} + \frac{v^2}{0.254(a/9.81+g)}$$

v = speed (km/h)
t = driver perception-reaction time (seconds)
a = deceleration rate (m/s^2)
g = gradient e.g. 0.05 for 5% gradient, downhill gradient to be in negative value

Due to different assumption of the values of "t" and "a", SSD values vary in different countries. This is shown in ***Table 2.1.1.1***.

TABLE 2.1.1.1 SSD VALUES FOR SELECTED COUNTRIES

Countries	SSD (m) for Design Speed (km/h)						
	120	100	80	60	40	30	20
China	210	160	110	75	40	30	20
China (Trucks)	245 [273]	180 [200]	125 [139]	85 [95]	50	35	20
Thailand	-	185	130	85	50	35	20
Bangladesh	-	180	120	-	-	-	-
India	-	180	120	80	45	30	20
Korea	215	155	110	75	40	30	20
France	233 {275}	159 {185}	104 {119}	65 {73}	36 {39}	24 {26}	15 {15}
UK	295 (215)	215 (160)	150 (110)	90 (70)	-	-	-
UK(MfS)	-	-	-	56	31	20	12
TERN	200	150	100	70	-	-	-
TEM	200 {250}	150 {188}	100 {125}	-	-	-	-

[ ] Values to be adopted at maximum gradient permitted for the road class in China
( ) Values of "one step relaxation" not to be used at immediate approach to intersections but acceptable on free-flow link sections in the UK
UK(MfS) Manual for Streets, for urban streets with design speed =< 60km/h based on a= 4.41m/s
{ } Values for curve radius (m) less than 5V, where V= speed in km/h
TERN Trans-European Road Network (International E-Roads)
TEM Trans-European North-South Motorway

Table 2.1.1.2 gives the values adopted in the United Kingdom. These values are based on relatively conservative assumptions of t = 2s and a = 2.45m/s^2 (=0.25G) which would be sufficient for the majority of situations including snow-covered roads.

TABLE 2.1.1.2 RECOMMENDED STOPPING SIGHT DISTANCE [2]

Design Speed (km/h)	120	100	80	70	60	50
SSD (m)	295	215	150	120	90	70
SSD(m) with relaxation	215	160	110	90	70	50

Visibility Envelopes

Visibility envelope is the required space to be free of visibility obstructions. It is defined by the zone between the range of observer eye heights and the range of target heights, on plan and in elevation. An observer is a road-user and the target may be another road-user, a vehicle, vehicle lights, the road pavement, signs, line markings, safety facilities, objects etc..

Isolated slender objects are generally acceptable in the visibility envelope, provided that they do not constitute continuous blockage of visibility. Visibility envelopes should take into account possible overgrowth of ground level plants.

Definition of eye-heights, target types and target heights is an important component of specifying visibility requirements. ***Table 2.1.1.1*** summarises the vales adopted in selected countries.

TABLE 2.1.1.1 EYE-HEIGHTS, TARGET TYPES AND TARGET HEIGHTS IN SELECTED COUNTRIES

	Drivers	Motor-cyclists	Cyclists	Pedestrians	Ground objects	Other vehicles
China	1.2- 2m	-	-	-	-	-
India	1.2m	-	-	-	0.15m	-
Korea	1.0m	-	-	-	0.15m	
France	1m	-	-	-	0.35m +	-
UK	1.05- 2.m	-	1- 2.2m	0.6-1.8m*	0.26m	1.05m
Malaysia		1.43m	-	-	-	-

+ 0.15m on roads subject to falling stones

On this basis, the recommended values of observer eye-height and target height are given in ***Tables 2.1.1.2*** and ***2.1.1.3*** respectively. Their position or extent is separately defined for each visibility requirement

TABLE 2.1.1.2 OBSERVER EYE-HEIGHTS

Drivers	1.05m- 2.0m
Motorcyclists	1.3m – 1.6m
Cyclists	1.0m - 2.2m
Pedestrians	0.6m -2.0m

TABLE 2.1.1.3 TARGET HEIGHTS

Ground objects	0.26m (0.15m)*
Rear of queues	0.6m
Pavement markings	0m
Median openings	0.15m
Pedestrians	0.6m- 2.0m
Motorcycles	0.6m
Bicycles	0.6m
Animals	0.3m
General	0.15m

* on road sections susceptible to falling stones

Forward Visibility

Forward visibility distance equivalent to SSD is required between a driver and the carriageway ahead on free-flow sections remote from an intersection. Relaxation is permitted on free-flow sections without foreseeable congestion or stopping traffic. Recommended values for forward visibility are given in ***Table 2.1.1.4***.

TABLE 2.1.1.4 FORWARD VISIBILITY DISTANCE [2]

Design Speed (km/h)	120	100	80	70	60	50*
Forward Visibility Distance (m)	295	215	150	120	90	70
Relaxation (m)	215	160	120	90	70	50

* not advisable to adopt values below the design speed of 50km/h.

Observer	Eye-height	Target	Object Height
Driver	1.05m – 2.0m	Ground Obstacle	0.26m (0.15m)**

** 0.15m on road sections susceptible to falling stones

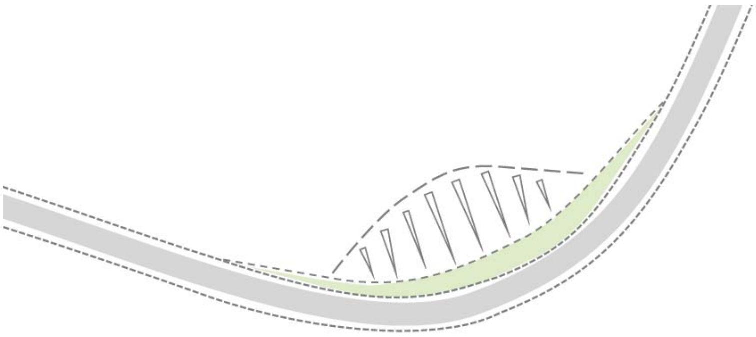
Forward visibility should be provided in both the horizontal and vertical planes between points in the centre of the lane nearest to the inside of the curve. Isolated slender objects such as sign supports, lighting columns and smaller bridge piers are generally acceptable inside the zone of forward visibility as long as the loss of visibility is less than 2s in travel distance.

Forward visibility may need to be provided by widening the paved shoulder or verge on the inside of a curve as shown in ***Figure 2.1.1.1***. In urban areas and where land or economic constraints predominate, forward visibility of free-flow sections may be based on the "relaxation" values.

In case of severe difficulties, the following widths clear of visual obstructions from the edge of an inside traffic lane may be adopted:

- Design speed of 100km/h: 4m
- Design speed of 80km/h: 3m

FIGURE 2.1.1.1 WIDENING FOR FORWARD VISIBILITY



Overtaking Visibility

Overtaking visibility is required for overtaking vehicles using the opposing traffic lane on an undivided road. For new roads this should be provided on as much length as possible. ***Tables 2.1.1.5*** summarises the requirements of overtaking visibility distance in selected countries. The recommended values are given in ***Table 2.1.1.6***.

TABLE 2.1.1.5 OVERTAKING SIGHT DISTANCE IN SELECTED COUNTRIES *(values in m)*

	Design Speed km/h						
	120	100	80	60	40	30	20
China	-	-	550 (350)	350 (250)	200 (150)	150 (100)	100 (70)
Thailand	-	-	-	-	-	-	-
Bangladesh	-	720	500	340	180	120	-
India	-	640	470	300-	165	-	-
Korea	-	-	540	400	280	200	150
France	-	500	500	500	-	-	-
UK	-	580	475	345	-	-	-
TEM	-	600 (400)	475 (325)	-	-	-	-

( ) Minimum values

TABLE 2.1.1.6 OVERTAKING VISIBILITY DISTANCE [2]

Design Speed (km/h)	100	80	70	60	50	40	30
Overtaking Visibility Distance (m)	580	475	410	345	290	200	150

Observer	Eye-height	Target	Object Height
Driver	1.05m – 2.0m	Opposing vehicle	0.6m – 2.0m

Other Visibility Requirements

Specific visibility requirements are needed for a diversity of road features and scenarios. These are separately given under the respective topics. Examples of these include:

- Visibility towards tunnels, toll plazas, escape ramps, laybys etc.
- Visibility towards pedestrian crossings
- Visibility at intersections, signalised intersections, merges and diverges
- Visibility towards road features: tunnels, toll plazas, escape ramps, laybys, traffic islands etc.
- Visibility towards pedestrian and slow vehicle crossings
- Visibility towards traffic signs and directional signs
- Visibility towards line markings, particularly Stop and Give-way markings

2.2 Design Speed and Alignment

Design Speed

Design speeds should be compatible with drivers' expectation. For new and major road improvement projects, it is recommended that:

- The design speed for Primary class roads should be at least 80km/h
- The design speed of 50km/h should only be adopted for Class I roads on non-access-controlled roads within and in the periphery of built-up areas
- The design speed for Class I access-controlled roads should be at least 60km/h and preferably higher
- The design speed for Class II roads is preferably 60km/h or more outside built-up areas
- The design speed for Classes II and III roads is desirably not less than 50km/h outside built-up areas

Asian Highway routes will need to have homogeneous characteristics over a sufficiently long section of road. It is very important that changes of road class, design speed or speed limit are located at a change in road environment or conditions which is obvious to drivers. Examples are approach to built-up areas, boundaries of topography, intersections, toll plazas, border control points etc.

Horizontal Curves

On primary roads, long straight sections and small changes of direction should be replaced with large radii curves. Adjacent curves should be similar in length.

Compound curves in the same direction should be replaced by a single curve or else separated by a straight section at least 200m long. Opposing curves may be directly connected by transition curves.

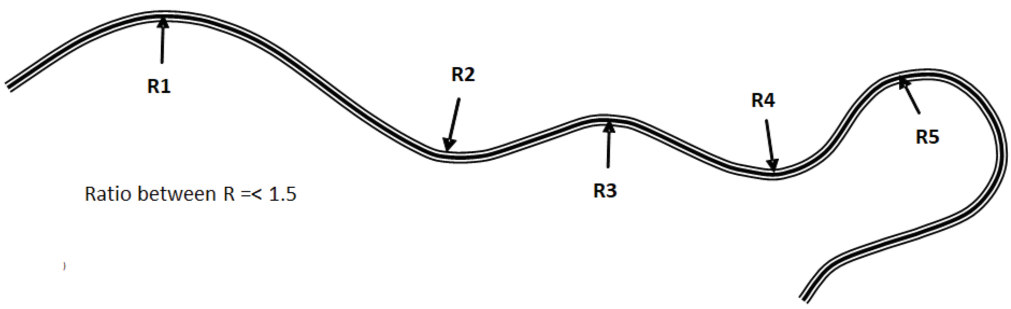
On Primary class roads and outside built-up areas, horizontal curves should be provided with sequencing rules [3] as follows:

- Smaller radius horizontal curve is preceded by larger radius curve at a ratio not exceeding 1.5

(***Figure 2.2.2.1***)

- Horizontal curves are tightened progressively to coincide with a change of the road environment in difficult terrains
- Two horizontal curves in the same direction are separated by a straight section

FIGURE 2.2.2.1 SEQUENCING RULES



Vertical Curves

Crest profiles should always satisfy forward visibility requirements for both divided and undivided roads. On existing Classes II and III roads with speed limit exceeding 60km/h, visibility at crests should not fall below 90m.

The following vertical curve profiles should be avoided, particularly for speed limit of 70km/h or more:

- Successive short crest and sag curves (“Roller Coaster” profile)
- Successive crest or sag curves linked by short straight sections (“Broken Back” profile)
- Hidden dip where a section of road on a sag curve is hidden by the upstream road profile

Coordination of Horizontal and Vertical Curves

At and on the immediate approach to intersections, horizontal and vertical curves should be as gentle as possible to ensure visibility. At-grade intersections are preferably located on straight sections or on the outside of large radius curves.

On all high speed roads, horizontal curves and vertical curves should be well coordinated for safety, visual comfort and aesthetics. In rural areas Primary class roads and Class I access-controlled roads should be designed with a generous “flowing” alignment. This is illustrated in ***Figure 2.2.2.2***. Bridge structures should form part of the flowing alignment.

Primary class roads in urban areas and Class I roads other than high standard access-controlled roads have lower design speeds and are often constrained in alignment and the siting of intersections. This would supersede the requirements for a flowing alignment and coordination between horizontal and vertical curves. In fact, these requirements may induce excessive speeds on roads with characteristics of urban or rural arterials.

Classes II and III roads should be designed with long straight sections in conjunction with moderate curves to facilitate overtaking.

FIGURE 2.2.2.2 FLOWING ALIGNMENT ON A PRIMARY CLASS ROAD

For Primary class roads the use of long sections of horizontal curves or vertical curves, together or individually, are preferred. Where they are together, horizontal curves and vertical curves should be phased to coincide, or else a vertical curve is wholly within a horizontal curve

This is particularly important if horizontal and vertical curve radii are smaller than 2,000m and 15,000m respectively. Their ratio should be in the order R*vertical* > 6*R*horizontal*.

Sharp horizontal curves should not be introduced at or near the top of a significant crest. As a general rule, the beginning of a curve of radius less than 300m should not coincide with or in the immediate proximity of a crest.

A sharp horizontal curve should not be introduced at or near the bottom of a steep grade with a significant sag curve.

The following curve combinations should be avoided as they tend to result in poor visual guidance and give rise to a poor appearance of the road:

- A sag curve immediately upstream of a horizontal curve
- A sag curve immediately downstream of a horizontal curve
- A sag curve commencing ahead of and overlapping the beginning of a horizontal curve

On straight sections and long horizontal curves, local undulations should be avoided as they tend to give a broken view.

On Primary class roads, hidden sections of the alignment should be eliminated. Otherwise, the road after the hidden section should not be visible within 500m from the drivers' view. In some cases, this may be achieved with plantings or roadside features.

To relieve the monotony of driving in areas with excellent forward visibility, roads in rural areas should be aligned to give a view of prominent and attractive landscape features in the background.

Primary Class Roads in Difficult Terrains

Primary Class roads and Class I roads in mountainous areas pose particular challenge in road safety. Such sections generally consist of frequent curves, long steep grades and often, both. Additionally, tunnels and viaducts are often necessary and may account for a significant proportion of the route. ***Figures 2.2.2.3*** and ***2.2.2.4*** illustrate typical examples.

FIGURE 2.2.2.3 A PRIMARY ROAD ON DIFFICULT SECTIONS WITH EXTENSIVE EARTHWORKS

FIGURE 2.2.2.4 PRIMARY ROAD ON DIFFICULT TERRAINS WITH EXTENSIVE VIADUCTS AND TUNNELS

Such roads often lie in environmentally sensitive areas in terms of nature and landscape with tourist values. They should therefore be well integrated with the landscape with judiciously located rest areas and viewpoints.

The beginning of such roads should be introduced in conjunction with obvious changes in the terrain e.g. mountain pass, edge of plateau, canyon etc. The rule of curve sequencing is particularly important.

While admitting the technical difficulties involved, the design speed of such roads should not be lower than 80km/h. Tighter geometry of grade-separated intersections are generally acceptable. Yet coordination of the horizontal and vertical alignment and coherence with the topography should be sought in order to achieve an excellent level of clarity and visibility.

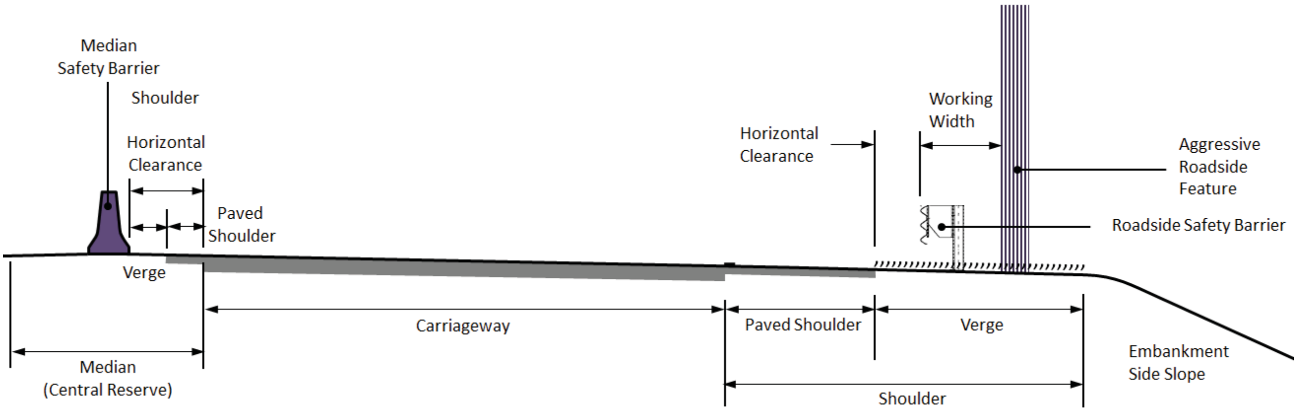
2.3 Cross-sections

The cross-section of a road consists of the following elements:

- Carriageway with one or more traffic lanes
- Median (for divided roads)
- Shoulder
- Verge (unpaved shoulder)
- Side slope

A typical cross-section is illustrated in ***Figure 2.2.3.1***.

FIGURE 2.2.3.1 COMPONENTS OF ROADSIDE CROSS-SECTION



Traffic Lanes

Standard width of traffic lanes is given in ***Table 2.2.3.1***. It may be desirable to adopt a wider lane width of 3.65m on Primary class, Classes I and II roads. Lane width up to 3.75m may also be adopted on Primary class roads. Narrower traffic lanes may be used on urbanised sections, for visual traffic calming and in conjunction with wide centreline markings.

Table 2.2.3.1 Traffic Lane Widths

Primary class	Class I	Class II	Class III
3.5m	3.5m	3.5m	3.25m (3.0m)

Traffic lanes should be widened on horizontal curves with radii smaller than 250m to take into account the swept path of long vehicles.

Medians

The median of Primary class and Class I roads consists of a physical separation and shoulders. The physical separation divides opposing traffic allowing them to travel without interference from each other.

Shoulders

The shoulder consists of a paved shoulder and a verge. Paved shoulder has a bituminous or concrete surface serving the following functions:

- Emergency stoppage and temporary parking of vehicles in an emergency
- Usage by emergency vehicles to access incident sites
- Part of the clear zone allowing an errant vehicle to recover
- Use by pedestrians, slow vehicles and low powered motorcycles etc.
- Additional space for roadwork

If the paved shoulder of a Primary class road is utilised as a traffic lane, the width of all traffic lanes should not be less than 3.5m and a paved shoulder of 1.0m should be maintained. Additionally, emergency laybys should be provided at regular intervals.

Verges (Unpaved Shoulder)

A verge is a hardened and/or stabilised ground surface which may be in earth, grassed or laid with crushed rocks or gravels forming the remaining part of the shoulder to serve the following functions:

- Clear zone and installation of vehicle restraint systems
- Refuge area for stranded road-users
- Visibility needs
- Passage of pedestrians, maintenance staff or animal herds
- Provision of footpaths and slow vehicle tracks
- Space for signs and equipment
- Space for underground utilities and inspection chambers
- Accommodation of drainage system
- Snow storage

Where ducting and inspection chambers are required, it is advisable to provide a verge at least 2m wide.

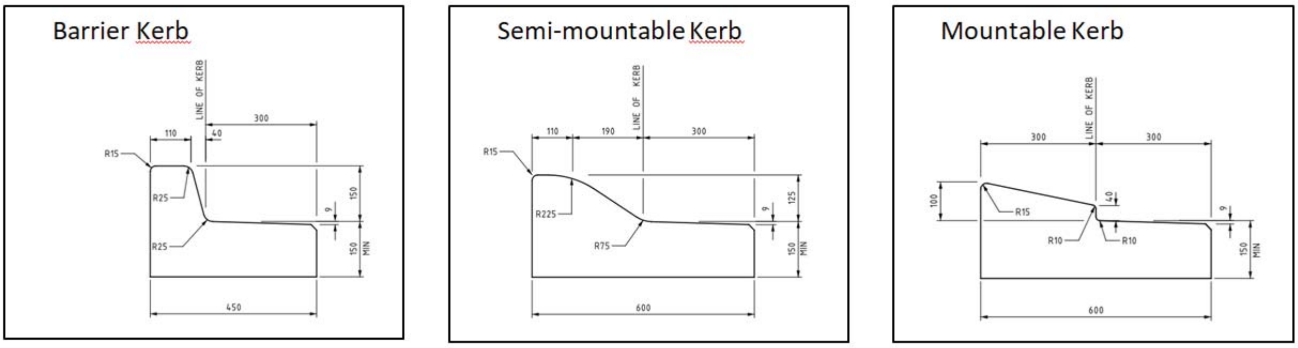
Roadside Kerbs

Outside built-up areas where traffic speeds exceed 70km/h, kerbs are not recommended as they could cause an errant vehicle to jump or roll over. If kerbs are necessary for drainage purpose, mountable or semi-mountable design should be adopted. Within built-up areas where traffic speed is constrained, it is preferable to adopt near-vertical kerbs for footpaths. ***Table 2.2.3.2*** and ***Figure 2.2.3.2*** provide guidance on the shapes and dimensions of kerbs.

TABLE 2.2.3.2 RECOMMENDED KERB PARAMETERS

Location	Main purpose	Shape	Height	
			Desirable	Maximum
Outside built-up areas	Drainage	=< 45°	75mm	100mm
Within built-up areas	Footpath and drainage	Near vertical	100mm- 125mm	150mm

FIGURE 2.2.3.2 TYPICAL KERB TYPES [4]



Traffic Islands

Physical traffic islands are areas defined by kerbs, barriers or unpaved areas to preclude or discourage usage by traffic. They are used for a variety of purposes including:

- Pedestrian refuge
- Median
- Side road channelisation island
- Protected offside turn lane
- Nearside turn lane

Physical traffic islands should be preceded by markings guiding traffic to avoid the traffic island. This may be further supplemented by delineator posts, raised pavement markers or rumble strips. On urbanised sections and their peripheries, road lighting is desirable if traffic islands are provided.

A traffic sign guiding traffic to pass to one or both sides should be erected on traffic islands facing approach traffic. This sign is preferably slim in design and mounted at low level to avoid blocking the visibility of crossing pedestrians. Where installed outside built-up areas, the sign is preferably flexible and self-restoring for reasons of passive safety.

Main road drivers on the approach should be able to see a traffic island and the associated traffic sign with a visibility distance not less than 1.5*SSD. For this reason, traffic islands should be located on straight sections ahead of any significant curves or crest profiles.

In general, the choice of kerb types is based on the location of traffic islands within or outside built up areas. However, this does not preclude the use of mountable or semi-mountable kerbs in built-up areas where occasional mounting is needed for a vehicle to slowly bypass a stopped or broken down vehicle. This is illustrated in ***Figure 2.2.3.3***.

FIGURE 2.2.3.3 TRAFFIC ISLAND WITH SEMI-MOUNTABLE KERBS
(driving is on the right side of the road)

The kerbs and surface of physical traffic islands should have a colour in adequate visual contrast with the carriageway e.g. use of light colour surfacing or concrete finishing for an asphalt pavement. Kerbs facing approach traffic may be painted white with high reflectivity paints to increase their conspicuity.

Clearance Requirements

The cross-section of the road should consist of adequate space and margin for the safe travel of all types of authorised vehicles. These include:

- Horizontal Clearance- the minimum width between the edge of the running carriageway and roadside obstructions such as traffic signs, gantry sign supports, safety barriers, railings etc.

- Headroom- the minimum height between the road surface and overhead obstructions such as bridges and overhead gantry signs or traffic signals

Structural Gauge is the space requirement consisting of horizontal clearance and headroom for special structures such as tunnels and bridges.

Horizontal Clearance

Horizontal clearance (set back) provides additional room to accommodate for:

- recovery from momentary deviation of travel paths
- protruded side mirrors
- opening of vehicle doors in an emergency
- additional margin in case the paved shoulder is used for running traffic or emergency vehicles

Horizontal clearance is defined relative to:

- Outside edge of the paved shoulder
- Kerbline at the edge of a footpath or traffic island
- Edge line at medians

The recommended horizontal clearance for different roadside conditions is given in ***Table 2.2.3.3***. These values apply to all roadside features including safety barriers.

TABLE 2.2.3.3 RECOMMENDED HORIZONTAL CLEARANCE

Category	Circumstances	Reference Point	Horizontal Clearance	Minimum Value
1	With paved shoulder	Outside edge of paved shoulder	600mm	450mm
2	Verges without paved shoulder	Edge of carriageway	1200mm	• 1000mm • 600mm (Speed limit =<80km/h)
3	Median	Edge of carriageway	1200mm	• 1000mm • 600mm (Speed limit =<80km/h)
4	Footpath with 50km/h speed limit and crossfall =< 4%	Kerbline of footpath	600mm	450mm

* for paved shoulders not less than 0.6m wide, else values of Category 2 apply relative to the edge of carriageway

Discrete vertical features such as traffic signs or lighting columns should be provided on verges or footpaths which are physically or visually differentiable from the paved shoulder. The horizontal clearance is measured from their interface.

If safety barriers are provided, the horizontal clearance may be provided as an extension of the paved shoulder or a flushed verge. If the paved shoulder has a width not less than 3.0m, it is acceptable not to provide horizontal clearance for safety barriers. This may be the case for bridge structures where cost is a primary consideration.

For practical reasons, the horizontal clearance for pedestrian fence installed on urbanised sections may be set at 500mm from the kerbline of a raised footpath. Under difficult conditions, this may be reduced to not less than 300mm behind a kerbline provided that pedestrians are unlikely to stand or walk outside the fence.

Headroom and Structural Gauge

The recommended minimum headroom is 4.5m. This may need to be increased to 5.1m if the route is used by full height double decker buses. Where overhead features coincide with a significant sag curve, the headroom will need to be increased with appropriate corrections.

In order to further protect light overhead structures such as gantries which may collapse upon impact, an additional headroom of 0.4m should be provided. Similarly, an additional 0.2m headroom should be provided to protect overhead equipment inside tunnels.

2.4 Overtaking

Availability of overtaking opportunities is crucial to the safety of undivided roads. The lack of such opportunities could lead to indiscriminate overtaking with increased risk of head-on collisions. This is illustrated in ***Figure 2.2.4.1***.

FIGURE 2.2.4.1 INDISCRIMINATE OVERTAKING ON AN UPHILL SECTION *(driving is on the right side of the road)*

On Classes II and III roads, opportunities should be systematically provided to facilitate safe overtaking. In general, overtaking zones should be maximised and uniformly distributed along a route and non-overtaking zones are restricted to not more than a few kilometres. In case of unsurmountable difficulties, additional laybys should be provided. Signs indicating availability of overtaking sections ahead may be installed to alleviate frustration of drivers.

Overtaking Zones

The various categories of overtaking zones are given in ***Table 2.2.4.1***:

TABLE 2.2.4.1 OVERTAKING ZONES

Category		Characteristics
Opposing Lane Overtaking Section		Road sections with adequate overtaking visibility distance
Divided 4-lane Section		Provision of a limited length of divided road
“2+1” Overtaking Sections	Overtaking Section	Provision of a limited length of two lanes in one direction, with possibilities of: • Discrete use • Continuously alternation (“2+1” roads)
	Climbing Lane	Two-lane section on uphill direction with slower vehicles using the outer lane
	Downhill Auxiliary Lanes	Two-lane section on downhill direction with slower vehicles using the outer lane
Laybys		Slower vehicle actively giving way to following vehicles

On high speed undivided roads, opposing lane overtaking sections are provided by long straight sections (***Figure 2.2.4.2***).

FIGURE 2.2.4.2 OPPOSING LANE OVERTAKING ZONES

Divided 4-lane sections and “2+1” overtaking sections preclude traffic from using an opposing traffic lane to overtake. They are preferred on safety grounds if traffic volume is high and in hilly areas where overtaking visibility distance is difficult to attain.

Non-overtaking Zones

Non-overtaking zones consist of the following road sections and their approaches:

- Horizontal curves not compliant with overtaking visibility distance
- Vertical curves of crest profile not compliant with overtaking visibility distance
- Roundabouts or intersections with protected turn lane
- Tunnels and narrow bridges

On undivided roads with heavy traffic volume, it may be necessary to restrict overtaking on straight sections even if overtaking visibility is adequate.

Centreline Markings

For new projects of Classes II and III roads, the alignment preferably consists of long straight sections appropriate for overtaking and interspersed with horizontal curves which are evidently unsuitable for overtaking. Where ample safe overtaking opportunities are available, extensive use of solid line markings would not be required.

For both existing and new roads with a constrained alignment, solid centreline markings will be needed more extensively.

Dotted centreline markings are generally adopted to indicate that traffic may overtake if this is safe. On roads with lighter traffic and moderate speeds, dotted warning centerline markings may be used throughout a road to indicate the need for prudence when overtaking.

The following road markings should be provided to delineate non-overtaking zones:

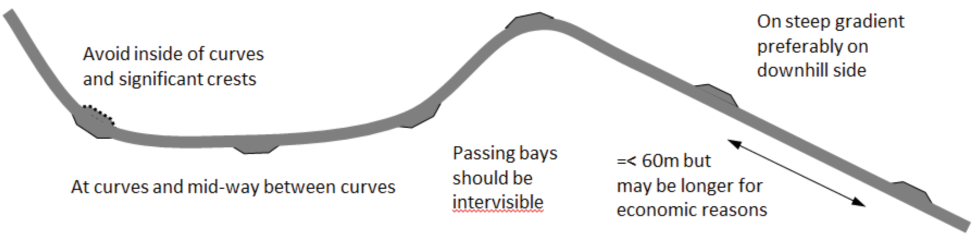
- Solid lines which may be single or double, with the latter advisable for speed limit at or more than 60km/h, to indicate prohibition of overtaking in both directions
- Mixed dotted and solid lines which indicate prohibition of overtaking in the direction adjacent to the solid line
- Curly arrow markings which direct traffic to stay on or return to the normal lane of travel

Solid line markings may also be laid along and ahead of narrow bridges, tunnels and intersections with offside turn lanes. For narrow bridges, solid line for approach traffic may commence 50m ahead and terminate shortly after the bridge.

Narrow Roads

All Asian Highway routes should have adequate width for bidirectional traffic. At pinch points and along narrow sections pending improvements, consideration may be given to single lane operation with ample passing bays. This is illustrated in ***Figure 2.2.4.3***.

FIGURE 2.2.4.3 PASSING BAY STRATEGY FOR NARROW ROADS

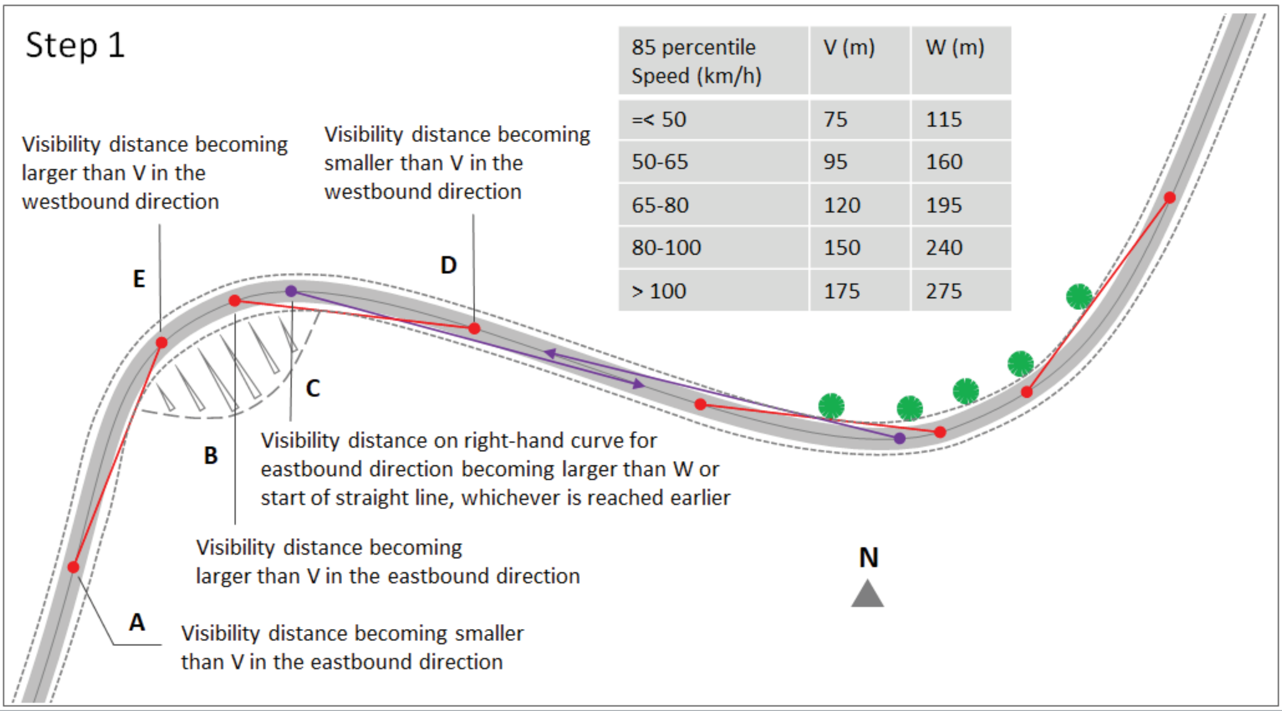


Design of Centreline Markings

Figure 2.2.4.4 illustrates a pragmatic method [5] to determine the extent of solid line marking systems where overtaking opportunities are limited. The values of visibility are less than overtaking visibility requirements, taking into account that drivers will exercise caution.

The method should be applied in both the horizontal and vertical plane and verified with site surveys. The resulting line markings layout should be further optimised on a route-wide basis to ensure adequate overtaking opportunities in both directions.

FIGURE 2.2.4.4 DESIGN OF CENTRELINE MARKING SYSTEM *(for driving on the right side of the road)*



85 percentile Speed (km/h)	V (m)	W (m)
=< 50	75	115
50-65	95	160
65-80	120	195
80-100	150	240
> 100	175	275

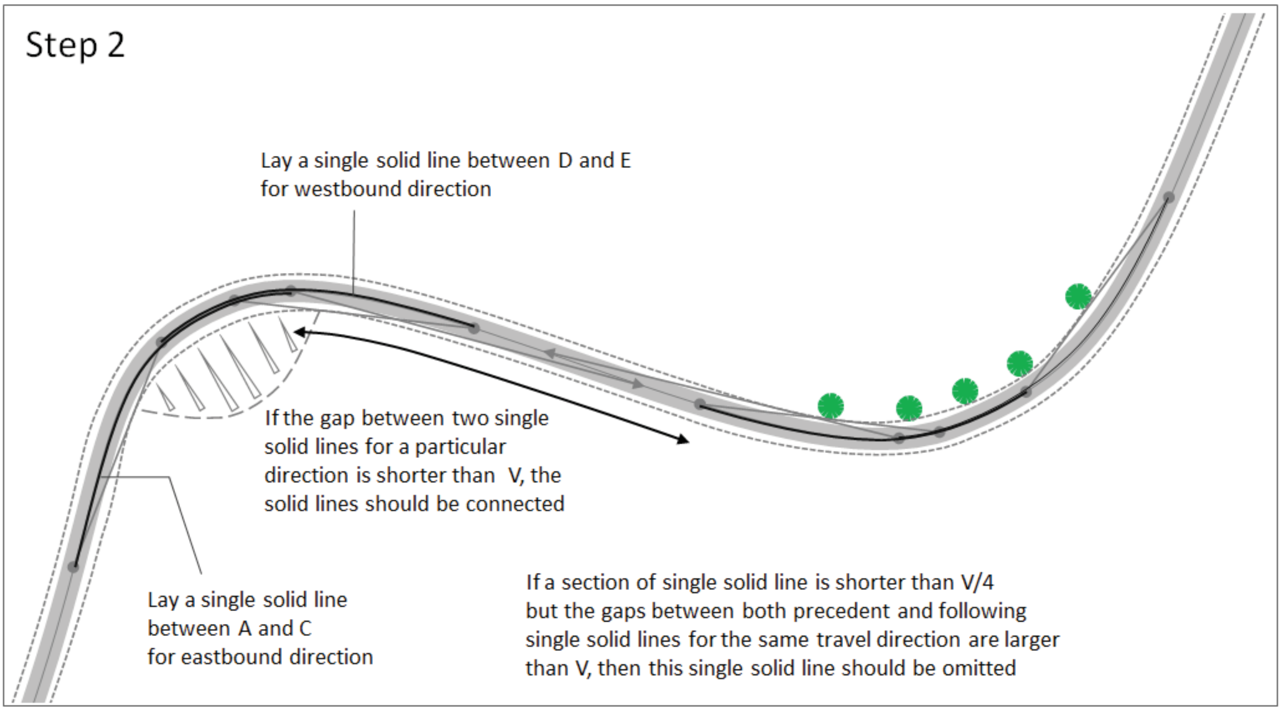
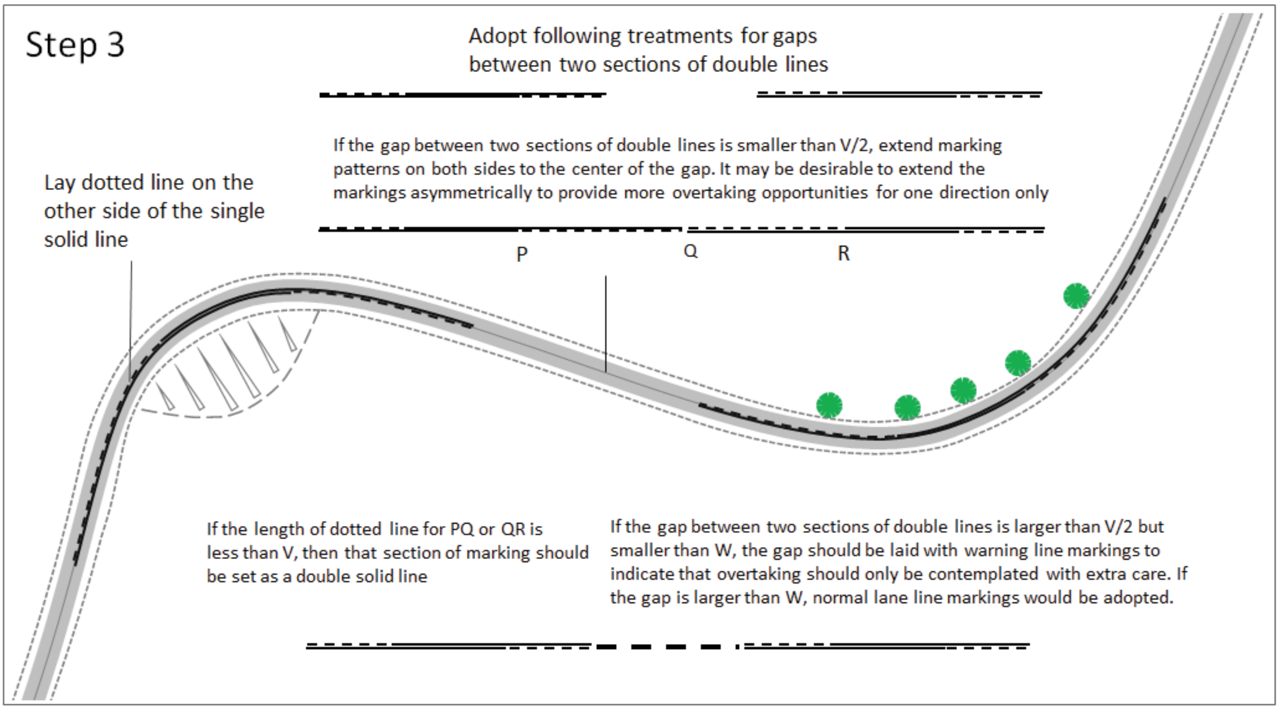


FIGURE 2.2.4.4 DESIGN OF CENTRELINE MARKING SYSTEM *(for driving on the right side of the road)* (to be cont'd)



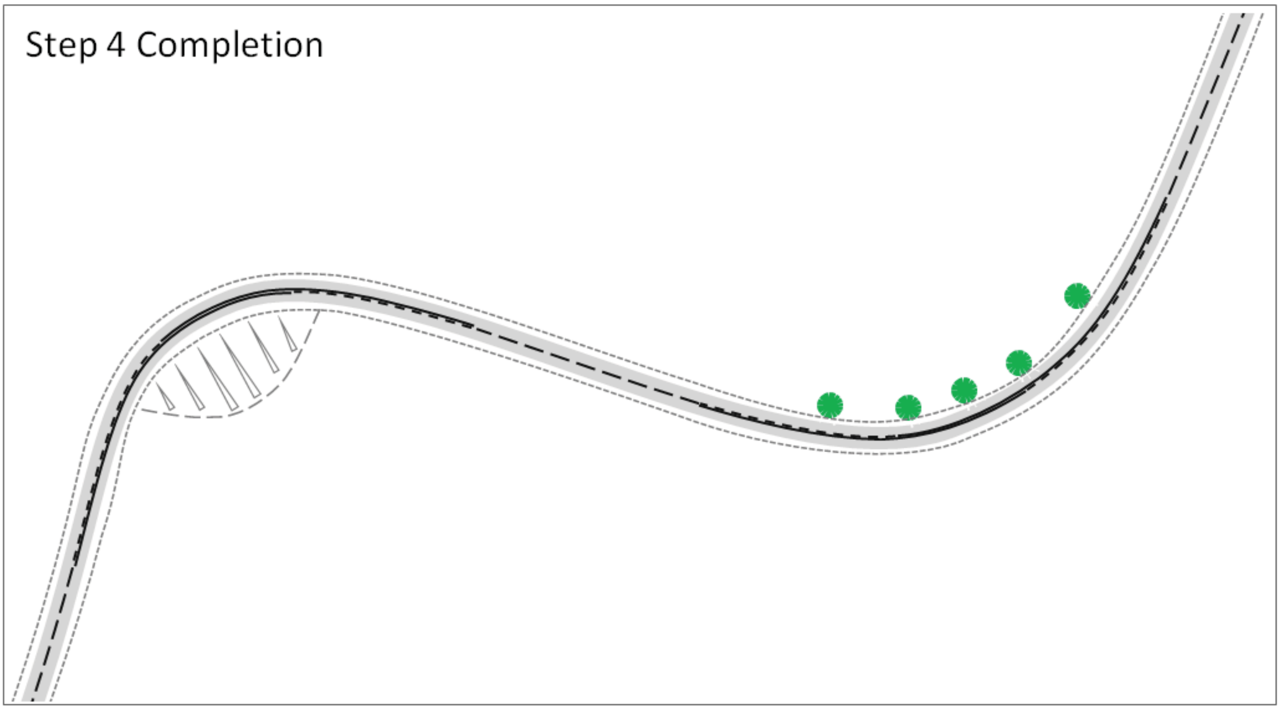
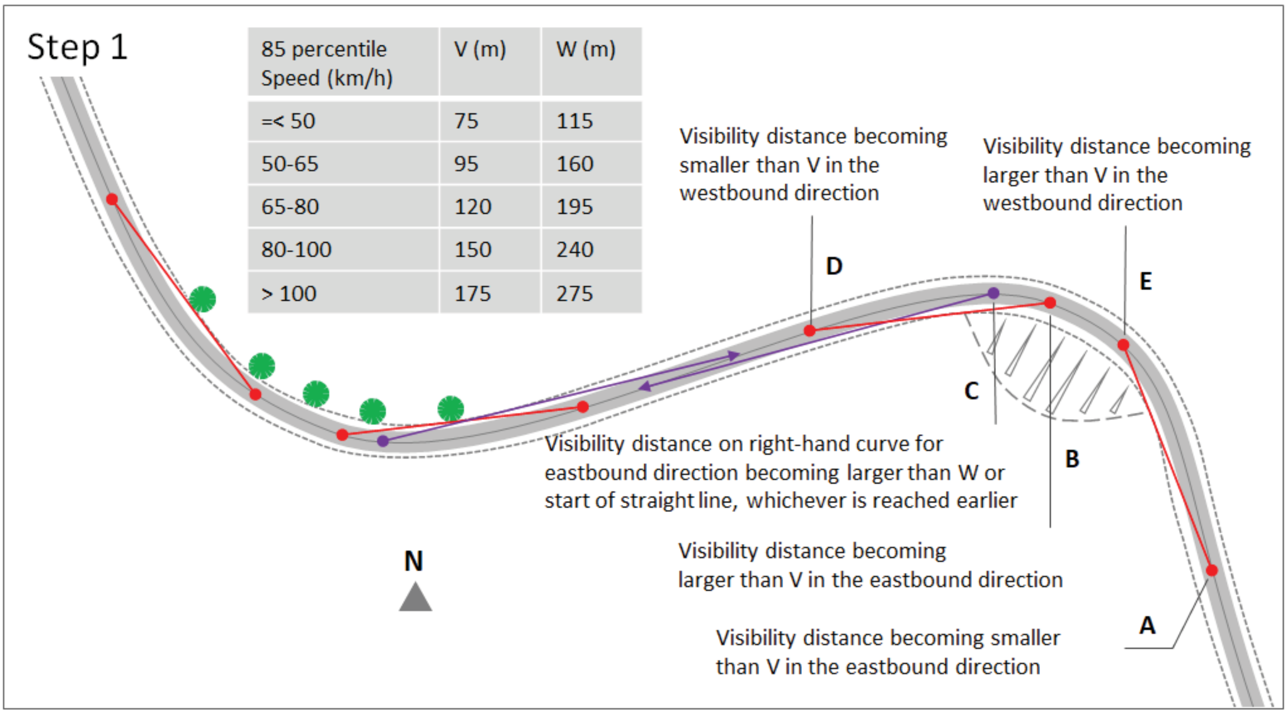


FIGURE 2.2.4.4 DESIGN OF CENTRELINE MARKING SYSTEM
(to be cont'd)

(for driving on the left side of the road)



85 percentile Speed (km/h)	V (m)	W (m)
=< 50	75	115
50-65	95	160
65-80	120	195
80-100	150	240
> 100	175	275

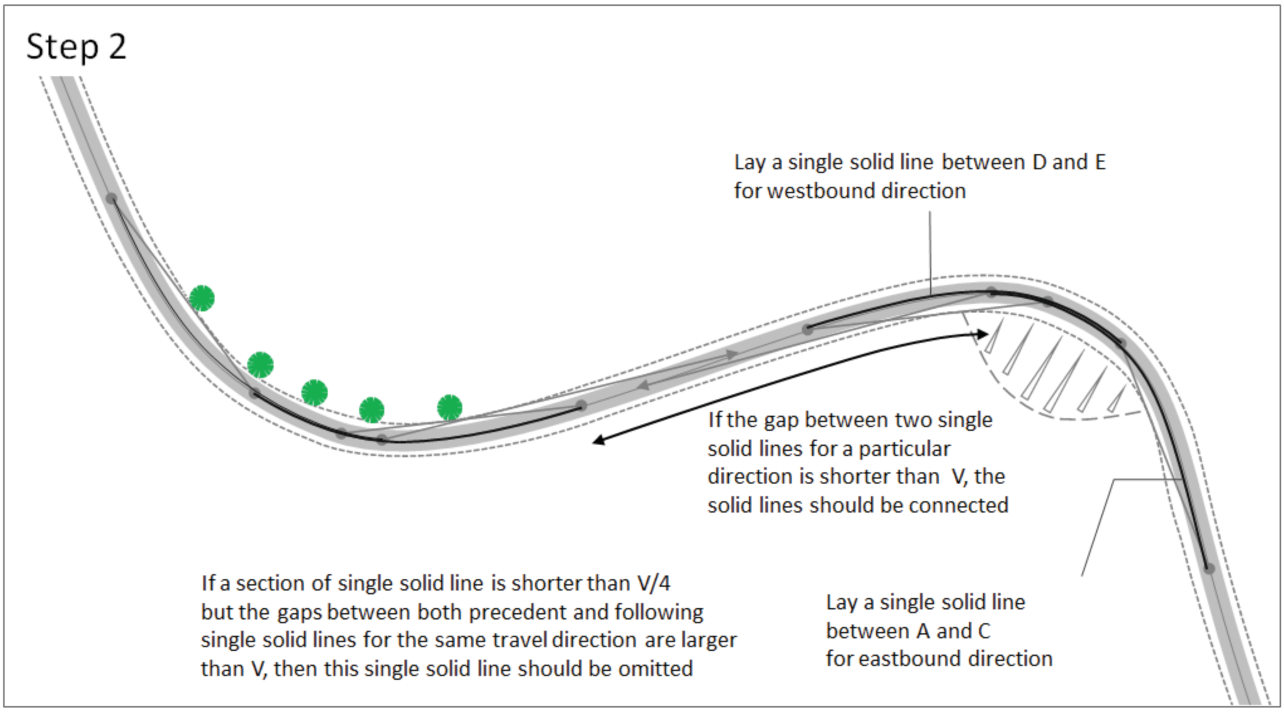
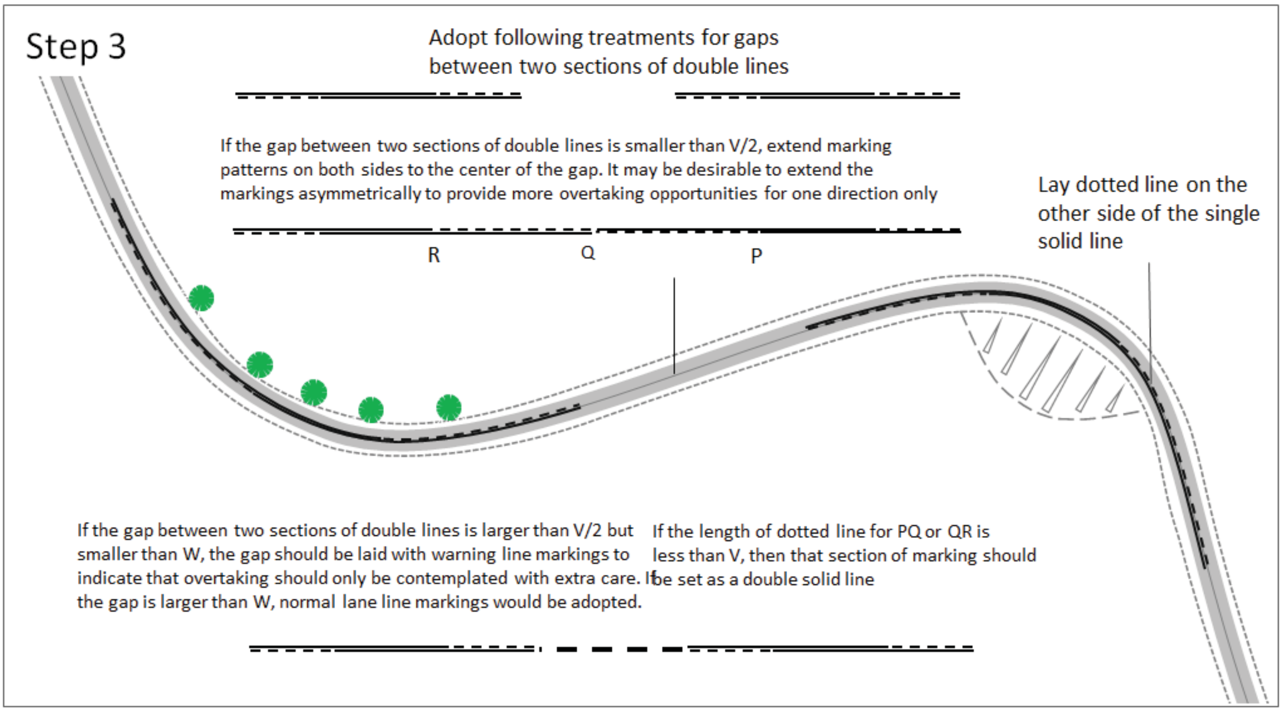
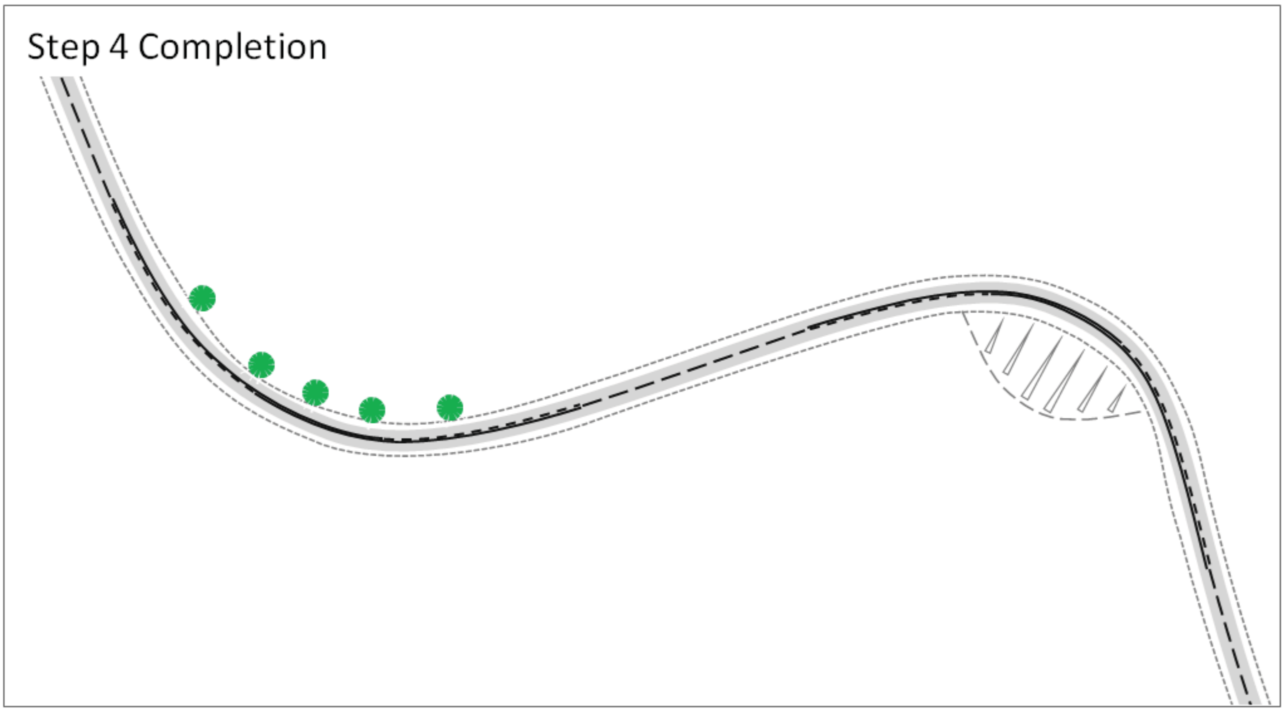


FIGURE 2.2.4.4 DESIGN OF CENTRELINE MARKING SYSTEM
(to be cont'd)

(for driving on the left side of the road)



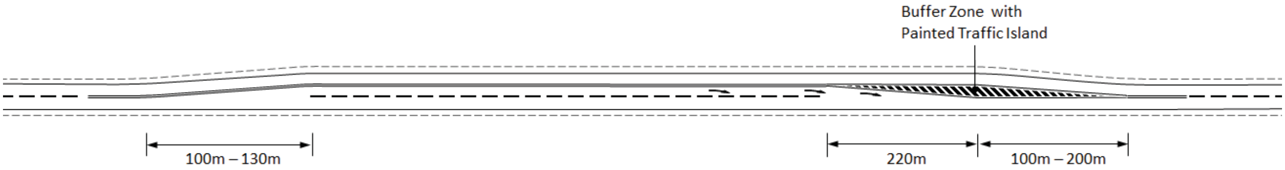


2.5 "2+1" Overtaking Sections and "2+1" Roads

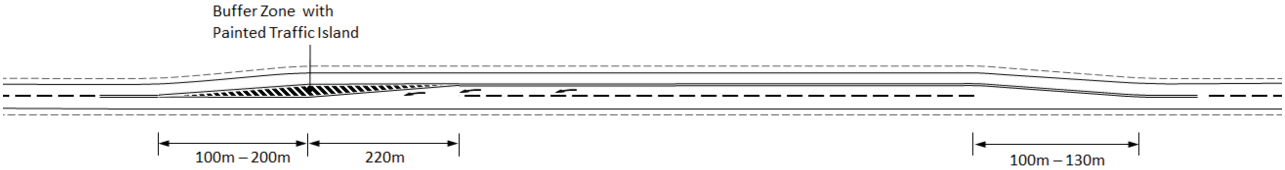
"2+1" overtaking sections consist of a "Single Lane Section" in one direction and a "Two-Lane Overtaking Section" in the opposite direction. This is illustrated in ***Figure 2.2.5.1***. They may be used as discrete units or in pairs. The same principle is applied to climbing lanes and downhill auxiliary lanes which are provided for steep gradients.

FIGURE 2.2.5.1 "2+1" OVERTAKING SECTIONS

(for driving on the right side of the road)



(for driving on the left side of the road)



The length of an overtaking section should be between 800m to 1500m with a maximum of 2000m. Longer lengths could lead to excessive speeds.

Buffer zones are necessary downstream of the termination of the two-lane section and between opposing "2+1" overtaking sections provided in pairs. The section with three traffic lanes should lie on straight or gentle horizontal curves whereas buffer zones may be located on curves. Buffer areas on curves facilitate the development of a smooth alignment with the additional benefit of a wide centerline.

The centreline is desirably widened to 1m with rumble strip markings and possibly infilled with hatched markings or coloured surfacing.

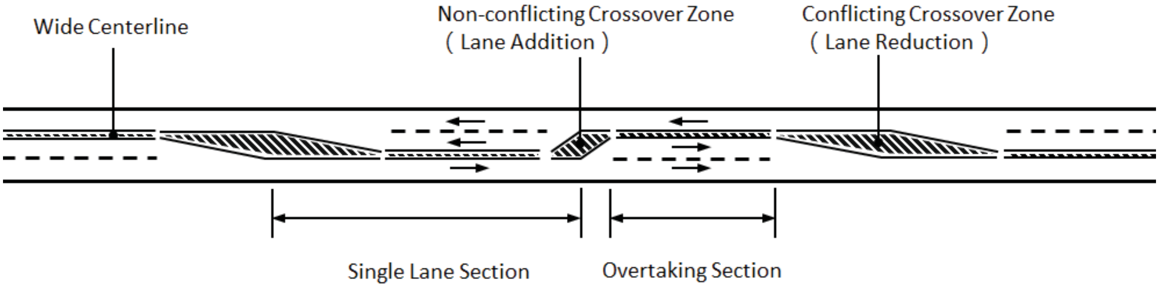
"2+1" Roads

On "2+1" roads, "2+1" overtaking sections are continuously alternated in sequence. This is illustrated in ***Figure 2.2.5.2***. For Class II roads with heavy traffic volume, in the order of 12,000 to 20,000 veh/day, "2+1" roads could be an economic alternative to a Primary class or Class I divided road. High percentage of head-on or rear-front collisions and considerable traffic delays are also factors for their usage.

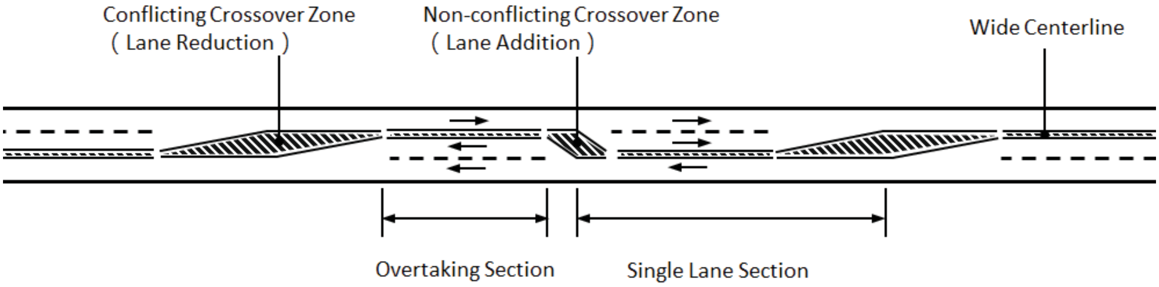
"2+1" roads generally have speed limit in the range of 70 to 100km/h. They are not suitable for built-up areas and their peripheries as well as roads with a constrained alignment.

FIGURE 2.2.5.2 BASIC FEATURES OF "2+1" ROADS [6]

(for driving on the right side of the road)



(for driving on the left side of the road)



To facilitate alternation of overtaking zones, crossover zones are needed as a buffer between opposing traffic. "Conflicting crossover zones" where the number of lanes is reduced should be about 200m long. "Non-conflicting crossover zones" where the number of lanes is increased requires a shorter length in the order of 50m. This concept is also applied for "2+1" overtaking sections provided in pairs.

The nominal width of traffic lanes is 3.5m, but may be reduced to 3.25m for the overtaking lanes or both lanes of the two-lane section. Excessive lane widths could lead to excessive speeds.

To further enhance the safety of "2+1" roads, it is desirable to provide a physical safety barrier over the centreline to separate opposing traffic. A range of safety barriers could be considered including rigid concrete barriers or wire-rope safety barriers. This is illustrated in ***Figure 2.2.5.3***.

FIGURE 2.2.5.3 "2+1" ROAD WITH MEDIAN SAFETY BARRIER

(driving is on the right side of the road)

If safety barriers are provided to separate opposing traffic, adequate shoulders are required on the single lane section to permit traffic passing a broken-down vehicle. Laybys should also be provided at regular intervals.

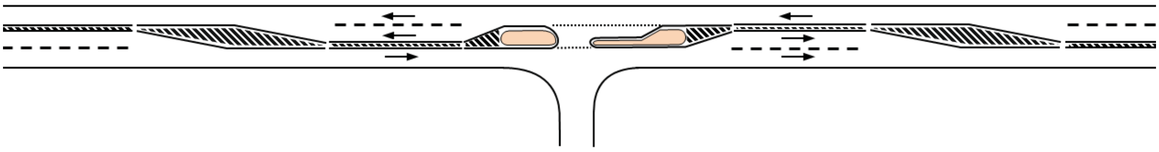
Pedestrians, Slow Vehicles and Intersections

It is generally necessary to exclude pedestrians or slow vehicles travelling along "2+1" overtaking sections or "2+1" roads operating at high traffic speeds. Segregated parallel facilities may be considered on each side of the road.

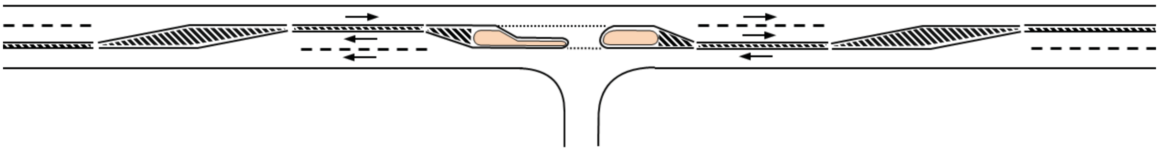
Furthermore, at-grade intersections and crossings for pedestrians or slow vehicles should not be provided within the three lane section. Such intersections or crossings may be provided at non-conflicting crossovers or by first changing the road back to a two-lane road. This is illustrated in ***Figure 2.2.5.4***.

FIGURE 2.2.5.4 PROVISION OF INTERSECTIONS ON "2+1" ROADS

(for driving on the right side of the road)



(for driving on the left side of the road)



Divided 4-lane Overtaking Sections

These are limited sections of 4–lane roads to facilitate overtaking in both directions. They are equipped with a median safety barrier and therefore are desirable from the safety point of view. Their extremities may be in the form of tapers or roundabouts. The speed limit may be locally raised to facilitate overtaking.

Divided Single Lane Roads

These roads have a single lane in each direction with a median safety barrier. They have been conceived to enhance the safety of traditional undivided two-lane roads. Overtaking sections are provided regularly between intersections. Traffic lanes on these road types require adequate unobstructed width (> 6m) for traffic to bypass a stranded vehicle.

2.6 Changes in Cross-sections

Changes in cross-sections may be needed in the following circumstances:

- Interface between an undivided road and a divided road
- Changes in the number of traffic lanes
- Local narrowing to single lane
- Reduction of paved shoulder width
- Reduction of traffic lane width
- Redistribution of cross-sections on urbanised sections

Changes in cross-sections should be introduced with a taper according to ***Table 2.2.6.1***. Where traffic speed is in the order of 60km/h or lower, sharper tapers in the order of 1:15 or even 1:10 are generally acceptable. On urbanised sections where cross-sections are redistributed to accommodate the needs of local activities, sharper tapers are generally appropriate.

Table 2.2.6.1 Tapers at Changes in Cross-sections

Speed Limit (km/h)	Taper
50	1:25
60	1:30
70	1:35
80	1:40
100	1:50
120	1:55

Changes in the Number of Traffic Lanes

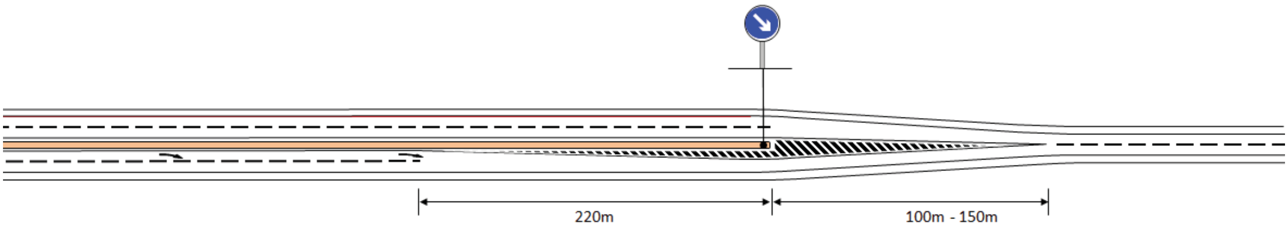
Changes in number of traffic lanes should be treated with adequate guidance and advanced warning to reduce the risk of side-swipes and rear-front collisions.

Where a divided 4-lane road terminates onto an undivided two-way road, it is recommended that the offside traffic lane merges to the nearside. This is illustrated in ***Figure 2.2.6.1***. In addition, the following features should be provided:

- At least two sets of advanced signs for lane reduction (400m and 200m) and curly arrow markings (***Figure 2.2.6.2***)
- Merging taper with markings, typical at 1:15 to 1:40 depending on speeds
- Buffer zones based on road markings after the merge
- Traffic sign(s) indicating “Two-way Traffic” around the commencement of undivided road
- Traffic sign guiding traffic to pass to the correct side of the traffic island

FIGURE 2.2.6.1 TREATMENTS AT TRANSITION BETWEEN CLASS I ROADS AND CLASSES II, III ROADS

(for driving on the right side of the road)



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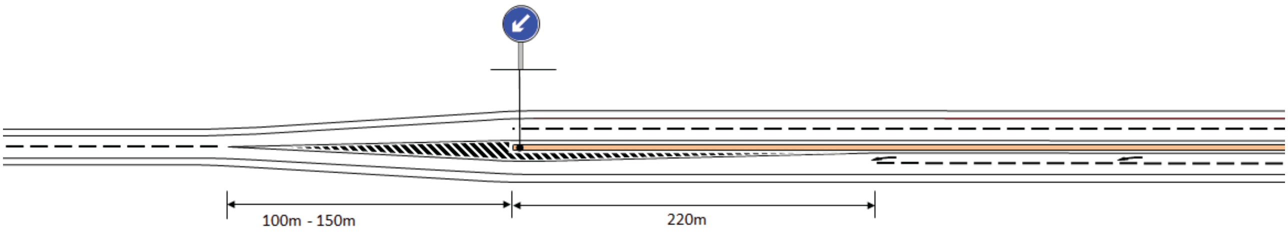


FIGURE 2.2.6.2 ADVANCE MERGING SIGN (DRIVING IS ON THE RIGHT SIDE OF THE ROAD)

Reduction of Hard Shoulder Width

On Primary class roads, full width paved shoulders should be maintained. They may need to be narrowed down due to:

- Transition to tunnel cross-section
- Substitution by climbing lanes or downhill auxiliary lanes
- Substantial technical or economic constraints

In these circumstances, the preferred minimum width of paved shoulder is 1.0m.

Local Narrowing to Single Lane

Where a narrow bridge or a section of narrow road requires traffic to reduce speed substantially or even operates as a single lane road, adequate warning signs and markings should be provided to highlight the situation. Visibility distance towards the narrowed section should not be less than the value of 1.5*SSD.

2.7 Sharp Curves

The following alignment conditions should be avoided for new roads:

- Long straight sections leading to a sharp curve
- Long steep grade leading to a sharp curve
- Continuous curves in reverse directions
- Smaller radius curve within a large radius curve
- Substandard crest leading to a sharp curve
- Hairpins

Special attention should be given to combination of substandard crests and smaller radius curve radius. On Class II roads with 85 percentile traffic speeds exceeding 80km/h, curve radius less than 600m requires attention. It is generally unacceptable if the curve starts after crest. Substandard crests should also not coincide with direct frontage accesses, intersections, narrowing of the road or reduction of traffic lanes etc.

For Classes II or III roads outside built-up areas, the first curve after a straight section should have a relatively large radius according to ***Table 2.2.7.1***.

Table 2.2.7.1 Recommended Minimum Radius of Curves [7]

Length of upstream straight section	Radius of curve not smaller than
> 5km	400 m
> 1 km	300 m
> 0.5 km	200 m

Identification and Treatment of Sharp Curves

The safety risk of curves depends on the difference between traffic speed on the approach and through the curve. A larger difference gives rise to higher safety risk.

A vehicle entering the first curve will usually experience a larger speed difference. If a second curve is encountered after a short straight section, the vehicle will approach this second curve at reduced speeds. The safety risk of the second curve will then be lower than the first curve even if they have the same radius.

The safety risk and the associated level of signing are not purely based on curve radius. Through the calculation of operating speed in both directions of the road, a speed distribution profile is obtained. All curves requiring speed reduction should be individually addressed.

On existing roads, traffic speeds on the approach and within a curve may be measured on site. In addition, vehicles crossing centreline markings may also be recorded.

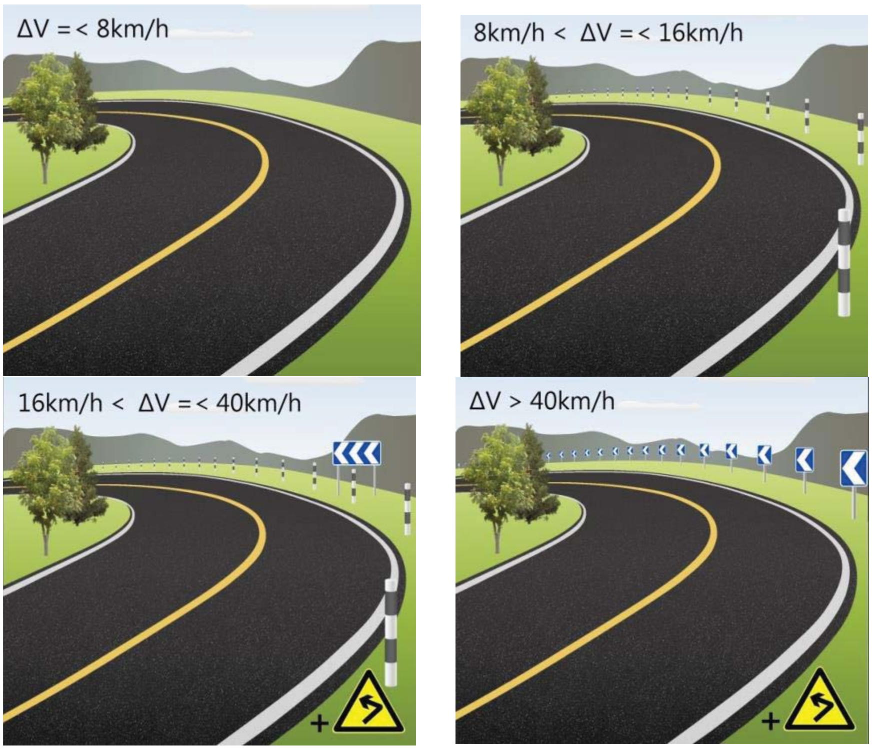
A higher level of curve severity could be assigned under the following circumstances:

- Open fields, valleys or embankments on the outside of the curve
- High slopes, cliffs or rivers on the outside of the curve
- Presence of linear features in line with the approach such as lines of trees, channels, intersecting roads which could mislead drivers
- Presence of accesses or intersections on the inside of the curve
- Curves with inadequate forward visibility distance
- Long curves
- End of the curve is not visible at the start
- Inadequate superelevation

Curve Signing System

The principal measure to improve the safety of sharp curves is a Curve Signing System consisting of curve warning signs, delineation posts and chevron marks. The system is categorised into different levels according to curve severity. This is illustrated in ***Figure 2.2.7.1***. To facilitate recognition by drivers, the composition of signs for a particular level should be consistent.

FIGURE 2.2.7.1 CURVE SIGNING SYSTEM



Chevron marks should cover the forward view of approach drivers at right angle. Appropriate mounting height relative to the bottom of the sign should be in the order of 1.0 to 1.5m. This may be increased for the sign to stand clear of safety barriers. Where a curve is located around a crest, the mounting heights of chevron marks should be raised to ensure that they are visible to approach drivers.

Other than curve signing system, trees and shrubs may be planted for visual guidance on the outside of curves with open background. This is illustrated in ***Figure 2.2.7.2***. In the case of trees, they should only be planted outside clear zones.

FIGURE 2.2.7.2 VISUAL GUIDANCE BY ROWS OF TREES ON THE OUTSIDE OF A CURVE

Additional Measures

On the basis of the curve severity classification system, the following additional measures may be used to address specific concerns:

- Provide high friction surfacing which starts and ends on a straight section
- Reduce the speed limit or provide advisory speed signs
- Provide a wide centreline (***Figure 2.2.7.3***)

FIGURE 2.2.7.3 WIDE CENTRELINE MARKING ON A SHARP CURVE *(driving is on the right side of the road)*

- Provide transverse rumble strip markings on the approach
- Provide clear zone on both inside and outside of the curve
- Provide a safety barrier

If it is necessary to further alert drivers of the curve severity, the following measures may be adopted:

- Provide a yellow background border for the chevron signs
- Provide flashing amber lights above the signs
- Reinforce the display with LED light-emitting elements

Hairpins

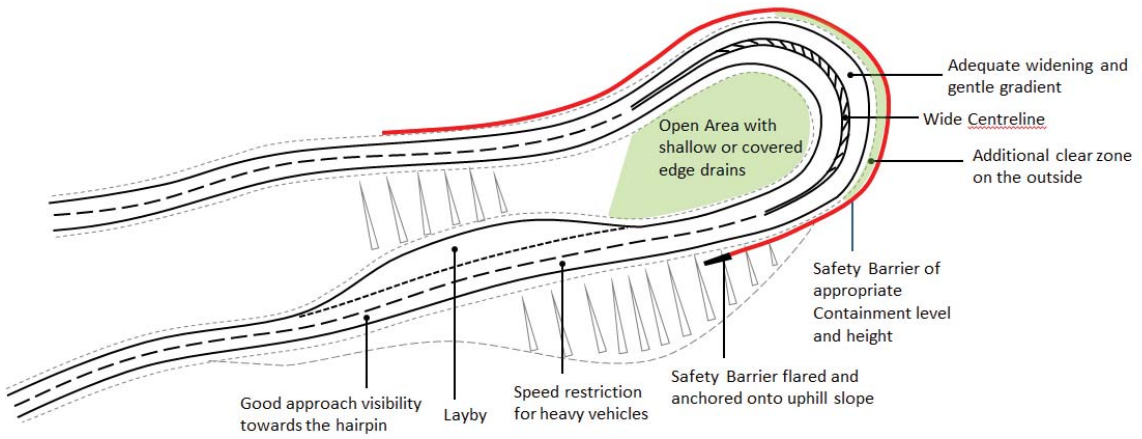
A hairpin is a curve of very small radius where traffic reverses in direction. Drivers have to reduce speeds substantially, often to not more than 20km/h. Hairpins are undesirable for Asian Highway routes but may be justified by topography and economic considerations. They are not appropriate for divided roads and road sections with more than one lane in a direction.

Where hairpins are adopted, adequate widening of the carriageway should be provided at the curve. The need for safety barriers on the outside of hairpins should be determined according to terrain conditions. Where space is available, a clear zone may be provided.

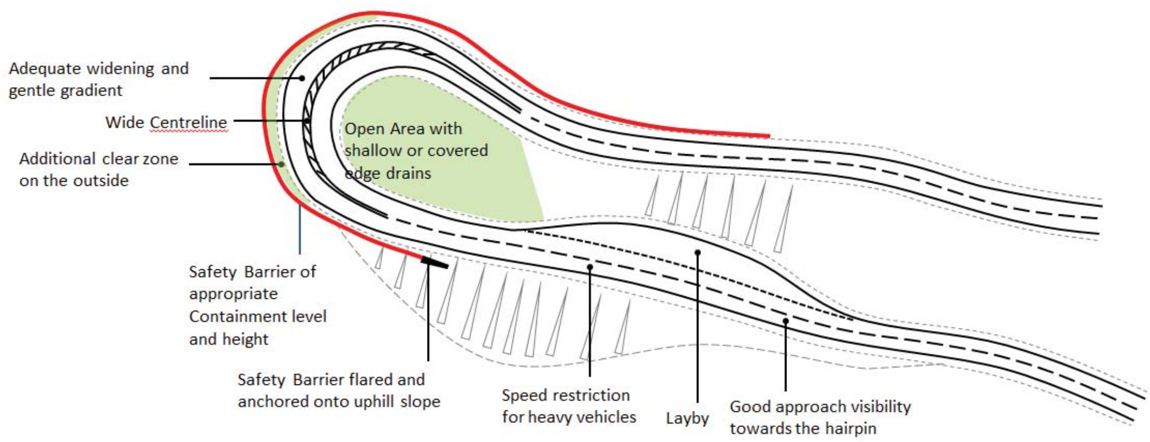
Drivers should be able to see the hairpin on the approach with good visibility. Clear visibility should be provided in the inside of the hairpin with low plantings only. This is illustrated in ***Figure 2.2.7.4***. In addition, the roadside should be clear of roadside hazards including any drainage facilities of aggressive design.

FIGURE 2.2.7.4 SAFETY TREATMENTS FOR HAIRPIN CURVES

(for driving on the right side of the road)



(for driving on the left side of the road)



On steep gradients, laybys should be provided on both approaches of a hairpin. On narrow roads, priority should be given to providing laybys for downhill traffic to permit uphill traffic to continue without stopping.

Additional emphasis should be given to line markings and curve signing systems for hairpins. Furthermore, particular attention is needed for the first hairpin and intermediate hairpins preceded by a generous horizontal alignment. If hairpins are associated with long steep grades, the following additional treatments should be considered:

- Provision of advance informatory signs
- Reduce speed limit on road sections with a series of hairpins
- Provide signs warning rollover risk of heavy vehicles and speed limit
- Formulation of a strategy for laybys, rest areas, viewpoints etc.
- Provision of a clear zone on the outside of the hairpin
- Provision of escape ramps

2.8 Steep Downhill Gradient

Precaution is needed for downhill road sections at average gradient of 3% or more with a level difference more than 40m. Warning signs should be provided ahead of the start of the downhill section. Long steep grades are sections at average gradient of 3% or more with a level difference more than 130m [8].

The following precautions apply to long steep grades:

- Adequate laybys should be provided ahead of and along the steep road section.
- Avoidance of straight or long, large radii curves
- Avoidance of sharp curves
- Avoidance of service areas, bus stops, at-grade or grade-separated intersections, tunnels and urbanised areas within the long steep grades and up to several hundred metres thereafter
- Clear commencement of the steep gradient instead of progressive increase of gradients
- Avoidance of a vertical profile where road sections on steep gradient are interspersed with short sections, typically less than several hundred metres, on gentle gradient
- Enhanced containment level of roadside and median safety barriers
- Restriction of overtaking by heavy vehicles

Horizontal Curves

If a long steep downhill grade section is preceded by an approach of generous horizontal alignment, it is desirable to provide a series of curves with progressively smaller radius. This would help to increase the awareness of drivers consistent with the change of terrain.

Escape Ramps

For Primary class, Class I and II roads with non-negligible proportion of heavy vehicles, a long steep grade safety strategy should be formulated with the provision of escape ramps. Such strategy is particularly important if the route is used by unfamiliar drivers on a seasonal basis, overloading is prevalent and vehicle condition or performance is generally poor.

Escape ramps should be provided in the middle and lower part of the downhill grade section. They should be located upstream of potential hazards including:

- Critical curves
- Urbanised areas and where crowds aggregate
- Roundabouts, signalised intersections and priority intersections
- Tunnels
- Toll plazas and border control points
- Road sections with recurrent congestion or frequent maintenance activities
- Road sections where stoppage or collisions are more likely

A critical curve is one where a runaway heavy vehicle may enter at a speed exceeding the curve cornering speed [9]. Curves of radius smaller than 400m are deemed to be potentially critical.

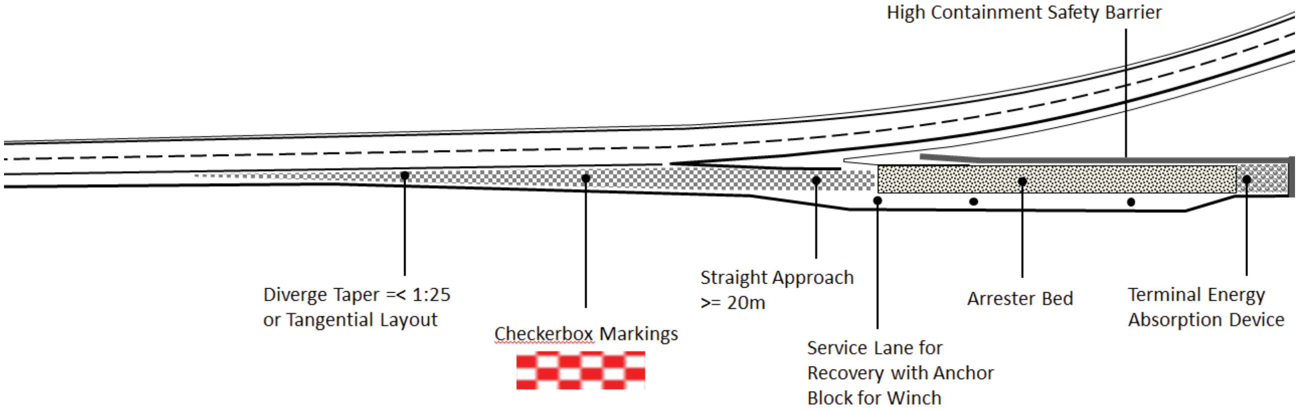
Drivers of heavy vehicles should be able to see the start of taper of an escape ramp at a visibility distance of 1.5*SSD with a minimum of 170m. At this point, the escape ramp entry sign, the commencement of checkerboard markings and desirably the entire the escape ramp should be visible.

There are two primary types of escape ramp, namely slip road type and parallel type. They are generally located on the nearside roadside but diverge gores may also be appropriate location. The choice of these types is site-specific based on the road alignment, roadside topography and environment impact.

Slip road escape ramps generally require a shorter arrester bed and are preferred if the topography is favourable. This is illustrated in ***Figures 2.2.8.1*** and ***2.2.8.2***.

FIGURE 2.2.8.1 TYPICAL LAYOUT OF SLIP ROAD ESCAPE RAMP

(for driving on the right side of the road)



(for driving on the left side of the road)

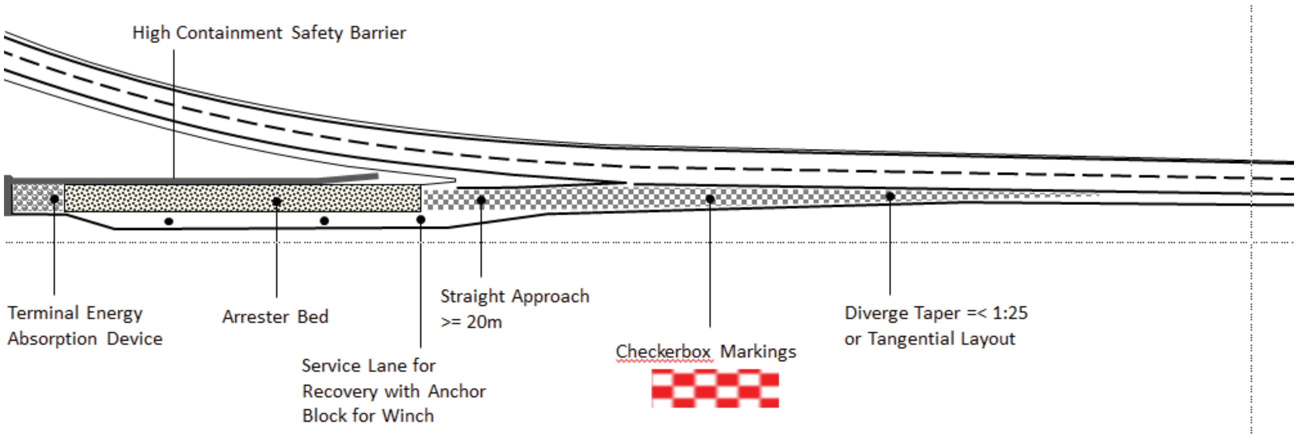


FIGURE 2.2.8.2 SLIP ROAD ESCAPE RAMP WITH A STEEP UPHILL ARRESTER BED

Parallel escape ramps require a long arrester bed but would be more feasible along an embankment over downhill side slopes. This is illustrated in ***Figures 2.2.8.3*** and ***2.2.8.4***.

FIGURE 2.2.8.3 TYPICAL LAYOUT OF PARALLEL ESCAPE RAMP

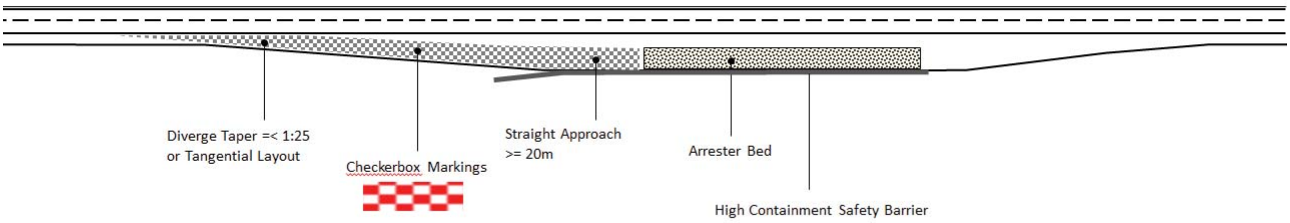


FIGURE 2.2.8.4 PARALLEL ESCAPE RAMP
(driving is on the right side of the road)

An escape ramp generally consists of four components, namely a tapered approach, a full width approach, an arrester bed and a terminal section. Additionally, for slip road type escape ramp a service lane with anchor blocks should be provided alongside the arrester bed to facilitate recovery. Nominal design parameters for escape ramps are given in ***Table 2.2.8.1***.

TABLE 2.2.8.1 DESIGN PARAMETERS OF ESCAPE RAMPS

Component	Design Parameters
Tapered Approach	Preferably tangential but may be in taper not exceeding 1:25
Full width Approach	>=20m but depending on approach alignment
Arrester Bed	Length determined by formula*, Width desirable up to 8m and not less than 5m
Terminal Section	Length >= 10m but varies with energy absorbing design solution

* Length of arrester bed $L = v^2/(254(i + Di)$ where

v Speed of errant vehicle (km/h) (generally up to 130km/h with a top speed of 150km/h where justified on a Primary class road)

i gradient (e.g. 0.05 for 5%, +ve for uphill gradient)

Di rolling resistance of arrester bed materials
(0.25 for pea gravel, 0.15 for sand, 0.1 for loose gravel, 0.05 for loose crushed aggregates)

Signing Requirements

The following signs should be provided at the commencement and along long steep grade:

- Brake check or inspection areas
- Long steep grade information signs- gradient and length
- Use Low Gear/Apply engine brakes

On Primary class roads with traffic speed exceeding 100km/h, consideration should be given to erection of warning signs for increased risk of rear-front collisions.

The signing system for escape ramps should consist of the following signs:

- Information signs about the number of escape lanes ahead
- Advance signs at 500m, 1km (2km)
- Directional signs guiding drivers to enter escape lanes
- Delineation of the layout and end of the escape lane
- No stopping sign at the escape ramp and on the immediate approach
- Sign showing distance to the next escape lane

Checker box markings in the form of red and white squares are recommended over the taper and full width approach section. In order to guide an errant vehicle to enter the escape ramp, delineator posts should be erected on both sides of the facility. The recommended spacing is 15m at the entrance with larger spacing thereafter to cover the entire facility. Red colour reflectors may be used to deter inadvertent entry by normal traffic.

Downhill Auxiliary Lanes

Heavy vehicles travelling at low speed on continuous downhill gradients increase the risk of rear-front collisions. On Classes II or III roads, lack of overtaking opportunities may lead to long and slow moving platoons of vehicles.

Downhill auxiliary lane is a potential solution to relieve the problem [10]. The design concept is similar to a 2+1 road or climbing lane section. To further enhance safety, the centreline may be laid with rumble strip or substituted with a median safety barrier.

The primary objective of downhill auxiliary lanes is to dissipate queues. A prolonged section may encourage excessive speed. As such they should be limited to about 2km in length and may be alternately provided in conjunction with climbing lanes for the opposite direction.

Similarly, downhill auxiliary lanes should be considered for Primary class and Class I roads if slow moving heavy vehicles contribute to an unacceptable level of service (***Figure 2.2.8.5***). In this situation, it is acceptable to replace the hard shoulder by an auxiliary lane with an edge strip of 1m. Emergency laybys should be provided at intervals of 500m.

FIGURE 2.2.8.5 DOWNHILL AUXILIARY LANE ON A PRIMARY ROAD
(driving is on the right side of the road)

2.9 Climbing Lanes

Road sections with climbing lanes allow lighter vehicles to overtake heavy vehicles or other users travelling uphill at low speeds without encroaching onto the opposing traffic.

Climbing lanes may be needed for peak uphill traffic volume and heavy vehicle volume exceeds 200 veh/h and 20 veh/h respectively. Further justification may be based on one or more of the following conditions:

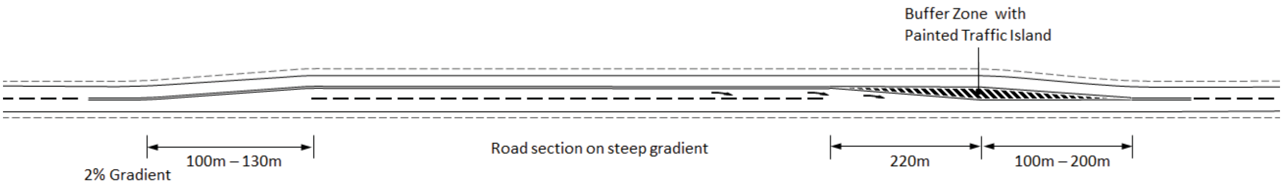
- Speed reduction more than 25km/h for a typical heavy vehicle
- Speed reduction to less than 50km/h on a controlled access road
- Level of service E or F based on Highway Capacity Manual on the road section
- Reduction of two or more level of service approaching the start of the grade

Classes II and III Roads

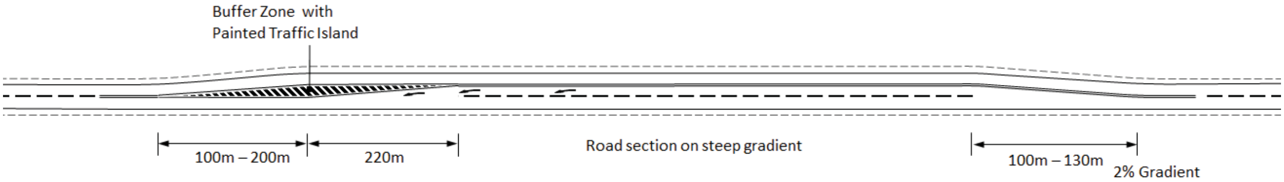
Climbing lanes should be provided on road sections with gentle horizontal alignment and good visibility. The typical layout of climbing lane is illustrated in ***Figure 2.2.9.1***. They should not commence, terminate or cover sharp curves or hairpins. Intersections, particularly crossroads and important intersections, should be avoided within road sections with climbing lanes.

FIGURE 2.2.9.1 TYPICAL LAYOUT OF CLIMBING LANE FOR CLASSES II OR III ROADS

(for driving on the right side of the road)



(for driving on the left side of the road)



Opposing traffic should be separated by a solid centerline line, preferably double-sided. Increasing protection may be offered with the use of a wide centerline, longitudinal rumble strips and lane delineators. Alternatively, a median may be provided with physical separation as illustrated in ***Figure 2.2.9.2***. In this case, the downhill lane will need to have adequate clear width for traffic to bypass a stranded vehicle.

FIGURE 2.2.9.2 CLIMBING LANE WITH A MEDIAN *(driving is on the right side of the road)*

Where the length of uphill gradient is limited and the alignment is favourable, a climbing lane should be continuous. In other cases, discrete sections of climbing lane may be sufficient with overall consideration of traffic volume, topography and economics. Such discrete sections generally should be more than 400m in length excluding tapers and buffer areas.

The width of all traffic lanes should be 3.5m, but narrower widths are acceptable to reduce the need for road widening. A possible scheme consists of a 3.2m wide climbing lane and 3.4m wide traffic lanes.

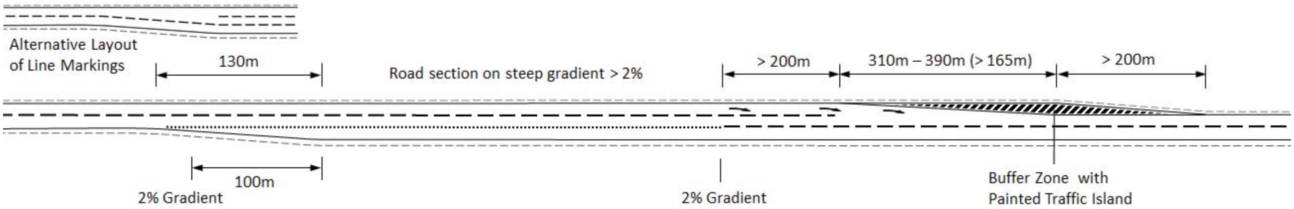
The width of paved shoulders may be narrowed down to 0.5m. If motorcycles are frequent on the downhill direction, the width of the hard shoulder should be maintained at 1.5m to 2m. Emergency parking laybys should be considered for both directions of roads on steep gradients.

Primary Class and Class I Access-controlled Roads

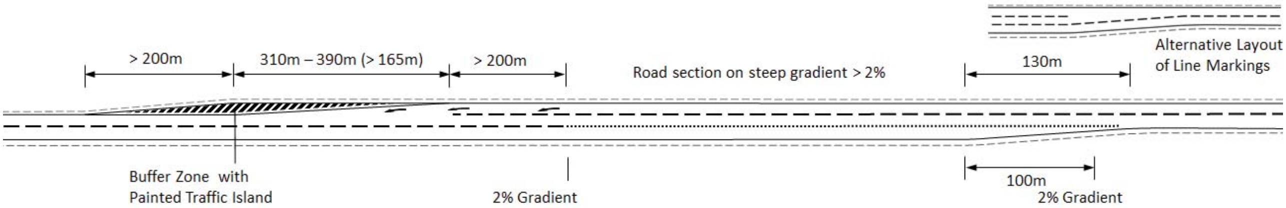
The layout of climbing lanes on these road types is illustrated in ***Figure 2.2.9.3***. They should be continuous without interruption. As such the vertical alignment should be well coordinated with tunnels to avoid escalated cost of an additional tunnel lane. It is generally acceptable to reduce the paved shoulder width to 1.0m and exceptionally 0.5m along climbing lanes. Emergency parking laybys should be provided at a maximum interval of 1km.

FIGURE 2.2.9.3 TYPICAL LAYOUT OF CLIMBING LANE FOR PRIMARY CLASS ROADS

(for driving on the right side of the road)



(for driving on the left side of the road)



3 PARKING AREAS

3.1 General Requirements

Parking areas consist of the following categories according to their function and layout:

- Parking areas
- Emergency parking areas
- Rest areas
- View Points
- Bus Stops
- Maintenance parking strips

They are provided for the following purposes:

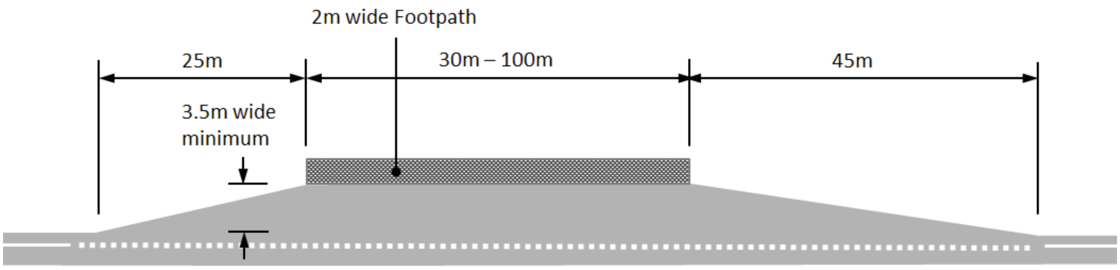
- Rest, toilet and replenishment
- Vehicle inspection and refilling
- Pulling off to allow overtaking by other vehicles

The provision of parking areas should be planned on a route-wide basis between population centres. Their precise locations are governed by availability of land, local circumstances and economics. The adequacy of parking areas may take into account availabilty of private commercial services such as restaurants or vehicle repair shops.

3.2 Parking Laybys

Parking laybys are widened areas on the roadside which may be paved or unpaved. On high speed roads they should be paved with a deceleration lane. A parking layby in simple layout is shown in ***Figure 2.3.2.1***.

FIGURE 2.3.2.1 PARKING LAYBY IN SIMPLE LAYOUT [11]
(for driving on the right side of the road)



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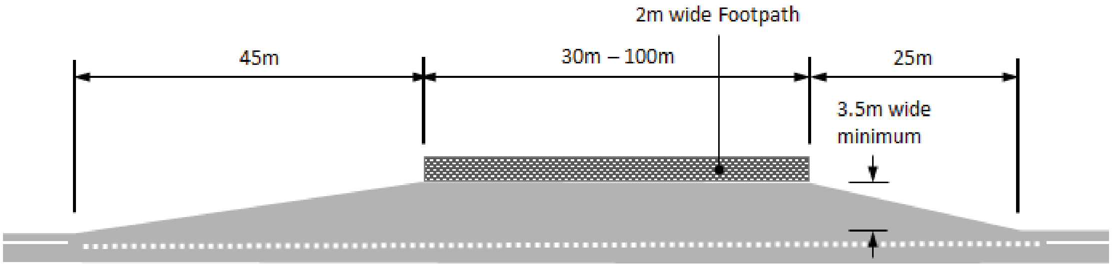
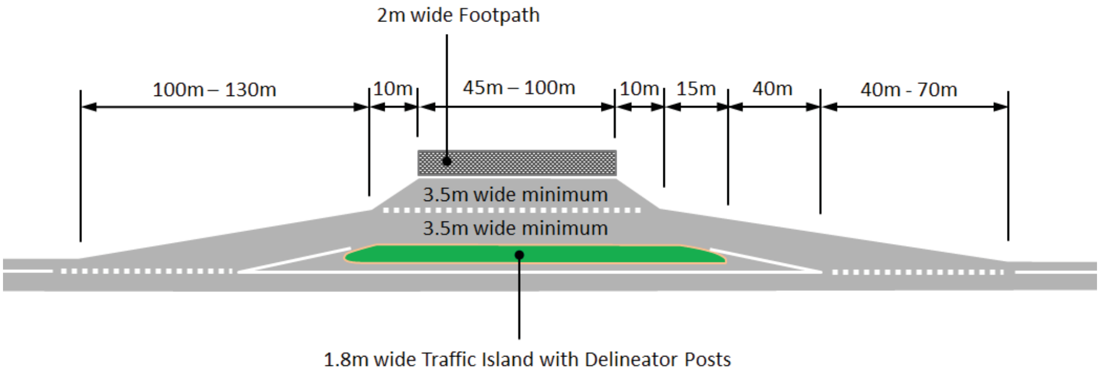


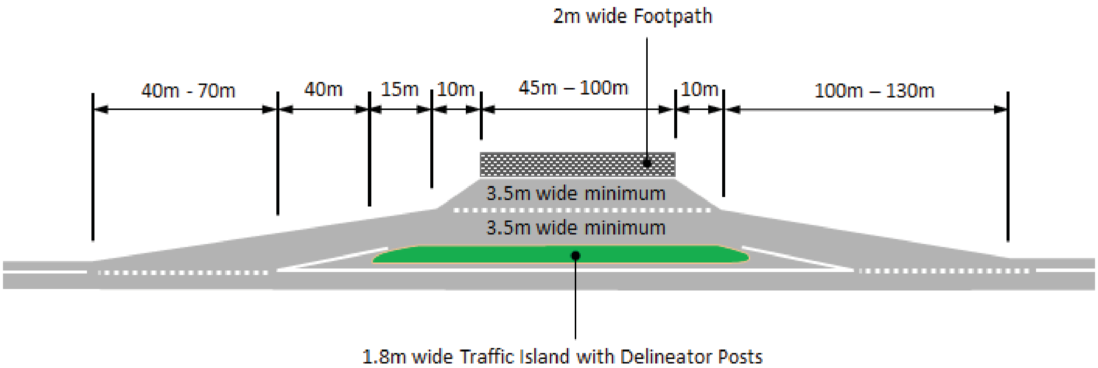
A parking layby in protected layout is separated from the main road by a traffic island. Such layout is desirable if land is available, particularly on Class I and Class II roads and where there is a high volume of heavy vehicles. This is shown in ***Figure 2.3.2.2***.

Figure 2.3.2.2 Parking Layby in Protected Layout with Acceleration Lane [11]

(for driving on the right side of the road)



(for driving on the left side of the road)



Note: Acceleration lane should not be provided for undivided roads and where the paved shoulder is used by slow vehicles

The recommended parking layby types and spacing are given in ***Tables 2.3.2.1*** and ***2.3.2.2***.

TABLE 2.3.2.1 SELECTION OF PARKING LAYBY TYPES

Road Class	General Parking Area	Emergency Parking Area
Class I (> 60km/h speed limit and absence of slow vehicles lane)	A2	B
Class I (=<60km/h speed limit or presence of slow vehicles lane)	A1	B
Classes II, III, IV	A1 · B	B
Long Steep Grade (both uphill and downhill)	B	B

A1 Protected layout
A2 Protected layout and acceleration lane
B Simple layout

TABLE 2.3.2.2 RECOMMENDED SPACING OF PARKING LAYBYS

Road Type	Two-way Traffic Volume (veh/day)	Average Spacing
Class I	Any	2.5 km
Classes II, III	>8,000 <8,000	2 – 5 km 5 – 8 km
Long Steep Grade	Any	500-1000m
Scenic Areas	Any	Route-specific

Drivers on the main road should be able to see and a parked vehicle in the layby with a visibility distance equal to SSD. On primary roads they should also be able to see the parking sign at least 150m ahead.

Parking laybys for general purpose should avoid road gradient exceeding 4% and crest profiles. It is also advisable to avoid horizontal curves, both on the inside and outside, of radii smaller than values given in ***Table 2.3.2.3***.

TABLE 2.3.2.3 RECOMMENDED MINIMUM RADIUS FOR POSITIONING PARKING LAYBYS [11]

Speed Limit (km/h)	Radius m
100	1440
80	950
70	720
60	510
=< 50	360

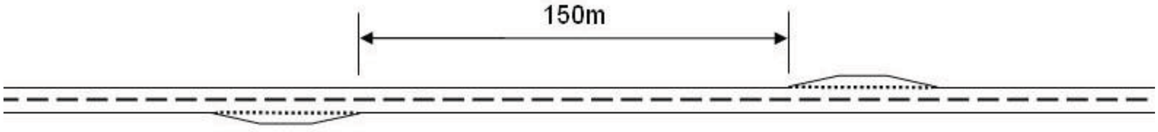
Suitable sites for parking laybys are often constrained on mountain roads. In general, it is acceptable to provide parking laybys on the outside of sharper curves.

Where the overall width of the paved shoulder and verge is less than 1.5m, notably road sections bounded by continuous safety barriers, informal laybys should be provided at regular intervals not exceeding one kilometre. Such laybys do not need to be paved and may be created by local flattening of slopes and extending low embankments at transition of cuts and fills.

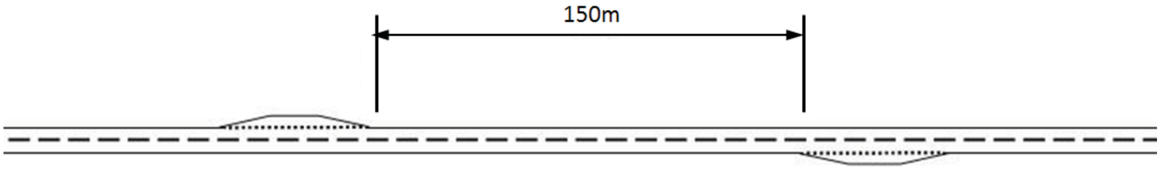
To avoid drivers crossing onto parking areas for opposing traffic, parking laybys on an undivided road should be arranged in a staggered layout with separation preferably exceeding 150m. This is illustrated in ***Figure 2.3.2.3***.

FIGURE 2.3.2.3 STAGGERED POSITIONING OF PARKING LAYBYS

(for driving on the right side of the road)



(for driving on the left side of the road)



Parking laybys are preferably provided away from intersections with a separation of at least 3.75V metres (V= speed in km/h). Siting of a parking layby between an intersection and the associated advance direction sign should be avoided.

All formal laybys should be indicated by an informatory sign at the entrance as well as one or more advance informatory sign.

Laybys on Primary Class Roads

On primary roads additional laybys should be considered where:

- the paved shoulder is 2.5m or less in width
- there is high volume of heavy vehicles
- there is an increased need for emergency stoppage e.g. along long steep grades

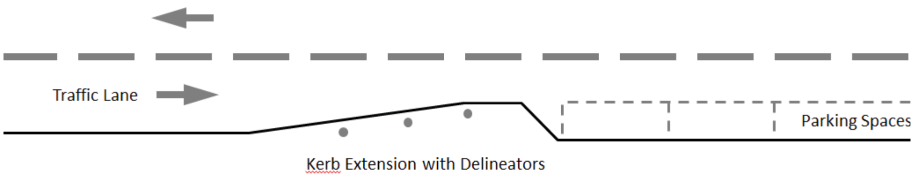
The spacing between laybys is generally 2km but closer spacing in the order of 1km or less will be justified if the shoulder is inadequate for the parking of a stalled vehicle. A layby should be at least 4m wide inclusive of the paved shoulder with tapers at both ends.

Parking Areas on Urbanised Sections

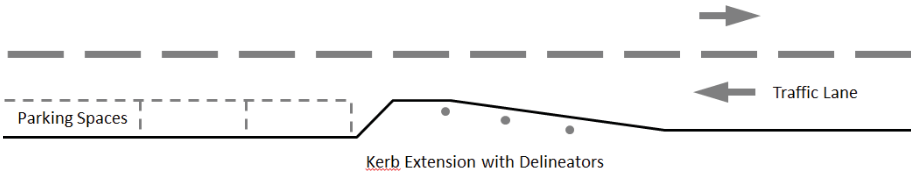
Roadside parking spaces on urbanised sections should be shielded by kerb extensions as shown in ***Figure 2.3.2.4***. This is particularly important where approach visibility is constrained and on multi-lane roads.

FIGURE 2.3.2.4 SHIELDED ROADSIDE PARKING AREA

(for driving on the right side of the road)



(for driving on the right side of the road)



3.3 Rest Areas

Rest areas should be provided along Asian Highway routes between service areas to provide a protected and comfortable stopping environment. For Primary class roads traversing rural areas, they should be separated by not more than 30km apart. For other roads, the maximum separation is 45km or 30 minutes of travel.

The location of rest areas should be determined on a master plan, taking into account the visual quality of users and integration with the landscape. It is not advisable to construct rest areas with major earthworks thereby damaging the landscape. It is also necessary to avoid locations susceptible to geological hazards including rockfalls, flooding or lightning strikes. In the vicinity of scenic sites along the highway, consideration should be given to provision of viewpoints with parking spaces.

A typical rest area is illustrated in ***Figure 2.3.3.1***. Facilities at rest areas should be determined according to prevailing conditions and needs. In general, restaurants and shops are not essential at rest areas. Essential facilities should include toilets, shelters, seats and tables, maps, rubbish bins etc., with adequate consideration for universal accessibility. Facilities can be provided gradually over time.

FIGURE 2.3.3.1 ENTRANCE TO A PROTECTED REST AREA ON AN UNDIVIDED ROAD
(driving is on the right side of the road)

Viewpoints

Viewpoints should be provided at vantage locations along scenic sections of Asian Highway routes. Attractions may include natural landscape, notable architecture and remarkable infrastructure. A typical example is illustrated in ***Figure 2.3.3.2***. Planning of these facilities should take into account:

- Adequacy of parking capacity to avoid indiscriminate parking on the roadside
- Proper intersection design for accesses to parking facilities
- Need for footpaths and pedestrian crossing facilities

FIGURE 2.3.3.2 REST AREA WITH VIEWPOINT TOWARDS A HISTORIC CITY

3.4 Service Areas

Services areas should be provided at regular intervals in the order of 30 to 40km (maximum 60km) along Primary class roads and other access-controlled roads. Other than serving the general traffic, service areas may need to serve long-distance trucks with specialised parking areas and rest facilities. Service areas on only one side of the road with bridge linkage could be more economical on less busy Primary class roads.

Service areas on access-controlled roads should be physically separated from the main road and are only accessible via merging and diverging areas. They may be integrated into a grade-separated intersection provided that general traffic does not need to pass through the service area.

In general, the following basic service should be provided:

- Parking spaces for different vehicle types
- Restaurants, cafes, shops
- Information kiosks
- Telephones and wi-fi services
- Filling stations
- Toilets
- Hotels, where appropriate

Signage

Directional signs for service areas should constitute an independent system comprising advance direction signs, direction signs and confirmatory signs. Confirmatory signs should indicate the location and service provided at next two or more service areas.

Service areas are preferably well separated from other intersections, otherwise directional signing has to be carefully designed for the clear guidance of drivers.

Within a service area, it is important to provide clear and timely guidance for different vehicle types and towards the various services. Directional signs should also clearly indicate the path back onto the main road.

Traffic Calming

Rest areas and service areas entail the risk of traffic colliding with pedestrians at elevated speeds or during low speed manoeuvres such as reversing. For these reasons, the layout of these facilities should result in minimum the needs for pedestrians to interact with vehicles through the provision of footpaths and clearly defined crossing points. It is also necessary to avoid pedestrians crossing or interacting with heavy vehicles.

Traffic from Primary class roads or other high speed roads entering rest areas or service areas should be prompted to slow down through speed limit not exceeding 40km/h, visual traffic calming measures or rumble strips. Within the facilities, appropriate traffic calming measures such as speed tables should be provided. ***Figures 2.3.4.1*** and ***2.3.4.2*** illustrate possible design schemes at service areas.

Figure 2.3.4.1 Guidance and Traffic Calming at the Entrance to an Expressway Service Area in the Republic of Korea *(driving is on the right side of the road)*

Figure 2.3.4.2 Segregation of Heavy and Light Vehicles, Pedestrian Paths and Traffic Calming at an Expressway Service Area in the Republic of Korea *(driving is on the right side of the road)*

3.5 Bus Stops

Bus service on Asian Highway routes range from inter-city connections to regional or local transit. With light to moderate usage, bus stops are readily accommodated along the main road. Heavy bus usage will warrant the provision of bus lanes or relocation of facilities away from the main road.

Bus lanes have been increasingly recognized and adopted along main roads including urban arterials and urban expressways. Furthermore they may be provided in conjunction with dedicated bus-to-bus interchange facilities.

The need and location of bus stops should take into account the convenience and safety of users. They should be located in the proximity where passengers wish to board or alight from a bus. Users should not be required to walk alongside the main road over excessive distance.

Local and regional bus stops, in particular, should be as close as possible to key destinations such as schools, railway stations, long distance bus termini, clinics and hospitals etc. Along urbanised sections, bus stops should be spaced 200 to 400m apart with shorter distance on gradients.

Bus stops should be well connected to footpaths and crossings. Traffic calming is highly desirable in the vicinity of bus stops where passengers regularly need to cross the road.

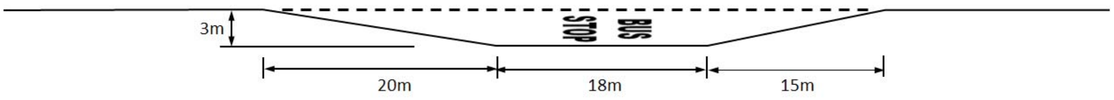
Additional space and facilities may be needed for bus passengers interchanging to local transport such as feeder buses, rickshaws, motorcycles or bicycles. Adequate space and bus shelters should be provided for the comfort of waiting passengers.

Bus Stop Types

In built-up areas with lower traffic speeds, bus stops are desirably provided directly along roadside kerbs. At higher speeds and to minimize interference with main road traffic, bus bays are generally preferred. Typical bus bays are illustrated in ***Figures 2.3.5.1*** and ***2.3.5.2***. The length of kerbside bus stops and bus bays will need to be extended for heavy usage.

FIGURE 2.3.5.1 STANDARD BUS BAY

(for driving on the right side of the road)



(for driving on the left side of the road)

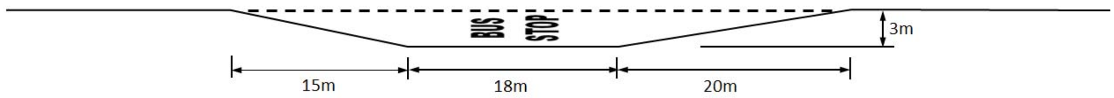
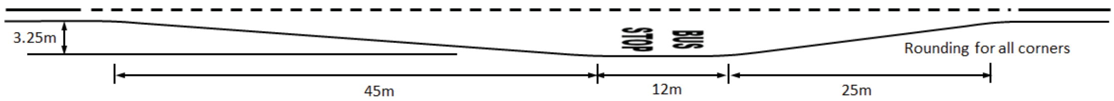
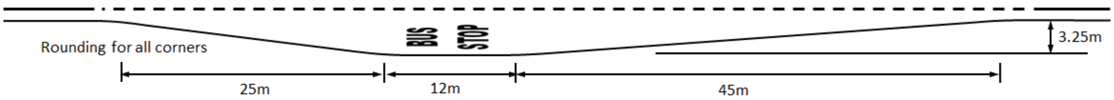


FIGURE 2.3.5.2 BUS BAY FOR HIGH SPEED ROADS

(for driving on the right side of the road)



(for driving on the left side of the road)



Bus stops are potential weak points of roadside safety in terms of lightly protected waiting passengers and unguarded aggressive roadside features including bus shelters. This especially the case for bus stops on Class I roads and other roads with speed limit of 70km/h or above. Notwithstanding the conflicting needs for permeability of passenger movements and continuity of safety barriers, intermediate solutions should be sought.

Possible solutions include segregation of the bus stop with a traffic island and usage of passively safe bollards (***Figure 2.3.5.3***). Safety barriers may also be provided with layouts which are acceptable for both bus stop operation and technical criteria for the equipment.

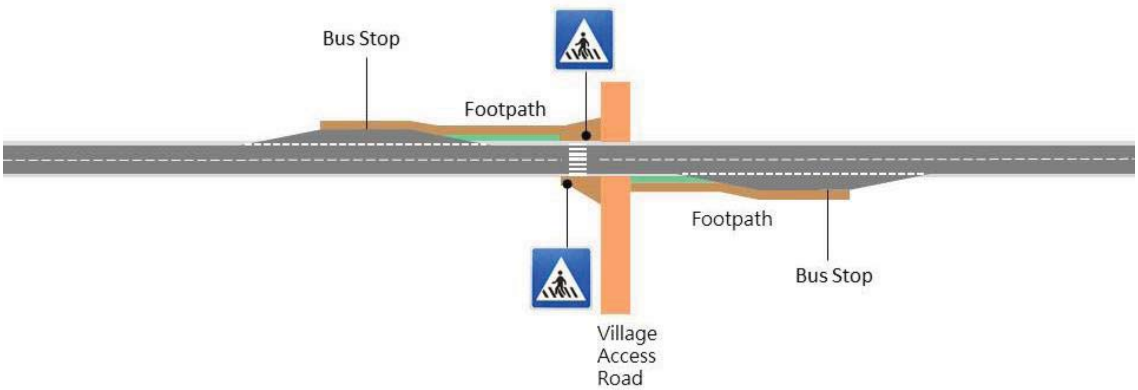
FIGURE 2.3.5.3 PASSIVELY SAFE BOLLARDS AT A BUS STOP IN SINGAPORE

Positioning of Bus Stops

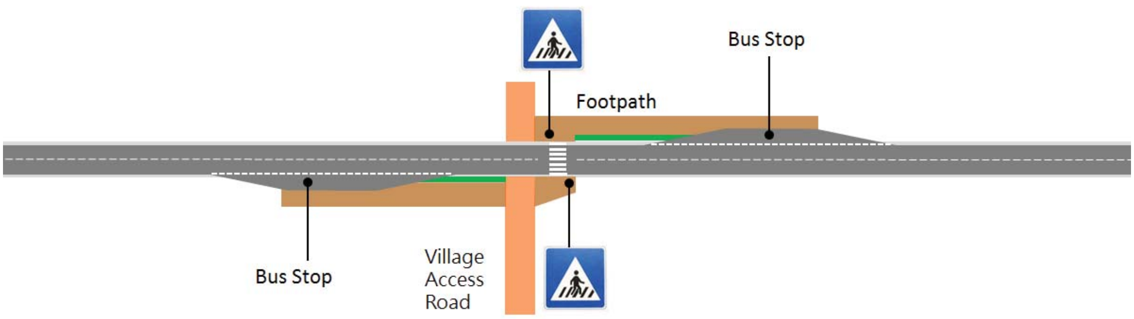
Bus stops should be located on straight sections or slight curves to ensure visibility. Opposing bus stops are preferably arranged in a staggered layout so that pedestrians cross the road at the rear of buses with better visibility. This is illustrated in ***Figure 2.3.5.4*** .

FIGURE 2.3.5.4 LAYOUT OF BUS STOPS ON CLASSES II, III ROADS

(for driving on the right side of the road)



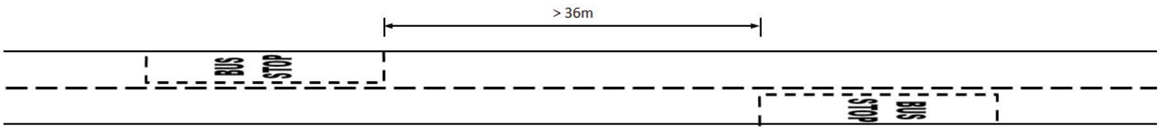
(for driving on the left side of the road)



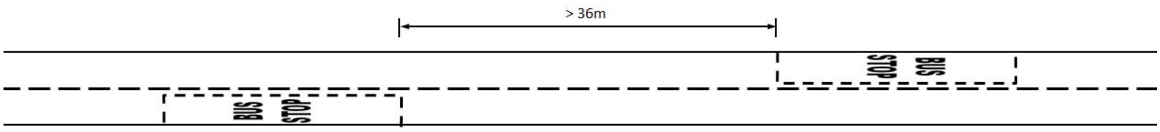
If bus bays are not provided, opposing bus stops should be separated by at least 36m ***(Figure 2.3.5.5)***.

FIGURE 2.3.5.5 GENERAL LAYOUT OF OPPOSING BUS STOPS

(for driving on the right side of the road)



(for driving on the left side of the road)

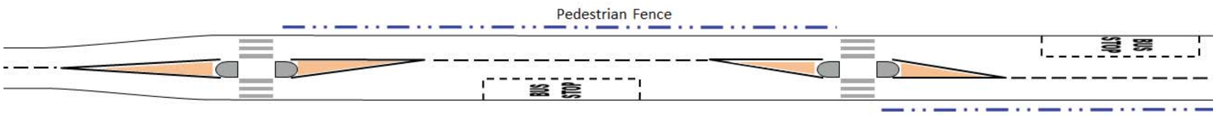


In built-up areas, consideration should be given to the integration of bus stops and pedestrian crossings as shown in ***Figure 2.3.5.6***. Lane widths may be redistributed to facilitate vehicles to overtake a stopped bus.

FIGURE 2.3.5.6 LAYOUT OF BUS STOPS IN BUILT-UP AREA

(for driving on the right side of the road)

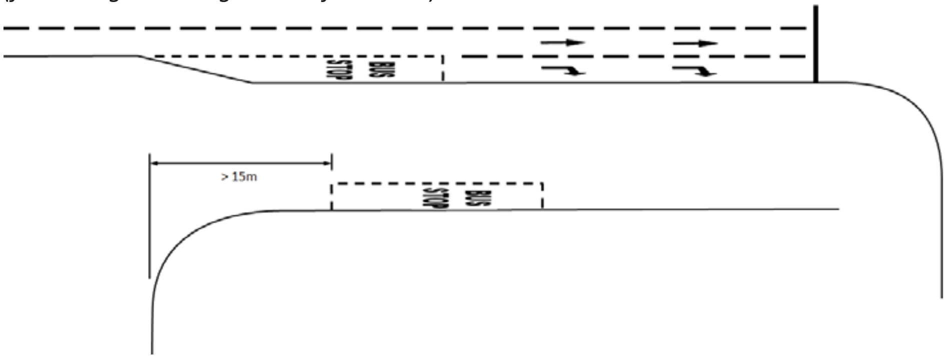
(for driving on the left side of the road)



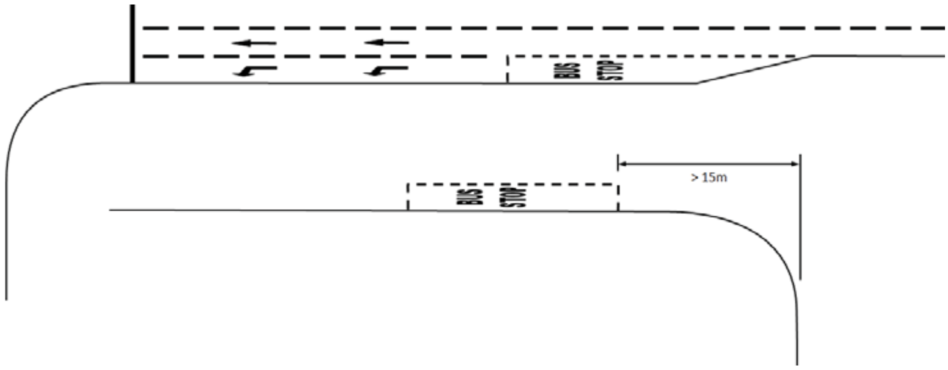
Bus stops should be located away from intersections. Otherwise they are preferably located downstream of an intersection or in conjunction with a nearside turn lane. This is illustrated in ***Figure 2.3.5.7***. Any adverse implications on visibility and traffic flow at the intersection should be evaluated for each case.

FIGURE 2.3.5.7 BUS STOPS IN THE VICINITY OF INTERSECTIONS

(for driving on the right side of the road)



(for driving on the left side of the road)



The continuity of slow vehicle routes should be maintained by bending them to the back of a bus stop. With this arrangement, conflicts between slow vehicles and bus passengers should be managed with adequate space, visibility and traffic calming for the slow vehicles.

3.6 Roadside Stalls

The primary road safety concerns of roadside stalls are:

- Traffic stopping and re-entering the road
- Stopped traffic intruding into traffic lanes
- Unprotected hawkers and customers

The management of roadside stalls will depend on national and local policies. From the road safety point of view, problems could be alleviated by:

- Informal local widening of shoulders
- Protected laybys

Widened areas should only be provided on the downstream side of an intersection.

4 SPECIAL FACILITIES

4.1 Toll Plazas

Tolling facilities generally fall into two categories: toll plazas or multi-lane free flow tolling systems. Toll plazas may be located on the mainline or at interchanges. Tolling may be based on travel mileage between entry and exit points or a single passage through toll plazas.

Main line toll plazas on Primary class roads and other high speed roads are susceptible to failure of stopping leading to collision with toll booths or rear-front collisions. Similar concerns also apply to interchange toll plazas with long straight approaches or approaches with constrained visibility.

Mainline toll plazas should be provided with the immediate approach on straight alignment and gentle gradient. They should not be located on or at the bottom of significant downhill gradients.

It is not uncommon that drivers wish to stop at toll plazas for a variety of purpose. Designated parking areas may be provided ahead of or after toll plazas. There is also the need of laybys for toll staff, the Police or other authorised personnel to resolve payment problems and to conduct inspections. For these reasons, adequate space should be allocated on the downstream nearside of toll plazas with demarcation to minimise conflicts between through traffic and stopped vehicles.

Signing Requirements

Toll plazas are formed from progressive widening of the road. Gradients should be relatively flat within the toll plaza and on immediate approaches. Long steep downhill gradients on the approach should be avoided or else special treatments will need to be provided.

An approach sign sequences informing about the toll plaza should commence at an advance distance of 1000m to 2000m ahead, depending on traffic speeds. This should be reinforced with speed reduction measures such as transverse rumble strips, transverse yellow bar markings and speed limit signs. Toll plazas and the immediate approach should be equipped with lighting.

Toll Lanes

Toll lanes should have a minimum width of 3.1m and the cross-section should allow a vehicle to stay close enough to the toll booth to complete the manual payment procedures. A wide toll lane may be required on the outer side of the toll plaza to accommodate a special wide vehicle.

A variable lane signal and a barrier gate should be provided for each toll lane to indicate the opening status of the toll lane. The barrier gate should be passively safe and its position should be interlocked with the variable lane signal for consistent operation.

There should be adequate guidance and advance signing for heavy vehicles and light vehicles if restriction of vehicle types applies to certain toll lanes.

Electronic toll lanes should be clearly signed and adequate approach guidance is provided. Passage through these toll lanes should be subject to speed limit not exceeding 40km/h unless special high speed passage design is in place.

Toll lanes should be designed with safety in mind covering:

- Limitation of injury consequences to vehicle occupants colliding onto toll islands
- Protection of staff inside and outside toll booths
- Availability of safe walking paths for staff

4.2 Border Control Points

Border control points range from relatively simple arrangements to elaborate facilities occupying substantial area. They generally consist of a plaza with inspection facilities for immigration, customs, security and traffic control. There are also holding areas for passenger cars, buses or trucks.

Separated pedestrian and slow vehicle passages should be provided at border crossing points to minimise conflicts between traffic and these user groups. Such passages should be integrated with public transport facilities.

Attention should be given to the adaptation for international drivers in the first few kilometres of road section after a border control point. This is particularly the case if road conditions and driving rules differ.

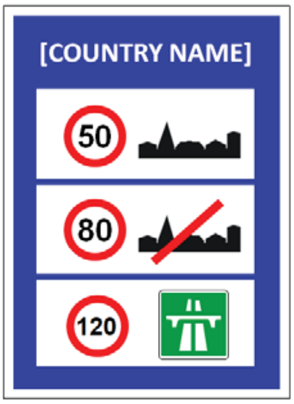
Signing

The principle for provision of traffic lanes and signing is similar to toll plazas. However, special attention should be given to the followings:

- U-turn opportunities for traffic wishing to turn back
- Signing and guidance of lanes and directions for small passenger cars, buses and trucks
- Directional signing on the approaches to indicate clearly approach to a border crossing

Signs should be readily understandable by international drivers in appropriate languages and symbols. A sign indicating the national speed limit system (***Figure 2.4.2.1***) should be installed at a prominent location.

FIGURE 2.4.2.1 NATIONAL SPEED LIMIT INFORMATORY SIGN



Switchover of Driving Direction

Where the driving direction changes at the border, it will be necessary to inform and assist drivers to adapt to the new driving direction.

Changeover of driving directions requires special infrastructures to set drivers into the correct position. For Primary class and Class I highways, grade-separated facilities are often required to cope with heavy traffic flows. For other roads, these could be in the form of an at-grade facility, possibly involving traffic lights. Changeover should ensure low speed conditions for at-grade facilities.

It is advisable to provide special information signs or warning signs indicating the driving directions in force. These signs should be shortly after the borders and are repeated.

4.3 Emergency and Maintenance Facilities

For Primary class roads, an emergency access strategy is needed to facilitate efficient response to incidents. The strategy will aim at minimizing response time between an incident site on the highway and the following emergency response centres:

- Fire and ambulance services
- Police services
- Highway emergency response centres
- Hospitals with trauma service

Emergency access may be facilitated by the following road features:

- Hard shoulders
- Grade-separated Intersections
- U-turn facilities
- Median crossings
- Roadside emergency access points

Median Crossings

There are three categories of median crossings, namely emergency crossings, contingency crossings and maintenance crossings. Their functions are given in ***Table 2.4.3.1***.

TABLE 2.4.3.1 MEDIAN CROSSING TYPES

Crossing Types	Functions	Length	Opening Time*
Emergency Crossings	Passage for emergency vehicles	Adequate for passage	< 3 minutes
Contingency Crossings	Traffic diversion due to incidents	16m- 25m	< 30 minutes
Maintenance Crossings	Traffic diversion for road maintenance	To be established from desired crossing speed	1 – 2 hours or more

* indicative only

Contingency crossings should be provided at both ends of major tunnels, special bridges and interchanges. If single tube contra-flow operation is required for tunnels or bridges on a routine basis, the crossing will need to be designed for rapid opening not exceeding 5 minutes. On free-flow sections, they should be spaced 3 to 5 km apart on average along straight or near straight sections away from curves.

Emergency crossings should be selected on the basis of emergency needs and rescue routing. They may be standalone facilities or combined with contingency crossings.

Median crossings should not be readily utilised by ordinary traffic. The crossing should normally be fenced off by appropriate safety barriers or barrier gates. For narrower medians, special movable or dismountable safety barriers will usually be required. This is illustrated in ***Figure 2.4.3.1*** and ***Figure 2.4.3.2***.

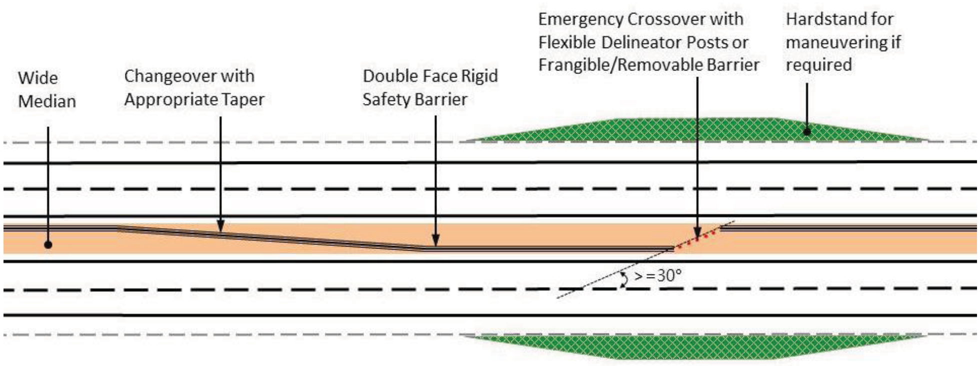
FIGURE 2.4.3.1 EMERGENCY CROSSING WITH CRASHWORTHY BARRIER GATE

FIGURE 2.4.3.2 CONTINGENCY CROSSING WITH CRASHWORTHY SAFETY BARRIER

Wide Medians

With wider medians, it would be possible to provide emergency crossings without special barrier gates. This is illustrated in ***Figure 2.4.3.3***. An opening is provided with the median safety barrier in a staggered layout to minimise the hazard of end terminals. The adequacy of swept paths has to be verified.

FIGURE 2.4.3.3 EMERGENCY CROSSING FOR A WIDE MEDIAN



Roadside Emergency Access Points

Where grade-separated intersections are far apart on access-controlled roads, emergency access points should be considered if there is a parallel or intersecting road in the vicinity. Their provisions will need to be discussed with the emergency service with respect to response time and rescue strategy. Such access points have to be effectively managed to prevent indiscriminate usage by pedestrians, traffic and animals. An example of this facility is illustrated in ***Figure 2.4.3.4***.

FIGURE 2.4.3.4 EMERGENCY ACCESS POINT ON A PRIMARY CLASS ROAD
(driving is on the right side of the road)

Mileage Signs

Mileage signs are needed on Asian Highway routes for the purpose of asset management, maintenance and emergency response. They should be passively safe and may be integrated with delineators.

Maintenance Access

Adequate consideration should be given to the safety of maintenance operation, particularly on primary roads. Safety may be enhanced with special laybys, maintenance access openings and walkways. Well-conceived facilities can help to reduce exposure of maintenance staff to live traffic.

4.4 Facilities for Wildlife and Animals

Interactions between vehicle traffic and wildlife or herded animals could be a major issue for roads in rural areas. A major concern is collisions between vehicles and animals. The other major concern is severance and fragmentation of habitats. Collisions could lead to injuries or fatalities for both vehicle occupants and the animals. There are also secondary risks due to killed animals on the road and activities to clear up the site.

The type of animals of interest is highly dependent on geographical areas and local conditions. Specific issues could be associated with road sections traversing nature reserves or areas of wilderness. Typical targets of management include:

- Large wild animals: deer, goats, boars, horses, bears etc.
- Herded farm animals: cattle, sheep, goats, horses, donkeys, camels etc.
- Stray animals around built-up areas: dogs, cats
- Small Fauna: mongooses, badgers, amphibians, reptiles etc.

The precise scenario and risk have to be established from studies of land-use and ecology. Ecological studies would need to be of sufficient details to identify the type of wildlife, environmental preference, movement patterns and migration routes.

Mitigatory measures for wildlife are generally intended for both ecological conservation and road safety with strategies based on the following measures:

- Fence off the roadside
- Improve safety for at-grade crossings with warning signs, speed control and adequate visibility
- Channelise animals to safer crossing locations
- Provide dedicated grade-separated crossings

Mitigation measures for herded animals generally rely on facilities belonging to local farmers including fences, walls and gates which are preferably self-closing. However, additional measures may still be necessary within the jurisdiction of road authorities. These measures may include fencing, cattle grids, animal crossings, herd warning signs or signals.

Applications

On all roads with speed limit of 70km/h or above, warning signs (***Figure 2.4.4.1***) should be provided where there is a high likelihood of encounters with larger animals. Such signs may also be appropriate for roads with lower speed limits, especially where visibility is impaired.

FIGURE 2.4.4.1 WARNING SIGNS FOR ANIMALS *(driving is on the right side of the road)*

Where Primary class roads and Class I roads with design speed of 80km/h or above pass through areas of wilderness and areas frequently traversed by animals, a wildlife exclusion system should be provided to prevent animal access. Such system may contain a combination of the following facilities:

- Wildlife exclusion fencing,
- One-way gates and jumpouts
- Ungulate guards
- Dedicated overpasses and underpasses

General Requirements

The basic provision is a continuous fence with light metal mesh along the boundary of the right of way of the highway. Fence height ranges from 1.2m to 2.5m depending on the type and population of animals. A higher fence is also needed in areas of heavy snowfall.

Dedicated overpasses and underpasses are desirable from both the safety and ecological perspective. This is illustrated in ***Figure 2.4.4.2***. Animal passages may also be available above tunnels and underneath viaducts, bridges or culverts. Since different animals may have their particular preference for movements, additional facilities may be needed e.g. fencing, plantings and provision of a raised corridor within a culvert. Expert advice should be sought from ecologists on the planning and design of these facilities.

FIGURE 2.4.4.2 DEDICATED WILDLIFE OVERPASS ON A PRIMARY CLASS ROAD

5 ROAD PAVEMENT

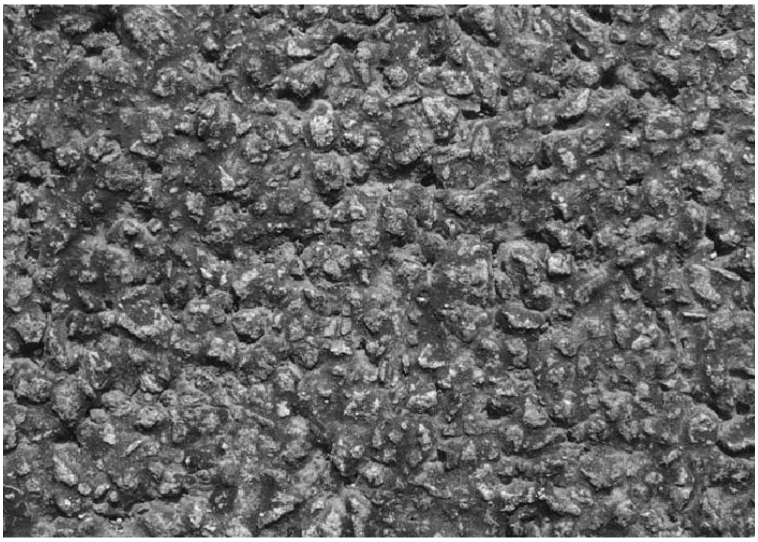
5.1 Skid Resistance

The skid resistance (grip) of the road surface is part of the road surface condition contributing to road safety. As skid resistance increases, the likelihood of skidding on the road surface will be reduced.

At low traffic speed, the skid resistance of a road surface is predominantly controlled by the “microtexture” of the aggregate used, and its resistance to polishing. As speed increases beyond 50 km/h, the “macrotexture” of the pavement becomes increasingly important, particularly in permitting the escape of the water film between the tyre and a wet pavement. The texture depth is therefore an important factor influencing skidding in wet conditions on high speed roads.

A minimum average texture depth of 0.7 mm is recommended for concrete carriageway surfaces. However, the texture depth required at high speeds on bituminous surfacing is almost double the texture depth required for concrete roads. As the typical texture depth of bituminous wearing course material is only between 0.3 mm to 0.5 mm, it is advisable to adopt stone mastic asphalt (SMA) or porous friction course materials which provide higher texture depths (***Figure 2.5.1.1***) for high speed traffic.

TABLE 2.5.1.1 BITUMINOUS SURFACING WITH HIGH TEXTURE DEPTH



Testing and Priority

Skid resistance is not readily determined by routine road inspections. The pendulum tester simulates the effect of a braking tyre travelling at 50 km/h, and thus provides a guide to the skid resistance of the road surface for a vehicle travelling at this speed. Its operation is slow causing disruption to normal traffic. For more efficient and holistic assessment of skid resistance, other equipment such as the SCRIM or Griptester would be more appropriate.

Adequate skid resistance should be provided on all sections of the road with particular emphasis on curves and where braking is required. Priority may be assigned in the following order:

Priority 1

- Approaches to intersections, roundabouts and traffic signals
- Approaches to pedestrian crossings
- Gradient >10% and longer than 50m (not for uphill gradient on one way roads)
- Curve radius <500m for speed limit >= 80km/h on Primary class and Class I Roads
- Curve radius <100m for speed limit >= 50km/h on Primary class and Class I Roads

Priority 2

- Curve radius <500m for speed limit >= 80km/h on Classes II and III Roads
- Curve radius <100m for speed limit >= 50km/h on Classes II and III Roads
- Within roundabouts
- Gradient >5% and longer than 50m (not for uphill gradient on one way roads)

Priority 3

- General sections of the road

Where there is a notable skid resistance problem, possibly supported by crash data, skidding warning signs should be erected in the interim together with measures to reduce approach traffic speeds.

Porous friction Course Material

It is a very permeable asphalt layer with continuous voids which can contain runoff of low to moderate intensities of rainfall. Water can percolate through the material to the pavement edges and discharge into appropriate drainage systems. The material has the following properties in comparison with continuously graded materials:

- Improved skid resistance at high speeds
- Reduced water spray from the rear of vehicles during wet weather
- Reduced possibility of aquaplaning
- Reduced tyre/road noise

In view of the above merits, porous friction course material is suitable for top surfacing of high speed roads. Due to its high porosity, however, it is more susceptible to damages. Furthermore, when the pores are cogged by dust or dirt, some of the merits will diminish. Its suitability for use should therefore be examined against local conditions.

High Friction Surfacing

High friction surfacing (Anti-skid surfacing) should be considered at Priority 1 sites where additional skid resistance is desirable. On approaches to intersections and crossings, commencement of the surfacing should coincide with the point where drivers apply their brakes. Usage may be limited to a single direction of traffic (***Figure 2.5.1.2***). A maintenance program is necessary to ensure that the material is kept in good condition.

FIGURE 2.5.1.2 HIGH FRICTION SURFACING ON A DOWNHILL GRADE
(driving is on the right side of the road)

5.2 Road Drainage

Water on road pavement can cause aquaplaning, splashing, or even direct hindrance to traffic. Pavement drainage aims to drain rainfall dropping on the road pavement in the most effective way.

Pavement Surface Drainage

Adequate pavement surface drainage is needed to avoid ponding and aquaplaning. Pavement slope (crossfall , camber) should be provided for all roads to drain storm water to roadside channels or kerbside edge channels. Along curves, pavement slope is provided as superelevation.

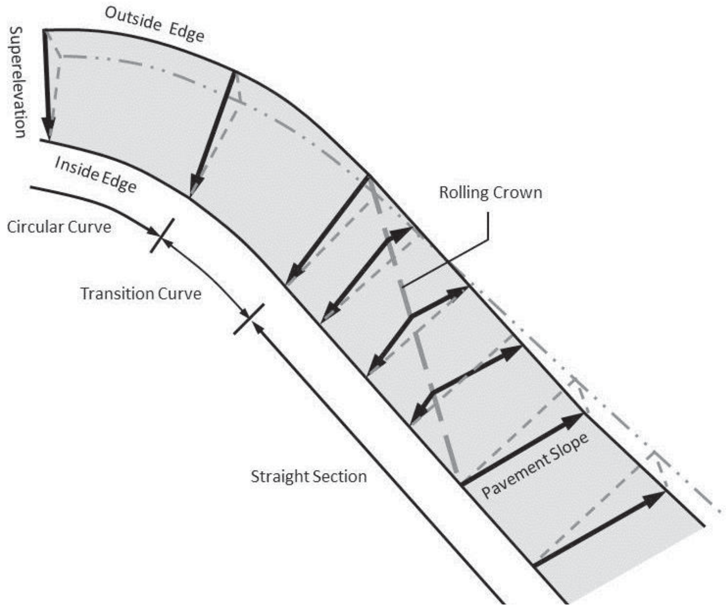
In general, pavement slope of 2.5% is desirable, accounting for undulations due to rutting. A minimum pavement slope of 2% should be maintained at all locations on the road. Furthermore, on roads designed with kerbed edge drainage, a minimum longitudinal gradient of 0.5% is necessary along any parts of the road.

At transitions between pavement slope and superelevation, the pavement should be free of large area of flat gradients or kinks. Adequate longitudinal gradient should be provided in order to maintain a minimum gradient of 0.5% for the carriageway edge profile along transition of superelevation.

For satisfactory visual appearance, carriageway edge profile should not vary in grade by more than about 1% from that of the edge line if no superelevation is applied. On Primary class roads of high design speed, such variation in grade of the edge profile should be limited to 0.5%. Smoothing should be applied where edge profile changes.

Rolling crowns provide an attractive solution at transition areas, especially for asphalt pavements. This method is illustrated in ***Figure 2.5.2.1***. Gradients on either side of the rolling crown should be set at 2% for one lane width to limit the change of angle across the crown axis.

FIGURE 2.5.2.1 ROLLING CROWN [12]



Roadside Channels

Open channels have large hydraulic capacity, high drainage efficiency, and any blockage of which can be easily identified during daily inspection of the roads. In view of these advantages, it is recommended to provide roadside channels at the verge of roads to drain away storm water received from the road pavement if roadside kerbs are not provided.

Roadside channels can also be designed to prevent runoff on the adjacent area or uphill slope from flowing onto the road and causing flooding. They can also serve as the contingency measure to receive surface flow on the carriageway overtopping the kerbs or discharging from drain holes through roadside barriers and other intermittent drainage outlets under extreme situations.

As roadside channels are a vital part of the discharge measures, their hydraulic capacities should be adequate for the discharge of all the anticipated runoff. This may be taken as heavy rainstorms with a specified return period.

Underground Carrier Drains

For roads with footpaths and kerbs, the pavement drainage system generally consists of roadside gullies in association with an underground drainage system comprising gully connection pipes and carrier drains. The carrier drains should be designed to ensure that all water collected from roadside gullies is drained away in a timely manner. This may be taken as heavy rainstorms with a specified return period.

For roads with kerbs, part of the road width adjoining the kerb will unavoidably be flooded with water during rainstorms. The design flooded width is controlled by the spacing and efficiency of gullies. The flooded width can be reduced with reduction of the gullies spacing. Such spacing may be based on the limitation of flooded width to the extent that normal commuting of traffic will not be substantially affected. Consideration may be given to a design flooded width of 0.75m. With this width stormwater will just begin to encroach into the wheel paths of the general traffic.

Rainfall Intensity

For Primary class roads, the design flooded width should remain within the paved shoulders even for very heavy rainstorms. For roads without paved shoulders, gullies are provided to limit the flooded width to a reasonable magnitude,

The design rainfall intensity could be extremely high for tropical or sub-tropical regions with a large return period. To strike the balance, depending on the rainfall statistics of individual regions, a shorter return period e.g. twice per year, would be acceptable in the design of spacing of gullies to limit the design flooded width.

It would generally require 2 to 5 times more gullies in order to reduce the flooded width by 50%. Consequently, a modest improvement in flow condition would involve significant additional cost. Therefore, the design flooded width should represent a compromise between the need to restrict water flowing on the carriageway to acceptable proportions and the additional costs involved.

Gullies at Sag Points

Sag points include the trough of vertical curves at the bottom of a hill, or locally at horizontal curves created by superelevation. Any surface water not collected by intermediate gullies upstream will end up at the sag points. It is therefore important to provide spare gully capacity at sag points. Where necessary, a series of gullies may be constructed at a single sag point to cater for the flow from the respective catchment.

Since the gullies are closely spaced, it is convenient to connect them into a series for discharging at a single outlet pipe connected to the carrier drain. However, to avoid sterilizing the function of multiple gullies, the capacity of the outlet pipe has to be adequate.

5.3 Pavement Defects

Road pavement should be maintained in such a manner that traffic could commute without incurring safety hazards. Problems associated with pavement damage lead to a decrease in the level of service and in some case adversely affect safety. Potential safety issues are:

- Evasive stopping leading to rear-front collisions
- Evasive manoeuvres leading to side-swipes or loss of control
- Poor skid resistance increasing the risk of loss of control or collisions at intersections or crossings
- Aquaplaning increasing the risk of loss of control
- Uneven road surface at roundabouts increasing the risk of overturning of heavy vehicles

Increased risks are associated with unexpected situations at high traffic speeds. Riders of bicycles and motorcycles are particularly prone to losing balance with road defects.

Many pavement defects which have significant safety implications e.g. pot-holes, stepping, substantial rutting etc. could be detected by visual inspection (***Figure 2.5.3.1***). They should be identified and recorded in regular inspections and rectified in a timely manner.

FIGURE 2.5.3.1 A POTHOLE ON THE CARRIAGEWAY

Asphalt Pavement

Common defects of asphalt pavement requiring attention are given in ***Table 2.5.1.1***.

TABLE 2.5.1.1 COMMON DEFECTS OF ASPHALT PAVEMENT AND SAFETY IMPLICATIONS

Defect Type	Characteristics	Road Safety Implications
Cracking	Cracks are fissures resulting from partial or complete fractures of the pavement surface and underlying layers. They can range from isolated single cracks to a series of interconnected cracks spreading over the entire pavement surface.	Cracks could finally lead to complete disintegration of the pavement structure if not timely tackled, but they are normally not immediate hazard to road traffic.
Deformation	This is any change of the road structure, which leaves the road surface in an undesirable shape. It may be due to traffic load or environmental) influences. Deformation is an important element of pavement condition as it affects serviceability and may reflect structural inadequacies. It also has significant impact on vehicle operating costs. Common types of deformation include corrugation, depression, rutting, shoving.	Rutting is longitudinal deformation along a wheel path which could induce imminent hazard to road traffic, especially under high speeds.
Surface texture deficiencies	This includes loss of surfacing materials, loss of surface macrotexture and microtexture. Although they may not reflect pavement structural inadequacy, they have a significant effect on its serviceability including riding quality and safety. The principal defect types include flushing, polishing and ravelling.	Polishing is smoothening and rounding of the upper surface of the road stone which usually occurs in the wheel tracks. Ravelling is progressive disintegration of the pavement surface by loss of both binder and aggregates. Depending on the extent and magnitude of the defects, these could develop into significant hazard to road traffic, especially under high speeds.
Pothole	These are bowl-shaped defects in the pavement surface developing from another defect e.g. cracking, delamination etc.. They result in the entry of water and disintegration with removal of materials by traffic over weakened spots on the surface.	Potholes are always imminent hazard to road traffic under high or moderate speeds.

Concrete Pavement

Common defects of concrete pavement requiring attention are given in ***Table 2.5.1.2***.

TABLE 2.5.1.2 COMMON DEFECTS OF CONCRETE PAVEMENT AND SAFETY IMPLICATIONS

Defect Type	Characteristics	Road Safety Implications
Cracking	Tiny cracks in concrete surface are rather common due to shrinkage taking place during the hydration process. However, settlement, movement or restraint at joints may also lead to the development of cracks and subsequent failure.	Tiny cracks would not induce hazard to road traffic. However, depending on their extent and magnitude, cracks could develop into significant hazard to road traffic.
Deformation	This is any change of the road structure, which leaves the road surface in an undesirable shape. Two deformation defect types are common: joint stepping and rocking. Rocking is a dynamic phenomenon and its area of influence is not readily quantifiable. Rocking may be felt with the passage of a vehicle over the affected slab. Joint stepping is evidenced by permanent displacements and can be measured.	Depending on their extent and magnitude, rocking and joint stepping could be hazardous to road traffic, especially at high speeds.
Joint sealant defects	Joint sealants maintained in an effective condition can preserve their function of preventing silt, grit, stones and water from entering the joints which are provided to accommodate movement in the slab.	Joint sealant defects could finally lead to hazardous defects if not tackled in time, but they are normally not immediate hazard to the traffic.
Spalling	Spalling is a condition where pieces of concrete have flaked or are showing a tendency to flake from the concrete surfaces. This occurs usually at joints, edges, corners or forms directly over reinforcing steel particularly when the steel has inadequate cover.	Spalling could affect riding comfort and, if left unrectified, could develop into hazardous conditions. However, it is normally not an immediate hazard to the traffic.
Surface texture defects	These groups of defects are related to surface quality and are concerned with the properties of the upper 10mm to 20mm of concrete. Two defect types, namely ravelling and loss of surface texture, are common. Ravelling is the progressive breakdown of the slab to shallow depths. Mortar and aggregates are disintegrated from each other, leaving an irregular running surface for the traffic. Loss of surface texture is essentially caused by polishing by the traffic leading to reduction of skid resistance.	Depending on the extent and magnitude of the defects, ravelling and loss of surface texture could develop into significant hazards to road traffic, especially at high speeds.

Other Defects on the Road

Any obstructions on the carriageway should be considered hazards requiring immediate attention. Examples of other road defects which need immediate attention include:

- Missing gullies, drain covers or inspection covers
- Damaged safety barriers or pedestrian fences protruding into the footpath or the road
- Road equipment knocked over onto the road
- Damaged safety barriers, bridge parapets, crash cushions etc. losing their function
- Oil spillages on the road
- Objects and debris on the road
- Lamp columns knocked down, wires exposed or lanterns hanging loose
- Sign posts knocked down or signs hanging loose
- Traffic signals not working or damaged

Metal Works

Metal works include utility and drainage covers, gratings and longitudinal joints on bridges. Due to lower skid resistance, they are potentially hazardous for bicycles and motorcycles. For this reason, metal works should be minimised and sited away from paths where these vehicles need to turn, accelerate or decelerate.

Metal works could be particularly hazardous if damaged. Common defects are:

- Damages
- Polished surface
- Misplacing/Loosening
- Level difference relative to adjacent pavement
- Missing parts

Pedestrian and Slow Vehicle Facilities

Keeping pedestrian and slow vehicle facilities in a reasonable state of maintenance is important to road safety. Poor conditions could result in hazardous evasive manoeuvres or users being forced to come into conflict with vehicles.

Surface defects including depression, ravelling and damages to kerbs or paving blocks could contribute to tripping of pedestrians and destabilization of slow vehicles. Tripping in particular could lead to serious injuries for elderlies and where a pedestrian is crossing or walking in very close proximity of running traffic.

An even surface free from loose gravels, detritus and ponding should be maintained with adequate skid resistance on pedestrian and slow vehicle facilities.

PART 3 INTERSECTIONS

1 OVERVIEW

1.1 General Requirements

An intersection is the meeting zone between two or more roads. Intersections also include direct frontage accesses where isolated premises are directly connected to the main road. Intersections of Asian Highway routes with navigation channels, power transmission lines, telecommunication lines etc. are not covered in this document.

Figure 3.1.1.1 provides guidance on the initial selection of intersection types according to traffic volume.

FIGURE 3.1.1.1 INTERSECTION TYPES AND TRAFFIC VOLUME
(ref: Transport in the Urban Environment, CIHT 1997)

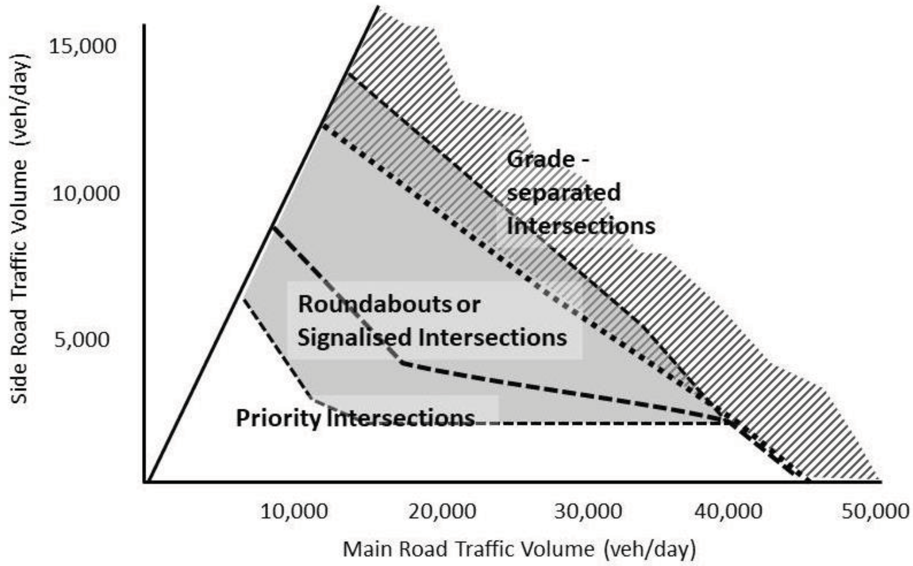


Table 3.1.1.1 provides further guidance on the appropriate intersection types on Asian Highway routes according to the classification of intersecting roads.

TABLE 3.1.1.1 INTERSECTION TYPES AND ROAD CLASSIFICATION

		Intersecting Road*				
		Primary class**	Class I	Class II	Class III	Below Class III
Intersecting Road*	Primary class**	I	-	-	-	
	Class I	G (I)	G, S, R	-	-	
	Class II	G (N)	S, R (G)	S, R, P	-	
	Class III	G, N	S, R, N (P)	S, R, P	P (S) (R)	P
	Below Class III	N	N (P)	P (N)	P	P

* to or equivalent to Asian Highway Network Road classification
** including access-controlled Class I roads
( ) usage may be justified
I: Interchange
G: Grade-separated Intersection
S: Signalised Intersection
R: Roundabout
P: Priority Intersection
N: Non-intersection Crossing

Bearing in mind the importance of consistency and having a clear pattern along a route, the precise choice of intersection type requires a detailed analysis of the following factors:

- Road safety
- Road type and function
- Number of branches
- Traffic volume, types and speeds
- Priority setting
- Topography and available space
- Adjacent land use
- Service to neighbouring population
- Network considerations and consistency
- Environmental considerations
- Economics

Intersection Strategy for Class I Roads

An intersection strategy is particularly important for the operation and safety of Class I roads. ***Table 3.1.1.2*** provides a recommended strategy which may be further adapted to suit national circumstances. For Class I roads carrying mainly long distance through traffic, grade-separation should be planned in the early stage with possible phased implementation.

TABLE 3.1.1.2 INTERSECTION STRATEGY FOR CLASS I ROADS

	Layout and Speed Limit	Direct Frontage Accesses	Secondary Intersections	Main Intersections
1	Divided 4-lanes 50- 60 km/h	Direct frontage accesses permitted, Median openings permitted	Priority intersections, Signalised intersections, Priority U-turn facilities,	Roundabouts, Signalised intersections, Priority U-turn facilities,
2	Divided 4-lanes 60- 70 km/h	Direct frontage accesses restricted and combined, Median openings permitted exceptionally	Priority intersections, Signalised intersections Priority U-turn facilities,	Roundabouts, Signalised intersections, Priority U-turn facilities,
3	Divided 4-lanes 80 km/h	Direct frontage accesses stringently restricted, Median openings not permitted	Restricted in numbers	Signalised intersections, Roundabouts, Grade-separated intersections (above also serving as U-turn facilities)
4	Divided 6/8-lanes 80 km/h	Direct frontage accesses stringently restricted, Median openings not permitted	Nearside-in nearside-out intersections only	Signalised intersections, Grade-separated intersections (above also serving as U-turn facilities)
5	Divided 4/6/8-lanes 80- 100 km/h	Direct frontage accesses permitted exceptionally, Median openings not permitted	Nearside-in nearside-out intersections only	Grade-separated intersections (above also serving as U-turn facilities)

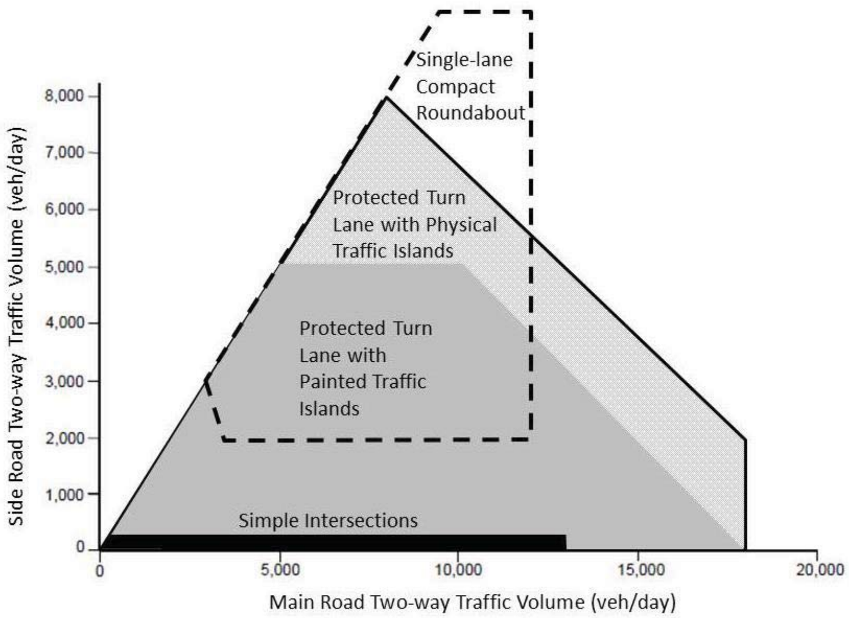
1.2 At-grade Intersections

Common types of at-grade intersections are:

- Priority intersection
  - Simple intersection
  - Protected turn lane with painted traffic islands
  - Protected turn lane with physical traffic islands
- Roundabout
- Signalised intersection
- At-grade U-turn facility

Figure 3.1.2.1 gives guidance on the initial selection of at-grade intersection types according to traffic volume. In areas frequented by tourists and at filling stations, consideration should be given to more usage of protected turn lane and roundabout.

FIGURE 3.1.2.1 AT-GRADE INTERSECTION TYPES FOR MODERATE TRAFFIC VOLUME
(ref: partly based on DMRB TD42/95, UK)



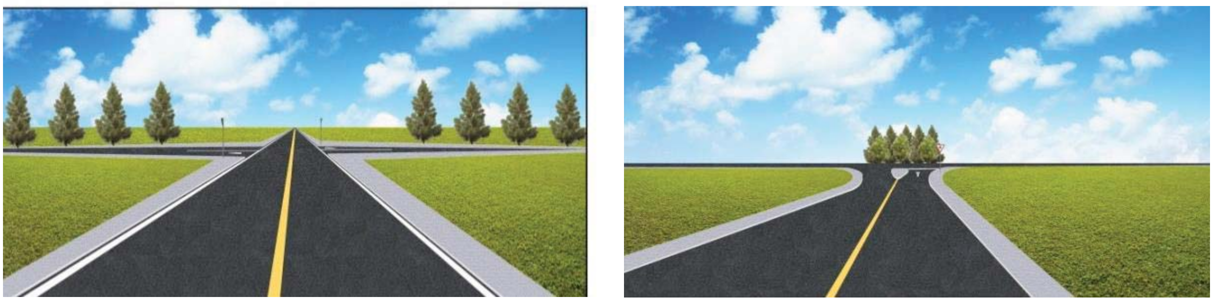
Outside built-up areas major at-grade intersections should be spaced at 600m to 900m intervals or more on high standard undivided roads to ensure adequate overtaking opportunities. Shorter spacing may be adopted to suit local circumstances.

The safety of at-grade intersections may be enhanced by:

- Reducing and separating conflict points
- Limiting the area and duration of conflict
- Highlighting areas of conflict
- Well-defined priority or signalisation
- Facilitating turning or crossing in steps
- Avoiding right-angle conflicts
- Reducing traffic speeds
- creating a forgiving roadside

Other than engineering measures and usage of signs, the awareness of intersections among drivers may be enhanced through subtle road features in the open countryside. Examples are illustrated in ***Figure 3.1.2.2***.

FIGURE 3.1.2.2 LANDSCAPING TREATMENTS ON THE APPROACH TO INTERSECTIONS [13]



1.3 Channelisation

Channelisation is the separation and guidance of different traffic movements using traffic islands. If properly designed, channelisation improves capacity, safety and comfort by:

- reducing the area of conflict among vehicles and different road users
- optimising the path of traffic streams
- defining priority control
- controlling traffic speeds
- providing a refuge for crossing and turning vehicles or crossing pedestrians.
- deterring prohibited manoeuvres or wrong-way driving
- providing space for traffic control facilities
- segregating different road-user groups or opposing traffic

Traffic Islands

Painted traffic islands are pavement areas bounded by edge line markings with hatched marking or coloured surfacing infills. They are flexible and less costly to install, but are more susceptible to being driven over.

Physical traffic islands are raised areas bounded by kerbs. They may also be areas of grass, compacted earth or gravels on a flushed, slightly raised or slightly depressed ground surface. Physical traffic islands are generally more effective in channelising traffic.

In built-up areas it is generally preferable to adopt non-mountable kerbs for traffic islands. However, mountable or semi-mountable traffic islands may be adopted in case traffic needs to bypass a stranded vehicle.

Where physical traffic islands are installed at intersections or crossing facilities, it is crucial to ensure that critical visibility is not obscured by safety barriers, plantings and any other significant features exceeding 0.6m in height above the pavement.

2 PRIORITY INTERSECTIONS

2.1 General Requirements

Priority intersections are categorised into the following types:

- Simple intersection
- Protected offside-turn lane with painted traffic islands
- Protected offside-turn lane with physical traffic islands
- Direct frontage access

There are three principal priority intersection layouts, namely T-intersection, staggered T-intersection and crossroad. Their suitability for typical road classes and road types is given in ***Table 3.2.1.1***.

TABLE 3.2.1.1 PRIORITY INTERSECTION TYPES AND ROAD CLASSES

Road Class	Road Types				Remarks
Class II, III	Undivided 2-lane Road	✓	✓	+	Number of crossroads should be minimised
Class I	Divided 4-lane Road	#	#	X	Criteria for median opening • offside-turning traffic <3,000 veh/day • speed limit should not exceed 70km/h
Class I	Divided 6-lane/8-lane Road	X	X	X	

✓ generally suitable
\+ only appropriate for crossroads with very low crossing traffic, generally < 500 veh/day
X priority intersection involving median openings normallynot permitted
\# offside-turn lane in conjunction with a wide physical traffic island

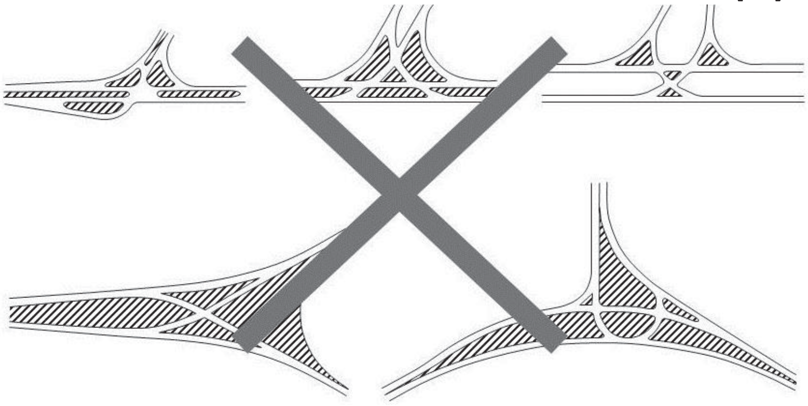
Restriction of Layouts

The layout of priority intersections should be simple and consistent. Only one traffic lane should be provided for a particular crossing or turning movement of side road traffic. Likewise, the following layouts are prone to safety problems:

- Layouts with excessive pavement area or corner radii
- Layouts with more than four branches
- Addition of through traffic lanes at the intersection
- Channelisation which encourages offside turning in a smooth and generous path
- Complex channelisation layouts
- Skewed, tangential or Y intersections
- Divided or multi-lane side roads directly terminating at or crossing a two lane main road

Examples of inappropriate channelisation layouts for priority intersections are illustrated in ***Figure 3.2.1.1***.

FIGURE 3.2.1.1 COMPLEX PRIORITY INTERSECTION LAYOUTS [13]



Control of Side Road Gradient

Side roads joining the main road on steep uphill gradients entail problems of poor visibility and slowly crossing or turning vehicles. Side roads joining the main road on steep downhill gradients entail risks of vehicles overshooting onto the main road. They are desirably on gentle gradients not exceeding 2% within 15m of the Give-way or Stop line marking.

Crossroad Intersections

Priority crossroad intersections are not advisable if main road traffic volume exceeds 12,000 veh/day or side road crossing traffic volume exceeds 300 veh/day. Alternative layouts such as staggered priority intersection, roundabout or signalised intersection should be considered.

Priority crossroad intersections should not be adopted on Class I roads. If they are not avoidable, the median will need to be adequately widened to permit the majority of vehicle types to cross in two steps.

For any crossroads, adequate warning and speed reduction measures will need to be provided for both the main road and the side road. Furthermore visibility should be ensured across verges, medians and physical traffic islands.

Skewed Intersections

Skewed T-intersections encourage non-priority traffic to turn at speed. This also endangers pedestrians and slow vehicles using the intersection. Skewed crossroads are prone to additional safety problems as crossing traffic takes more time to complete the manoeuvre.

Skewed T-intersections should be rectified as right angle intersections as shown in ***Figure 3.2.1.2***. Skewed crossroads should be replaced as right-angle crossroads or staggered intersections as shown in ***Figure 3.2.1.3***. ***Figure 3.2.1.4*** illustrates the modification of a skewed crossroad to a right-angle crossroad. However, staggered intersections are preferred if cross movements form a significant proportion of side road traffic.

FIGURE 3.2.1.2 RIGHT-ANGLE TREATMENT OF SKEWED T-INTERSECTION FOR A MINOR SIDE ROAD

FIGURE 3.2.1.3 IMPROVEMENT OPTIONS OF SKEWED CROSSROADS

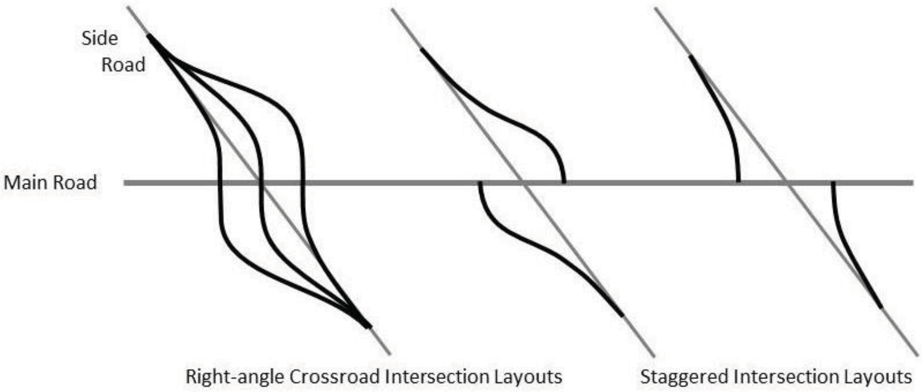


FIGURE 3.2.1.4 MODIFICATION OF SKEWED CROSSROAD AS RIGHT ANGLE CROSSROAD

Staggered Intersections

A staggered intersection consists of two opposing T-intersections joining the main road in a staggered layout. They may exist as simple intersections or protected turn lane intersections.

Staggered intersections should be avoided along sections with climbing lanes, downhill auxiliary lanes or “2+1” overtaking sections. The road should first be reverted to a two-lane road to accommodate the intersection.

Table 3.2.1.2 contains the recommended minimum stagger distance between the centreline of two side roads for the proper development of turn lanes and manoeuvring of long vehicles.

TABLE 3.2.1.2 MINIMUM STAGGER DISTANCE [14]

<table>
<tr><th>Speed Limit (km/h)</th><th>Simple Intersection</th><th>Protected Offside Turn Lane</th><th>Median Opening of Divided Roads</th></tr>
<tr><td>50</td><td rowspan="4">50m</td><td>50m</td><td>60m</td></tr>
<tr><td>60</td><td>50m</td><td>60m</td></tr>
<tr><td>70</td><td>60m</td><td>60m</td></tr>
<tr><td>80</td><td>75m</td><td>75m</td></tr>
</table>

Tangential and Y-Intersections

Tangential intersections are layouts where the main road enters a curve while the side road continues on a straight line. Y-intersections are layouts where both the main road and the side road branch off. Tangential layouts may be created with bypass projects as illustrated in ***Figure 3.2.1.5***.

FIGURE 3.2.1.5 TANGENTIAL INTERSECTION WITH THE BYPASS TURNING TO THE LEFT
(driving is on the right side of the road)

These layouts are susceptible to misinterpretation of the direction of the main road. Furthermore, side road traffic may fail to slow down when joining the main road. Tangential or Y-intersections should be modified such that the axis of the side road intersects the main road at right angle.

Intersection Visibility

Visibility at priority intersections consists of three components as shown in ***Figure 3.2.1.6*** and ***Table 3.2.1.3***. Additional visibility requirements apply if pedestrians and slow vehicle facilities are provided around the intersection. It is not advisable to provide excessive visibility distance for side road traffic towards main road traffic so that drivers are not distracted from the immediate approach.

FIGURE 3.2.1.6 VISIBILITY REQUIREMENTS AT PRIORITY INTERSECTIONS [14]

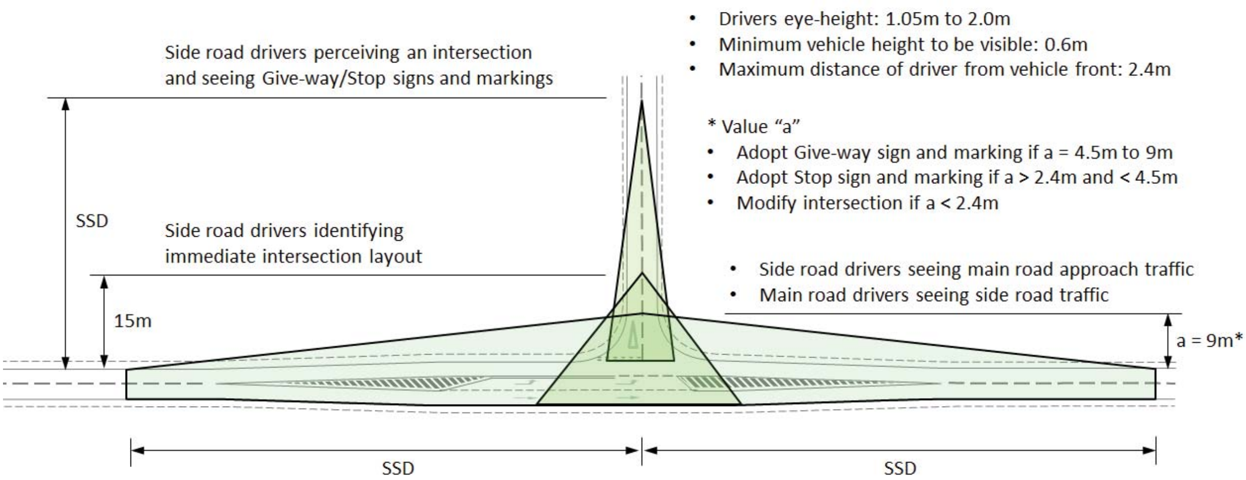


TABLE 3.2.1.3 RECOMMENDED VISIBILITY DISTANCE AT PRIORITY INTERSECTIONS

Speed Limit (km/h)	100	80	70	60	50
Visibility Distance = SSD (m)*	215	150	120	90	70

Visibility distance may be expressed in travel time rather than SSD. ***Table 3.2.1.4*** illustrates an alternative approach which incorporates the additional time for manoeuvring through protected turn lanes.

TABLE 3.2.1.4 RECOMMENDED TIME-BASED VISIBILITY DISTANCE FOR SIDE ROAD TRAFFIC [13]

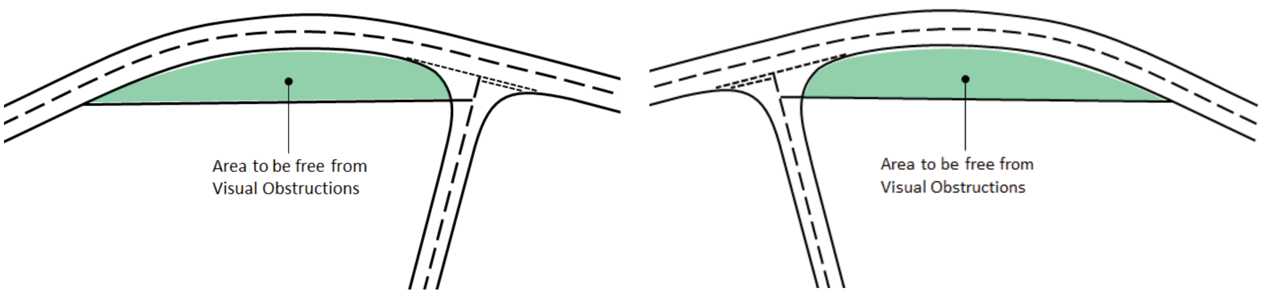
Control Method	Priority Intersection Layout	Visibility in Time (s)		Visibility Distance (m) for Speed Limit (km/h)				
				100	80	70	60	50
STOP	2-lanes Simple Layout	Desirable	8	222	178	156	133	111
		Minimum	6	167	133	117	100	83
	2-lanes with Protected Turn Lane*	Desirable	9	250	200	175	150	125
		Minimum	7	194	156	136	117	97
Give-way	2-lanes Simple Layout	Desirable	10	278	222	194	167	139
		Minimum	8	222	178	156	133	111
	2-lanes with Protected Turn Lane*	Desirable	11	306	244	214	183	153
		Minimum	9	250	200	175	150	125
Left-turning Traffic		Desirable	8	222	178	156	133	111
		Minimum	6	167	133	117	100	83

* Left-turning from side road in one step

Priority intersections should be located on straight sections or on the outside of large radii curves with gentle gradients. ***Figure 3.2.1.7*** illustrates the substantial need of visibility area for intersections on the inside of a curve.

FIGURE 3.2.1.7 PRIORITY INTERSECTION ON THE INSIDE OF A CURVE

(for driving on the right side of the road) *(for driving on the left side of the road)*



Signing Requirements

Give-way signs and markings are needed at all priority intersections. Stop signs and markings should be used if the full visibility is not attained until side road traffic is very close to the intersection. Signs and markings may be omitted for direct frontage accesses or minor intersections if the need to give way is obvious.

For priority intersections with high traffic speeds or constrained visibility, additional signs, markings or speed reduction measures may be needed. These include:

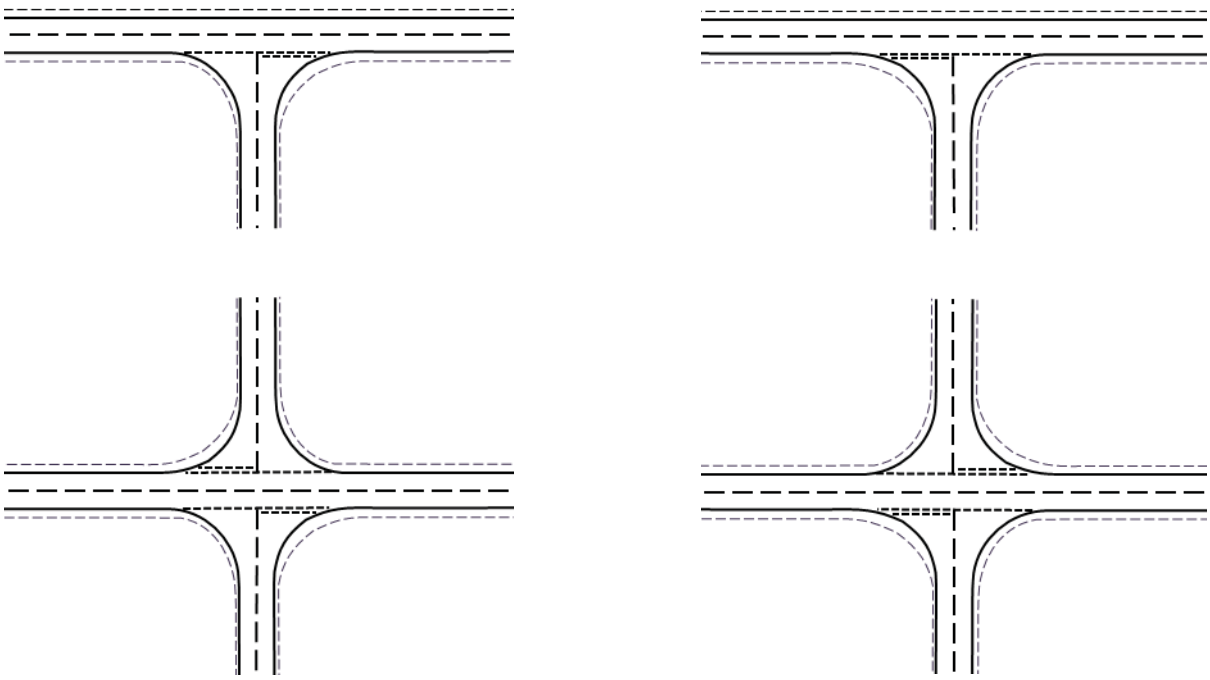
- Advance give-way or stop warning sign on the side road
- Warning sign of T-intersections or crossroads ahead on the main road
- Transverse rumble strips or visual speed reduction measures on the approaches
- Vertical speed reduction device on the side road approach
- Access delineation posts

2.2 Simple Intersections

Simple intersections are direct connections between two roads with rounded corners. This is illustrated in ***Figure 3.2.2.1***. They are adequate to cater for occasional offside-turning or crossing traffic up to 300 veh/day and main road traffic volume not exceeding 12,000 veh/day. Beyond this level, other layouts should be considered.

FIGURE 3.2.2.1 SIMPLE T-INTERSECTION AND SIMPLE CROSSROAD

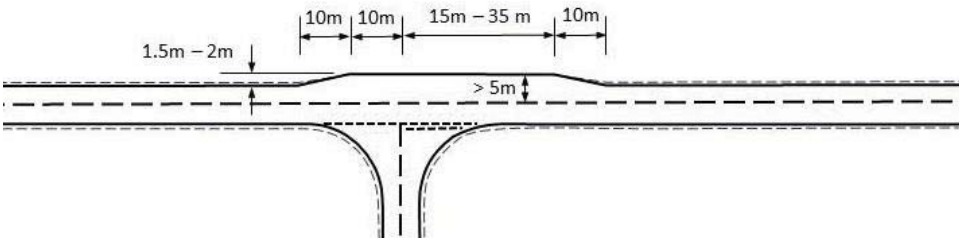
(for driving on the right side of the road) *(for driving on the left side of the road)*



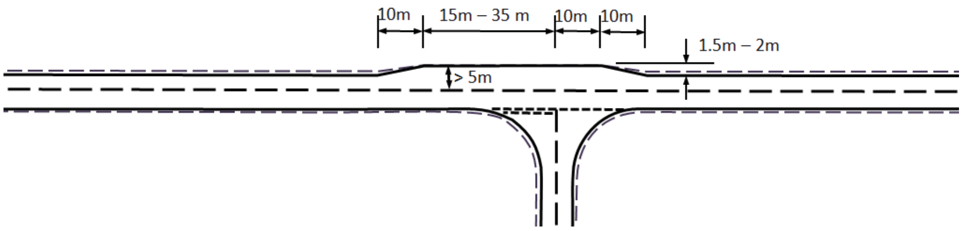
If congestion happens intermittently despite low volume of offside-turning traffic, the paved shoulder may be widened to allow main road traffic to bypass traffic waiting to turn. This is illustrated in ***Figure 3.2.2.2***.

FIGURE 3.2.2.2 WIDENED SHOULDER AT SIMPLE T-INTERSECTION [13]

(for driving on the right side of the road)



(for driving on the left side of the road)



2.3 Side Road Channelizing Islands

Side road channelisation islands are physical traffic islands located on the centre of the side road at an intersection as illustrated in ***Figure 3.2.3.1*** and ***Figure 3.2.3.2***. They have the following safety benefits:

- Alerting drivers of the presence of an intersection
- Slowing down side road traffic on the approach
- Constraining the path and speed of side road traffic
- Providing the space for a pedestrian refuge

FIGURE 3.2.3.1 SIDE ROAD CHANNELIZING ISLANDS AT A T-INTERSECTION
(driving is on the right side of the road)

FIGURE 3.2.3.2 SIDE ROAD CHANNELIZING ISLANDS AT A CROSSROAD INTERSECTION
(driving is on the right side of the road)

Side road channelizing islands are recommended at:

- major priority and signalised intersections
- crossroads where there is a high risk of crossing traffic failing to give way
- intersections with a skewed approach

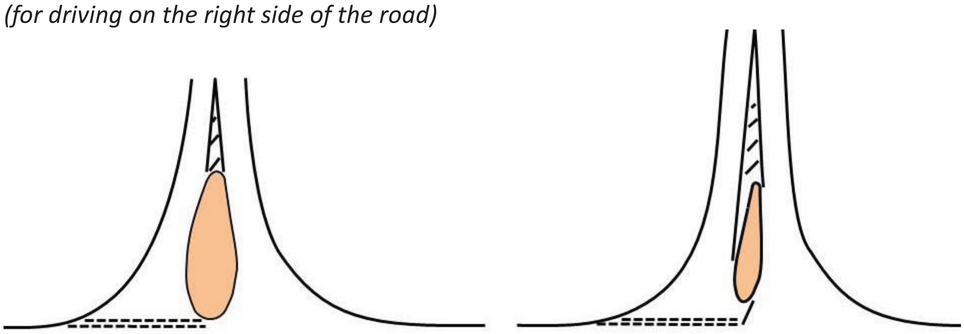
The geometric layout of side road channelisation islands may be based on:

- Simple shape which is sufficient for turning
- Compound shape determined by turning radii
- Compound shape determined by swept paths

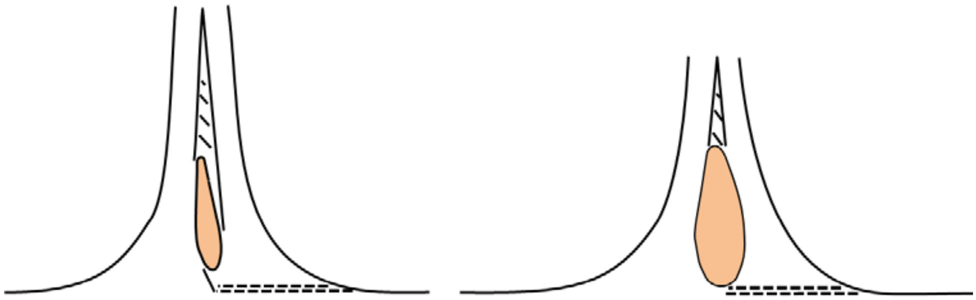
When using turning radii or swept paths for offside turning traffic, a horizontal clearance of at least 0.3m should be maintained from the physical traffic island. Typical layouts are given in ***Figure 3.2.3.3***.

FIGURE 3.2.3.3 TYPICAL LAYOUTS OF SIDE ROAD CHANNELISATION ISLAND

(for driving on the right side of the road)



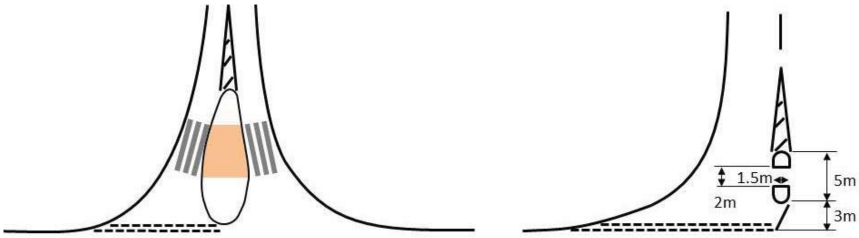
(for driving on the left side of the road)



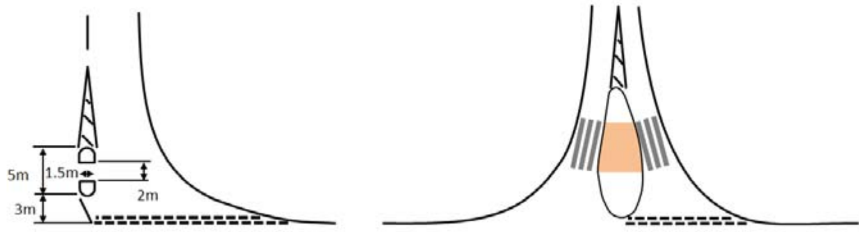
Side road channelisation islands may serve as a refuge for pedestrian crossings. Typical layouts are illustrated in ***Figure 3.2.3.4***.

FIGURE 3.2.3.4 PEDESTRIAN CROSSING THROUGH SIDE ROAD CHANNELISATION ISLANDS

(for driving on the right side of the road)



(for driving on the left side of the road)



2.4 Protected Offside Turn Lane with Painted Traffic Islands

This facility consists of an offside-turn lane delineated by line markings. An example is illustrated in ***Figure 3.2.4.1***. The turn lane provides a refuge for turning vehicles to slow down, wait and queue up without blocking main road traffic.

FIGURE 3.2.4.1 PROTECTED OFFSIDE TURN LANE WITH PAINTED TRAFFIC ISLANDS
(driving is on the right side of the road)

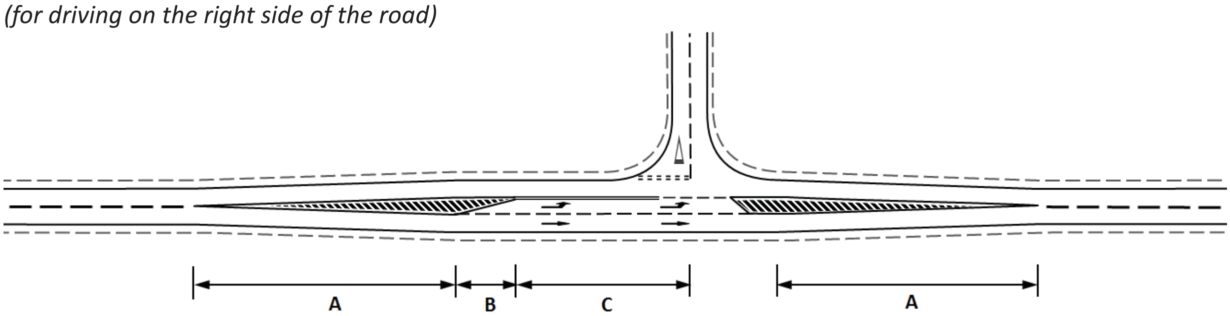
Protected offside turn lane with painted traffic islands are desirable for:

- intersections where turning traffic volume exceeds 300 veh/day
- intersections located on curves
- road sections where direct frontage accesses or intersections are closely spaced

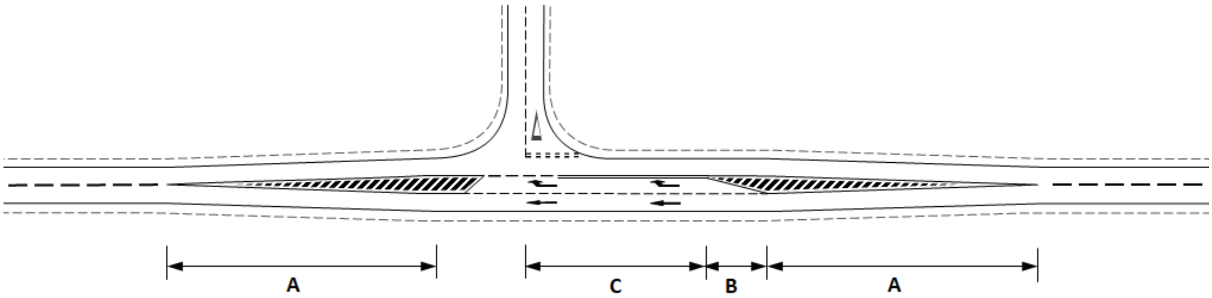
Design Features

The key features of protected offside turn lane with painted traffic islands are illustrated in ***Figure 3.2.4.2***. The turn lane may be created with symmetrical or asymmetrical widening of the main road.

FIGURE 3.2.4.2 PROTECTED TURN LANE WITH PAINTED TRAFFIC ISLANDS
(for driving on the right side of the road)



(for driving on the left side of the road)



A	Approach Taper	Taper Angle	1 : 20 (=<70 km/h) 1 : 25 (>= 80 km/h)
B	Turn Lane Taper	Length	5m (=< 60 km/h) 15m (70- 80 km/h)
C	Queuing Zone	Length	15m- 60m depending on volume of turning traffic, extension is needed on gradients > 4%

Lane Widths

The recommended width of main road traffic lanes and turn lane is 3.5m or equal to the approach through lane width if this is smaller than 3.5m. It is acceptable to provide narrower widths, down to 3m for the through lanes and exceptionally, 2.5m for the turn lane. The width of the turn lane may be increased, up to 5m, on busy urbanised sections. For intersections on a curve, additional widening should be applied.

The width of paved shoulders should not be reduced below 0.5m. In case they are regularly used by pedestrians or slow vehicles, the width should not be reduced to less than 1.75m and exceptionally, 1.5m. Changes to the width of traffic lanes or paved shoulders should be introduced progressively along the approach tapers or further upstream of the intersection.

Signing Requirements

Painted traffic islands should be clearly defined with retroreflective markings, directional signs and possibly coloured surfacing. Audio-tactile line markings or delineator posts may also be adopted to discourage traffic intruding onto the painted traffic islands.

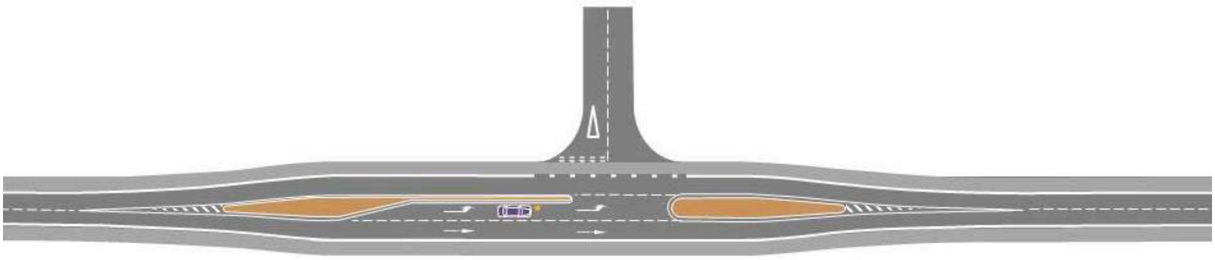
2.5 Protected Offside Turn Lane with Physical Traffic Islands

This facility consists of an offside-turn lane protected by physical traffic islands. Typical designs are illustrated in ***Figure 3.2.5.1***.

FIGURE 3.2.5.1 TYPICAL PROTECTED OFFSIDE TURN LANE WITH PHYSICAL TRAFFIC ISLANDS
(driving is on the right side of the road)

The basic layout consists of two traffic islands with an opening about 15m in length as shown in ***Figure 3.2.5.2***.

FIGURE 3.2.5.2 TYPICAL LAYOUT OF PROTECTED TURN LANE WITH TRAFFIC ISLANDS



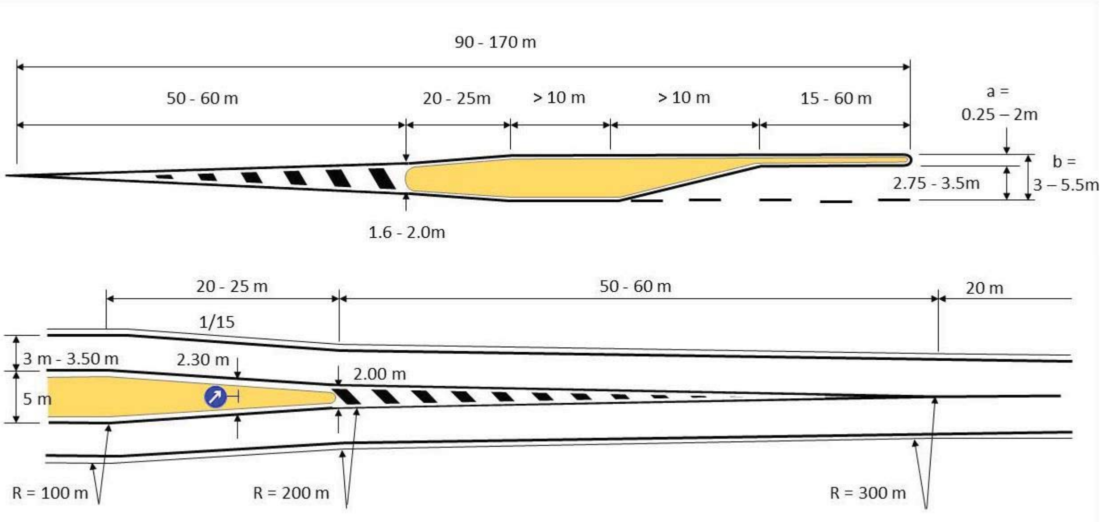
Physical Traffic Islands

Typical design details of traffic islands are illustrated in ***Figure 3.2.5.3***. The precise geometry is relatively flexible provided that the design principles are observed. The carriageway bounded by traffic islands should have a minimum paved width of 6m (>= 5.75m) to allow a large vehicle to bypass a broken down vehicle. This may be reduced to 4.0m comprising a 3.0m traffic lane and 0.5m wide shoulders. In this case additional verges or mountable traffic islands should be provided such that a 6m wide unobstructed clear width is available.

In case the roadside is regularly used by pedestrians or slow vehicles, the paved shoulder width should not be reduced to less than 1.75m and exceptionally 1.5m.

The traffic islands should be free of visual obstructions and aggressive roadside features other than essential traffic signs. The height of any ground cover plants should not exceed 600mm above the pavement.

FIGURE 3.2.5.3 TYPICAL LAYOUT OF TRAFFIC ISLANDS [13]



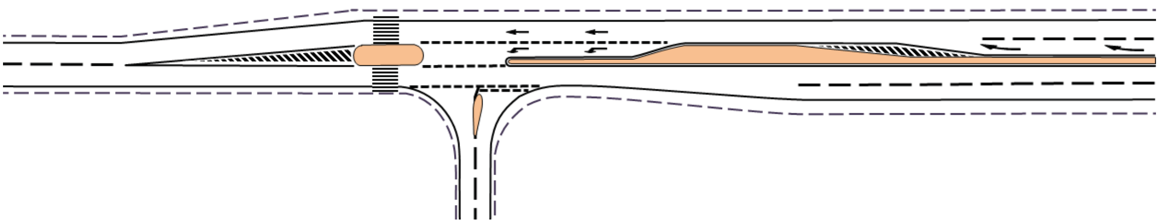
Where space is constrained it is acceptable to reduce the value "a" to 0.25m and the section of traffic island is replaced by a solid line marking. This is illustrated in ***Figure 3.2.5.4***.

FIGURE 3.2.5.4 EARLY TERMINATION OF PHYSICAL TRAFFIC ISLAND *(driving is on the right side of the road)*

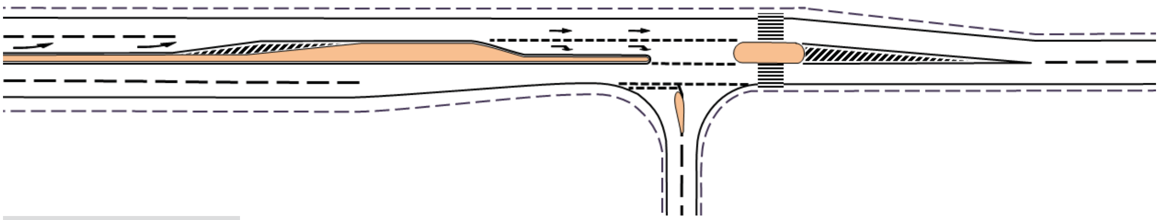
Interface of Divided and Undivided Roads

Where a priority intersection is located at the interface between a Class I road and a Class II or Class III road, it is preferable to design the layout according to ***Figure 3.2.5.5***.

FIGURE 3.2.5.5 PRIORITY INTERSECTION AT INTERFACE OF DIVIDED AND UNDIVIDED ROADS
(for driving on the right side of the road)



(for driving on the left side of the road)

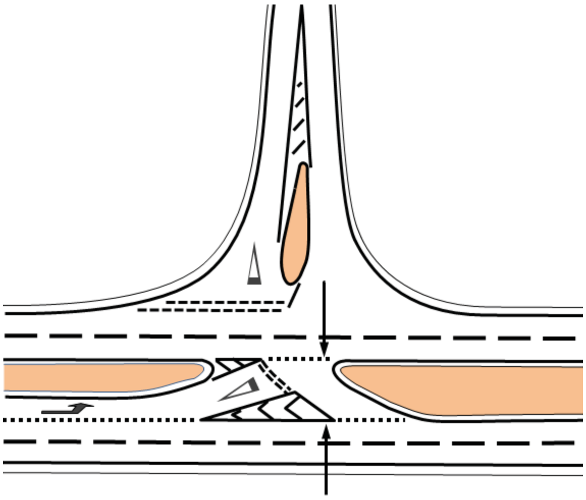


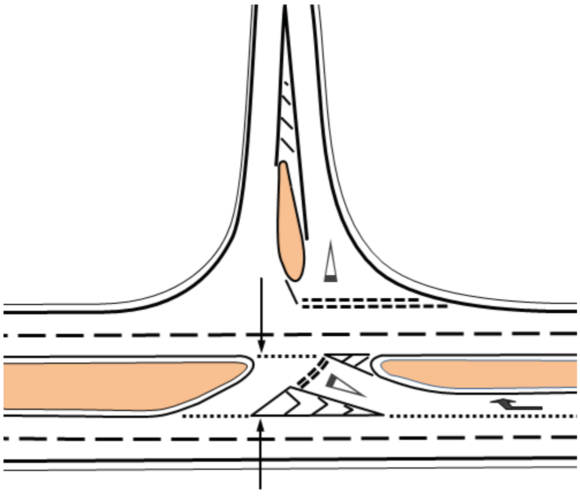
Median Widening

For priority intersections on divided roads, a wide median is needed to provide a refuge for offside-turning vehicles from the side road to complete the manoeuvre in two steps. This is illustrated in ***Figure 3.2.5.6***. Such wide medians may also be adopted on undivided roads.

FIGURE 3.2.5.6 WIDE MEDIAN [14]

(for driving on the right side of the road) *(for driving on the left side of the road)*





Widened medians may also be applied to crossroad intersections to serve crossing traffic including slow vehicles. The required median width depends on the type of vehicles needing to turn or cross. Indicative values are given ***Table 3.2.5.1***.

TABLE 3.2.5.1 RECOMMENDED WIDTH OF WIDE MEDIANS

Vehicle	Width of Wide Median (m)	
	Offside-turning	Crossing
Car	6	7.5
Truck (11m)	10	13
Articulated Vehicle (15.5m)	14	*

* Crossing at priority intersection should be avoided

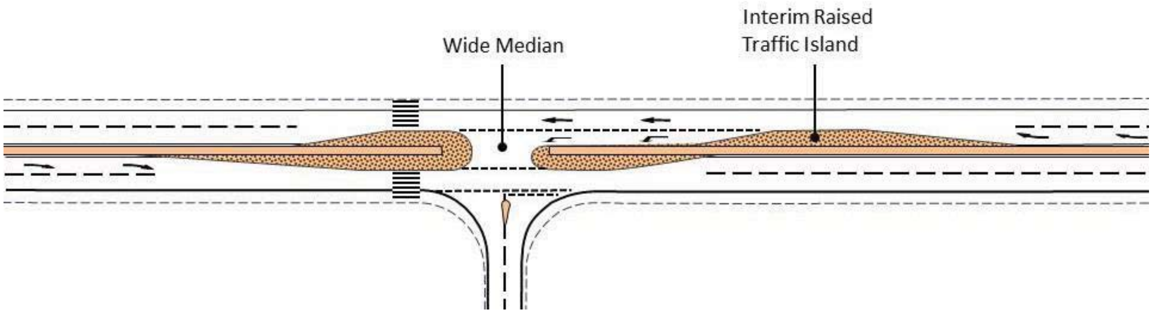
Phased Development of Class I Roads

A possible strategy to enhance the safety of priority intersections on Class I roads is to convert the road to single lane sections if two-way traffic volume is relatively low i.e. <12,000 veh/day. Between intersections, four-lane sections of the Class I road may be retained for overtaking or redesigned as urban streets. This is illustrated in ***Figure 3.2.5.7***.

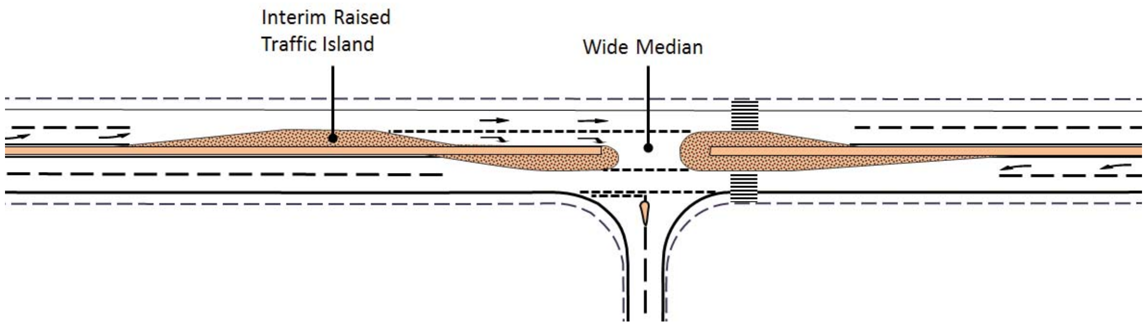
Such strategy should be planned on a route-wide basis with adequate signing and speed management. When traffic volume becomes critical i.e. >15,000 veh/day, the intersection may be reverted to the original layout with signalisation.

FIGURE 3.2.5.7 INTERIM LAYOUT OF CLASS I ROADS

(for driving on the right side of the road)



(for driving on the left side of the road)



2.6 Direct Frontage Accesses

Direct frontage accesses are intersections directly joining the main road to serve vehicle traffic for one or more properties. These properties include:

- individual house or houses
- agricultural tracks with regular or seasonal traffic
- factories
- quarries, mines and distribution points of construction materials
- maintenance compound of special facilities

Direct frontage accesses should be provided on local roads or service roads which join the main road at limited intersections with adequate capacity and safety features. They may be further minimised by combining individual accesses.
There should be stringent control for new direct frontage accesses or increased use of existing accesses. In particular, direct frontage accesses onto Class I roads should be strictly controlled as frequent turning could adversely undermine road safety.

Access Layouts

Where direct frontage accesses are unavoidable, they should be designed with a proper layout. Traffic movements should not exceed 500 veh/day.

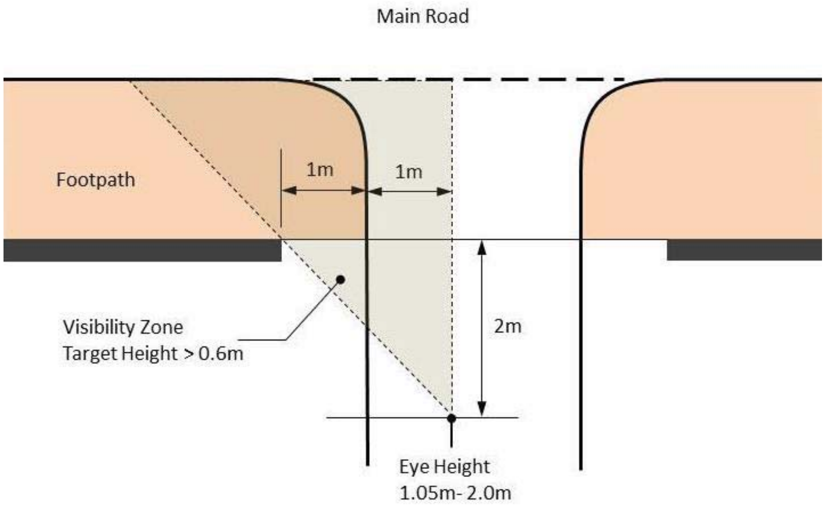
The layout of direct frontage accesses should accord with road classes and the volume and type of access traffic. Direct frontage accesses should not be sited on or around the inside of curves which could significantly reduce intersection visibility. Access layouts fall into the following categories:

- Field access
- Single house run-in
- Simple T-intersection
- Protected turn lane T-intersection
- Nearside-in nearside-out intersection
- Rural access for long vehicles with or without prohibited offside turning
- Gateway entry
- Nearside diverge or merge

Interfaces with Footpaths

Direct frontage accesses should take into account the safety of pedestrians and slow vehicles travelling on or alongside the main road. Particular attention should be given to those with frequent heavy vehicle movements. Conflict areas may be highlighted in special paving materials or coloured surfacing. Attention should also be given to the layout of boundary walls of premises to ensure adequate visibility between access traffic and pedestrians or slow vehicles. A corner splay should be provided to improve visibilty. This is illustrated in ***Figure 3.2.6.1***.

FIGURE 3.2.6.1 VISIBILITY REQUIREMENTS OF DIRECT FRONTAGE ACCESS WITH FOOTPATH [15]



Direct frontage access should not result in any vehicles queuing or waiting to enter the facility. If door gates are provided, these should be designed and located to allow a waiting vehicle to be completely clear of the main road including shoulders and footpaths.

Access for Special Facilities

Special attention should be given to direct frontage access for facilities with frequent heavy vehicles e.g. quarries, mines or selling points for sand and stones. The safety risks of these facilities are associated with heavy vehicles turning at low speed, damaged pavements and possibly traffic queues. Safety provisions should aim at raising awareness of approaching drivers and may include warning signs with specific description of the facility.

Merge and Diverge Tapers

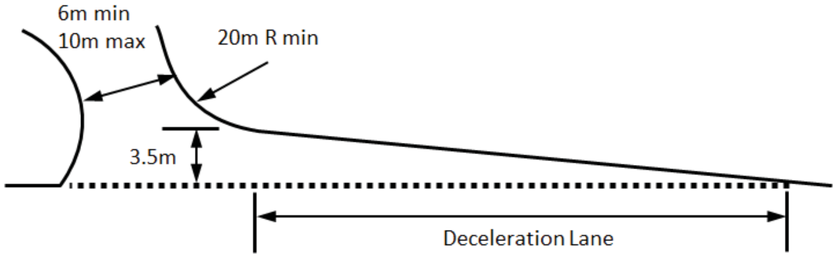
Tapers should be considered on all road types where traffic associated with direct frontage accesses interfere with main road traffic at high traffic speeds and traffic volume. In particular, they should be provided if the following criteria are met:

- Traffic speeds exceed 80km/h and turning traffic in either direction approaches 450 veh/day and the main road consists of > 20% of large or slow moving vehicles
- Road gradient exceeds 4%

Typical dimensions of diverge tapers and merge tapers are given in ***Figures 3.2.6.2 and 3.2.6.3*** and ***Table 3.2.6.1***. Acceleration lane merge tapers should only be provided on a divided road.

FIGURE 3.2.6.2 DECELERATION LANE DIVERGE TAPER FOR DIRECT FRONTAGE ACCESSES [15]

(for driving on the right side of the road)



(for driving on the left side of the road)

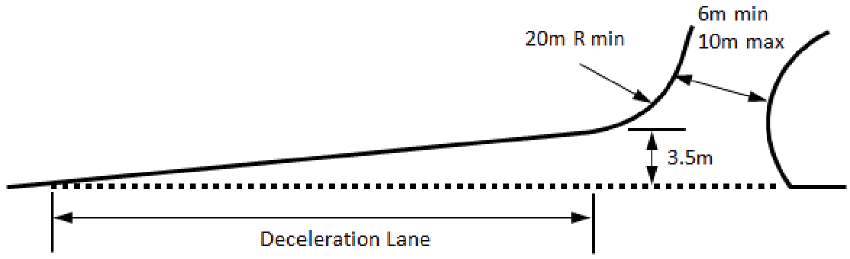
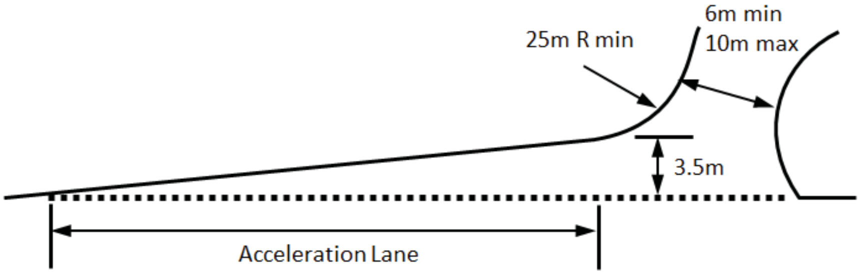


FIGURE 3.2.6.3 ACCELERATION LANE MERGE TAPER FOR DIRECT FRONTAGE ACCESSES [15]

(for driving on the right side of the road)



(for driving on the left side of the road)

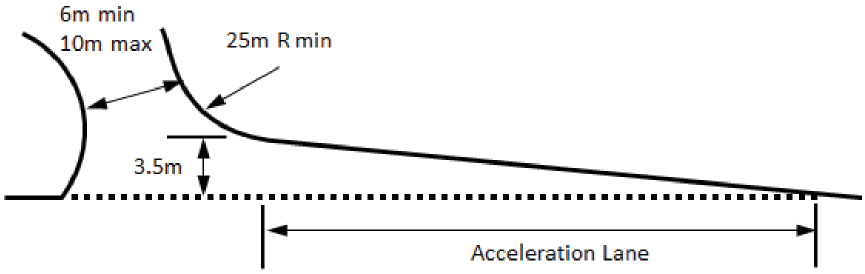


TABLE 3.2.6.1 **TAPER LENGTH** [15]

Speed Limit (km/h)	Diverge Taper Length			Merge Taper Length
	< 4%	>4% Uphill	>4% Downhill	
50	25m	25m	25m	-
60	25m	25m	25m/40m*	-
70	40m	25m	40m/55m*	50m
80	55m	40m	55m/80m*	70m
100	80m	55m	80m/110m*	90m

3 ROUNDABOUTS

3.1 General Requirements

Roundabouts are at-grade intersections where traffic enters and exits via a one-way circulatory carriageway around a circular central island. Roundabouts generally have a good safety record due to reduced speeds of all approach traffic and potential conflicts at an oblique angle instead of right angle.

From the road network perspective, roundabouts are beneficial in differentiating roads with different characteristics and calming traffic at the entrance of an urbanised section. They should be considered for intersections with relatively high proportion of turning traffic or in the following circumstances:

- At the start of a bypass
- To highlight the change of road class and design speed
- To replace a priority crossroad
- To connect more than four branches of traffic
- To define the start and end of an urbanised section

Single lane compact roundabouts (***Figure 3.3.1.1***)are recommended for roundabouts on Classes II and III undivided roads. Two-lane compact roundabouts or turbo roundabouts may be adopted on Class I roads with design speed of 80km/h or below.

FIGURE 3.3.1.1 TYPICAL SINGLE LANE COMPACT ROUNDABOUTS *(driving is on the right side of the road)*

The following roundabout types are not recommended for Asian Highway routes:

- Roundabout with oval or irregular central islands
- Roundabout on 6-lane Class I roads
- Mini-roundabouts

The design of roundabouts should address potential crash types given in ***Table 3.3.1.1***.

TABLE 3.3.1.1 MITIGATION OF ROUNDABOUT COLLISIONS

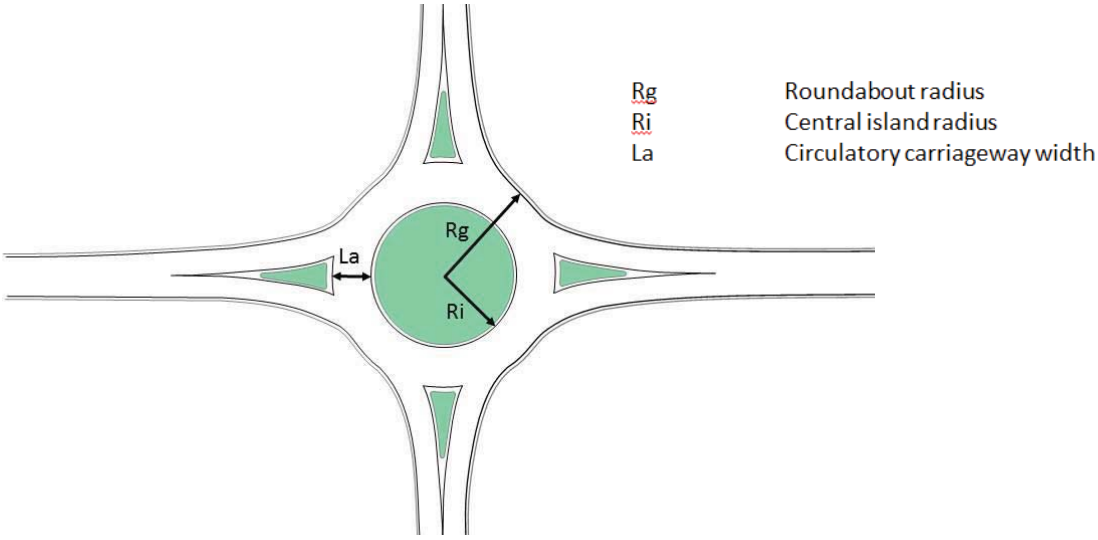
CrashType	Mitigatory Measures
Rear-front collision on approach	Appropriate geometry, signing, visibility, speed reduction measures
Entry traffic colliding with circulatory traffic	Appropriate geometry, signing, visibility, speed reduction measures
Entry traffic crashing onto central island	Appropriate geometry, Signing, visibility, speed reduction measures
Exit traffic colliding with circulatory traffic	Limitation of traffic lanes and speeds
Rollover of heavy vehicles	Limitation of abrupt changes in super-elevation and avoidance of uneven road surface
Motorcycle crashes	Visibility, avoidance of service covers, segregated paths in case of large roundabouts
Pedestrian crashes	Footpaths and crossings, limitation of traffic lanes and speeds,

Roundabouts are preferably located on road sections with gentle gradients. It is undesirable to provide roundabouts on road sections along and at the bottom of road sections on steep gradients.

Geometry and Capacity

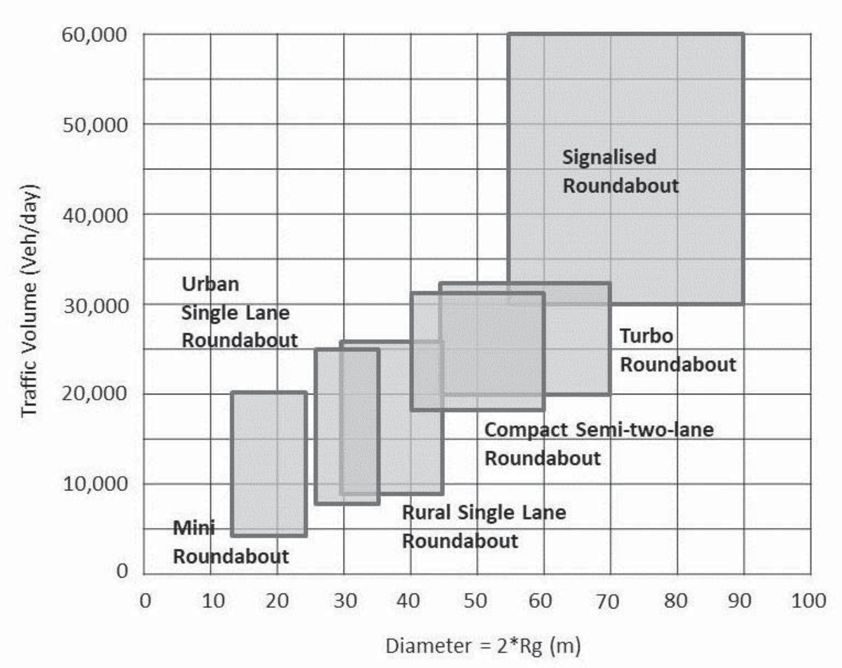
The basic design features for a roundabout are illustrated in ***Figure 3.3.1.2***.

FIGURE 3.3.1.2 KEY DESIGN PARAMETERS OF ROUNDABOUTS



The capacity and size requirements for roundabout types are given in ***Figure 3.3.1.3***.

FIGURE 3.3.1.3 ROUNDABOUT TYPES AND CAPACITY [16]



The capacity range for single lane compact roundabouts is given in ***Table 3.3.1.2***.

TABLE 3.3.1.2 CAPACITY OF SINGLE LANE COMPACT ROUNDABOUTS

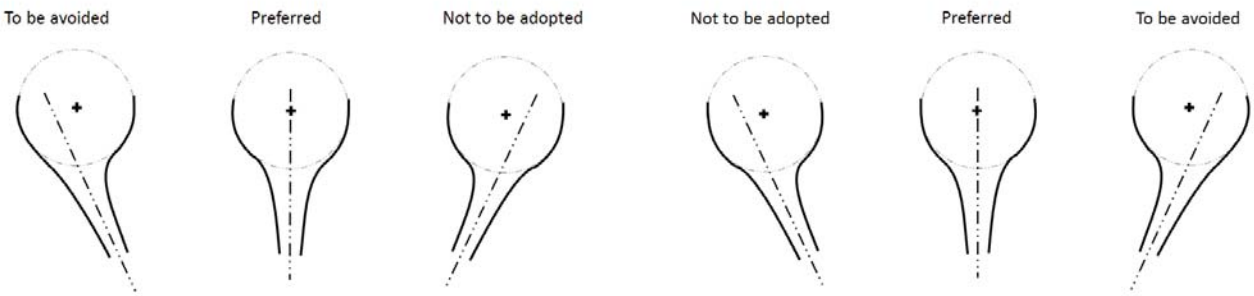
	Bidirectional Traffic Volume (veh/day)	
	General	Maximum
Overall Traffic Volume (main road +side road）	20,000	24,000
Any branch of the roundabout	8,000	12,000

Geometry

Roundabouts should be circular in shape with the axis of branches traversing the centre of the circle. This is illustrated in ***Figure 3.3.1.4***. Road sections joining the roundabouts are preferably straight for at least 250m.

FIGURE 3.3.1.4 ROUNDABOUT AXIS

(for driving on the right side of the road) *(for driving on the left side of the road)*



As a general rule, it is not advisable to increase the number of traffic lanes at roundabout entries unless there is strong justification on capacity reasons.

Segregated Turn Lanes

At roundabouts with heavy nearside-turning traffic, a segregated nearside turn lane may be adopted to increase the capacity. The merits of these facilities should be balanced against complications in the routing of any at-grade pedestrian footpaths or slow vehicle facilities. Additionally, the following considerations should be taken into account:

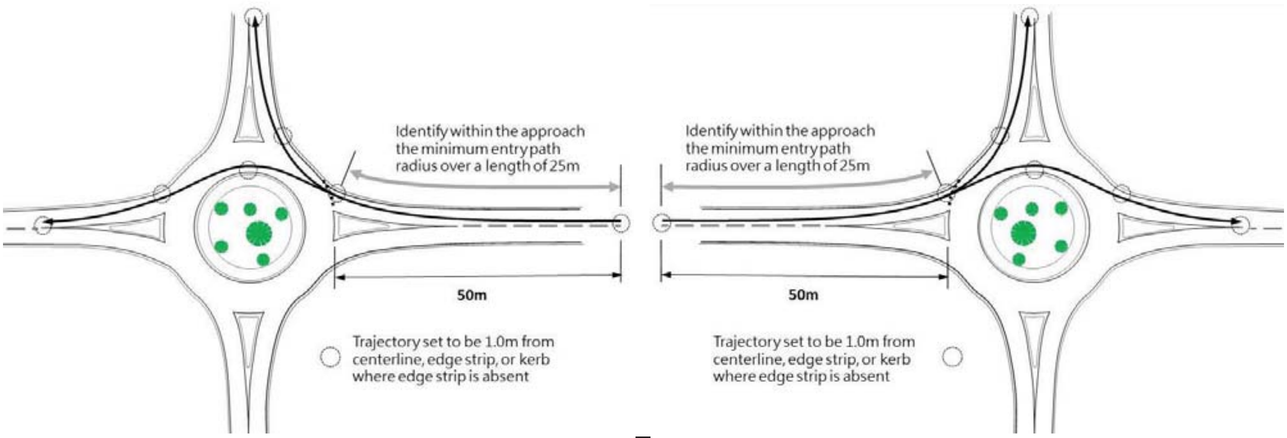
- Both physical and non-physical segregation island may be used
- Minimum radius of 40m is preferred
- Only one nearside turn lane should be adopted
- Adequate visibility on the approach and within the nearside turn lane
- Clear guidance with directional signing

Entry Path Radius

In order to limit traffic speeds passing through a roundabout below 50km/h, entry path radii should not exceed 100m. For roundabouts with slow vehicles or crossing pedestrians, it is desirable to further limit entry path radii. The measurement of entry path radius is illustrated in ***Figure 3.3.1.5***.

FIGURE 3.3.1.5 ENTRY PATH RADIUS

(for driving on the right side of the road) *(for driving on the left side of the road)*



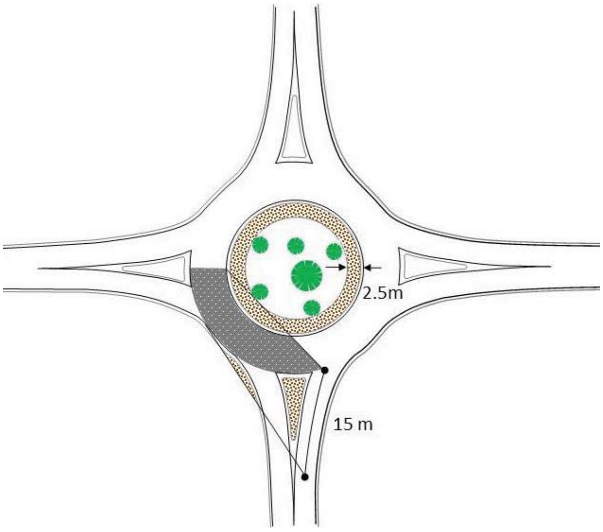
Visibility

Drivers approaching a roundabout should be able to identify traffic signs on the central island together with give-way signs and markings at least 150m ahead. They should also be able to see any pedestrian crossings including the waiting area on the footpath.

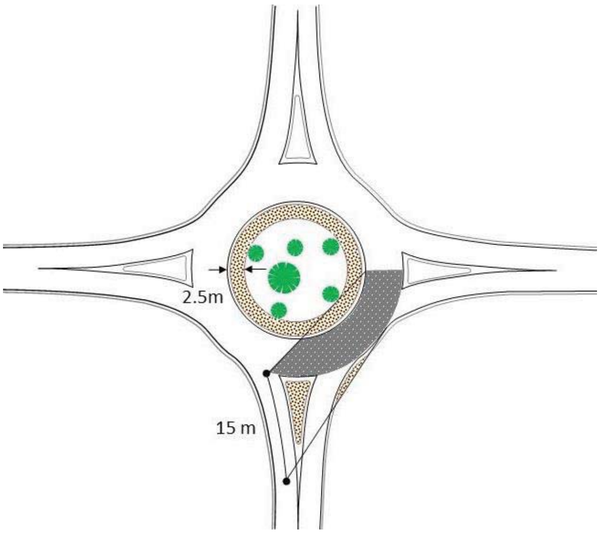
At the immediate approach to a roundabout, drivers should be able to see one-quarter of the roundabout circulatory carriageway to the offside. In addition, circulatory visibility should be provided over a width of 2.5m along the edge of the central island. These inter-visibility areas should not contain any features more than 500mm in height including plantings. This is illustrated in ***Figure 3.3.1.6***.

FIGURE 3.3.1.6 VISIBILITY AT ROUNDABOUTS [13]

(for driving on the right side of the road)



(for driving on the left side of the road)

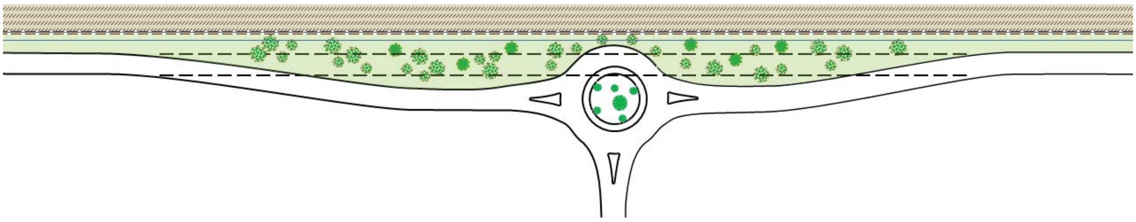


Masking of Route Continuity

On roads with a straight alignment drivers can be misguided by remote traffic lamps or linear features and overlook an intervening roundabout. To minimise this risk, forward visibility should be carefully controlled in both the horizontal and vertical plane to limit drivers' vision beyond the roundabout. This may be achieved with a mound profile or plantings on the central island or the roadside as shown in ***Figures 3.3.1.7*** and ***3.3.1.8***.

FIGURE 3.3.1.7 MASKING OF ROUTE CONTINUITY ON THE CENTRAL ISLAND OF A ROUNDABOUT

FIGURE 3.3.1.8 MASKING OF ROUTE CONTINUITY ON THE ROADSIDE OF A ROUNDABOUT

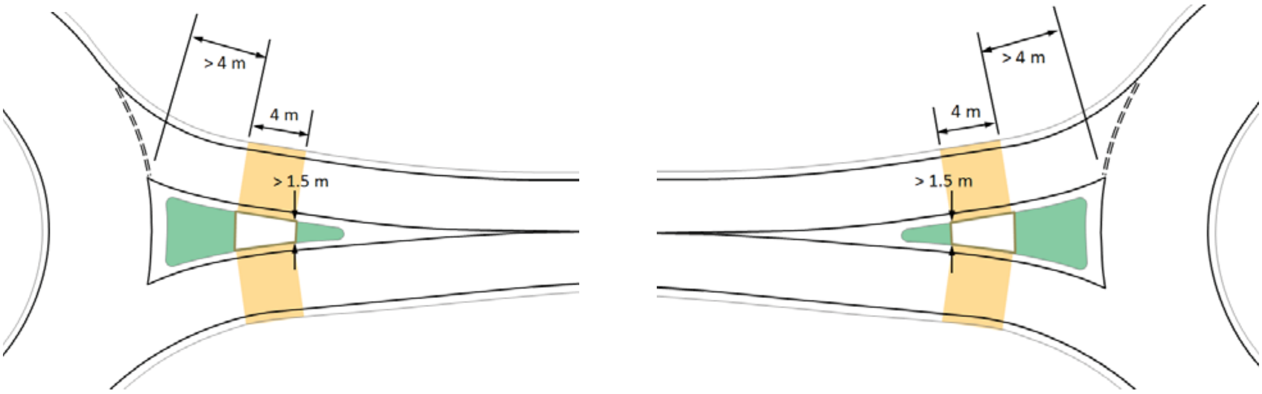


Pedestrian Facilities

Where built-up areas, schools and industrial areas etc. are in the vicinity of a roundabout, footpaths and crossings should be provided to match the needs and preference of pedestrians. Pedestrian crossings should be located more than 4m ahead of a give-way line so that pedestrians can cross behind a vehicle waiting to enter the roundabout. The typical layout of pedestrian crossings is illustrated in ***Figure 3.3.1.9***.

FIGURE 3.3.1.9 PEDESTRIAN CROSSING AT SINGLE LANE ROUNDABOUTS

(for driving on the right side of the road) *(for driving on the left side of the road)*



Roadside Treatments

Forgiving roadside principles have to be applied at critical areas, notable the central island and splitter islands. The central island of a roundabout should have a gentle profile and may be in the form of a mound with gradients not exceeding 15%.

Aesthetically pleasing designs may be adopted to highlight local culture whereas subtle and natural designs are generally more compatible in the countryside. Landscaping design is highly flexible and does not need to be symmetrical. Design of the central island including any ground profile, landscaping, decorations and traffic signs should comply with the forgiving roadside principle, taking into account possible trajectories of an errant vehicle.

Runover Areas

Runover areas for long vehicles are not generally required for roundabouts with outside radius exceeding 15m. They may be required for special purpose transport vehicles according to specific needs. Runover areas may be designed as a rough texture surface with 3-6% crossfall towards the outside of the roundabout. The design should clearly indicate that they are not suitable for general traffic. If the runover area is delineated as a raised area, then this preferably does not exceed 30mm above the road surface.

Circulatory Carriageway

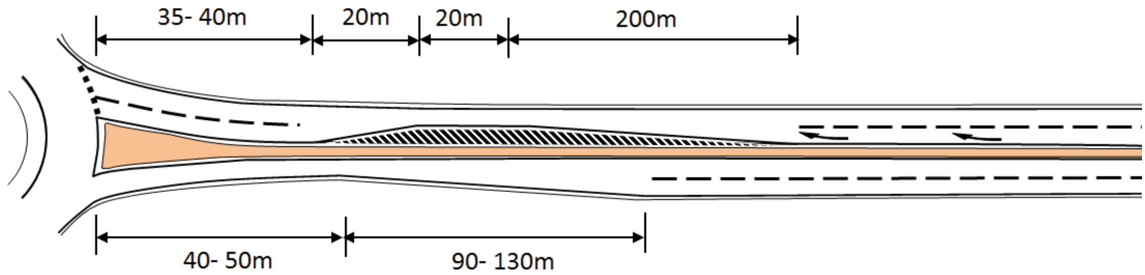
The circulatory carriageway of compact roundabouts should have crossfall not exceeding 2.5% towards the outside to facilitate drainage. For larger roundabouts it may be desirable to divide the circulatory carriageway into two parts. The inner part occupying two-third of the road width has a super-elevation towards the inside and the outer part occupying the remaining one-third of the road width has a crossfall of 2.5% towards the outside. It is crucial to limit the overall change of gradients and to smoothen their boundary in order to reduce the risk of falling loads or rollover of heavy vehicles.

The surface of the circulatory carriageway should be well maintained with sufficient skid resistance. For the safety of motorcycles it is not advisable to position utility or drainage covers within the circulatory carriageway.

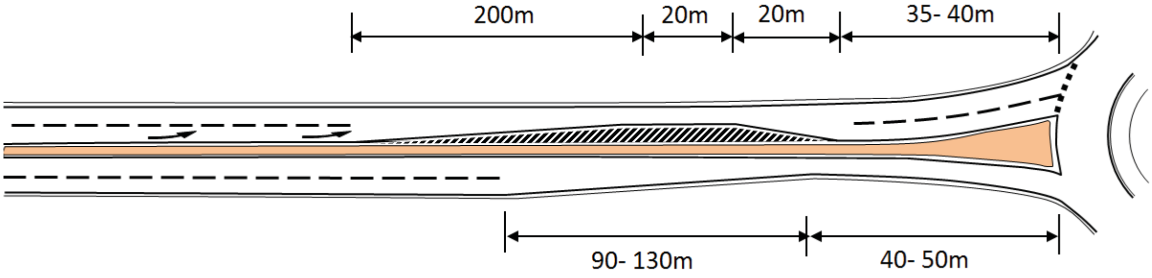
Roundabouts on Class I Roads

Roundabouts on divided four-lane Class I roads should have outside radius in the order of 20m to 25m. Where traffic volume is moderate, it is advisable to narrow down the approach to single lane as shown in ***Figure 3.3.1.10***. This arrangement is particularly recommended where a divided road terminates and becomes an undivided road after the roundabout. At higher traffic volume, a two lane layout may be adopted throughout or at the roundabout entrance. The exit of these roundabouts is preferably single lane.

FIGURE 3.3.1.10 SAFETY TREATMENTS FOR ROUNDABOUT APPROACH ON DIVIDED ROADS [13]
(for driving on the right side of the road)



(for driving on the left side of the road)



These roundabouts are generally unsuitable for the use of pedestrians and slow vehicles, especially where traffic volume is high and heavy vehicles are frequent. At these roundabouts, pedestrians and slow vehicles should be routed to follow a segregated path where crossings are set back from the roundabout and are preferably equipped with traffic signals. Wherever feasible, grade-separated facilities should be considered.

4 SIGNALISED INTERSECTIONS

Signalisation is a form of traffic control which provides conflicting movements the right of way by time separation. While the general objective is to reduce delays and increase capacity of vehicle traffic, the interest of pedestrians and slow vehicles should be given equal weight. Safety should be a primary consideration with adequate allowance for failure on the part of users to comply with rules.

Signalisation is adopted where traffic volume is high with a significant proportion of crossing or turning traffic. It is also adopted to provide pedestrians and slow vehicles a safer opportunity where traffic volume or speeds are high and there are multiple traffic lanes.

Traffic signals for vehicle traffic consist of three-aspect displays of red, amber and green. Green signal display and sometimes red signal display could be in the form of an arrow pointing upward, to the left or the right.

Outside built-up areas, it is generally not advisable to provide isolated signalised intersections where traffic speeds are high and drivers may not expect signalised control.

4.1 General Requirements

The key principle of signalised intersection is separation and allocation of conflicting traffic streams to different stages of signal display. It may be acceptable to permit offside-turning on a full green signal against conflicting straight ahead traffic, subject to relatively low traffic speeds, simple intersection layout and clear indication of give-way markings.

It may be desirable to restrict certain movements such as offside turning to increase the capacity of a signalised intersection as long as the implications of diversion are fully considered. The geometry of street corners and channelisation layouts should be designed to discourage the banned turning movements.

It is generally necessary to limit the cycle time of traffic signals within 120 seconds and desirably 90 to 100 seconds. Above a cycle time of 120 seconds, almost no extra capacity is gained due to the build-up of long vehicle headway, and delays increase considerably. The intergreen period between the end of the green signal on one stage and the start of the green signal on the next stage should be determined from conflict points specific to the intersection geometry and the paths of traffic and pedestrians. Intergreen values should not be less than 5 seconds and larger values up to 15 seconds may be required:-

- when the distance across the junction is excessive
- to improve safety on high speed roads
- where there is insufficient offside-turning traffic to justify provision of a separate stage

The length of the intergreen period will need to be optimised between increased risk of conflicts and excessive delays which could lead to non-compliance by drivers.

It is desirable to provide at least two sets of traffic signals with synchronised displays for each approach arm. The primary signal is located just upstream of the intersection and the secondary signal is located just downstream of the intersection. Pedestrian signals should be provided to give positive indications to pedestrians.

Traffic signals may be mounted on poles or overhead structures in cantilever or gantries. Irrespective of the mounting form, consistent usage should be adopted along a road.

Signal controllers should be provided at vantage position to facilitate manual control or testing. Their position should not result in obscuring of critical visibility.

Pedestrian Crossings

Pedestrian signals should be provided at signalised crossings wherever there is reasonable demand for crossing pedestrians. The layout of signalised intersections should, as far as practical, facilitate pedestrians with minimum crossing width, limited number of lanes to cross and reduced traffic speeds, especially where there is still ample reserve capacity for vehicle traffic. A full pedestrian stage may also be considered in these circumstances.

Nearside turn channelizing islands may not be in the interest of pedestrians since they increase the number of steps to cross a road. If they are required, the layout should not induce high traffic speeds through a pedestrian crossing.

It is preferable to allow pedestrians to cross a divided road in one attempt at a signalised intersection. If this is not practical and pedestrians have to wait at the median or refuge island, sufficient space should be provided for pedestrians to wait and pass each other, with a minimum average pedestrian area occupancy of 0.2 m^2/person.

If a staggered pedestrian crossing is provided, pedestrian paths are preferably oriented towards approach traffic. Furthermore, pedestrian signals should be positioned on the upstream side of the crossing for the same reason.

Where pedestrian demand is low at a signalised crossing, consideration should be given to the installation of push buttons for pedestrians to activate the pedestrian signal stage. Push buttons should be located at each side of a pedestrian crossing with additional ones on wide pedestrian refuge islands. They should be positioned to encourage pedestrians looking towards approaching traffic.

Where a straight pedestrian crossing with a limited median or refuge is provided, the overall green period for pedestrians including both green displays and flashing green time should be sufficient to enable pedestrians to cross the full width of the road at normal walking speed. The length of the flashing green time would be determined from the maximum distance from safe refuge to safe refuge. Green displays should be sufficient to clear all waiting pedestrian but not less than 5 seconds.

The adequacy of the overall green period may be checked by the formula:

$$PC = K * GTP * W$$

where PC = Pedestrian crossing capacity in pedestrians per hour
GTP = Green time proportion= (Pedestrian green + flashing green time)/Cycle time
W = Width of pedestrian crossing
K = Saturation flow for pedestrians= 1,900 ped/metre/hour

The separation distance between a pedestrian crossing and the stop line should normally be 2m but extension up to 6m could be desirable with a high speed approach.

There should be adequate green time for a pedestrian to cross at the walking speed of 1.1m/s. Where the crossing is frequently used by elderlies and pedestrians of special needs, and in the case of heavy pedestrian usage, it is recommended to reduce the design walking speed to the order of 0.9m/s.

Both straight ahead and offside turning traffic movements should not be permitted over a pedestrian crossing when the pedestrian signal is on green display. It is also strongly advised not to permit traffic making nearside turn on red signals at any time. It is tolerated but not advisable to permit nearside turning into an arm when pedestrian signals are green， particularly where turning traffic speeds are high and drivers are not willing to give way.

Where one traffic stream is stopped while another traffic stream is running on the same approach, pedestrians could be tempted to cross in front of waiting traffic. In this case, it is strongly advisable to provide a channelizing island separating the traffic streams with an additional set of traffic signals. Alternatively, green signals are concurrently displayed for both through traffic and turning traffic.

The following additional safety measures could be considered:

- Traffic calming measures
- Staggered crossings with a median or refuge island
- Countdown timer
- Automatic extension of flashing green signals for pedestrians
- Audible signals
- Red light speed cameras

Signing and Delineation

Advance warning signs showing “Traffic Signals Ahead” are needed for approaches with inadequate visibility. They are also needed for high speed approaches and isolated traffic signals.

Traffic lanes may be narrowed down on the approach to a signalised intersection. Lane widths down to 3.0m would be readily acceptable in urban area.

Two or more sets of arrow markings showing the permitted movements should be provided on each traffic lane ahead of the Stop line. To encourage compliance to lane arrow markings, the number of traffic lanes on the downstream side of an intersection should be the same as the number of upstream lanes marked as straight ahead lanes.

Where traffic movements are restricted for a particular set of traffic signals, appropriate traffic signs indicating the mandatory or prohibited movements should be provided.

4.2 Visibility Requirements

The primary visibility requirements for signalised intersections are:

- Visibility of traffic signals
- Visibility of pedestrian and slow vehicle crossings
- Intervisibility at the intersection
- Control of undesirable visibility

Visibility of Traffic Signals and Crossing Areas

The minimum visibility distances to the primary signal(s) required by drivers is given in ***Table 3.4.2.1***.

Table 3.4.2.1 Visibility of Traffic Signals [17]

85 percentile Speed (km/h)	Minimum Visibility Distance (m)
50	70
60	95
70	125
80	150
100	225

Traffic signals should be readily visible by vehicles waiting at the stop line. This is achieved by providing:

- a single set of signals after the intersection
- a set of secondary signals after the intersection

These signals should be orthogonal or else within 30 degrees of the sightline of approach drivers. A backing board in black of dark colour and light colour border should be provided around traffic signals if they are viewed against the sky or a distracting background.

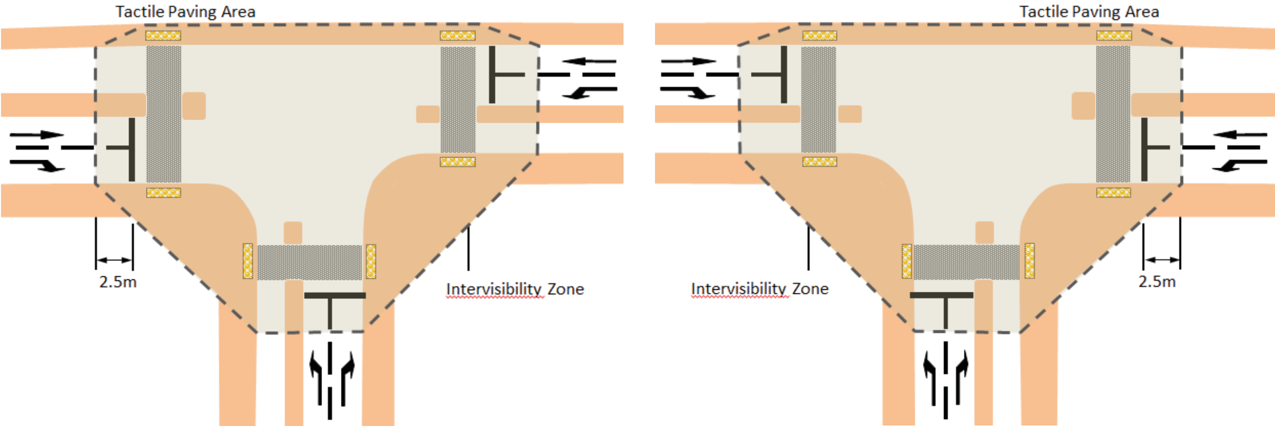
Adequate visibility is required for both the pedestrian crossing and waiting area on the footpath. Further guidance is given under the topic of pedestrian crossings.

Intervisibility

Visibility should be provided between drivers located 2.5m ahead of a Stop line and a vehicle located on a conflicting traffic stream and waiting areas of pedestrian crossings (***Figure 3.4.2.2***).

FIGURE 3.4.2.2 INTERVISIBILITY ZONE AT SIGNALISED INTERSECTIONS

(for driving on the right side of the road) *(for driving on the left side of the road)*



Observer	Eye-height	Target	Object Height
Driver	1.05m – 2.0m	Vehicle	0.6m – 2.0m

Control of Undesirable Visibility

Misinterpretation of traffic signals could lead to severe collisions. For this reason, traffic signals for one traffic stream should not be visible to another traffic stream.

Where two independent sets of traffic signals along a route are in the proximity, drivers at the upstream signals could be misguided by the downstream signals. The problem may be alleviated by synchronizing the two sets of traffic signals and installing hoods or louvres over the signal aspects.

It is also necessary to check that drivers are unlikely to follow traffic signals for conflicting arms by mistake. This is particularly the case for skewed intersections.

Lane control signals or variable message signs showing green or red colour arrows should not be installed immediately downstream of a signalised intersection to avoid misleading drivers.

4.3 Signalised Intersections on High Speed Roads

Signalised intersections with approach speeds exceeding 70km/h require special attention. Traffic signals should not be adopted if traffic speeds on any approach exceed 100 km/h.

It is always desirable to reduce traffic speeds on the approach and through a signalised intersection. Outside built-up areas, traffic speeds preferably do not exceed 70km/h. In built-up areas, traffic speeds should be limited to 50km/h and desirably even lower where there are many pedestrians or slow vehicles. It may be desirable to reduce speed limits locally around an intersection.

Additional care is needed to reduce traffic speeds on the approach at the end of a free-flow divided road and for signalised intersection with a steep downhill approach.

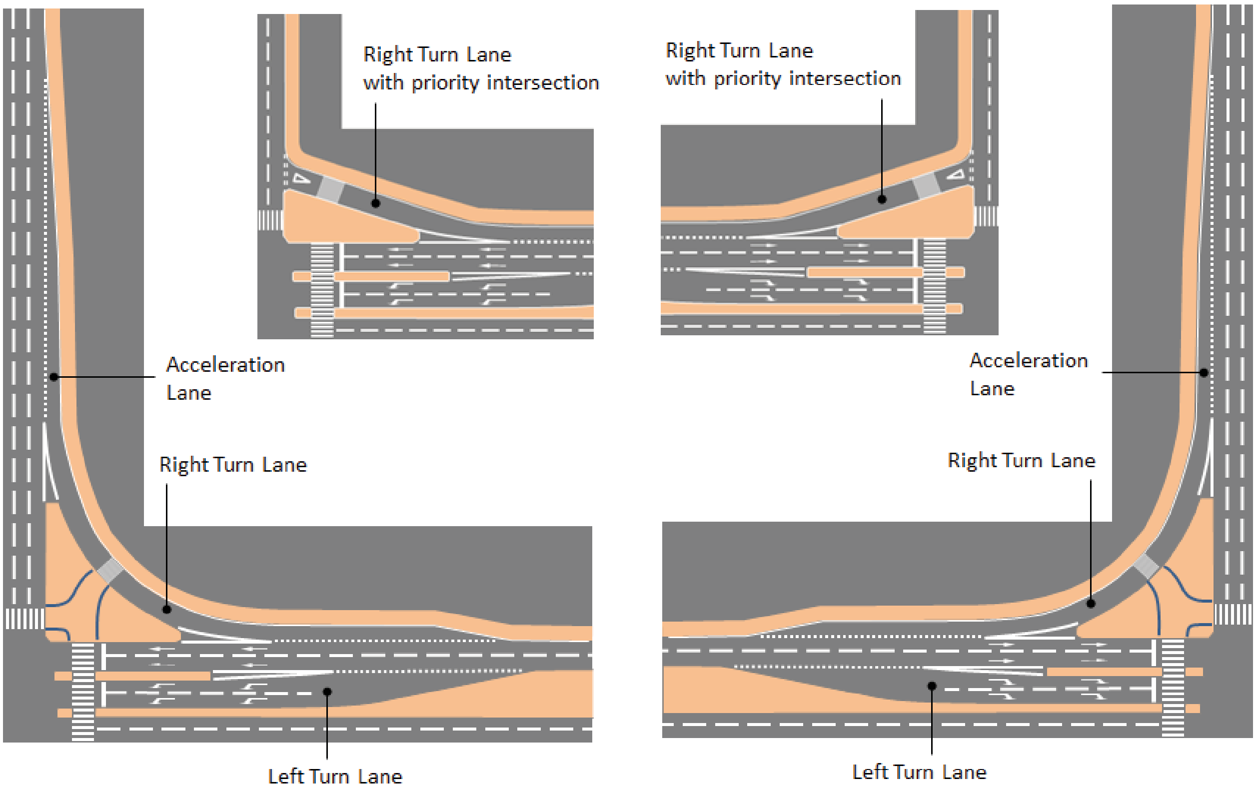
Additionally, the following measures should be considered for signalised intersections on high speed roads:

- Adoption of high intensity signal aspects of large size, in the order of 300mm diameter
- Duplicate primary signals
- Provision of backing boards on signals
- Use of advance warning signs on all approaches
- Use or addition of overhead traffic signals to complement pole mounted signals

Typical Layouts of High speed or major signalised intersections are illustrated in ***Figure 3.4.3.1***.

FIGURE 3.4.3.1 HIGH SPEED/MAJOR SIGNALISED INTERSECTIONS [18]

(for driving on the right side of the road) *(for driving on the left side of the road)*



Offside-turning Movements

It is generally not advisable for offside turning traffic proceeding with a green signal to give way to opposing through traffic. This is particularly the case for traffic speeds exceeding 50km/h and the opposing direction consists of multiple through traffic lanes. Separate signals should be provided for offside turning traffic to proceed when all through traffic on the opposing direction has stopped.

On high speed roads and where offside turning traffic exceeds 300 veh/hour, one or more offside turn lanes segregated from straight ahead traffic lanes should be provided with a separate set of traffic signals.

Nearside-turning Movements

Segregated nearside turn lanes should be considered if there is a significant volume of nearside turning traffic. A free-flow right-turn lane with an acceleration lane will provide a larger capacity.

The alternative layout without an acceleration lane is more favourable for the provision of pedestrian or slow vehicle crossings. It is also appropriate where nearside-turning traffic joins a road of lower hierarchy.

To facilitate pedestrians crossing a nearside turn lane, a speed table may be considered in conjunction with other traffic calming measures.

Additional Measures

Signalised intersections with increased risk due to high approach speeds on long steep downhill grade may require additional measures including:

- Warning signs
- Narrowing of traffic lanes
- High friction surfacing
- Transverse rumble strips

Measures based on intelligent transportation system techniques include:

- Speed related signal changes including extension or delay in signal onset
- Countdown timer for traffic and/or pedestrians and slow vehicles
- Red light speed cameras
- Light-emitting warning signs
- Vehicle activated signs
- Variable message signs

5 U-TURN FACILITIES

In the absence of adequate U-turn opportunities, drivers may attempt to U-turn on the main road causing a safety hazard.

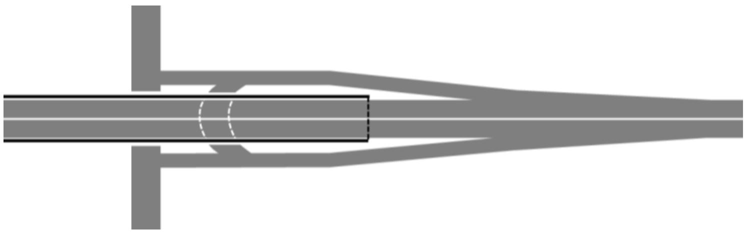
On undivided roads offside turning from side roads is normally permitted at intersections. The need for U-turning may be satisfied by roundabouts as well as informal facilities such as wide parking laybys, rest areas or side roads.

On divided roads with heavy or free flow traffic at high speed, offside turning from side roads through median openings is undesirable. The alternative strategy is to systematically provide nearside-in nearside-out intersections in conjunction with U-turn facilities. The preferred U-turn facilities are:

- Roundabout
- Compact grade-separated intersection
- Grade-separated U-turn facility

Grade-separated U-turn facilities may be incorporated into diamond intersections, other intersection layouts or underneath a flyover. A typical layout is illustrated in ***Figure 3.5.1.1***.

FIGURE 3.5.1.1 GRADE-SEPARATED U-TURN FACILITY



Priority U-turn Facilities

These facilities require U-turning vehicles to cross the path of opposing vehicles. They are not recommended for Class I roads with heavy U-turn traffic or main road traffic, and speed limit exceeding 60km/h.

Where provided, at-grade priority U-turn pockets should be located on straight sections with unobstructed intersection visibility. Alternatively, U-turn pockets may be provided just ahead of a signalised intersection with or without signalized control.

U-turn facilities should be provided with a widened median so that a U-turning vehicle is aligned at right angle to main road traffic prior to completing the U-turn manoeuvre. In case of site constraints, U-turning may be facilitated at median openings in conjunction with a widened shoulder. Occasional U-turning needs may also be accommodated by offside-turning into a side road or parking area.

Wrong-way Traffic

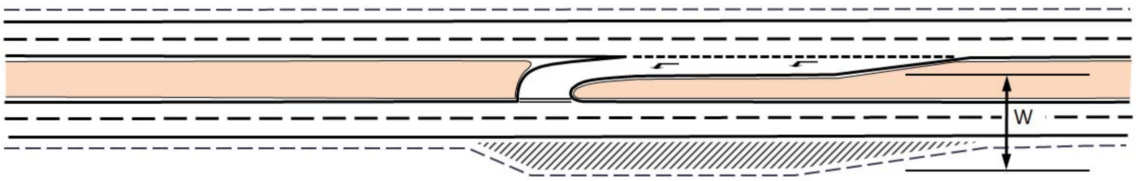
Although U-turn facilities in conjunction with nearside-in nearside out layout may reduce the risk of offside-turning from side roads, drivers of side road traffic including slow traffic may attempt to avoid diversion by travelling in the wrong way direction. Detour via a downstream U-turn pocket also increases the risk exposure of slow vehicles.

The layout of nearside-in nearside-out intersection should be arranged to encourage side road traffic turning into the correct direction with adequate signing.

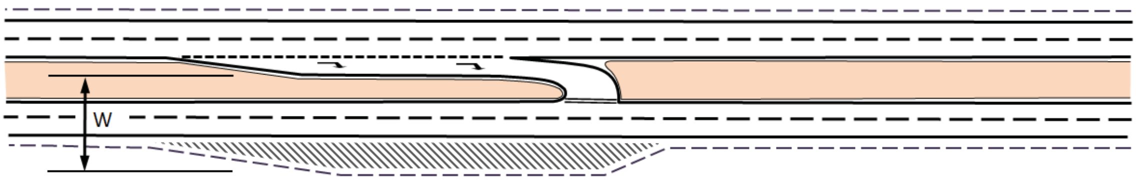
In principle, grade-separated passages and compact grade-separated intersections should be systematically provided on Class I roads. Where these cannot be accommodated, median openings for pedestrians and slow vehicles may be considered together with traffic calming.

FIGURE 3.5.1.2 AT-GRADE U-TURN POCKET ON A CLASS I ROAD WITH WIDENED PAVED SHOULDER

(for driving on the right side of the road)



(for driving on the left side of the road)



W: 13m for cars; 24m for heavy vehicles of length 9m to 15m

6 GRADE-SEPARATED INTERSECTIONS

6.1 General Requirements

Grade-separated intersections are intersections where conflicting movements of intersecting roads are accommodated at different levels using bridges, underpasses or tunnels. Linkages are provided by connector roads.

Connector roads joining one of the intersecting roads may be in the form of an at-grade intersection such as priority intersection, signalised intersection or roundabout. Interchanges are grade-separated intersections where traffic from one main road is connected to another main road via free flow connecting roads.

Grade-separated intersections are provided for all Primary class roads and access-controlled Class I roads. It may be desirable to provide grade-separated intersections along other Class I roads on an individual basis or in stages. For Classes II and III roads, grade-separated intersections are not generally provided except:

- where necessitated by local topography
- on "2+1" roads
- on divided roads where only one carriageway has been constructed

In all these cases, special measures are required to minimise safety risks due to misinterpretation by drivers. Furthermore, grade-separated intersections should be avoided on a divided road within 0.5 km from its interface with a Class II or Class III road.

A grade-separated intersection may consist of both free flow connections and at-grade intersections serving different traffic directions. However, free-flow connections within a grade-separated intersection should not consist of any intermediate at-grade intersections as this may contradict drivers' expectation.

Siting of Grade-separated Intersections

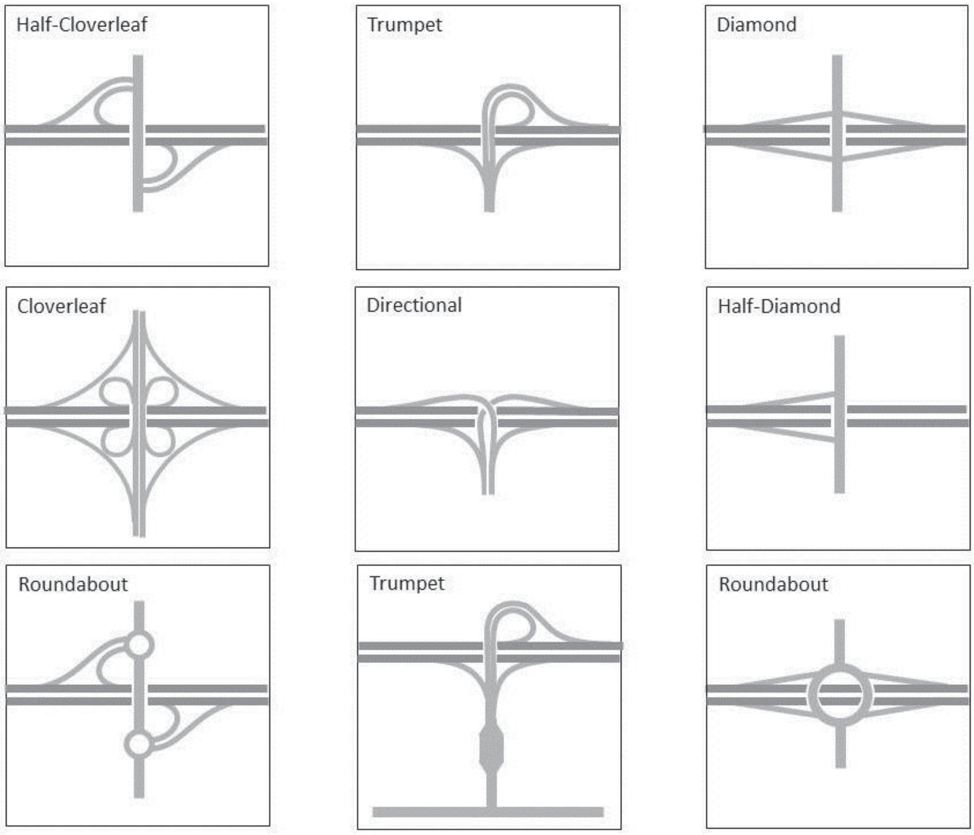
On Primary class roads grade-separated intersections are desirably provided at spacing in the order of 20km outside built-up area. Merging and diverging areas are preferably sited on straight or near straight alignment with gentle gradients.

Wherever feasible, it is desirable to provide exit slip roads on uphill gradient to facilitate deceleration, and conversely, entry slip roads on downhill gradient to facilitate acceleration. As such, it is generally not advisable to locate grade separated intersections at a hilltop due to unfavourable gradients. Drivers are also more likely to be affected by bright sun glare on the approach.

Forms of Grade-separated Intersections

Basic categories grade-separated intersections are illustrated in ***Figure 3.6.1.1***. Variations are possible with partial connections or a mix of different layout features.

FIGURE 3.6.1.1 COMMON GRADE-SEPARATED INTERSECTION LAYOUTS

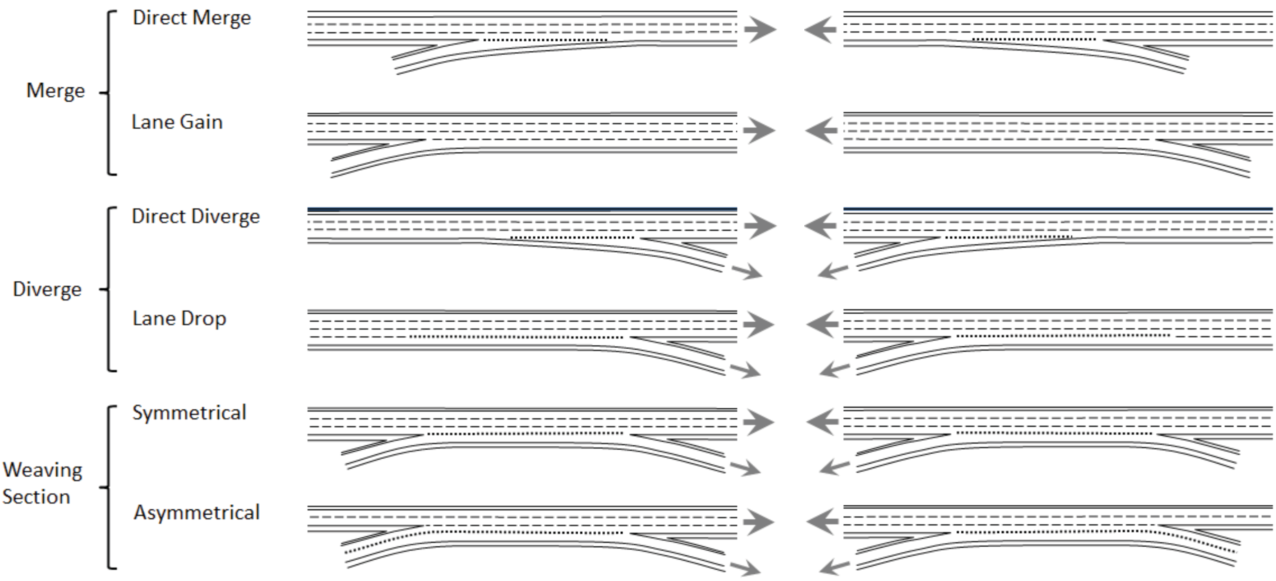


Grade-separated intersections should be relatively simple with minimum number of decision points which are spaced well apart. They should enable all drivers to readily identify the direction with minimal need for lane changing. Where more complex road connections are unavoidable, notably within cities and at their peripheries, every effort should be made to simplify the layout and to provide adequate and well-designed directional signing.

The layout and dimensions of merging and diverging areas are dependent on site constraints and traffic volumes. ***Figure 3.6.1.2*** are basic layouts which may vary with the number of lanes on the mainline and connector roads. Irrespective of such variations, merging and diverging areas should appear simple and consistent to drivers.

FIGURE 3.6.1.2 BASIC LAYOUTS OF MERGING AND DIVERGING AREAS

(for driving on the right side of the road) *(for driving on the left side of the road)*



6.2 Design Features

Connector Roads Design Speed

Connector roads generally have lower design speeds than the mainline but the difference should not be excessive. This is given in ***Table 3.6.2.1***. It is important that changes to a lower design speed are predictable and obvious to drivers, and there is adequate distance for deceleration.

TABLE 3.6.2.1 RECOMMENDED MINIMUM DESIGN SPEEDS FOR CONNECTOR ROADS [19]

		Mainline Design Speed (km/h)		
		80	100	120
Connector Road Design Speed (km/h)	Interchange Link [1]	70	80 (70)	100/80 (70)
	Slip Road [2]	60 (50)	70 (60)	70
	Link Road [3]	80 (70)	100 (80)	120 (100)

1 Free-flow connector roads within an interchange
2 Connection between a Primary class road and the local road network
3 Parallel road network serving as collector and distributor for a Primary class road

Other than loops, the radius of the first curve on a slip road after an exit should not be less than100m. Two lane slip roads should have larger radius in the order of 240m or above.

Merging Areas

Merging areas may be in the following forms:

- Taper merge
- Parallel merge
- Lane gain
- Weaving section

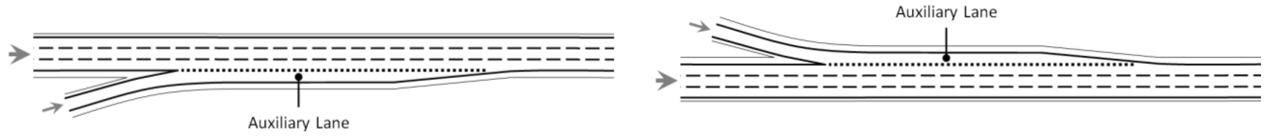
Merging areas should have good visibility such that mainline and merging traffic can see each other on the approach.

FIGURE 3.6.2.1 INTERVISIBILITY AT MERGING AREAS *(driving is on the left side of the road)*

If a merge is located on the inside of a curve or on steep uphill or downhill gradient, it is advisable to adopt a parallel merge with an auxiliary lane of sufficient length. This is illustrated in ***Figure 3.6.2.2***.

FIGURE 3.6.2.2 PARALLEL MERGE

(for driving on the right side of the road) *(for driving on the left side of the road)*



An acceleration section should be provided to enable merging traffic on the slip road to accelerate to mainline traffic speeds from 55km/h at a rate of $1m/s^2$.

A buffer area should always be provided at the end of an acceleration lane to allow a merging vehicle to overrun if it fails to merge at the end of the merge taper. A paved shoulder at least 2.5m wide will generally serve this purpose. In the absence of a paved shoulder, creation of a short buffer area is still desirable.

Merging areas of two lane slip roads may be confusing to drivers. This can be improved by the following methods:

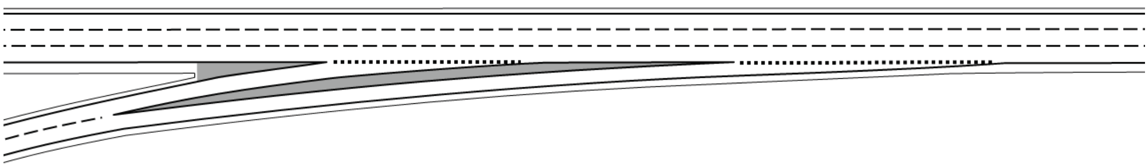
- Narrowing to single lane from the offside ahead of the merging area, if capacity permits
- Two lane merge separated by a painted traffic island

If joining flow is larger than one lane capacity, then lane gain should be considered.

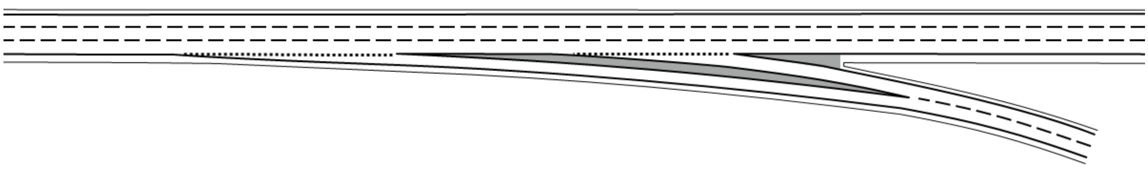
Painted traffic islands help to separate merging traffic on different lanes and provide a buffer area. This is illustrated in ***Figure 3.6.2.3***. It is recommended that they are used for two lane merges on Primary class roads in rural areas. A minimum width of 2m is recommended at the widest point of the traffic island.

FIGURE 3.6.2.3 TWO-LANE DIRECT MERGE WITH PAINTED TRAFFIC ISLANDS

(for driving on the right side of the road)



(for driving on the left side of the road)



Diverging Areas

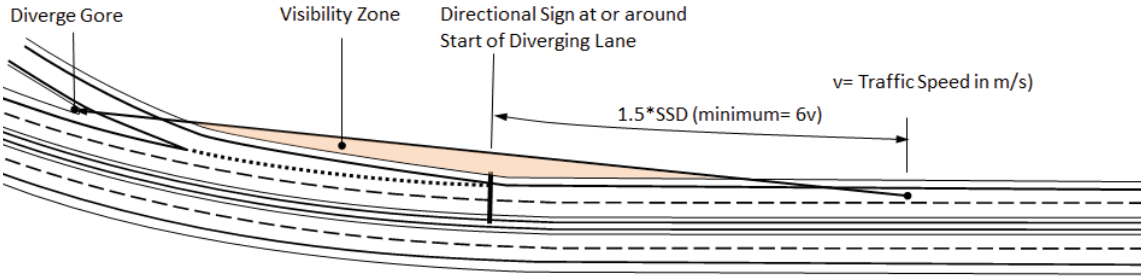
Diverging areas may be in the following forms:

- Taper diverge
- Parallel diverge
- Lane drop
- Weaving section

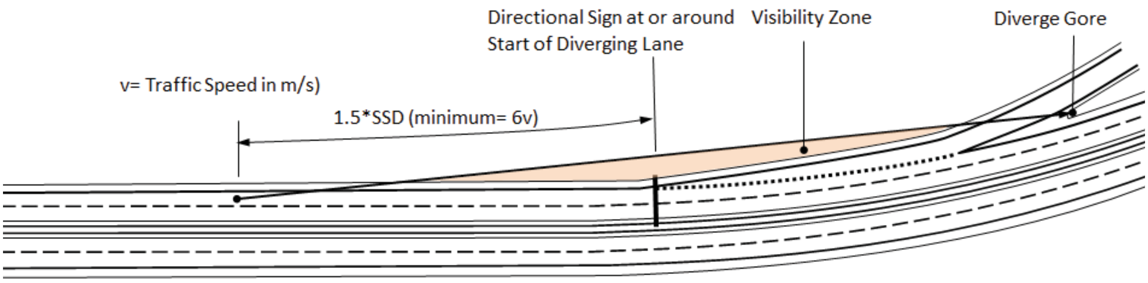
On the approach to diverge gores on Primary class roads or other roads, drivers should be able to see the start of the diverging lane, the associated directional sign and the diverge gore at a distance equivalent to 1.5*SSD. This is illustrated in ***Figure 3.6.2.4***. Diverge gores should not be located after a significant crest to ensure adequate visibility.

FIGURE 3.6.2.4 VISIBILITY AT DIVERGING AREAS

(for driving on the right side of the road)



(for driving on the left side of the road)



Observer	Eye-height	Target	Object Height
Driver	1.05m – 2.0m	Diverge gore	0m – 2.0m

At exit areas, sufficient length of straight section should be provided on the diverging lane for deceleration ahead of the first curve. Such deceleration section may be based on a speed of 70km/h at the diverge point and deceleration rate of $1.5m/s^{2}$.

Regular queues of exit traffic extending onto the mainline should be avoided to minimise the risk of rear-front collisions. To alleviate the problem, the capacity of the downstream intersection should be increased or else a parallel diverge layout is provided with an auxiliary lane. Advance warning signs should be considered if traffic queues often extend onto the mainline and forward visibility is restricted.

Lane Drops

Lane drops are diverge layouts where one or more mainline traffic lanes become diverging lanes. As a result there is a net reduction of mainline traffic lanes after the diverge. .

In general, lane drops are not desirable from the safety point of view since through traffic has to change lane to continue on the mainline. This could lead to the following concerns:

- Heavy vehicles on the nearside changing lanes to remain on the mainline
- Unfamiliar drivers may not be aware of this layout and react at a late stage
- Exit traffic speeds could be too high if the exit is immediately followed by sharp curves or intersections

Lane drops are not advisable on significant uphill gradients.

However, it may be necessary or more economical to adopt lane drops where exit traffic volume is high. In these circumstances, an alternative is to reduce the number of mainline traffic lanes after the interchange with narrowing on the offside.

It is also generally appropriate to split traffic lanes into different directions at major interchanges leading to two directions, both being continuation of Primary class roads.

From the long term planning point of view, it is highly desirable to maintain enough road reserve between an upstream lane drop and a downstream lane gain. In this situation, bridge structures at grade-separated intersections should not constitute a bottom neck in the road system.

To enhance the safety of lane drops, adequate and well-presented directional signs should be provided. Additionally, exit traffic lanes should be demarcated with adequate length of distinct line marking in conjunction with the advance direction sign.

Weaving Sections and Successive Diverges

Weaving sections are road sections comprising an upstream merge and a downstream diverge within a relatively short distance, in the order of 2 km or less. They may consist of one or more auxiliary lanes.

Weaving sections should be of adequate length to accommodate weaving traffic volume. They should not be less than 500m on a Primary class road.

Directional signing within weaving sections and on the approach should be able to clearly guide drivers to get into the correct traffic lanes.

Successive Merges and Diverges

Successive merges or diverges and diverges followed by merges should be separated by adequate distance for drivers to adapt to the changing road conditions and to negotiate through decision points. The recommended separation distance is 3.75V where “V” is the prevailing traffic speed in km/h.

In order to minimise the disturbance to mainline traffic on Primary class roads with high traffic volume and traffic speeds, it may be desirable to provide a segregated parallel link road to accommodate successive merging, diverging or weaving movements. This is particularly beneficial where major grade separated intersections are located in the proximity of each other.

Auxiliary Lanes

The safety and capacity of merging and diverging areas may be undermined by unfavourable alignments and heavy traffic volume. An auxiliary lane would help to alleviate the problem in the following situations:

- Merging on the inside of a curve
- Diverging on the outside of a curve
- Steep uphill or downhill gradients
- heavy traffic joining the mainline
- high volume of heavy vehicles

In case of unfavourable alignments, auxiliary lanes should be extended to commence ahead of curves or crests.

Non-typical Layouts

Consistency and simplicity are critical for the safety of grade-separated intersections. In this context, merging and diverging areas should always be on the nearside except at interchanges where a Primary class roads splits to join another Primary class road. Furthermore, mainline priority should be maintained even if merging traffic is higher than mainline traffic.

Non-typical merging, diverging or weaving layouts should not be adopted without good justifications:

- Direct merges or lane drops on the offside
- Direct diverges or lane gains on the offside
- Weaving sections consisting of the above elements
- Layouts requiring complex weaving movements

Loops

Loops are slip roads which turn through more than 120 degrees on a small radius curve. They are typical of grade-separated intersections in the trumpet or cloverleaf layout. Loops should not consist of more than one lane per direction.

Loops should have radius in the order of 60m and not less than 40m. On difficult terrains with lower design speeds, loop radius may be reduced to 30m. The safety of loops may be enhanced by:

- providing clear visibility across the entire loop on the approach
- continuous delineation and chevron signs
- use of safety barriers
- road lighting
- use of high friction surfacing

It is always desirable to provide a straight or near straight section between the loop and the nose of merges or diverges. At merging areas, this helps traffic to accelerate to match mainline traffic speeds. At diverging areas, this helps traffic to decelerate to traffic speeds commensurate with the curvature of the loop. If such sections cannot be provided satisfactorily, an auxiliary lane should be considered to extend the merging and diverging areas.

It is not advisable to accommodate two-way traffic in a loop on an undivided carriageway. Physical separation of opposing traffic by a median safety barrier is recommended.

Where a Primary class road terminates and intersects another Primary class road, an interchange in directional layout is preferred to trumpet layout with small radius curves including loops. If this is not avoidable, measures will be needed, in particular, to increase the awareness of mainline traffic on the intersecting road. Appropriate strategy includes narrowing to single lane and speed reduction measures on the approach.

Primary Class Roads Service Areas

Access for service areas on Primary class roads should have all the features of a grade-separated intersection, except that a lower design standard may be applied to diverging areas.

If lighting is provided on the mainline, then lighting should also cover the slip roads of a service area. Otherwise, lighting should be restricted to the immediate linkage with the service areas.

Major Interchanges

Interchanges connecting to another Primary class road or urban areas may carry very heavy traffic volume. Interchanges involving three or more lanes of merges or diverges are considered major Interchanges. They require special treatments in terms of capacity and safety.

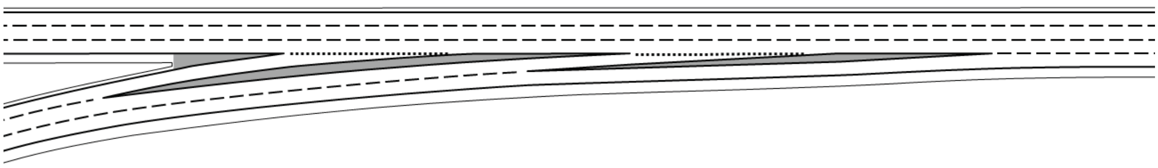
For efficient operation, grade-separated intersections on Primary class roads should be simple without the need for multiple weaving manoeuvres.

At major interchanges where more complex layouts are necessary, potential safety problems may be compensated by:

- providing adequate separation between successive merging or diverging areas
- provide clear guidance with directional signing

Where several connector roads or a multi-lane connector road join the mainline and the overall number of lanes is reduced, the number of lanes should be reduced ahead of the merge with the mainline. Alternatively, painted traffic islands may be introduced between successive merges. These are illustrated in ***Figures 3.6.2.5*** and ***3.6.2.6***.

FIGURE 3.6.2.5 MERGING LAYOUT WITH PAINTED TRAFFIC ISLANDS AT A MAJOR INTERCHANGE
[19] *(for driving on the right side of the road)*



(for driving on the left side of the road)

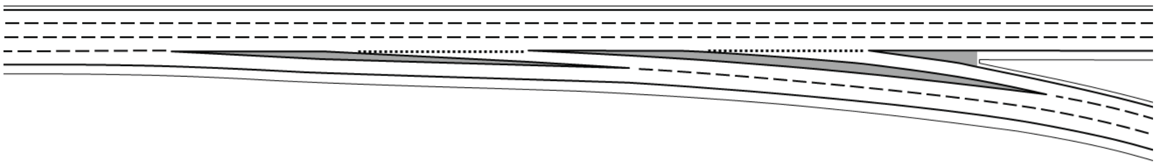
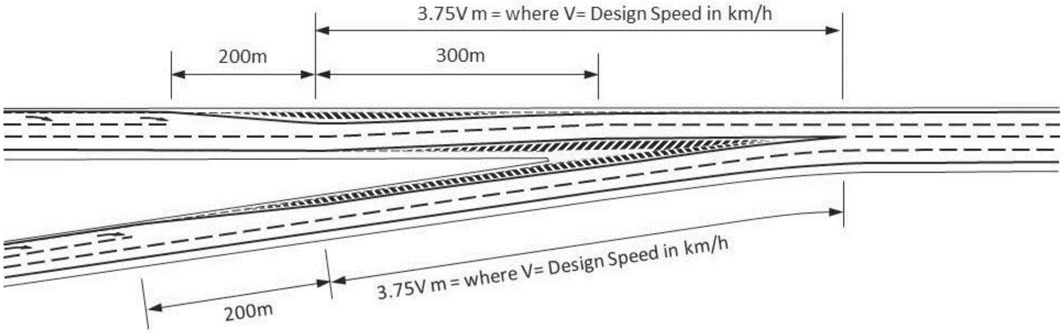


FIGURE 3.6.2.6 MERGING LAYOUT WITH ADVANCE LANE REDUCTION [19]

(for driving on the right side of the road)



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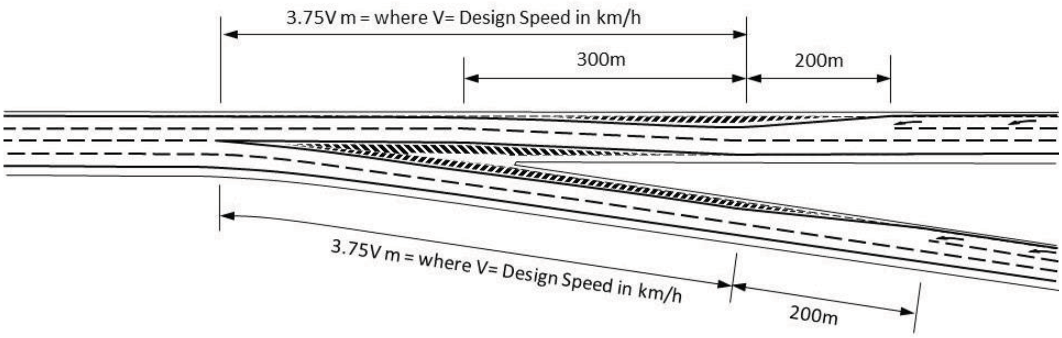


Signing and Delineation

Traffic signs of particular relevance to road safety for grade-separated intersections are given in ***Table 3.6.2.2***.

TABLE 3.6.2.2 SELECTED TRAFFIC SIGNS OF IMPORTANCE AT GRADE-SEPARATED INTERSECTIONS

Sign Type	Typical Usage
Merge ahead signs	Ahead of merges, particularly important for direct merges
Speed limit signs	At exit slip roads with tight geometry, loops or approach to intersections
Chevron marks	At sharp curves or loops
No-entry	At locations where traffic may enter into wrong-way slip roads

On direct or parallel merging lanes and wherever a traffic lane is terminated, curly arrow markings should be considered to better direct traffic to merge.

Pedestrians and Slow Vehicles

Appropriate crossing facilities are needed at grade-separated intersections for pedestrian and slow vehicle routes running parallel to or in the vicinity of Primary class or Class I roads.

Any at-grade crossings should be located away from high speed and free flow areas within a grade-separated intersection. In particular they should be avoided just ahead of merging areas where traffic will be accelerating to join the mainline. If provided, they are preferably located near an at-grade intersection with good visibility. Alternatively, consideration may be given to the use of grade-separated crossings.

At-grade Intersections

At-grade intersections are associated with diamond, half cloverleaf or trumpet layouts. Toll facility may be located in the vicinity of the intersection.

Drivers leaving a Primary class road should be well alerted of the loss of priority at T-intersections or crossroads. Crossroad layouts may need to be signalised or transformed to roundabouts for improved safety. Particular emphasis is needed for adequate visibility towards give-way and stop signs or markings as well as traffic signals and directional signs.

Where traffic on a one way slip road is joining an undivided road at a grade-separated intersection, the layout should be relatively simple to avoid misconception of a divided road.

6.3 Compact Grade-separated Interchanges

Compact grade-separated interchange is a simple, low-speed grade-separated intersection layout. An example is illustrated in ***Figure 3.6.3.1***. In general only one overpass or underpass is required. They are appropriate for Class I roads with traffic volume between 12,500 and 30,000 veh/day. Intersecting traffic volume should be low, in the order of 10% or less of mainline traffic volume.

FIGURE 3.6.3.1 COMPACT GRADE INTERSECTION INTEGRATED INTO THE LOCAL ROAD NETWORK *(ref: Google Satellite, (driving is on the left side of the road))*

Compact grade-separated intersection should be integrated into the local road network with the objective of reducing the number of at-grade intersections on the Class I road and discouraging their use for short-distance local traffic. Their locations should be determined during feasibility stage of Class I roads, taking advantage of the topography to reduce the gradients of the intersecting road

Figure 3.6.3.2 Compact grade-separated intersection with Nearside-in Nearside-out Intersections

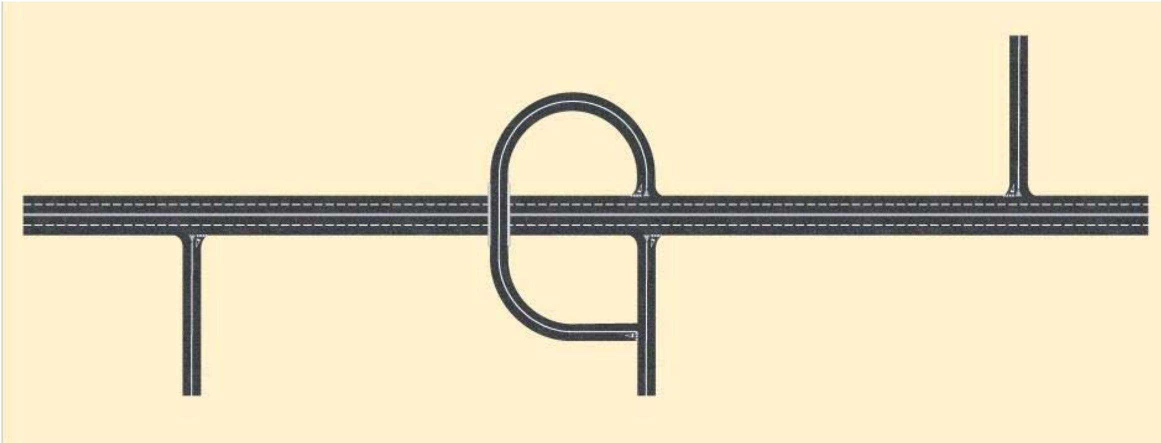
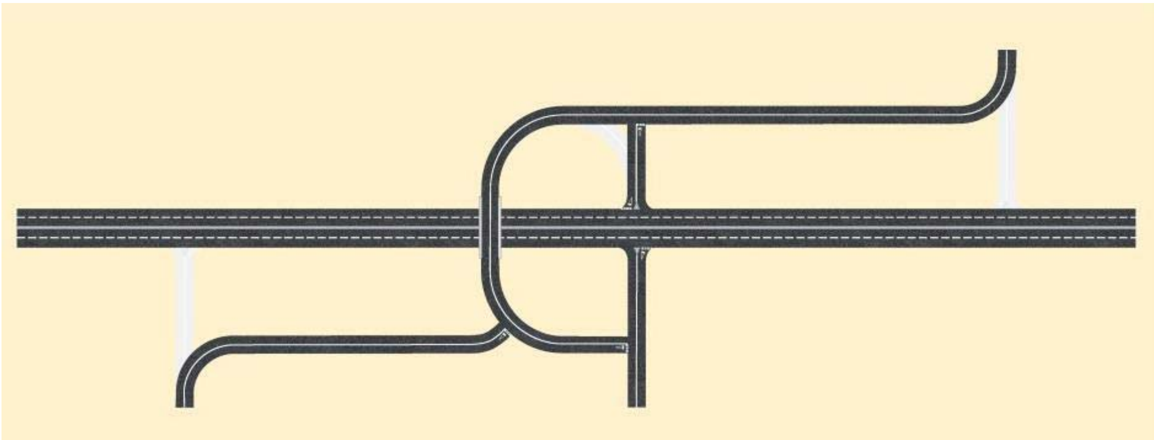


Figure 3.6.3.3 Integration of Compact grade-separated intersection with Local Road Network



Slip roads should be based on small radii curves, typically in the order of 40m for the design speed of 30km/h. The need for pedestrians and slow vehicles should be taken into account.

Nearside-in nearside-out intersections may be designed in simple layout where exit traffic has to slow down and entry traffic has to give-way to mainline traffic. Alternatively, deceleration and acceleration lanes may be incorporated. Special treatments will need to be provided if the paved shoulder on the main road is used for slow vehicles.

6.4 Prevention of Wrong-way Traffic

Inadvertent entry onto the wrong direction of Primary class and Class I roads could lead to head-on collisions with severe consequences. Certain layouts of intersections are more prone to wrong-way traffic. Exits from Primary class and Class I roads should be designed with adequate measures to minimise the risk of wrong-way traffic. Particular attention should be given to the followings:

- Grade-separated intersection, notably diamond layout
- Undivided loops
- Undivided road becoming a divided road

- Exit from service areas

The layout of grade-separated intersections should be designed to be obvious with wrong-way entry constrained by tight corner radius and preferably traffic islands or medians. Other essential measures include the followings:

- Keep right/left signs
- Arrow markings
- Directional signs
- No entry signs

At high risk locations, additional measures (***Figure 3.6.4.1***) may include the following items

- Repeater "No entry" signs on slip roads
- Incorporation of red colour reflector on alignment delineators facing wrong-way traffic
- Flexible self-restoring marker posts on centrelines ahead of the commencement of a divided road
- Widened shoulders or verges on slip roads as emergency refuges

FIGURE 3.6.4.1 DELINEATORS AND REPEATED NO-ENTRY SIGN AT A GRADE-SEPARATED INTERSECTION
(driving is on the right side of the road)

7 RAILWAY LEVEL CROSSINGS

7.1 General Requirements

Railway level crossing is a special type of intersection in the road network. In reality, the types of crossings are diversified with different railway types, layout and usage level. Railways may be used for passenger service, freight transport or both. In general, trains have priority over vehicles and pedestrians at level crossings.

Collisions between a train and a vehicle, pedestrian, slow vehicle or animal are potentially severe or catastrophic in terms of both casualties and property damage. This is due to the enormous mass of a train at elevated speeds and possible secondary consequences such as derailing or explosion. Overhead power cable is also a potential hazard.

The safety risk of railway level crossings vary with the type of roads and railways as well as the frequency of trains and volume of vehicles or pedestrians. A particular concern is drivers or other users taking the risk to cross despite warning signals, red signals and activated barrier gates. Such risk could be aggravated by long waiting time and passage of a second train on another track.

Grade-separated crossings should always be provided for new projects. For existing level crossings, the following strategy should be adopted:

- Elimination of level crossings
- Provision of safety systems commensurate with risk

Table 3.7.1.1 provides recommendations on railway level crossings for existing Asian Highway routes.

TABLE 3.7.1.1 SUITABILITY OF RAILWAY LEVEL CROSSINGS FOR EXISTING ASIAN HIGHWAY ROUTES

Railway Category	Typical Characteristics	Primary class	Class I*	Class II	Class III
High speed railway	> 160 km/h	X	X	X	X
Trunk railway	80- 160 km/h	X	X	##	#
Regional railway	60- 120 km/h	X	##	##	#
Light railway/Tramway	30- 70 km/h	X	#	^	^
Industrial spur railway	=< 60 km/h	X	#	^	^
Special low speed railway	=< 40 km/h	X	^	^	^

X not permitted
high priority for elimination
priority for removal
^ tolerated
* no level crossing should be permitted for Class I roads with speed limit exceeding 60km/h

Elimination of railway level crossings on Asian Highway routes may be achieved by:

- Rerouting of the railway
- Relocation of the railway on viaduct or underpass
- Rerouting of the road
- Relocation of the road on viaduct or underpass
- Decommissioning of obsolete crossings

7.2 Infrastructure

Railway level crossings should be located on straight sections of both the railway and the main road. This will avoid an uneven road surface due to superelevation of the railway and maximise approach visibility for vehicle traffic.

There are two primary types of railway level crossing: those crossing the main road and those crossing a side road. The latter case typically involves in a railway running parallel and alongside the main roads.

Adequate visibility at least equal to SSD should be provided on the approach to a railway level crossing. In the event of a crossing on the side road, a channelised protected turn lane is desirable for both offside and nearside turning traffic. This helps to define the approach to the crossing and provide space for the installation of signs, signals and safety equipment.

Adequate visibility distance is particularly important for traffic and pedestrians towards approaching trains on passive crossings or active crossings without barriers. Visibility could be blocked by stationary trains due to multiple tracks or presence of train station.

Railway level crossings located in the vicinity of an intersection including roundabouts may require additional provisions to minimise the risk of traffic queues blocking the crossing area.

Roads should be on gentle gradient at and on the immediate approach to a railway level crossing.

The paved area of the road through the crossing should be extended for at least 30cm beyond the road shoulder with additional provisions for pedestrians. A pedestrian bypass is preferred to reduce the hazard of vertical automatic swing gates.

The vicinity of a tramway and similar facilities should be free from rigid columns or constructions to avoid an errant vehicle being crushed in a collision which could be otherwise survivable.

7.3 Safety Facilities

For trunk and regional railways, a very high level of reliable safety facility will be needed. For other railways, appropriate safety facilities should be based on risk taking into account train volume, speeds and operational characteristics.

Active crossings are those involving equipped with warning and/or traffic control devices that gives warning of the approach or presence of a train. Passive crossings are those where only fixed signs or markings are provided. Only active crossings should be provided for railway level crossings involving trunk and regional railways, light transit railway and industrial spur lines with regular train usage.

Active crossings may be unmanned or manned. Unmanned crossings may be automatically or remotely controlled. In the absence of advance protection systems and increased risk of infringement, manned crossing would be a reliable solution in conjunction with impenetrable barriers.

Communication systems including dedicated telephones and loudspeakers could be desirable especially where the crossing is unmanned. Display of an emergency phone number and identification number of the crossings is also desirable.

Consideration should be given to advance railway level crossing protection systems for all major railways. A typical system consists of detectors, surveillance cameras, enforcement cameras in addition to signs, signals and barriers. Detectors include those automatically sensing approach trains and their speeds as well as abnormal conditions at the crossing.

The system consists of advance logic for optimum sequence of operation, reduced delays and timely rectification of problems.

Increasing level of automatic protection system would be justified by:

- inadequate clear sight distance
- regular passenger trains and frequent heavy vehicles
- high level of school buses, buses, hazardous transport
- multiple tracks
- possible obscuring by second train
- frequent trains
- high approach traffic speeds
- high traffic or pedestrian volume
- multi-lane roads

Signing and Delineation

Typical provisions at crossings are railway crossing signs (Crossbuck signs), Stop signs, Stop markings and informatory signs. No stopping signs or yellow box marking to deter waiting or stoppage may also be required. Road lighting is desirable, especially at crossing sites with frequent trains, high traffic volume and complex layouts.

Possible approach measures include signs showing signs showing “Prepare to stop”, warning signs for overhead cables, speed limit signs and speed reduction measures. These approach measures help to reduce the risk of rear-front collisions, damage to barriers and intrusion into the crossings.

For all major railways, traffic signals should be adopted and are preferably automatically enforced with red light cameras. In other situations, warning signals alone may be appropriate.

Flashing lights may be used to reinforce warning signs and informatory signs on the approaches. Audible signals should be considered if the crossing is regularly used by pedestrians.

Consideration should be given to overhead signs or signals where approach speeds are high and there are multiple traffic lanes.

Barriers

Barriers may be in the form of a vertical or horizontal swing gate. A full barrier system extends across the entire carriageway and a half barrier system only covers the approach traffic lane. Consideration should be given to providing a refuge between the barrier and rail tracks for a trapped vehicle.

Where there are concerns of violation by pedestrians, slow vehicles or passage of animals, consideration should be given to the use of an impenetrable full barrier system. This may be based on barriers with skirts or sliding trolley gates. Additional fencing may also be required around the crossing.

Half-barriers have less risk of trapping a vehicle on the crossing, but a major disadvantage is temptation for drivers to force their way through the unprotected gaps. To improve the safety of half barriers, it is advisable to deter approach traffic crossing the centreline with a median or non-traversable centreline delineation system.

At unmanned crossings, barriers are operated automatically. At manned crossings, barriers may be operated manually, with local control or automatically.

PART 4 ROADSIDE SAFETY

1 OVERVIEW

The planning and design of roadside safety is an interactive process forming part of the road infrastructure design. This process should target at the optimum combination of clear zones and vehicle restraint systems, taking into consideration the relative cost of earthworks and equipment as well environmental impacts. The process will need to cover the following elements:

1 Roadside Safety on Plan

- Sections with clear zones
- Sections with safety barriers or parapets
- Sections for special treatments e.g. toll plazas, tunnels and interfaces
- Locations of end treatments and transitions
- Location of diverge gores
- Treatments at intersections and interchanges

2 Roadside Safety by Cross-section

- Clear zones, paved shoulders and verges
- Drainage features
- General roadside features such as lighting columns, signage, fire hydrants etc.
- Specific roadside features such as bridge piers
- Safety barriers with respect to horizontal clearance and working widths

3 Drawings and Technical Specifications of vehicle restraint systems

This process should be based on speed limits or operating speeds and identification of specific hazards associated with the roadside conditions, adjacent land-use and the road alignment. Roadside safety strategy may be separately formulated for urbanised sections.

2 FORGIVING ROADSIDE

2.1 General Requirements

The main objective of a “Forgiving Roadside” is to minimise the risk of severe injuries and adverse secondary consequences when an errant vehicle leaves the carriageway. A forgiving roadside may be attained by:

- creation of clear zones
- management of aggressive roadside features
- use of vehicle restraint systems

The following procedures should be followed:

- Identification of aggressive roadside features
- Assessment of safety risks in terms of probability of roadside crashes and consequences
- Formulation of measures which may include removal, relocation or redesign of the features
- Decision on the best scheme
- Assessment of the residual risk and further improvement
- Documentation of the process

2.2 Clear Zones

A clear zone is a traversable roadside area to be clear of aggressive roadside features. It may be formed from a combination of paved shoulder, verge and side slope. The space for horizontal clearance also forms part of the clear zone.

The main purpose of clear zones is reduced risk of damage for an errant vehicle and injuries for the occupants. There is also less likelihood of an incident obstructing the main road and causing congestion or secondary events.

Where a clear zone cannot be satisfactorily provided, an appropriate vehicle restraint system should be considered. Otherwise, safety risks may be lowered by reducing traffic speeds.

Clear zones should be provided with proactive design of the roadside in new road projects. For existing roads, clear zones may be created by formation widening or local re-profiling of side slopes

General Requirements

The recommended width of clear zones is given in ***Table 4.2.2.1***.

TABLE 4.2.2.1 CLEAR ZONE WIDTHS [20]

Traffic Volume	Speed Limit			
	50 km/h*	60 km/h**	70-80 km/h	>= 90 km/h
0-1500	2.5m	3m	5 m	6m
1500-4000	3m	4 m	6 m	7m #
4000-12000***	4m	5m	7m#	8m #
> 12000	5m	6m	8m#	10m #

* Not including urbanised sections

** Lower values are acceptable on tree-lined boulevards

*** Traffic volume of 4000-12000 veh/day may be assumed for new and existing roads with no data

\# Minimum value of 6m may be acceptable for non-access-controlled roads where provision of the full value is not feasible

Where land and economic constraints are substantial, variable widths of clear zones may be adopted with priority given to the outside of curves. The clear zone is then established by a step-wise decision process taking into account site conditions, crash risks and the likely trajectory of an errant vehicle.

On roads with speed limit of 80km/h or above, a paved shoulder at least 0.5m wide (0.25 m minimum) should be provided in conjunction with a 3.5m lane. If there is a high volume of heavy vehicles, the width of the paved shoulder should be increased to at least 1.0m. The remaining width of the shoulder is preferably paved and at least hardened and stabilised for drivers to regain control during momentarily loss of control. Loose gravels, muds and leaves should not be present on the paved shoulder.

Road rehabilitation should not result in an edge drop exceeding 60mm in height. If there is any significant raising of pavement (***Figure 4.2.2.1***), the side slope should be re-profiled with gradients not exceeding 1:4. In addition, existing safety barriers may need to be raised or reconstructed to maintain the required height.

FIGURE 4.2.2.1 HAZARDOUS EDGE DROP DUE TO ROAD REHABILITATION
(driving is on the right side of the road)

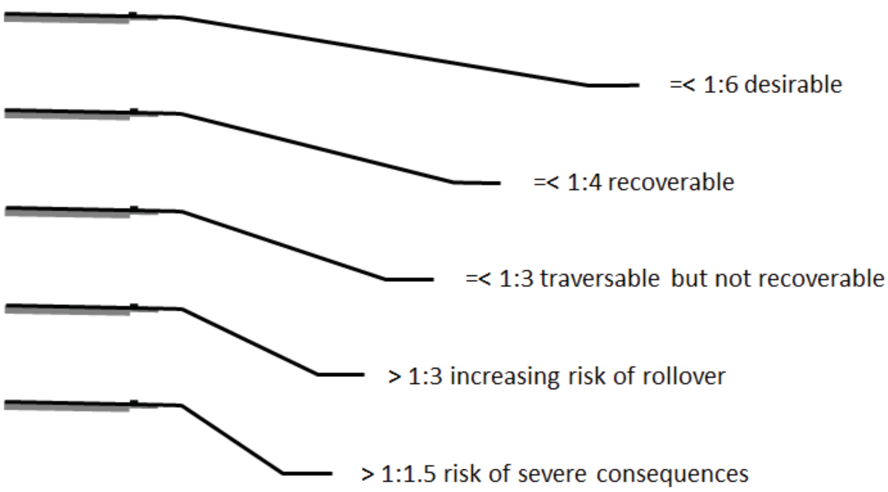
Clear Zones at Intersections

Turning at speeds or collisions between conflicting traffic streams at crossroads and T-intersections may result in vehicles crashing onto the corners of an at-grade intersection. The presence of aggressive roadside features and pedestrian activities at these locations could aggravate the consequences of such collisions. Consideration should be given to providing additional clear zones at intersection corners, setting back pedestrian paths and providing appropriate vehicle restraint systems over steep slopes or water bodies.

Embankment Side Slopes

The gradient of embankment side slopes is a key consideration for roadside safety design. This is illustrated in ***Figure 4.2.2.2***. Embankments with side slope gradient not steeper than 1:4 constitute a clear zone if they are free from aggressive features. Embankments between 1:3 and 1:4 constitute a clear zone only if their bottom is also free of aggressive features. Rugged rock-filled embankments are considered aggressive features irrespective of the gradient.

FIGURE 4.2.2.2 EMBANKMENT GRADIENT CLASSIFICATION



Opportunities for clear zones often exist on roads traversing relatively flat terrains. An example is illustrated in ***Figure 4.2.2.3***. However, side slopes may still need to be suitably re-profiled to ensure that roadside gradient is appropriate and free from excessive undulations.

FIGURE 4.2.2.3 OPPORTUNITIES FOR CLEAR ZONES ON GENTLE TERRAINS
(driving is on the right side of the road)

Side slope gradients of 1:1.5 or 1:2 are commonly adopted on embankments for economic and environmental reasons, but they can lead to rollover of an errant vehicle. This is illustrated in ***Figure 4.2.2.4***.

FIGURE 4.2.2.4 ROLLOVER OF A TRUCK ON 1:1:5 EMBANKMENT SIDE SLOPE
(driving is on the right side of the road)

Sheer Drops and Bridges

Roads in mountainous areas and along river gorges are often constructed alongside very steep and rugged side slopes or even sheer drops. An example is shown in ***Figure 4.2.2.5***. An errant vehicle running off the roadside is likely to roll over and fall down with severe deformation of the vehicle body and a high risk of fatalities for the vehicle occupants. The same concern also applies to sections of road on retaining structures, bridges and viaducts.

FIGURE 4.2.2.5 HAZARDOUS ROADSIDE SHEER DROP *(driving is on the right side of the road)*

Water Bodies

Water bodies include lakes, reservoirs, rivers, the sea, swamps, ditches, navigation channels etc.. An example is shown in ***Figure 4.2.2.6***. In principle, water bodies deeper than 0.5m are potentially hazardous. The actual risk should be assessed with respect to the likelihood of immersion and rollover when an errant vehicle runs off the road. Particular attention should be given to roads alongside deep water bodies and swiftly flowing rivers. The scenario of a bus falling into these water bodies also needs to be thoroughly considered.

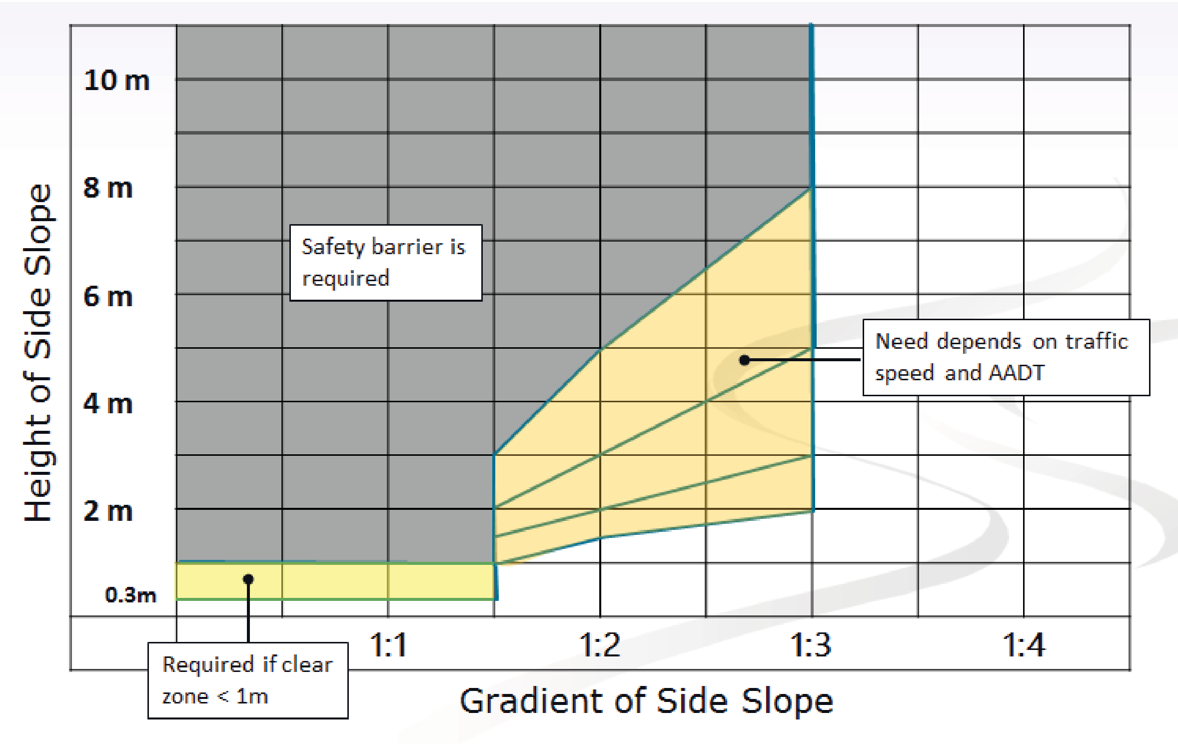
FIGURE 4.2.2.6 RIGID SAFETY BARRIER ALONGSIDE A LAKE *(driving is on the right side of the road)*

Requirements of Safety Barriers over Side Slopes

The need for safety barriers may be established from the gradient and height of embankment side slopes according to ***Figure 4.2.2.7***. Dense vegetation on side slopes may be able to safely contain an errant vehicle in some circumstances, but this would require engineering judgement on a case-by-case basis.

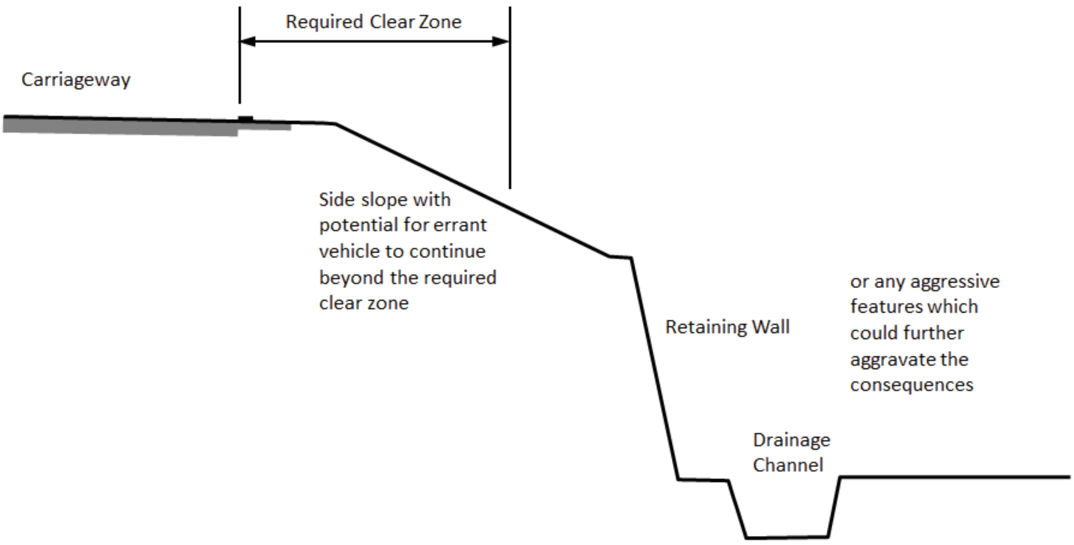
Side slopes not requiring a safety barrier should be free of aggressive features including concrete berms, drainage structures, isolated large trees or other rugged projections.

FIGURE 4.2.2.7 NEED FOR SAFETY BARRIERS OVER EMBANKMENT SIDE SLOPES [20]



Attention should be given to the possibility of an errant vehicle running down a relatively gentle side slope onto a sheer drop or colliding with aggressive roadside features at the bottom of the slope. This is illustrated in ***Figure 4.2.2.8***.

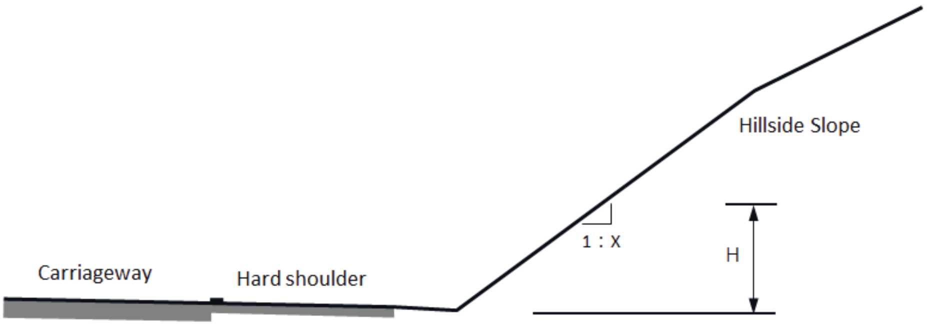
FIGURE 4.2.2.8 HAZARDOUS ROADSIDE BEYOND CLEAR ZONE



Uphill Side Slopes

Uphill side slopes with gradient not steeper than 1:2 are traversable forming part of the clear zone. Uphill side slopes steeper than 1:2 are non-traversable and only the bottom part is included as clear zone. This is illustrated in ***Figure 4.2.2.9***.

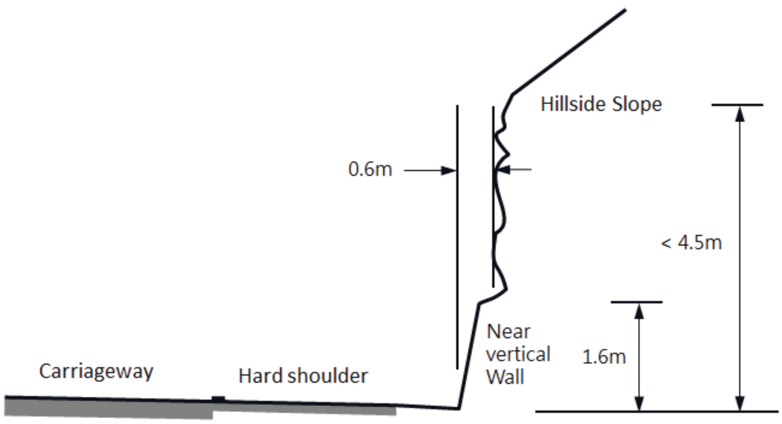
FIGURE 4.2.2.9 UPHILL SIDE SLOPES AND CLEAR ZONE



Uphill Side Slope Gradient	H
1:2	2.0m
> 1:2	1.6m

Retaining walls or steep continuous slopes are considered non-aggressive provided that the bottom part up to 1.6m is smooth without rugged projections exceeding 25mm in depth. This is illustrated in ***Figure 4.2.2.10***.

FIGURE 4.2.2.10 STEEP UPHILL SIDE SLOPE AND WALLS



Rock cuttings adjacent to the road should be treated to form a smooth slope face. There should not be any protruding rocks which could cause a vehicle to stop abruptly or impact onto vehicle occupants.

For rugged rock faces, the following treatments may be adopted:

- Install a safety barrier
- Provide a smooth toe wall at least 1.2m high
- Provide an earth bank at 1:1.5 gradient (***Figure 4.2.2.11***)

FIGURE 4.2.2.11 EARTH BANK AGAINST A ROCK CUTTING *(driving is on the right side of the road)*

Aggressive Roadside Features

Clear zones should be free of aggressive roadside features capable of:

- penetrating, crushing or abruptly stopping an errant vehicle
- destabilising or launching an errant vehicle into the air leading to rollover or falls
- collapsing or becoming projectiles leading to adverse secondary consequences

Typical roadside aggressive features include:

- Drainage features: culvert endings and headwalls, open ditches and their interface with covered drains, protruded maintenance covers
- Sign Posts, gantry columns, lighting columns, electricity poles
- Trees generally larger than 100mm in diameter
- Bridge structures, buildings and noise abatement facilities
- Boulders and exposed rock faces

Some roadside features entail the risk of secondary events which can be catastrophic:

- Railways including high speed railways
- Other roads including expressways
- Locations with crowds of pedestrians
- Electricity transmission pylons
- Environmentally sensitive sites

Attention should be given to the possible trajectory of an errant vehicle. Longitudinal ditches or ramp features may guide or launch an errant vehicle to collide with aggressive features.

Adequate consideration should be given to roadside features which are aggressive for motorcyclists and cyclists but not necessarily vehicle occupants.

The number and density of aggressive roadside objects should be systematically minimised with particular emphasis on curves and steep gradients. Wherever practical, bridges piers and large sign mounting structures should be avoided on narrow medians.

A high priority should be given to the guarding of substantial rigid objects. An example is shown in ***Figure 4.2.2.12***.

FIGURE 4.2.2.12 HIGHLY AGGRESSIVE UNGUARDED BRIDGE PIERS *(driving is on the right side of the road)*

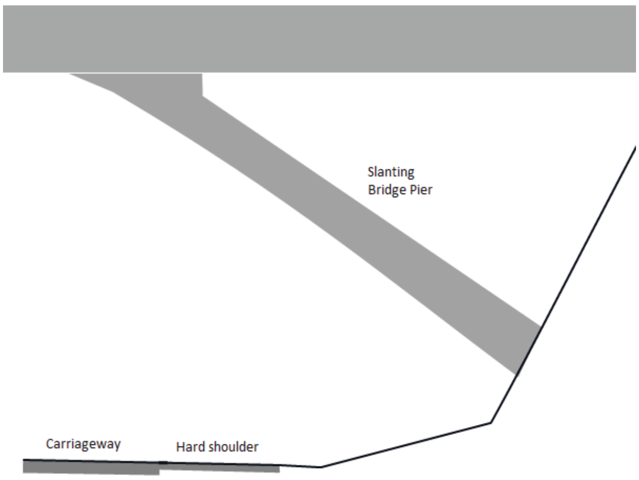
Outside built-up areas any aggressive features, inter alia, trees, utilities poles, sign mounting structures etc. which cannot be relocated or guarded by vehicle restraint systems, should be separated from the edge of carriageway by at least 3m in conjunction with a minimum horizontal clearance of 0.6m from the outside edge of the paved shoulder. In such circumstances, speed limits should be limited to 70km/h or below in conjunction with other active measures to enhance safety.

Massive decorations and landmark features along a main road and at the entrance of built-up areas should be positioned with adequate clear zone or guarded by vehicle restraint systems. Particular care is needed if these features are installed on traffic islands, roundabout central islands or diverge gores.

Overhanging Features

There are instances where overhanging or projecting constructions result in inadequate headroom over the shoulder or within the clear zone. Examples of such features include slanting bridge piers and staircase structures of footbridges. The scenario of a bus colliding with such features could be catastrophic. This is illustrated in ***Figure 4.2.2.13***.

FIGURE 4.2.2.13 POTENTIALLY HAZARDOUS SLANTING BRIDGE PIER



Utility Poles

Roadside utility poles and lighting columns are aggressive features and therefore should be located outside clear zones or else guarded by safety barriers. Where this is not feasible, the following strategy should be adopted on roads with speed limit of 60km/h or above:

- Reducing their density
- Positioning them at least 3m from the edge line with adequate horizontal clearance
- Avoiding their placement along ditches, on the outside of curves, on medians or at the corners of intersections

Passively Safe Roadside Structures

Passively safe roadside structures may be used without safety barriers if the following conditions are satisfied:

- The surrounding roadside constitutes a clear zone
- Collapse of the structure is unlikely to incur significant secondary hazards to other road users i.e. pedestrians, cyclists, occupants of other vehicles etc.

The following roadside structures are deemed to be passively safe for vehicles:

- Steel or aluminium posts of 89mmØ and 3.2mm thick, or smaller sections, at spacing larger than 750mm
- Passively safe structural posts to EN 12767 (EU) or equivalent standards (***Figure 4.2.2.14***)

Given their general availability, the above steel posts of 89mmØ or smaller sections should be systematically utilised for the majority of traffic signs and smaller directional signs.

FIGURE 4.2.2.14 PASSIVELY SAFE SIGN STRUCTURE IN ALUMINIUM TRUSS
(driving is on the right side of the road)

The specific needs of cyclists or motorcyclists should also be addressed by adopting flexible, self-restoring delineator posts or sign posts, particularly where there is increased risk for these users at curves and extremities of traffic islands. An example is given in ***Figure 4.2.2.15***.

FIGURE 4.2.2.15 PASSIVELY SAFE SIGNS ON A TRAFFIC ISLAND

2.3 Drainage Features

Aggressive drainage features could be detrimental to road safety if an errant vehicle runs off the road. The main concerns are drainage features lying within the clear zone of high speed roads, including:

- Open ditches, channels and outfalls
- Culvert endings, culvert headwalls, drop inlets
- Embankment berms

Open ditches and channels may cause an errant vehicle to roll over or be immersed in water. Roadside ditches may also guide a vehicle to collide with roadside objects such as the end terminal of a parapet.

Culvert endings and headwalls are potential hazardous objects in a collision. Cyclists and motorcyclists are also prone to serious injuries if they run into open ditches in rigid construction and with sharp edges.

Safety issues of drainage features on high speed roads should be addressed in the early stage of design. The risks may be minimised with the following approach:

- Reducing the number and extent of exposed drainage features
- Adopting safer ditch profiles with shallow depth, gentle side walls and rounding of edges
- Adopting piped drainage or providing covers for ditches
- Providing grille covers over culvert endings
- Modifying the shape and height of culvert headwalls
- Restricting the height of drop inlets below 100mm
- Providing safety barriers

Open Ditches

The main types of open ditches are V Channels, trapezoidal channels and rectangular channels. These are illustrated in ***Figure 4.2.3.1***.

FIGURE 4.2.3.1 COMMON TYPES OF OPEN DITCHES

On roads with speed limit exceeding 80km/h, V channels and trapezoidal channels should be traversable with gentle foreslopes and backslopes. The recommended parameters are given in ***Table 4.2.3.1***. These channels may be placed in front of, behind or across safety barriers.

TABLE 4.2.3.1 DIMENSIONS FOR V CHANNELS AND TRAPEZOIDAL CHANNELS *(Speed Limit > 80km/h)*

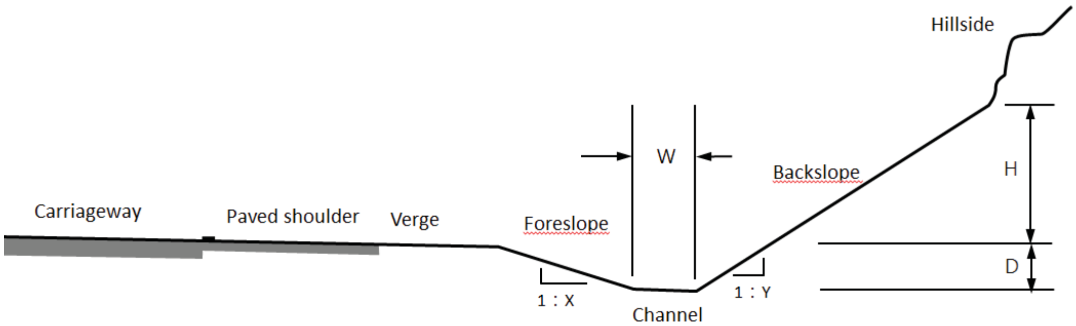
	Foreslope		Backslope		Depth
	Recommended	Maximum	Recommended	Maximum	
V Channel	=< 1:5	1:4	=< 1:5	1:4	=< 150mm
Trapezoidal Channel	=< 1:4.5	1:4	=< 1:4.5	1:4	=< 150mm

On roads with speed limit of 80km/h or below, steeper foreslopes and backslopes may be used with a deeper ditch. This is given in ***Table 4.2.3.2***. It is recommended that the ditch is constructed with rounded corners and preferably vegetated with grass.

TABLE 4.2.3.2 DIMENSIONS FOR TRAPEZOIDAL CHANNELS

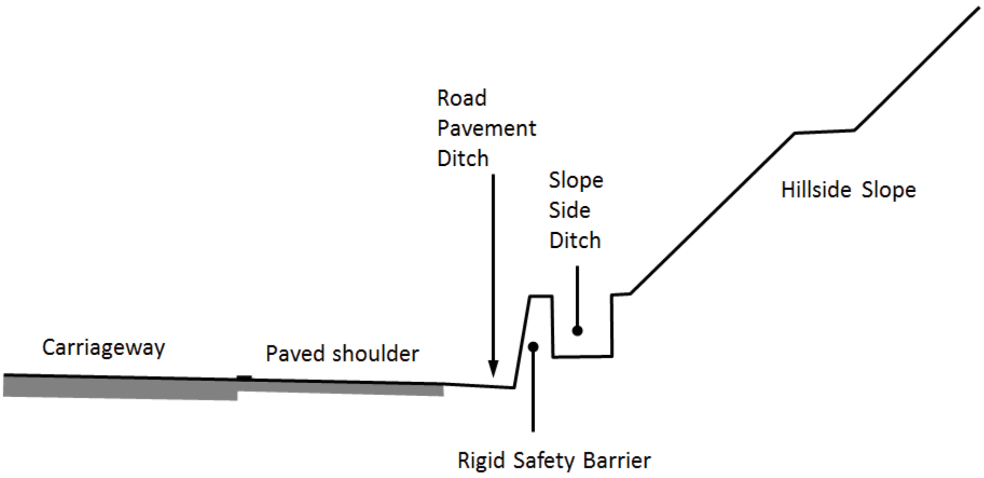
Foreslope		Backslope	D	W	H
Recommended	Maximum				
=< 1:4	1:3	1:2	0.3m (0.6m)	0.2m-0.5m	1.8m
=< 1:4	1:3	>= 1:1.5	0.3m-(0.6m)	0.2m-0.5m	1.4m

0.6m may be used for speed limit =<80km/h



Where roadside space is constrained, rectangular drainage channels may be guarded by safety barriers, covered up or buried beneath soil. Alternatively, it is possible to integrate a safety barrier with the drainage channel. This is illustrated in ***Figure 4.2.3.2***.

FIGURE 4.2.3.2 ALTERNATIVE DRAINAGE DESIGN AT HILLSIDE SLOPE

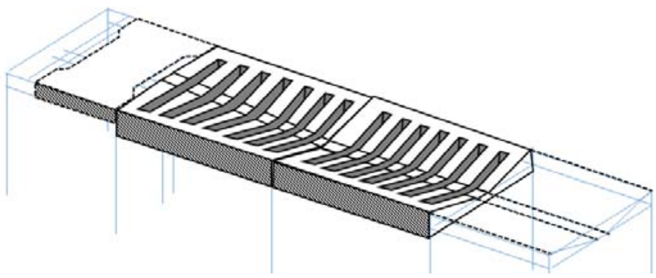


Culverts and Outfalls

Culverts and outfalls likely to be reached by an errant vehicle should be adequately treated to minimize potential hazardous outcome. For larger culverts on side slopes, a grille cover is desirable to render the area traversable.

Similarly, the transition between an open ditch and a covered ditch or a piped culvert should not cause an errant vehicle to jump or stop abruptly. A possible solution is illustrated in ***Figure 4.2.3.2***. The gradient at the transition is desirably not steeper than 1:8.

FIGURE 4.2.3.2 TRANSITION FROM OPEN DITCH TO COVERED DITCH



2.4 Diverge Gores

At diverging areas, the pavement occupied by chevron markings should have a smooth profile without an abrupt change of pavement slope or drop in levels. Additionally, diverge gores should have forgiving design in the form of a clear zone at least 20m in length. The ground profile of the clear zone should be gentle in gradient and free of aggressive features including sign posts, lighting columns, drainage structures and ditches unless these are traversable or passively safe.

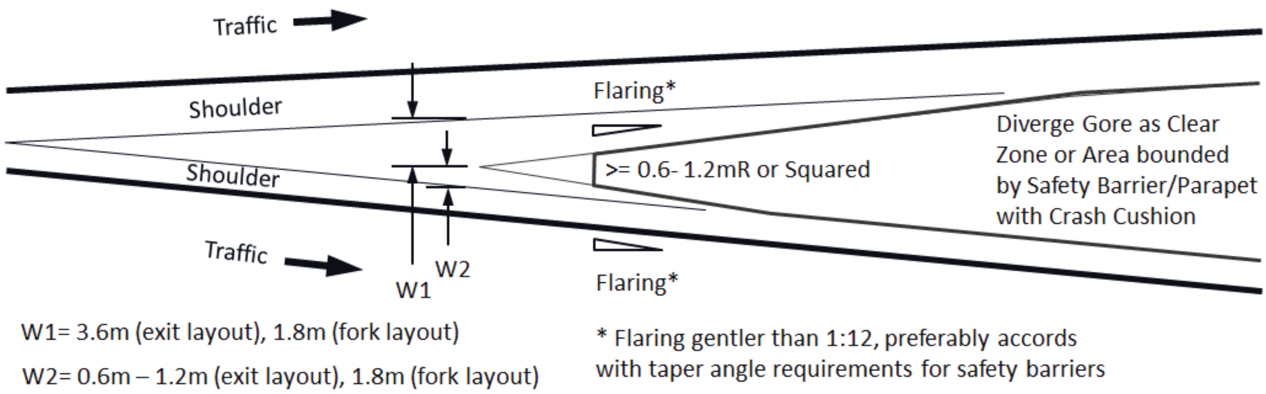
An example of treatment for a wide diverge gore is illustrated in ***Figure 4.2.4.1***. If this is not achievable due to lack of space or inevitable aggressive features, a crash cushion may need to be provided.

FIGURE 4.2.4.1 DIVERGE GORE IN CLEAR ZONE WITH MARKER SIGN ON PASSIVELY SAFE POST
(driving is on the right side of the road)

Wherever feasible, a flared layout as shown in Figure 4.2.4.2 should be considered for the following reasons:

- Reduced size of the hazard
- A more favourable recovery path
- Lower risk of errant vehicles reaching the gore
- Space for proper installation of crash cushion

FIGURE 4.2.4.2 FLARED DIVERGE GORES *(ref: AASHTO， 2011)*



3 VEHICLE RESTRAINT SYSTEMS

3.1 General Requirements

Vehicle Restraint Systems (VRS) are installed for the following purposes:

- Containing a vehicle departing from the normal path of travel, thereby preventing adverse consequences such as collision with bridge piers, oncoming traffic or falling off a sheer drop
- Redirecting the errant vehicle to recover its path
- Absorbing impact energy, controlling the vehicle to slow down or stop thereby minimizing injuries and harm

VRS are tested on the basis of containment level, vehicle occupant injury severity, redirective performance, vehicle stability and other applicable criteria. A particular containment level generally requires the concurrent testing of two or more vehicle types with separately specified impact speed and angle. VRS designed to contain heavier vehicles will also need to have satisfactory performance for light vehicles.

Standards from the United States and the European Union are widely recognized and quoted. Many fundamental principles for VRS testing were laid down in the National Cooperative Highway Research Program Report No. 350 (NCHRP Report 350) of the United States. In the European Union, the key applicable reference is European standard EN1317.

Since 2009, the “Manual for Assessing Safety Hardware” (MASH) was introduced in the US to provide an update to and supersedes NCHRP Report 350. New VRS are now tested to MASH but existing VRS and the use of VRS already tested to satisfy NCHRP Report 350 may continue to be used. Among the various changes, MASH requires testing of safety barriers at 25 degrees instead of 20 degrees. The weight of cars and pick-up trucks were also increased.

Vehicle Types and Composition

The types and performance of VRS, particularly safety barriers, should be specific to the composition of vehicle types, maximum permissible weights, operating conditions and vehicle law in different countries. ***Table 4.3.2.1*** illustrates the contrasting requirements for safety barriers in the United States, European Union and China.

Chinese standard JTG B05-01-2013 illustrates the need to address the prevalence of buses and very heavy vehicles which may also be the case in many Asian countries. The main features of adaptations include:

- Various categories of buses weighing 10t to 25t at impact speed up to 85km/h
- Heavy trucks of 55t at impact speed up to 65km/h
- Containment level at low to moderate impact speeds (40-60km/h)

Similarly, the need for adaptation is demonstrated in the design standards of Hong Kong which feature safety barriers and parapets to contain a 22t double decker bus with risk-based scores for their deployment.

Considerations for the composition of vehicle types and operating conditions should take into account changes and trends due to economic growth and international cross-border traffic on Asian Highway routes.

TABLE 4.3.2.1 COMPARISON OF KEY TEST REQUIREMENTS FOR SAFETY BARRIERS

Parameters	MASH	EN1317	JTG-B05-01-2013
Car	0.7t, 1t, 2.27t	0.9t, 1.3t, 1.5t	1.5t, 6t
Bus	Not specified	10t, 13t, 16t	6t, 10t, 14t, 18t, 25t
Trucks	10t, 36t	30t, 38t	6t, 10t, 18t, 25t, 33t, 40t, 55t
Impact Angle	25 degrees	20 degrees	20 degrees
Speed Range	50-100km/h	65- 110km/h	40- 100km/h
Crash Energy	Not available	41- 725kJ	40- 760kJ

3.2 Roadside Safety Barriers

Safety barriers are longitudinal vehicle restraint systems provided on the roadside to contain and smoothly redirect an errant vehicle. They may be of generic design or proprietary products. There are three main categories:

- Flexible systems
- Semi-rigid systems
- Rigid systems

Parapets are rigid systems installed on a bridge or retaining structure. In general, concrete safety barriers with suitable reinforcement and a proper foundation are rigid systems which do not deflect. They become semi-rigid systems if free-standing or without a proper foundation.

In addition to conventional safety barriers, new systems are ever undergoing development. Examples are passively safe bollards, tree guards, single pole guards and motorcycle protection equipment or accessories for safety barriers

Applications

Safety barriers should be considered where clear zones cannot be satisfactorily provided. Their need may be evaluated initially in terms of roadside conditions and approach speeds with priority given to:

- Traffic speeds >= 70km/h
- horizontal curves less than 250m radius on Primary class or Class I roads
- horizontal curves less than 150m radius on Class II or Class III roads
- road sections on and at the bottom of long steep downhill grades

Priority may be further given to the following circumstances:

- Two or more similar crashes in one year at a location where safety barrier would be beneficial
- Highly aggressive features such as bridge piers and tunnel portals with inadequate horizontal clearance or at a vulnerable frontal position
- Sheer drops or water bodies in close proximity to the carriageway
- Outside of sharp bends lacking clear zones
- Long straight section leading to a small radius bend
- Outside of sharp bend at the bottom of road sections on steep gradient
- Presence of crowds of people
- Hazardous roadside conditions with scheduled buses or along tourist routes

Safety Barrier Types

Safety barrier types should satisfy the requirements given in MASH (US), EN1317-2 (EU) or equivalent national standard. ***Figure 4.3.2.1*** shows the shape of common safety barrier types. ***Tables 4.3.2.1*** and ***4.3.2.2*** provide a summary of their typical performance. Actual performance depends on design details and is subject to crash testing.

FIGURE 4.3.2.1 COMMON SAFETY BARRIER TYPES

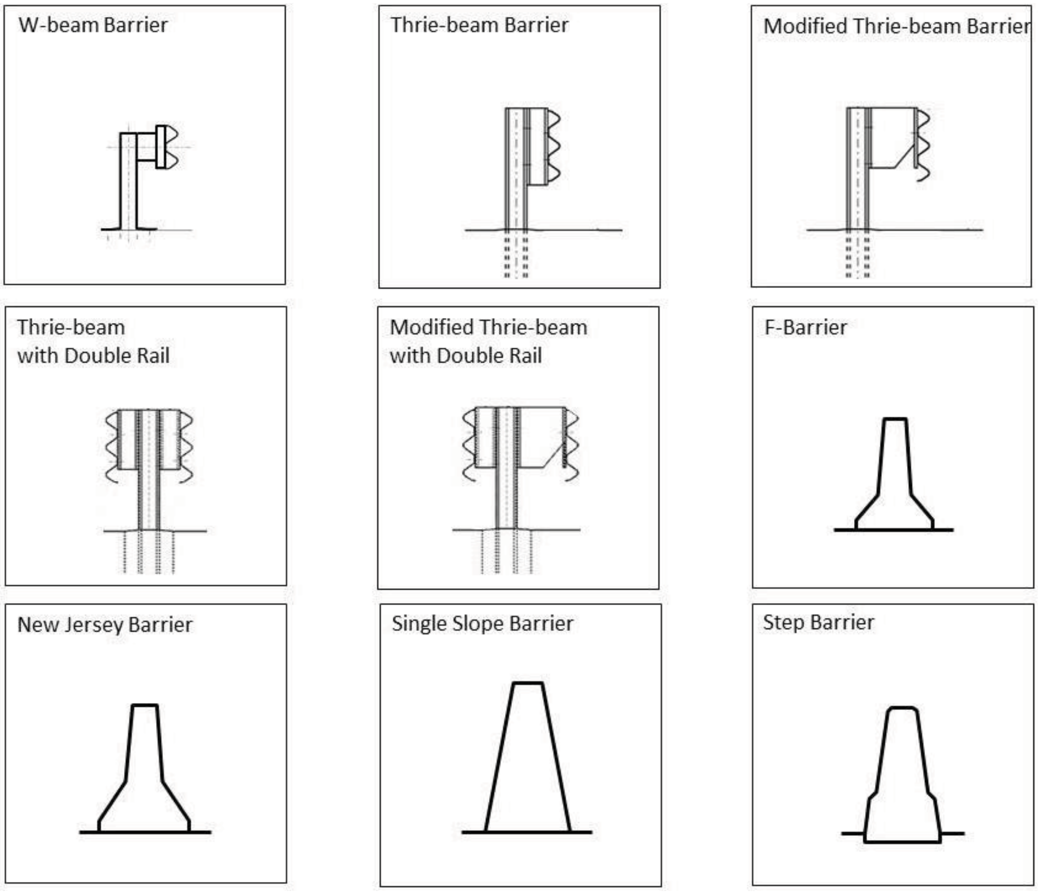


TABLE 4.3.2.1 TYPICAL SAFETY BARRIER PERFORMANCE

Safety Barrier Type	Category	MASH	EN1317-2			Note
			Containment Level	Working Width*	ASI^	
Flexible and Semi-Flexible Systems						
Wire Rope barrier	Flexible	TL-3	N2/H1	W4-W8	A	Need for substantial space for dynamic deflection
Box-beam barrier	Semi-flexible	TL-2/TL-3	N2	W1-W5	A	Susceptible to penetration and rollover for larger vehicles
W-beam barrier	Flexible/Semi-flexible	TL-2/TL-3/TL-4	N2/H1/H2	W2-W6	A	Susceptible to penetration and rollover for larger vehicles
Thrie-beam barrier	Semi-flexible	TL-3/TL-4	No data	W4-W5	No data	
Modified Thrie-beam barrier	Semi-flexible	TL-3/TL-4	No data	W4-W5	No data	Suitable for larger vehicles
Thrie-beam or Modified Thrie-beam barrier with rails on both sides	Semi-flexible	TL-5	H2	W4-W6	No data	Suitable for heavy vehicles; Modified Thrie-beam barrier on the traffic face is preferred for larger vehicle
Rigid Systems: Concrete Safety Barriers						
Low profile barrier	Rigid	TL-2	No data	W1-W2	No data	
New Jersey Barrier	Semi-rigid/Rigid	TL-3/TL-4/TL-5	H2/H3	W1-W2	B/C	More potential for rollover of light vehicles
F-barrier	Semi-rigid/Rigid	TL-4/TL-5	H2/H3	W1-W2	B/C	Less potential for rollover of light vehicles
Vertical barrier	Semi-rigid/Rigid	TL-4/TL-5	H2/H3	W1-W2	B/C	More potential for redirection onto oncoming vehicles
Single slope barrier	Semi-rigid/Rigid	TL-4/TL-5	H2/H3	W1-W2	B/C	
Step barrier	Semi-rigid/Rigid	TL-4/TL-5	H2/H3	W1-W2	B/C	Less potential for rollover of light vehicles
Very high containment barriers	Rigid	TL-5/TL-6	H4a/H4b	W1-W2	B/C	

* Typical range for reference only, working widths vary with system details

^ Accident Severity Index (A, B, C in order of higher potential for severe injury)

TABLE 4.3.2.2 TYPICAL SAFETY BARRIER DIMENSIONS*

	Roadside	Median	Height	Post Spacing
	Single Face Width	Double Face Width**		
Flexible and Semi-Flexible Systems				
Wire Rope barrier	94mm	113mm	780mm-900mm	3.2m
W-beam barrier	150mm-600mm	660mm	730mm-780mm	1m- 4m
Thrie-beam barrier	500mm	700mm-	875mm	1m- 4m
Modified Thrie-beam barrier	600mm	1110mm	900mm	1m-2m
Thrie-beam or Modified Thrie-beam barrier with rails on both sides	310mm-510mm	620mm-1020mm	875mm	2m
Rigid Systems: Concrete Safety Barriers				
Low profile barrier	No data	No data	400mm- 510mm	-
New Jersey Barrier	470mm	610mm- 820mm	810mm-1070mm	-
F-barrier	600mm	610mm- 820mm	810mm-1070mm	-
Vertical barrier	600mm	600mm	700mm-1070mm	-
Single slope barrier	No data	610mm	810mm-1070mm	-
Step barrier	No data	540mm	900mm	-

* Dimensions are only for indication and depend on design

** Double face safety barriers may be used at medians or on the roadside

Tables 3.3.2.3 and ***3.3.2.4*** are additional considerations for the use of typical safety barrier types.

TABLE 4.3.2.3 GENERAL CONSIDERATIONS FOR USAGE OF TYPICAL SAFETY BARRIER TYPES

Type	Category	Advantages	Disadvantages	Containment Level	Working Width
Cable	Flexible	- Reusable and readily reparable - Provide good visibility with minimum visual impacts - High flexibility of installation	- Limitation on small radius curves - Some concerns for injuries to motorcyclists and cyclists - Proprietary products	Possible to contain heavier vehicles if specified	1.0m to 2.8m (High tension) up to 3.5m (Low tension)
Box-beam	Semi-rigid	- Narrow and pleasing appearance - Minimum blockage of view - Suitable for areas of heavy snow	- Limitation on small radius curves	Mainly for light vehicles	0.6m to 1.7m
W-beam	Flexible/ Semi-rigid	- Lower installation costs - Relatively flexible placement criteria - Less injury potential	- Damage upon impact - Deflection distance is required - Vehicle damage	Mainly for light vehicles	0.6m to 1.2m (Strong post) 1.5m to 2.1m (Weak post)
Thrie-beam	Semi-rigid	Similar to W-beam	Similar to W-beam	Suitable for larger vehicles with modified design	1.0m to 1.7m
Concrete or Steel	Semi-Rigid*/ Rigid	- Minimal damage due to impact - Little or no deflection - Less vehicle damage at low angle impact	- Higher installation costs - More injury potential - Stricter placement criteria - Blocking of view - Storm drainage may be needed	Suitable for all vehicles including heavy vehicles	0.6m if rigid

* if free standing

TABLE 4.3.2.4 SPECIAL CONSIDERATIONS FOR USAGE OF TYPICAL SAFETY BARRIER TYPES

Safety Barrier Type	Small radius curves	Visibility and comfort	Areas with heavy snow	Narrow roadside	Sections with large differential settlement	Long straight sections	High risk sections, sheer drops and bridges
Cable	?	**	**	*	**	*	?
Box-beam			**	?			?
W-beam				?			?
Thrie-beam				?			**
Concrete or Steel	?	?	?		?	**	**

** very suitable * suitable ? potential problems or inadequacies

Selection of Safety Barrier Types

Selection of safety barrier types should be based on the likelihood of roadside crashes and their consequences. Other considerations are economics, roadside conditions and the number of transitions between different barrier types. ***Table 4.3.2.5*** provides some general guidance.

TABLE 4.3.2.5 GENERAL GUIDANCE ON SELECTION OF ROADSIDE SAFETY BARRIERS

Containment Level		Typical Applications
MASH	EN1317-2	
TL-2	N1	- Speed Limit =< 60km/h and traffic volume =< 12,000 veh/day - Speed limit >=70km/h and traffic volume =< 1,500 veh/day
TL-3	N2	- Primary class roads and Class I roads with roadside of moderate risk - Along loops at grade-separated intersections with roadside of moderate risk - Speed limit =< 80km/h with low to moderate volume of heavy vehicles
TL-4	H1/L1/H2/L2	- Primary class and Class I roads with roadside of moderate to high risk - Sections of roads with speed limit =<70km/h: - over bridges, retaining walls or sheer drops higher than 4m - over high risk water bodies - where collisions with roadside features would have severe consequences
TL-5	H2/L2/H3/L3 H4a/H4b/L4a/L4b	- Sections on Primary class roads and other roads with speed limit >= 80 km/h and high volume of heavy vehicles or buses, where the risk of running off the road is greater than usual with potentially very severe consequences - Where collapse or serious damage to roadside structures could lead to severe secondary consequences - On bridges and over sheer drops of significant height - On bridges that cross railways, and along roads where railways lie in the proximity
TL-6	H4a/H4b/L4a/L4b	- Over or adjacent to major or high speed railways and areas with potential for catastrophic secondary events - On high bridges and over sheer drops along Primary class roads with high volume of heavy vehicles or buses

The use of flexible or semi-rigid safety barriers with containment level in the region of TL-3 and TL-4 to (MASH) or N2 to H2 (EN1317-2) is sufficient for the majority of roadside conditions with moderate risks. Thrie-beam safety barriers have higher containment level and therefore are preferred with frequent buses or high volume of heavy vehicles.

Higher containment levels should be adopted if there is an increased risk e.g. due to high proportion of buses, heavy vehicles, sharp curves, long steep grades, icy conditions etc. For medians and embankments of moderate heights, containment level of TL-4 (MASH) or H2 (EN1317-2) are generally recommended.

Containment levels of TL-5 (MASH), H3 (EN1317-2) or higher are generally required to prevent a fully loaded bus from breaking through the safety barrier in very high risk situations including bridges and sheer drops. Where there is a high risk of catastrophic consequences such as a container truck falling onto a railway track, containment levels of TL-6 (MASH) or H4a/H4b (EN1317-2) should be adopted.

An errant vehicle may collide with the roadside perpendicularly or at high impact angles for certain road layouts such as very sharp curves, roads ending at a T-junction or roundabout central islands. Yet safety barriers may be needed at these locations due to presence of bridges, sheer drops or other roadside risks. The type and layout of safety barriers will need to be carefully balanced between injury potential for vehicle occupants and the consequences of the vehicle breaking through the barrier. It is advisable that comprehensive treatments are adopted to lower the overall risk.

Consequences

A bus rolling over, falling off a slope or colliding with rigid constructions could lead to very serious consequences involving multiple fatalities. This is due to their generally fragile vehicle body, lack of crumple zones and lower level of seat belt usage.

Where a safety barrier of lower containment level is deemed adequate, the consequences of a bus overcoming the barrier should be assessed for the following scenarios:

- Overturning onto aggressive ground features or structures
- Colliding with significant rigid or projected constructions
- Falling off high slopes, sheer drops or into deep water bodies

The following measures may be beneficial to reduce the severity of such consequences:

- Gentle ground profiles free of highly aggressive features beyond the safety barrier
- Double protection with a more flexible barrier on the inside of a rigid barrier

Length of Need

The "Length of Need" (LoN) is the required minimum length of safety barrier with full height and strength to shield an aggressive roadside feature. LoN should be determined in one direction for divided roads and both directions for undivided roads.

For general roadside aggressive features, LoN may be specified in accordance with ***Table 4.3.2.6***.

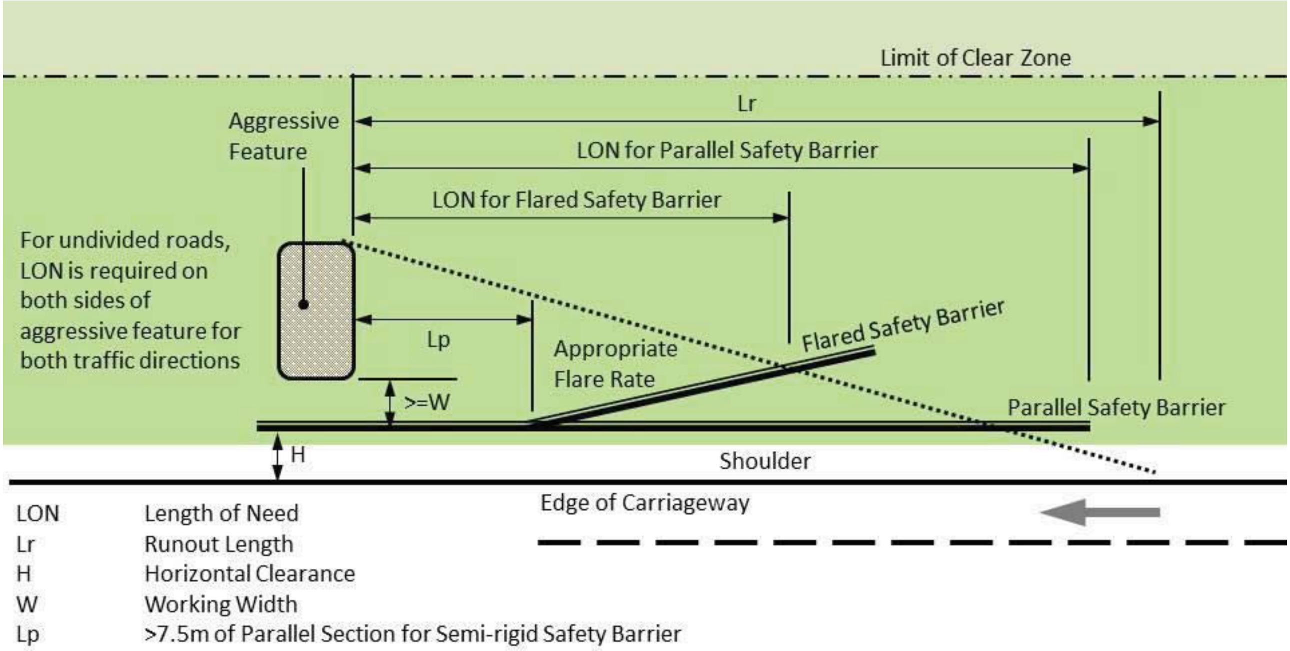
TABLE 4.3.2.6 NOMINAL VALUES OF LENGTH OF NEED [21]

Containment Level	Ahead of feature	Beyond feature
Normal	30m	7.5m
High	30m	10.5m
Very high	45m	18m

For wide, complex or highly aggressive features, LoN should be established from calculations according to ***Figure 4.3.2.1***. It should be noted that:

- End treatments are excluded from LON for semi-rigid systems
- Semi-rigid safety barriers are preferably positioned further away from the carriageway to reduce the likelihood of collisions
- Rigid safety barriers are preferably positioned closer to the carriageway to limit injury severity due to high angle impacts
- At least 7.5m of semi-rigid safety barrier ahead of the feature should be parallel to the carriageway

FIGURE 4.3.2.1 DETERMINATION OF LENGTH OF NEED [22]



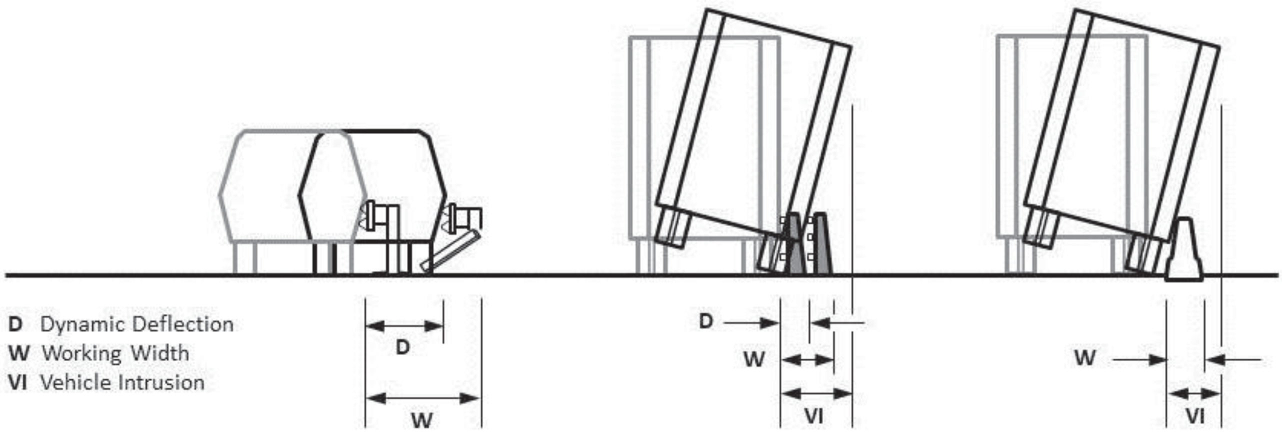
Design Speed (km/h)	Lr (m)
120	160 (130)
100	130 (105)
80	100 (80)
60	70 (55)

( ) for low to moderate traffic volume

Working Width

Adequate lateral space is required relative to roadside aggressive features in order to prevent an errant vehicle colliding onto the safety barrier to reach the feature. The various terms according to EN1317-2 is illustrated in Figure 4.3.2.2.

FIGURE 4.3.2.2 DEFINITION OF TERMS IN EN1317-2



Working width is specific to safety barrier types ranging from less than 0.6m for a rigid system to 3.5m for a flexible system. Working width class to EN1317-2 is given in ***Table 4.3.2.7***.

TABLE 4.3.2.7 WORKING WIDTH DEFINITION TO EN1317-2

Working Width Class							
W1	W2	W3	W4	W5	W6	W7	W8
=<0.6m	=<0.8m	=<1.0m	=<1.3m	=<1.7m	=<2.1m	=<2.5m	=<3.5m

Safety barriers should be set back from the carriageway with a horizontal clearance. Unless there are no other feasible solutions, installation of safety barriers should not normally result in a reduction of shoulder width at any location.

A minimum width of 600mm is needed between the back of a semi-rigid barrier and the top edge of a steep embankment in order that adequate passive resistance can be developed by the posts. In case of difficulties to achieve the above width, taller mounting posts up to 2.5m in lengths should be adopted.

Taper Angle

While safety barriers are generally parallel to traffic lanes, they may be aligned at an angle facing traffic in the following circumstances:

- In line with changes of cross-section of the road
- Flared layout forming part of an end treatment
- Downstream of accesses and merging lanes
- Downstream of openings for emergency or maintenance use

Taper angle should be controlled to reduce the risk of an errant vehicle colliding with the safety barrier at impact angles beyond the tested limit or being redirected towards opposing traffic.

TABLE 4.3.2.3 TAPER ANGLE OF SAFETY BARRIERS [22]

Design Speed (km/h)	Shy line Ls (m)	Maximum Taper within shy line	Maximum Taper beyond shy line	
			Rigid System	Semi-rigid System
120	3.2	1:33	1:22	1:16
100	2.4	1:26	1:18	1:14
80	2.0	1:21	1:14	1:11
60	1.4	1:16	1:10	1:8
50	1.1	1:13	1:8	1:7

For semi-rigid W-beam barriers, an angle of 1:5 may be acceptable beyond shy line if heavily dictated by site constraints.

Parapets

Bridge parapets are safety barriers installed on highway structures including bridges and retaining walls. A major objective for their installation is to constrain an errant vehicle from falling off the structure.

In general rigid parapets are preferred as they are more capable of containing larger vehicles. Admittedly this could lead to higher severity of vehicle occupants. If a parapet is deformable, it should be verified that the wheel of an errant vehicle is unlikely to intrude beyond the edge of the bridge structure as this could lead to rollover.

The extent and end treatment of bridge parapets should take into account the possible trajectory of an errant vehicle at the approach to the structures. In this respect, the parapet should be extended upstream or else connected to an upstream safety barrier of appropriate containment level with a transition.

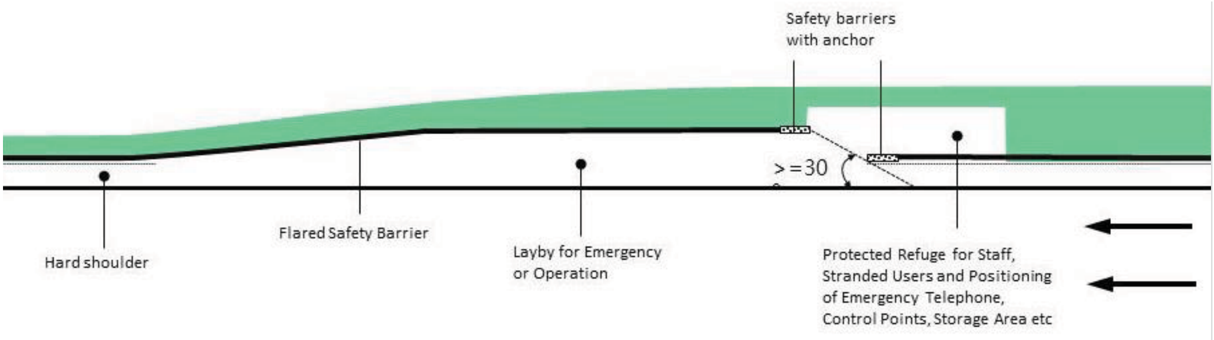
Where bridges or viaducts with high traffic volume are located above places where crowds gather- school entrances, markets, public transport facilities etc., it is advisable to provide a mesh or cover sheeting along parapets to contain loose stones or debris from dropping off the road.

Openings along Safety Barriers

Openings may be required along safety barriers to provide a refuge or to facilitate maintenance and management. Where openings are provided, the arrangement should prevent an errant vehicle leaving the road at 30 degrees to collide with the end terminal of the downstream safety barrier. This is illustrated in ***Figures 4.3.2.3*** and ***F4.3.2.3***. This arrangement does not apply for bidirectional roads where an errant vehicle may crash from either direction.

FIGURE 4.3.2.3 OPENINGS ALONG SAFETY BARRIERS

(for driving on the right side of the road)



(for driving on the left side of the road)

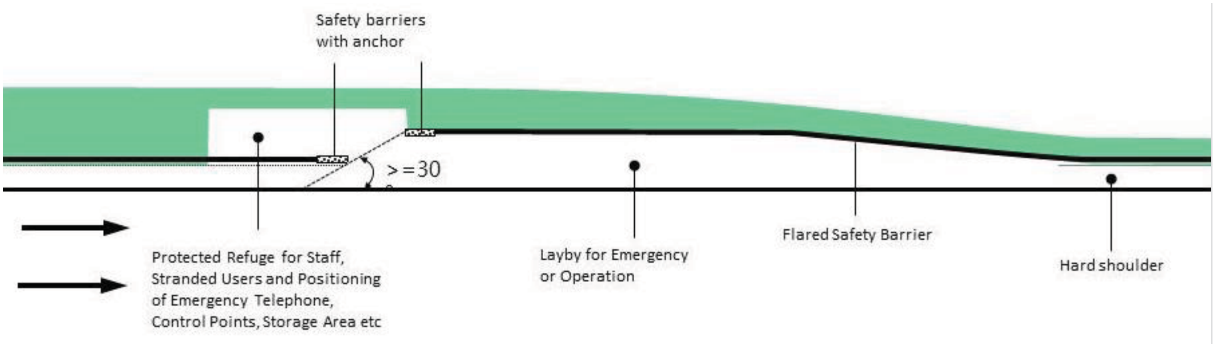


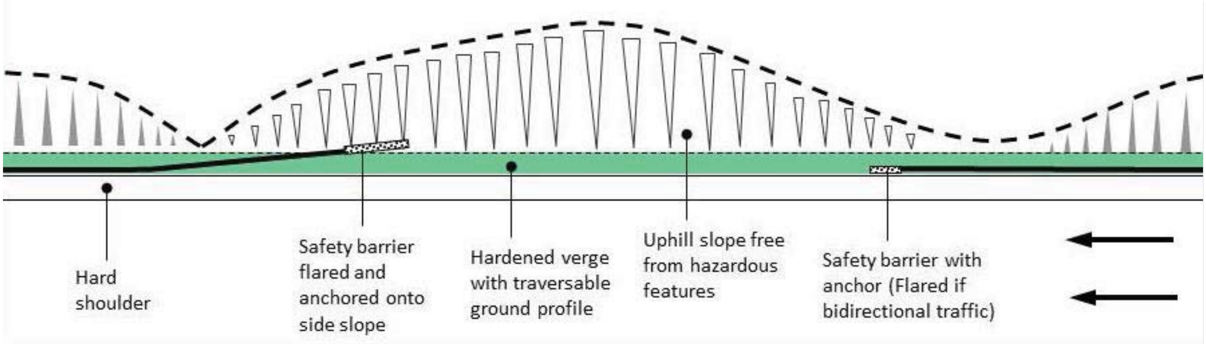
FIGURE 4.3.2.3 LAYBYS AND PROTECTED REFUGE ON A PRIMARY CLASS ROAD

Verges and Safety Barriers

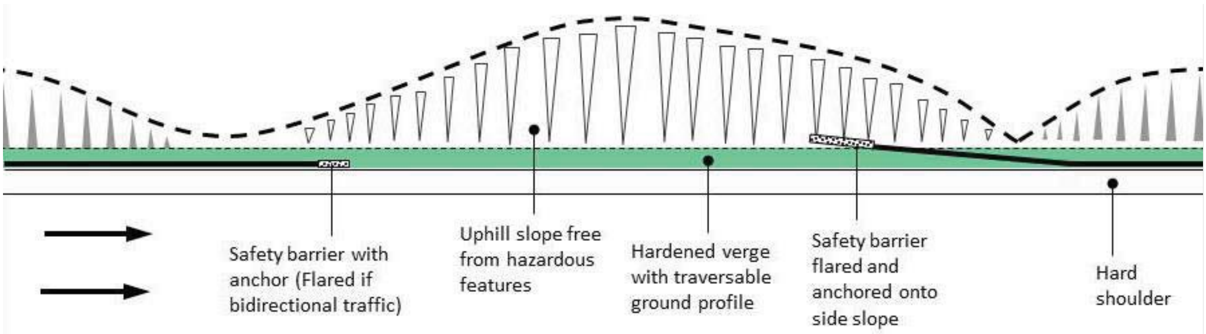
In addition to paved shoulders, unobstructed verges are important for the temporary refuge of vehicles and road-users in an emergency. For this reason, the benefits of an uninterrupted safety barrier system should be balanced against the availability of unobstructed verges. It is desirable that unobstructed verges not less than 50m long are provided intermittently where the terrain is favourable. This is illustrated in ***Figure. 3.3.2.4***.

FIGURE 4.3.2.4 PROVISION OF UNOBSTRUCTED VERGES

(for driving on the right side of the road)



(for driving on the left side of the road)



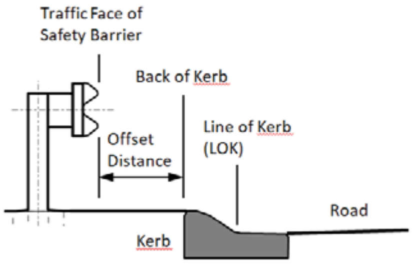
Kerbs

In general, it is not advisable to install safety barriers behind kerbs on high speed roads. If needed for drainage purpose, the traffic face of a safety barrier should be aligned with or suitably positioned relative to the kerb. Kerbs should not be used in front of concrete rigid barriers.

Table 4.3.2.4 provides guidance on the positioning of W-beam safety barriers relative to kerbs. There are less restrictions with gently sloping kerbs.

TABLE 4.3.2.4 OFFSET DISTANCE OF W-BEAM SAFETY BARRIERS [23]

Kerb Type	Design Speed					
	< 70km/h		70- 80km/h		> 80km/h	
	Desirable	Minimum	Desirable	Minimum	Desirable	Minimum
Barrier Kerb	>= 2.5m	Above LOK	>=4.0m	Above LOK	Not recommended	
Semi-mountable Kerb	>= 2.5m	=< 1.0m	>= 3.0m	=< 1.0m	>= 4.0m	=< 1.0m
Mountable Kerb	No restriction					



Local Strengthening

Bridge piers and similar rigid constructions are highly aggressive roadside features. On the other hand, gantry structures for signage are susceptible to collapse upon impact by heavy vehicles. Particular attention is therefore required in the detailed design of safety barriers for these features, including.

- Adequate containment level of safety barriers
- Adequate length of need
- Possibility of an errant vehicle mounting a ramped down safety barrier terminal
- Possibility of collision with overhead slanting bridge piers

For safety barriers of containment level TL-2 or TL-3 (NCHRP 350/MASH) or N2 (EN1317-2) such as W-beam barriers, it is desirable to increase the containment level at and on the approach to these features. This may be attained by adopting a Thrie-beam barrier or rigid barrier with a transition.

Alternatively it will be necessary to stiffen a semi-rigid metal safety barrier if the working width around these features is inadequate. This may be achieved by halving the spacing of mounting posts and installation of another beam on the opposite side (nesting). Another method is to attach another beam (rubrail) directly onto mounting posts without block-outs at the bottom part of the safety barrier.

Other Considerations

The appearance of safety barriers should be compatible with the surrounding environment including urbanised areas, countryside and scenic areas. Considerations may be given to:

- Simplification of safety barrier layouts
- Adoption of metal parapets to offer a more open view for vehicle occupants
- Use of safety barriers in wood finishing
- Use of subdue colours and avoidance of large areas of painted strips in bright colour
- Use of ornamental finishing which does not affect the performance of the equipment

Protruding corners or gaps on safety barriers are potentially hazardous to an errant vehicle. ***Figure 4.3.2.5*** illustrates two examples of deficiencies due to inadequate width of the median. Existing deficiencies may be corrected by retrofit of metal plates to maintain the smoothness and continuity of the safety barrier.

FIGURE 4.3.2.5 TYPICAL DEFICIENCIES OF SAFETY BARRIERS

Considerations for Motorcyclists and Cyclists

Motorcyclists and cyclists falling onto the road are susceptible to injuries upon impact with the pavement and roadside features including the vertical posts of metal safety barriers. The risk may be reduced by avoiding sharp edges on these features and installing a rub rail on the underside of safety barriers with discrete posts. This is illustrated in ***Figure 4.3.2.6***.

FIGURE 4.3.2.6 FLEXIBLE RUB-RAIL ON SAFETY BARRIER AT CURVES

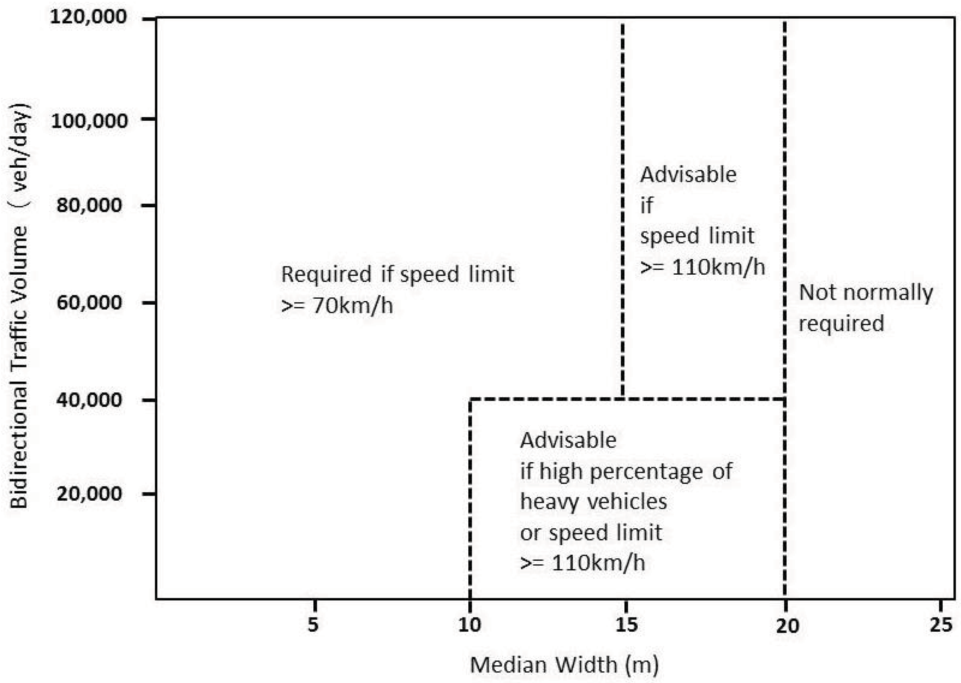
3.3 Median Safety Barriers

Median safety barriers are roadside safety barrier installed on the median to:

- separate opposing traffic on divided roads
- deter vehicles from overtaking or U-turning across the median
- prevent head-on collisions between opposing vehicles
- shield aggressive roadside features

Figure 4.3.3.1 provides general guidance on the need for median safety barriers on Primary class and access-controlled Class I roads.

FIGURE 4.3.3.1 RECOMMENDED REQUIREMENTS FOR MEDIAN SAFETY BARRIERS



For non-access-controlled Class I roads with speed limit of 70km/h or below, the following options may be considered:

- Adoption of a wider median in the order of 5m to 10m
- Provision of median safety barrier if the road has a high volume of heavy vehicles
- Adoption of low profile median safety barrier
- Adoption of raised median on kerbs if speed limit =< 50km/h

Median safety barriers may be provided as a double-sided unit with each side having the function of a safety barrier. They may also be provided as independent single sided safety barriers for each travel direction.

Table 4.3.3.2 provides some general guidance on selection of median safety barriers.

TABLE 4.3.3.2 GENERAL GUIDANCE ON SELECTION OF MEDIAN SAFETY BARRIERS

Test Criteria		Typical Applications *
MASH	EN1317-2	
TL-2/TL-3	N1/N2	- Wide medians - Medians of non-access-controlled Class I roads in built-up areas and their periphery (possible need of additional pedestrian fences)
TL-3	N2/H1	- Wide medians - Narrow medians =<3m on Primary class roads with low proportion of heavy vehicles - Class I roads with speed limit =< 70km/h with high proportion of heavy vehicles
TL-4	H2/L2	- Narrow medians =<3m on Primary class roads and Class I roads with speed limit >=80km/h and high proportion of heavy vehicles
TL-5	H4a/H4b/L4a/L4b	- Medians on the outside of sharp curves and along long steep grade sections on Primary class roads, access-controlled Class I roads and other roads with speed limit >= 80 km/h and a high proportion of heavy traffic

* Refer to table on roadside safety barriers for aggressive features on medians and roads with separate formations for the two traffic directions

Along wide medians on rural sections with relatively low traffic volume, flexible or semi-flexible safety barriers could be appropriate. These barriers may be laid out asymmetrically to provide variable widths of clear zones according to safety risks for each travel direction. They may also be discontinuous with an overlapping layout.

In order to limit the risk of errant vehicles breaking into the opposite carriageway on Primary class roads and access-controlled Class I roads, median barriers of higher containment level should be adopted:

- on urban sections with high traffic volume
- where there is a high volume of heavy vehicles:
- on the outside of sharp curves
- on road sections with long steep grades

Higher containment level may be obtained with the use of Thrie-beam barriers or rigid barriers on the median. Where there is a high risk of heavy vehicles overcoming the median, containment level TL-5 (NCHRP 350/MASH) should be attained by using a height of 1,070mm for concrete rigid safety barriers.

General Considerations

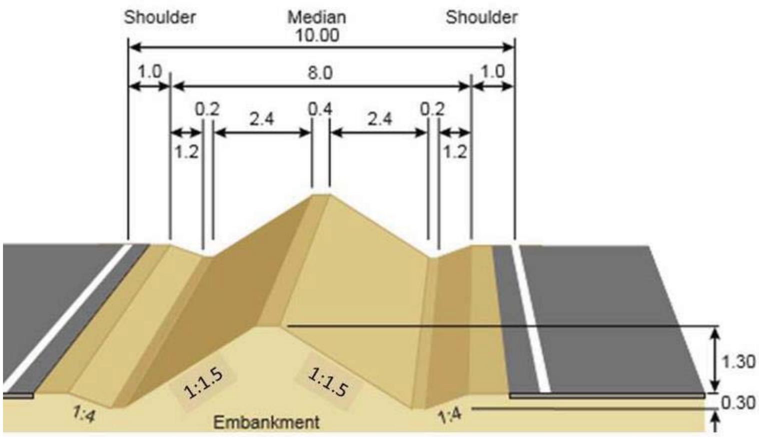
The use of median safety barriers should be planned in conjunction with the overall road cross-section. If lighting columns, traffic signs, gantry supports or bridge columns are envisaged on medians less than 4m in widths, particular care is needed to ensure that horizontal clearance and working width of safety barriers can be accommodated.

Median safety barriers have implications on visibility at bends and intersections and the problem could be aggravated by horizontal curves and crest profiles. It is important to ensure that visibility criteria are met with respect to safety barrier types, heights and layouts. It may be necessary to widen the median shoulder at bends, terminate the safety barrier earlier at intersections or adopt lower barrier types.

Use of Earth Embankments

For medians wider than 10m, an earth embankment may be provided to serve as a combined safety barrier and anti-glare screen. The embankment may be vegetated with grass or shrubs. Special treatments are required in terms of visibility and passive safety at median openings and terminations.

FIGURE 4.3.3.2 MEDIAN EARTH EMBANKMENT [20]



Wire Rope Safety Barriers

The merits of wire rope safety barriers are their narrow width and open view. They have a large working width and therefore require a median 4 to 7m in width. However, this does not preclude their use on medians down to 1.5m in width on Classes I or II roads. With these applications, there will be some risks of an errant vehicle intruding momentarily into the opposite direction.

3.4 Transitions

A transition is the connection joining two standard sections of safety barriers of different types, shapes or performance characteristics. They are provided to maintain the continuity of the safety barriers at their interface and to provide anchoring for semi-flexible barriers. Through a progressive change in terms of strength, rigidity and shape, transitions minimise the chance of an errant vehicle being stopped abruptly or penetrated by the end terminal of the downstream safety barrier. All transitions should be tested to MASH (US), EN1317-4 (EU) or equivalent national standard. Typical transitions are illustrated in ***Figure 4.3.4.1*** and ***Figure 4.3.4.2***.

FIGURE 4.3.4.1 TRANSITION BETWEEN CONCRETE SAFETY BARRIER AND METAL PARAPET

FIGURE 4.3.4.2 TRANSITION BETWEEN W-BEAM SAFETY BARRIER AND CONCRETE PARAPET
(ref: Ingal Civil Products)

Connection between Safety Barrier Sections

Discontinuity of sections of safety barriers could lead to an errant vehicle colliding frontally with the downstream safety barrier section. In the case of W-beam or Thrie-beam safety barriers, individual sections have to be securely fastened with overlapping in the direction of traffic. In the case of precast segments of rigid safety barriers, they have to be designed in such a manner that connection between successive units could be maintained during an impact.

3.5 End Treatments

Upstream terminals of safety barriers should not constitute a hazard by stopping an errant vehicle abruptly, penetrating into a vehicle or launching the vehicle air-borne. This is particularly important for roads with speed limit of 70km/h or above and also applies to locations susceptible to impacts by errant vehicles on roads with lower speed limit.

Treatment Strategy

The following end terminals should be avoided on roads with speed limit of 70km/h or above:

- Bullnose terminals
- Fishtail terminals
- Ramped down terminals
- Blunt terminals

Safety barrier terminals should not be positioned around bends where there is an increased risk of loss of control.

Attention should be given to combination of roadside features which could aggravate the consequences of a crash. Examples include a ramped down terminal located shortly ahead of highly aggressive features such as a bridge pier or a sheer drop. Roadside ditches may also guide an errant vehicle to collide with an end terminal.

The following strategy should be considered:

- Closing short gaps e.g. gaps < 50m of sections of safety barriers
- Extending the safety barrier upstream so that the terminal is located in an area of lower traffic speeds e.g. a slip road
- Extending the safety barrier upstream of curves and other locations susceptible to roadside crashes
- Extending and flaring the safety barrier to anchor onto an upstream slope

For any remaining safety barrier end terminals with speed limit of 70km/h or above, crashworthy terminals or crash cushions are appropriate end treatments if economics, availability and maintenance are not a constraint.

For any remaining safety barrier end terminals with speed limit of 60km/h or below, the following end treatments may be tolerated:

- Blunt end terminals with flaring

- Ramped down terminals preferably with flaring
- Blunt end terminals without flaring (speed limit =<50km/h)

These end terminals should be located on straight sections well ahead of bends and other locations susceptible to loss of control. Where ramped-down terminals are adopted, the adjacent roadside should not be highly aggressive in case a vehicle passes or rolls over the terminal.

End terminals should be highly visible to alert drivers in keeping their lateral position if they are in close proximity to the edge of carriageway. Possible treatments include the use of delineators, hazard markers and reflective paints or retro-reflective sheeting on the end terminal.

Anchoring onto Uphill Side Slopes

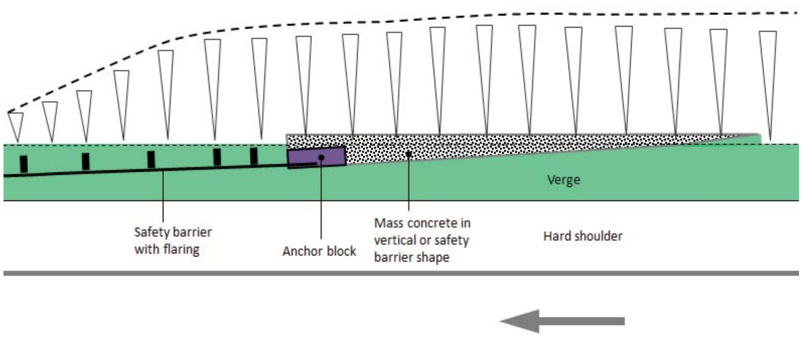
Anchoring onto uphill side slopes (Buried-in-Backslope) is the preferred end treatment if the slope is steeper than 1:1.5. This is illustrated in Figure 4.3.5.1. With semi-flexible safety barriers, one possibility is to bury and anchor an extended section of the safety barrier into the compacted slope. The barrier may also be directly anchored onto a retaining wall or rock cutting with suitable details. An additional beam (rubrail) may be required to prevent an errant vehicle going underneath the barrier due to the variation of roadside ground profile.

FIGURE 4.3.5.1 ANCHORING ONTO UPHILL SIDE SLOPES [22]*(driving is on the right side of the road)*

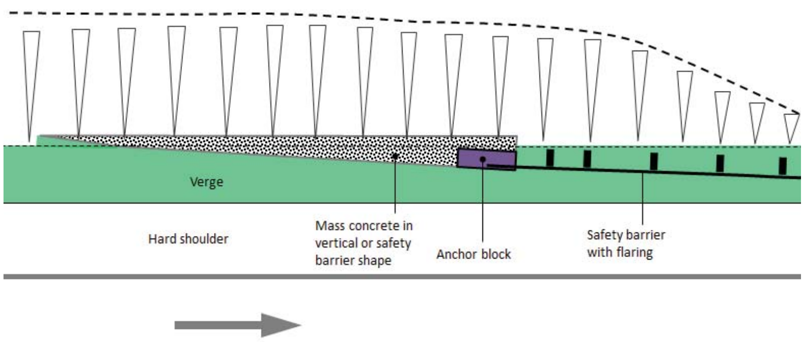
Another possibility is to provide a ground anchor and then backfill the approach with a concrete safety barrier. This is illustrated in ***Figure 4.3.5.2***.

FIGURE 4.3.5.2 ANCHORING ONTO UPSTREAM SLOPES ALTERNATIVE DESIGN

(for driving on the right side of the road)



(for driving on the left side of the road)



Downstream End Terminals

Downstream end terminals for unidirectional traffic may be anchored with a ramped down terminal or left unanchored. They should be provided with the following arrangements:

- Where a clear zone commences
- Overlapping another roadside safety barrier or acceptable uphill side slope
- Terminating near intersections or road sections where speed is low with no outstanding roadside aggressive features

Downstream end terminals for bidirectional traffic should be treated as upstream end terminals if they lie within the clear zone for opposing traffic including overtaking vehicles.

Median Openings on Class I roads

Where median barriers on Class I roads are terminated at median openings, priority intersections, signalised intersections or roundabouts, the layout will need to minimise the risk of collision and to tie up with visibility requirements. It would be desirable to flare the median barrier away from approach traffic and to defer the commencement of end terminals.

Crashworthy Terminals

Crashworthy terminals are generally non-redirective products associated with safety barrier systems, typically W-beams. They should be tested to conform to MASH (US), EN1317-4 (EU) or equivalent national standard. There are four classes under EN 1317-4 as shown in ***Table 4.3.5.1***. A typical installation of P4 crashworthy terminal is illustrated in ***Figure 4.3.5.2***.

TABLE 4.3.5.1 CRASHWORTHY TERMINALS CLASSIFICATION TO EN1317-4

Class	Test Speed (km/h)
P1	80
P2	80
P3	100
P4	110

FIGURE 4.3.5.2 P4 CRASHWORTHY TERMINAL TO EN1317-4 *(driving is on the left side of the road)*

As crashworthy terminals are non-redirective, an adequate clear zone is required in case an errant vehicle passes in front of or breaks through the system.

3.6 Crash Cushions

Crash cushions are proprietary equipment designed to reduce the severity of a crash by slowing down a vehicle to a safe stop for head-on impacts or redirecting a vehicle away from the fixed object for side impacts.

Crash cushions should be used for diverge gore on Primary class and Class I roads with design speed of 80km/h or above where a clear zone cannot be created. They should also be adopted for lower speed limits or other high risk situations where no other solutions are practical.

Other appropriate applications for crash cushions are

- Isolated bridge piers in the middle of a road
- Commencement of median safety barriers
- Toll islands
- Tunnel portals
- Hazards on traffic islands
- Works areas and installations as Truck Mounted Attenuators (TMA)

General Considerations

Crash cushions should satisfy the requirements of MASH (US), EN1317-3 (EU) or equivalent national standard. ***Table 5.3.6.1*** contains the general category of crash cushions according to test vehicles and speeds. It should be noted that crash cushions are mostly tested for cars and pick-up trucks and there is inadequate data regarding their performance for larger vehicles including buses.

TABLE 4.3.6.1 CATEGORY RANGE OF CRASH CUSHIONS

	MASH	EN1317-3
Test Level Category	TL-1/TL-2/TL-3	50/80/100/110
Test Speed	50/70/100/110 km/h	50/80/100/110 km/h
Test Vehicles	700/1000/2270 kg	900/1300/1500 kg

It is advisable to specify crash cushion with tested speed at least 10km/h above the speed limit. They may be based on one the following mechanisms:

- Kinetic energy absorption (***Figure 4.3.6.1***)
- Momentum transfer
- Mix of the above

Selection of the above crash cushion types should take into account space and maintenance requirements. Crash cushions based on momentum transfer are generally individual sand barrels which are easier to install and maintained.

FIGURE 4.3.6.1 REDIRECTIVE CRASH CUSHION FOR NARROW (LEFT) AND WIDE (RIGHT) DIVERGE GORES
(source: Traffic Safety System (HK) Limited) (driving is on the left side of the road)

Type Selection

Crash cushions are categorised into redirective (non-gating) or non-redirective (gating) products. Redirective products redirect an errant vehicle hitting the side of the crash cushion back onto its travel path. They should be specified in most circumstances to limit secondary consequences. Non-redirective products are more appropriate where adequate space or clear zone is available on the roadside.

Crash cushions are also categorised into unidirectional or bidirectional products. Unidirectional products are generally appropriate on the roadside and at diverge gores of divided roads as well as toll booths. In the following situations, bidirectional products are required to allow for vehicles colliding from the opposite direction:

- Roadside and diverge gores on a two-way road
- Isolated bridge piers in the middle of a road separating opposing traffic
- Hazards on traffic islands separating opposing traffic
- Installations on the median

Transition

Crash cushions should be contiguous with or overlap any downstream safety barriers. The downstream safety barrier must not protrude beyond the crash cushion and constitute a hazard.

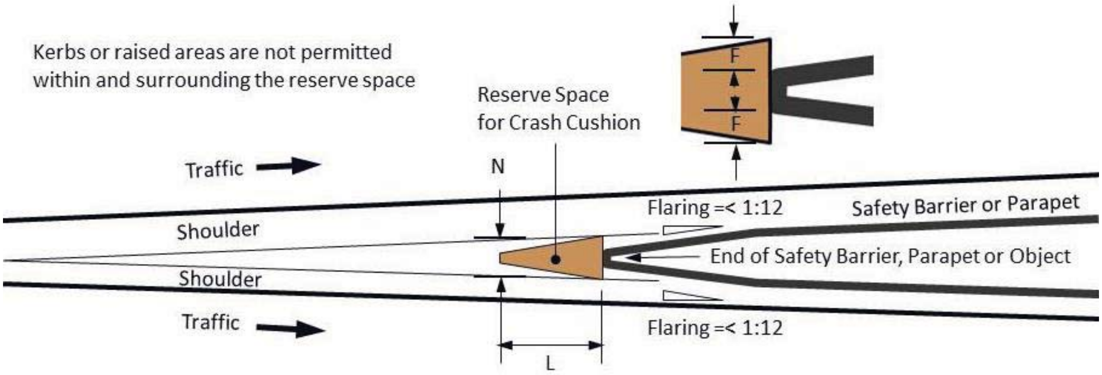
A well-organized maintenance programme is required to ensure that damaged crash cushions are repaired in time. Reusable crash cushions may be considered to reduce the need for repairs.

Reserve Space

In the design of new roads, a specific space should be reserved for the installation of crash cushions generally available in the market. This is illustrated in ***Figure 4.3.6.2***. Such space should have gentle pavement slope by controlling the vertical profile of the slip road. Additionally, presence of the crash cushion should not result in the shortening of the required diverge nose. The site also needs to be free from kerbs, drainage features and movement joints of bridge structures.

Crash cushion types should be appropriate for the site condition, notably gore width. They should not intrude into the traffic lane or the shoulder. Sand-filled barrels based on the momentum transfer principle are generally only appropriate at wide gores.

FIGURE 4.3.6.2 RECOMMENDED RESERVE SPACE FOR CRASH CUSHION [22]



Design Speed (km/h)	Minimum						Preferred		
	Restricted Conditions			Unrestricted Conditions					
	N	L	F	N	L	F	N	L	F
50	2	2.5	0.5	2.5	3.5	1	3.5	5	1.5
80	2	5	0.5	2.5	7.5	1	3.5	10	1.5
100	2	8.5	0.5	2.5	13.5	1	3.5	17	1.5
120	2	11	0.5	2.5	17	1	3.5	21	1.5

Signing and Delineation

The front of crash cushion should be highly visible to approach vehicles. This may be in the form of a marker sign in retro-reflective materials. Additional self-restoring flexible posts may be erected at diverge gores with poor visibility, on a curve approach and where there is a history of crashes.

•

PART 5 PEDESTRIANS, SLOW VEHICLES AND TRAFFIC CALMING

1 OVERVIEW

Urbanised sections on Asian Highway routes have the dual function of being a traffic corridor and a place for local activities. These two functions will need to be carefully balanced to satisfy the needs for different users of the road. Along these sections and their peripheries pedestrians and slow vehicles often need to travel along or cross the main road.

The fundamental approach to enhance the safety of urbanised section covers:

- Provision of adequate pedestrian facilities
- Provision of adequate slow vehicle facilities
- Managing traffic speeds
- Encouraging appropriate behaviour among all road-users

These initiatives will not only enhance road safety, but also alleviate the negative effects and severance due to highway traffic. Furthermore, there are always opportunities beyond basic provisions to enhance the quality of streetscape on urbanised sections. It would be most desirable to involve the participation of local communities to promote a sense of ownership.

Streetscape initiatives help to reinforce the self-explaining nature of urbanised sections. Their design should be commensurate with fundamental principles of road safety engineering in terms of visibility, passive safety and design parameters of road elements. There are ample possibilities with respect to culture, climate, materials, local customs, plant and tree species etc. Enhancement of streetscape may be implemented in stages.

The requirement for pedestrian and slow vehicle facilities is not restricted to urbanised sections and their peripheries. Their need will have to be established according to land use and road usage characteristics.

Access-controlled roads of high design speed should not be associated with any pedestrian or slow vehicle routes to minimise the risk of these users entering or crossing the road. Adequate grade-separated crossings should be planned for all access-controlled roads.

2 PEDESTRIAN FACILITIES

2.1 General Requirements

Pedestrian facilities consist of footpaths, crossings and associated provisions. Their primary objectives are to provide adequate capacity for pedestrian needs and to enhance safety. Additionally, pedestrian facilities should be designed with connectivity and comfort in mind. It is also necessary to provide for universal accessibility with a barrier-free pedestrian environment to encourage walking for all users.

The provision of pedestrian facilities should take into account the needs of those less capable of coping with the road and traffic environment, including:

- elderlies, accompanied or unaccompanied
- children, accompanied or unaccompanied
- persons with impaired visual, auditory, sensual or mobility capability
- persons with particular needs due to pregnancy, sickness etc.
- wheelchair users, accompanied or unaccompanied, including those on powered wheelchairs
- encumbered users carrying baggage or taking care of children etc.

Particular consideration should be given to their needs in the following aspects:

- Availability of readily accessible footbridges and underpasses across busy multi-lane roads
- Adequate visibility to cross a road
- Provision of signalised pedestrian crossings with adequate green time and audible signals
- Traffic calming and limitation of traffic speeds at crossings
- Limitation of the number of traffic lanes, complexity of crossings and detours
- Provision of tactile paving blocks at crossings, ramps and staircases
- Drop kerbs or flushed surface at crossings

School Children

The safety of school children interacting with highway traffic should receive utmost attention. Of particular concerns are:

- Children having to walk or cycle along busy highways
- Children being taken to school on motorcycles
- Children needing to cross busy, multi-lane highways without proper crossing facilities
- Aggregation of crowds outside school entrances

Given the diversity of circumstances, enhancement of the safety of school children requires a clear understanding of the travel patterns and routes to schools in each case. In general, the strategy would involve one or more of the following approaches:

- Availability of alternative routes with safer conditions
- Provision of footpaths, slow vehicle routes and crossing facilities along highways
- Positioning school entrances onto secondary roads
- School zones safety initiatives

2.2 Footpaths

Footpaths are part of the road cross-section designated for the exclusive use of pedestrians. They are physically segregated from the carriageway on a raised level using kerbs or with a lateral separation using verges, planters or barriers. Pedestrian footpaths should be part of a walking network to serve the needs of pedestrians within built-up areas and their peripheries.

Footpaths should offer a high quality walking environment with the following characteristics:

- Good connectivity
- Adequate level of service
- Absence of hazardous obstructions
- Reasonable evenness with little potential for tripping
- Non-slippery pavement surface
- Secure and within the sight of passing traffic
- Illuminated by street lighting

Footpaths should be provided along urbanised sections and their peripheries as well as on road sections where pedestrians are regularly present e.g. roadside tourist attractions. Pedestrian demand is preferably established with surveys based on land use, nature of trips and future demands. It may be sufficient or desirable to provide footpaths on only one side of the road if this accords with the desired paths of pedestrians.

On bridge crossings, roads with heavy traffic and where traffic speeds exceed 60km/h, consideration should be given to a footpath separated from the main road with a safety barrier, planter wall or grassed verge. Safety barriers should be adopted if there is an increased risk of errant vehicles crashing onto the footpath.

Footpaths should have sufficient width to accommodate anticipated pedestrian volume, and to allow for the installation of road facilities and utilities. It is also desirable to provide adequate space for streetscape, trees, plants, decorations, amenities etc.

General Requirements

The desirable width of footpaths is given in ***Table 5.2.2.1***. The recommended minimum width of a basic footpath is 2m with a clear passage width not less than 1.2m.

TABLE 5.2.2.1 BASIC WIDTH OF FOOTPATHS

Width	Function
1.5m	Acceptable if there are no obstructions
2m	Basic Provision allowing for isolated obstructions such as sign posts and lighting columns
3m	Where crowds aggregate e.g. outside schools, community or religious facilities
3m	At bus stops
4m	Outside shops

In case of severe constraints, narrower footpaths may be acceptable according to ***Table 5.2.2.2*** where pedestrians are infrequent. With these narrower widths, the footpath should be free of obstructions.

TABLE 5.2.2.2 POSSIBLE FOOTPATH WIDTHS WITH SEVERE CONSTRAINTS

Width	Adequacy of Passage
0.75m	An adult
0.9m	A wheelchair user
1.0m (0.9m)	Two opposing adults
1.35m (1.2m)	Two opposing adults freely passing

( ) Absolute minimum values

A footpath wider than 2m would be required for high pedestrian demands to achieve a reasonable "Level of Service" (LOS). The optimum LOS is in the region of LOS "C" allowing the comfortable passage both ways of 23 to 33 pedestrians per minute per metre width. LOS "D" may be tolerated allowing the passage of 33 to 49 pedestrians per minute per metre width. Beyond this, a wider footpath should be considered.

Flexibility should be applied to take into account availability of space, variable pedestrian demands at different locations and the need to provide for street facilities and utilities. Variation in cross-sections is also conducive to an attractive streetscape with additional space for plantings and amenities.

At urban centres, along wide busy roads and where space is available, it would be desirable to provide a pedestrian corridor comprising a landscaped belt, a footpath and a frontage zone for buildings. This is illustrated in ***Figure 5.2.2.1*** and ***Table 5.2.2.3***.

FIGURE 5.2.2.1 PEDESTRIAN CORRIDOR

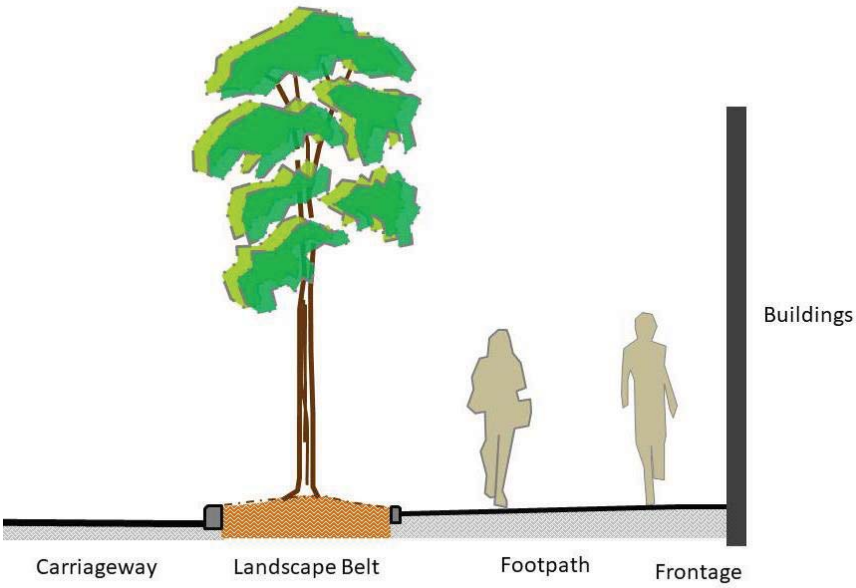


TABLE 5.2.2.3 RECOMMENDED WIDTH OF PEDESTRIAN CORRIDORS

Land Use	Pedestrian Flow per minute	Landscaped Belt	Footpath	Frontage
Rural	Very low	1.5m	2.0m	0.5m

General	Very Low to Low <60	1.5m – 3.0m*	2.0m	0.5m
High Usage	Medium to High 60-100	1.5m – 3.0m*	2.5m – 3.5m	0.5m
Urban Centre	High to very High >80	1.5m – 3.0m*	3.5m - 5.0m	1.0m**
Industrial	Very low - low	1.5m – 4.0m*	2.5m – 3.5m	0.5m

* At least 3.0m is desirable for planting of trees

** 0.5m may be adopted away from building entrances

Other Considerations

A headroom of 2.6m should be maintained along footpaths. This may be reduced to not less than 2.3m and exceptionally 2.1m for isolated features such as traffic signs.

For the convenience of wheelchair users and comfort of pedestrians, pavement slopes on footpaths should not be more than 3% and desirably less than 2.5%.

Footpaths may need to be designed to withstand occasional traffic load. To prevent illegal parking onto footpaths, bollards or pedestrian fences may be installed. Where traffic speeds are high outside built-up areas, it will be desirable to provide a safety barrier to protect pedestrians as shown in ***Figure 5.2.2.2***. In the provision of such safety barriers, adequate consideration has to be given to containment level, working width and elimination of features which could constitute a hazard for pedestrians.

FIGURE 5.2.2.2 FOOTPATH PROTECTED BY SAFETY BARRIER *(driving is on the right side of the road)*

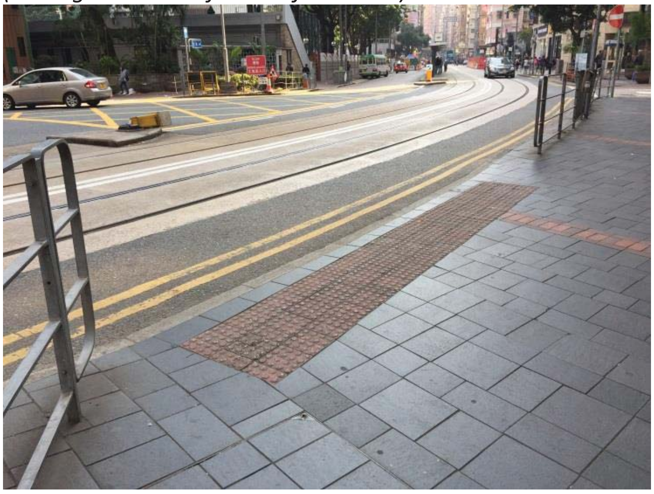
Along major bridges, consideration should also be given to the installation of a safety barrier along footpaths for the protection of pedestrians. Additionally, it may be desirable to provide the footpath at a higher level to further enhance the quality and safety of the pedestrian route.

Universal Accessibility

At pedestrian crossings or accesses, drop kerbs or a flushed surface should be provided with gradients not exceeding 8% respectively. Tactile paving blocks should be in the order of 600mm to 800mm in width extending across the width of the crossing. They should have adequate visual contrast with the surrounding surfacing and are set back by about 300mm from the edge of the carriageway. A typical arrangement is shown in ***Figure 5.2.2.3***.

FIGURE 5.2.2.3 DROP KERB AND TACTILE PAVING AT A PEDESTRIAN CROSSING

(driving is on the left side of the road)



If frequent accesses are encountered along a footpath, consideration should be given to a flushed footpath separated from the road with a verge. Alternatively, a raised run-in may be considered and this also serves as a speed hump. It is also desirable to highlight the priority of pedestrians at direct frontage accesses with colour contrast on the paved surface. This is illustrated in ***Figure 5.2.2.4***.

FIGURE 5.2.2.4 COLOUR CONTRAST AT A DIRECT FRONTAGE ACCESS

(driving is on the left side of the road)

2.3 Pedestrian Crossings

Pedestrian crossings are designated facilities which pedestrians should use to cross a road. They should be provided where there is a reasonable and regular demand by pedestrians in relation to communities, side roads, public transport and routes to school or work. They are important in assisting pedestrians, particularly those having more difficulties, to cross the road safely.

Pedestrian safety is affected by many factors and may not be improved by providing crossings alone. It is always desirable to enhance pedestrian safety from a holistic perspective, of which pedestrian crossing is a possibility.

There are often isolated or scattered locations where pedestrians need to cross on an occasional basis. In this situation, adequate visibility should be provided and the presence of pedestrians should be obvious. It is not always practical to provide crossing facilities at every location where pedestrians need to cross a road. In the case of smaller villages and scattered houses, the strategy could be creation of favourable crossing conditions with good visibility, warning signs and traffic calming measures.

Crossing Types

The principal types of pedestrian crossings are given in ***Table 5.2.3.1***.

TABLE 5.2.3.1 PEDESTRIAN CROSSING TYPES

Crossing Category		Crossing Type	Characteristics
At-grade Crossing	Non-signalised Crossing	Uncontrolled Crossing	Pedestrians do not have right of way
		Pedestrian priority Crossing (Zebra Crossing)	Pedestrians have right of way
	Signalised Crossing	Signalised Crossing at Intersection	Fixed time or activation by pedestrian or detector
		Standalone Signalised Crossing	Fixed time or activation by pedestrian or detector
Grade-separated Crossing		Footbridge	Standalone or forming part of an elevated walkway system
		Underpass	Standalone or forming part of an underground walkway system
		Grade-separated Intersection	• Elevated or underground crossings associated with grade-separated intersections for traffic • Passages underneath viaducts or bridges

Need for Pedestrian Crossing

The need and priority for provision of pedestrian crossings may first be established with an assessment of the intensity of conflict between vehicles and pedestrians. The method is commonly known as "PV2" in the United Kingdom. The formula has many versions with minor differences in the use of weighting factors among authorities. A typical formula is given below:

$$I = A*D*P*V^2$$

where

I = Intensity of Conflict

A = (1 + N/10), N being number of pedestrian injury collisions in last 3 years, estimated or from data
A = 1 for new roads
D = Difficulty factor

- Use 1.0 if speed limit =< 50km/h
- Use 1.2 if speed limit >=60km/h
- Additional weighting factor: Actual Crossing Width/7.0m

P = Average hourly pedestrian volume (ped/hour) along a 100m section of the road over four highest hours in a day with the following weighting:

- Children and young pedestrians = 4

- Elderlies and pedestrians with more difficulties = 4
- Disabled pedestrian = 6
- Cyclists and other slow vehicles = 1

V = Average hourly traffic volume (veh/hour) over four highest hours in a day with the following weighting

- Heavy vehicles and buses = 2.5

The need and priority for a pedestrian crossing are then established from ***Table 5.2.3.2***.

FIGURE 5.2.3.2 NEED AND PRIORITY FOR PEDESTRIAN CROSSINGS

	Intensity of Conflict	
	Classes II, III Undivided Roads	Class I Divided Roads* #
	where V > 600 veh/hour	where V > 800 veh/hour
High priority	>= 10^8	>= 2* 10^8
Medium priority	0.7 – 1.0 * 10^8	1.4 – 2.0 * 10^8
Pedestrian priority crossing, refuges	0.2 – 0.7 * 10^8	0.4 – 1.4 * 10^8
Special justifications required	< 0.2 * 10^8	< 0.4 * 10^8

* also applies to undivided roads with a wide refuge

Road Class and Speed Limit

Selection of crossing types should be based on safety considerations with respect to road classes and traffic speeds. This is given in ***Table 5.2.3.3***.

TABLE 5.2.3.3 RECOMMENDED CROSSING TYPES

<table>
<tr><th>Speed Limit km/h</th><th>Classes II/III Undivided Roads (1x2)</th><th>Class I Undivided Roads (4 lanes) Divided Roads (2x2)</th><th>Class I Undivided Roads (6 lanes or wider) Divided Roads (2x3 or wider)</th></tr>
<tr><td>> 80</td><td colspan="3">Grade Separated Crossings</td></tr>
<tr><td>80</td><td colspan="3">Signalised* or Grade Separated Crossings</td></tr>
<tr><td>70</td><td rowspan="2">Uncontrolled**, Signalised or Grade-separated Crossings</td><td>Signalised or Grade Separated Crossings</td><td rowspan="3">Signalised or Grade-separated Crossings</td></tr>
<tr><td>60</td><td>Uncontrolled**, Signalised or Grade-separated Crossings</td></tr>
<tr><td>=< 50</td><td>All crossing types</td><td>All crossing types ***</td></tr>
</table>

* Local speed reduction is advisable for signalised intersections
** Uncontrolled crossings may be tolerated for low traffic and pedestrian volume
*** Non-signalised crossings are not advisable unless pedestrian volume is low with frequent safe gaps in traffic

General Considerations

Table 5.2.3.4 lists the main considerations in the selection and design of pedestrian crossings. The presence of multiple unfavourable conditions may justify the provision of signalised crossings or grade-separated crossings. However, it may also be desirable to modify one or more conditions to favour the provision of at-grade crossings.

TABLE 5.2.3.4 KEY CONSIDERATIONS FOR PEDESTRIAN CROSSINGS

Parameters	Considerations
Traffic volume	Higher risk with increasing traffic volume due to exposure
Pedestrian volume	Higher risk with increasing pedestrian volume due to exposure
Pedestrian characteristics	Presence of school children, elderlies and pedestrians with particular needs
Prevalence of large vehicles	Large vehicles: • are more prone to certain blind spot problems • require longer braking distance • incur more severe injuries
No. of traffic lanes	Higher risk with increasing traffic lanes due to exposure as well as one vehicle obscuring another vehicle on adjacent lanes
Speed	Braking distance and injury severity increase with higher speeds
Very high speed vehicles	Some drivers may travel at grossly excessive speeds, especially outside day hours. This could also be a systematic issue e.g. illegal racing
Conspiciuty	Visibility affects the awareness of drivers and in turn their adoption of appropriate speed and reaction to brake in time
Visibility of the crossing and waiting area	Visibility affects the awareness of drivers and in turn their adoption of appropriate speed and reaction to brake in time
Presence of safe gaps	At high traffic volumes i.e. >12,000 veh/day, pedestrians' waiting time for a safe gap could become too long. Presence of upstream traffic signals may help to create safer gaps in the traffic stream
Drivers' readiness to give way	Drivers are more likely to give way at lower speeds. Publicity can help to improve drivers' readiness to give way
Appropriate geometry and location	Complex road layouts place a high demand on both pedestrians and drivers. Drivers may fail to see crossing pedestrians while merging, accelerating or turning at speed. Certain road layouts may result in pedestrians looking in the wrong way

The location of pedestrian crossings should follow closely the desired path of pedestrians and are oriented at right angle to traffic flows. At intersections, pedestrians should be routed to crossings with a well-conceived layout of footpaths.

At-grade Pedestrian Crossings

At-grade pedestrian crossings should be provided at locations reasonably expected by drivers. These include urbanised sections, intersections and sections with traffic calming. For at-grade crossings at isolated sites, the main considerations are given in ***Table 5.2.3.5***.

TABLE 5.2.3.5 COMPARISON OF AT-GRADE CROSSINGS AT ISOLATED SITES

Crossing Type	Mode of Operation	Merits	Potential Problems
Crossing	Pedestrians decide if it is safe to cross	No delay to vehicles; Minor delay for pedestrians for light to moderate traffic volume	Pedestrians misjudging safe gaps and drivers do not expect to stop, leading to collision with pedestrians
Pedestrian priority Crossing	Traffic gives way to pedestrians wishing to cross	Little delay for pedestrians and minor delay for traffic; Safe crossing conditions when vehicles have stopped completely	Drivers not stopping and collide with pedestrians; Opposing or overtaking vehicles not stopping; Rear-front collisions due to abrupt stopping
Signalised Crossing	Fixed time or activation by pedestrians or detectors	Pedestrians are able to cross safely, some delays for traffic	Pedestrians not observing signals and misjudging safe gaps while drivers do not expect to stop, leading to collision with pedestrians; Drivers may not observe signals especially when just turning to red

The width of at-grade pedestrian crossings may be based on the range of 600 to 1,200 pedestrians per metre per hour combined in both directions. The minimum width is 2.4m but 3m or more is recommended for a pedestrian priority crossing to become more conspicuous.

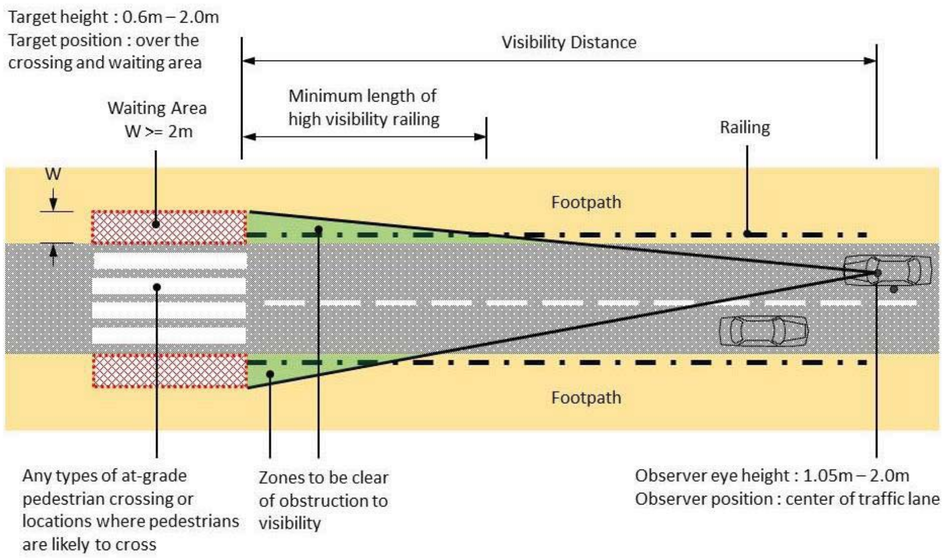
The width of footpaths should be increased at crossings to accommodate waiting pedestrians. It is also desirable to widen footpaths at road corners. The optimum LOS at waiting area of at-grade pedestrian crossings is in the region of LOS “C” allowing the comfortable space of 0.6 to 0.8m^2 per pedestrian. LOS “D” may be tolerated allowing the space of 0.3 to 0.6 m^2 per pedestrian. Beyond this, a wider waiting area should be considered.

Visibility

Adequate visibility distance is required for drivers towards a pedestrian crossing and its associated waiting areas on both sides. This is illustrated in ***Figure 5.2.3.1*** and the required visibility distance is given in ***Table 5.2.3.6***. Waiting areas may lie on the footpath, the median or a pedestrian refuge island. If pedestrians are likely to cross anywhere along a road, a high visibility environment should be provided throughout.

FIGURE 5.2.3.1 VISIBILITY REQUIREMENTS FOR PEDESTRIAN CROSSINGS

(for driving on the right side of the road)



(for driving on the left side of the road)

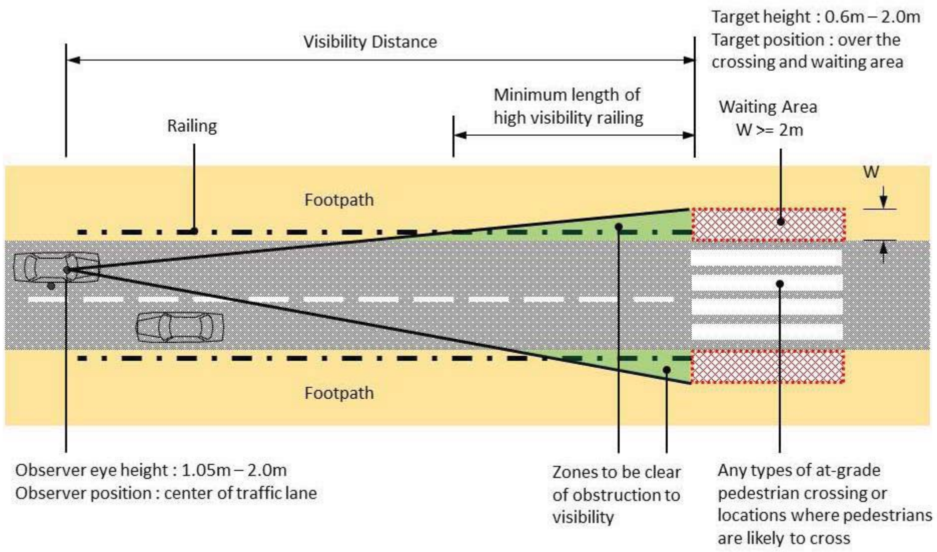


TABLE 5.2.3.6 VISIBILITY REQUIREMENTS AT PEDESTRIAN CROSSINGS

Speed Limit	Stopping Sight Distance Desirable Minimum	Stopping Sight Distance Absolute Minimum
50 km/h	70m	50m
60 km/h	95m	70m
70 km/h	125m	95m

Sightline	Observer	Eye-height	Target	Target Height
1	Driver	1.05m – 2.3m	Markings	0m
2	Driver	1.05m – 2.3m	Pedestrian	0.6m – 2.0m
3	Pedestrian	1.05m – 2.0m	Vehicle	0.6m – 2.0m

It is particularly important that the waiting areas of footpaths, medians and refuge islands at any at-grade crossings are not obscured by relatively wide objects including signs, plants, litter bins, cabinets, bridge piers, parked vehicles etc., or a continuous wall or noise barrier. If pedestrian fences are installed around a pedestrian crossing, these should be of high visibility design over a sufficiently long distance.

Crossing distance at pedestrian crossings should be minimised to reduce the exposure of pedestrians. At non-signalised pedestrian crossings, in particular, it is preferable that pedestrians only need to cross one traffic lane for each traffic direction.

At intersections, pedestrian crossings should be set back to reduce the crossing distance due to rounded street corners. On the other hand, smaller radii of street corners help to avoid excessive detour of pedestrians and slow down turning traffic. Where traffic capacity permits, it is also desirable to widen the footpath at the crossing by reducing the number of traffic lanes and providing parking or stopping places on the approach.

Conspicuity

The presence of pedestrian crossings should be conspicuous by virtue of their locations and layouts. This may be further enhanced by signing, delineation, road lighting or other features such as bollards, pedestrian fences, drop kerbs etc.

Appropriate traffic signs for pedestrian crossings include:

- Pedestrian crossing sign
- Advance warning sign of pedestrian crossing

These signs are desirable on the main road with higher speeds but are not necessary for signalised crossings, crossings located in a zone of good visibility and where traffic speeds are below 40km/h.

Where a vertical speed reduction device is provided at pedestrian crossings, the following signs should be provided:

- Advance warning sign “Speed hump ahead”, possibly in conjunction with speed limit signs of 30, 40 or 50 km/h as appropriate
- Position sign “Speed hump”, in conjunction with pedestrian crossing sign

Class I Roads

In dense urbanised areas, pedestrian crossings on Class I roads should be spaced not more than 200m apart on average. In practice spacing should tie in with pedestrian needs, intersections and land-use. Typical spacing between crossings may range from 50m to 300m.

At-grade non-signalised pedestrian crossings are not recommended on Class I roads. A major safety concern is that pedestrians may not realise that a slower or stopped vehicle on one traffic lane could obscure a fast moving vehicle on the neighbouring lane. These crossings may be acceptable in the following circumstances:

- Urbanised sections and their peripheries with road lighting
- Presence of clear crossing paths e.g. at intersections
- Number of traffic lanes per direction not more than two
- Relatively light traffic volume (< 1,000 veh/hour both ways) with low percentage of heavy vehicles
- Speed limit =< 50km/h
- Good visibility
- Occasional pedestrians only not involving unaccompanied children and vulnerable users
- Availability of refuges for Class I undivided roads
- Additional traffic calming including the possibility of speed tables
- Reduced lane widths and widened central refuges
- Frequent safe gaps in the traffic, possibly due to upstream signalised intersections

Non-signalised Crossings

Non-signalised crossings are categorised into pedestrian priority crossings and uncontrolled crossings. Pedestrian priority crossings, also known as zebra crossings, are generally defined by national law that approach vehicles have to stop if a pedestrian is waiting or has commenced crossing. On the contrary, pedestrians at uncontrolled crossings have to decide when it is safe to cross.

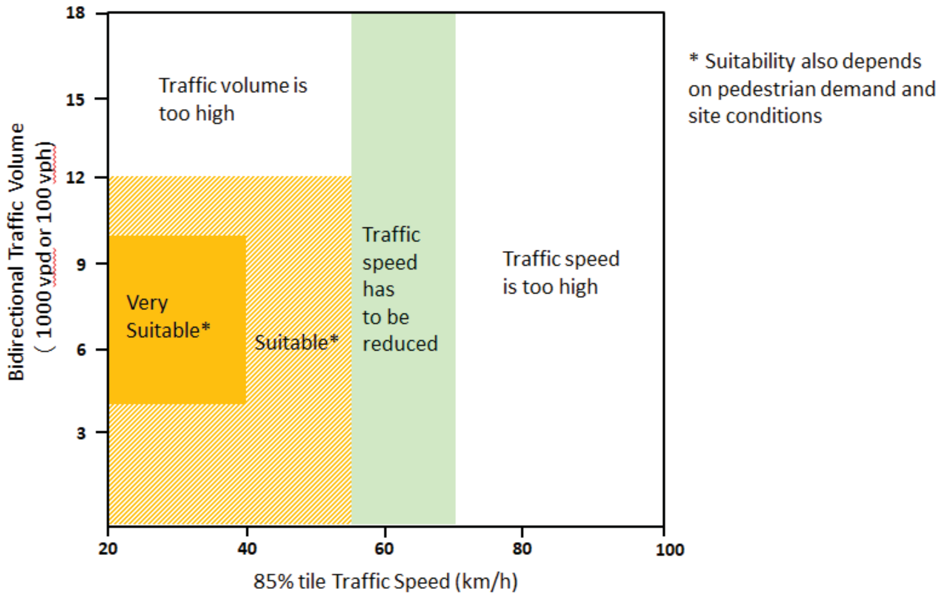
Pedestrian priority crossings consist of conspicuous parallel strip markings in white colour or yellow colour which may be enhanced with approach markings, signs and pedestrian fences. Uncontrolled crossings are not accompanied by these strip markings but may be accompanied by other markings, signs and pedestrian fences.

Admittedly the meaning of parallel strip markings varies in different countries, and it is not uncommon that they merely function as uncontrolled crossing.

At pedestrian priority crossings, drivers have to be prepared to stop and be able to stop in time. As such they should not be located outside built-up areas without adequate traffic calming. They are also not suitable on a steep downhill approach which aggravates traffic speeds.

Pedestrian priority crossings are most suitable on urbanized sections with relatively low pedestrian crossing demand and moderate traffic volume. This is illustrated in ***Figure 5.2.3.2***.

FIGURE 5.2.3.2 SUITABILITY OF ISOLATED PEDESTRIAN PRIORITY CROSSINGS



For all at-grade non-signalised pedestrian crossings, it is always advisable to ensure favourable conditions including:

- Low pedestrian crossing volume and at most moderate traffic volume (< 1,000 veh/hour)
- Existence of an obvious crossing route
- Traffic speeds not exceeding 55km/h
- Good visibility and conspicuity
- Vicinity of intersections with Stop or Give-way signs
- Within urbanised sections or their peripheries with traffic calming and road lighting
- Availability of safe gaps in traffic between upstream signalised intersections

Signalised Crossings

Signalised pedestrian crossings are controlled by traffic signals with a pedestrian phase. These crossings may be highlighted with parallel strip markings.

They should be provided at signalised intersections where there is a reasonable demand by pedestrians. It is generally not advisable to permit turning traffic while a pedestrian signal is green.

Standalone signalised pedestrian crossings (***Figure 5.2.3.3***) should be considered in the following circumstances:

- Traffic speeds are high (>55km/h)
- Traffic volume is high (>1,000 veh/hour)
- Class I roads/Multi-lane road sections

This may be further justified if pedestrian volume is high (> 70 ped/hour) and there is an elevated demand by elderlies, disabled persons and school children. If pedestrian demand is low and intermittent, the pedestrian phase is preferably activated by push buttons or pedestrian detectors.

FIGURE 5.2.3.3 STANDALONE SIGNALISED CROSSING

Grade-separated Crossings

Grade-separated crossings should, wherever feasible, be provided in coordination with the terrain and vertical profile of a road to minimise the detour and difference in levels of the pedestrian connection. Consideration should be given to semi-depressed underpasses where a road is constructed on a raised embankment. These underpasses are generally more suitable for shared use by pedestrians and slow vehicles. However, footbridges may be more practical on flat terrains. They offer better personal security where pedestrians are infrequent. Examples of underpasses and footbridges are given in ***Figure 5.2.3.3***.

The capacity of grade-separated crossing is in the order of 50 and 40 pedestrians per minute per metre for level sections and ramps or staircase respectively. The recommended minimum width of footbridges and underpasses are 2m and 3m respectively if used exclusively by pedestrians.

Pedestrian underpasses should have reasonable forward visibility to enable opposing pedestrians seeing each other around corners. In general, a minimum radius of 5m is needed and larger values are needed for combined pedestrian and slow vehicle underpasses. Pedestrian underpasses should have headroom not less than 2.7m and exceptionally 2.4m.

For universal accessibility, footbridges and subways should also be equipped with ramps or lifts. If this is not possible, alternative signalised at-grade crossings may be required within reasonable distance.

FIGURE 5.2.3.3 **UNDERPASS (LEFT) AND FOOTBRIDGE (RIGHT)** *(driving is on the right side of the road)*

Entrance to an underpass could be hazardous to occupants of an errant slow vehicle. The problem can be alleviated with a flared or rounded design of the abutment wall.

Handrails should be provided along stairs and ramps. The height of fences should be increased to 1.3m if the footbridge is more than 10m high or susceptible to adverse climate or windy conditions.

The piers of footbridges should be positioned in conjunction with any vehicle restraint systems. The horizontal clearance is preferably 4.5m or more with adequate consideration for any future needs of road widening. Pedestrian approaching or departing a footbridge should be separated or protected from high speed traffic.

The recommended maximum gradient of ramps is 5%. This may be relaxed to 6.7% with a maximum of 8.3%. On footbridge ramps steeper than 5%, intermediate ramps not less than 2m in length should be provided for level difference up to 2.5m. Changes in direction are preferably introduced where the level difference is larger than 3.5m.

2.4 Central Refuge Islands

Central refuge islands are physical traffic islands located in the middle of a bidirectional road to provide a reserve space for pedestrians. This is shown in ***Figure 5.2.4.1***. On divided roads, pedestrian refuge islands are part of the median which may be locally widened. Pedestrian refuge islands may also be part of a traffic island for the channelisation of traffic at intersections.

FIGURE 5.2.4.1 CENTRAL REFUGE ISLAND

The main purpose of central refuge islands is to reduce the difficulty and to improve visibility when pedestrians need to cross urbanised sections of Classes II or III roads with high traffic volume or wide urbanised sections. They also help to deter overtaking at speeds, especially if the road is straight.

To avoid pedestrians looking at the wrong traffic direction, pedestrian refuge islands should only be provided to separate opposing traffic and not traffic coming from the same direction. Where an offside-turning lane is provided, it may be appropriate to provide an auxiliary refuge island to separate straight-ahead and offside turning traffic.

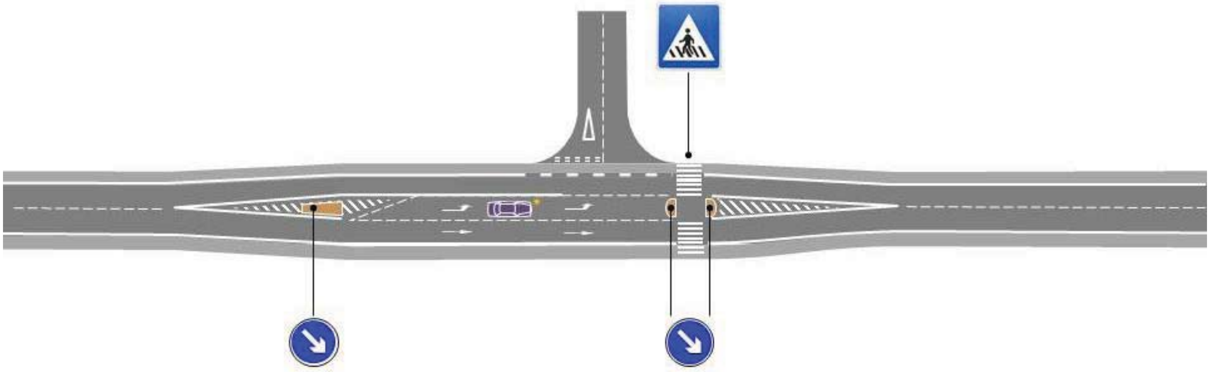
Design Features

Central refuge islands should be formed from kerbs and delineated by signs and approach markings. Kerbs should be clearly identifiable with good colour contrast. They are most suitable along urbanised sections and possibly their peripheries with road lighting. They may be provided on other road sections subject to speed limit not exceeding 70km/h, preferably in conjunction with traffic calming schemes.

The desirable minimum width of a central refuge island is 2.4m. This may be reduced to 1.5m where there are only occasional pedestrians. On the other hand, it may be desirable to increase the width to accommodate high volume of pedestrians, wheelchair users, bicycles or other slow vehicles.

It is often desirable to integrate central refuge islands with protected turn lanes and side road channelisation islands. ***Figure 5.2.4.2*** illustrates a minimal refuge island retrofitted at an intersection with hatched markings.

FIGURE 5.2.4.2 RETROFIT OF PEDESTRIAN REFUGE ISLAND AT PROTECTED TURN LANE INTERSECTION



Wide refuge may be designed in a staggered layout with pedestrian fences for pedestrians to cross in two steps. The stagger layout preferably brings pedestrians to face approach traffic while negotiating the refuge.

The surface of pedestrian paths through refuge islands should be flushed or slightly elevated to not more than 25mm in height with chamfer corners. The paving of pedestrian paths is preferably in colours or materials having a visual contrast with the carriageway pavement.

Class I Roads

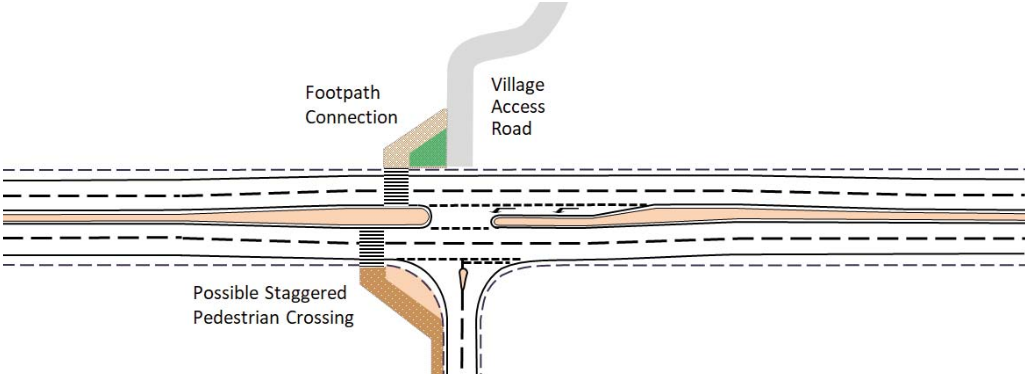
Central refuge islands on Class I divided roads are created from median openings. In urban areas, it is desirable to extend the refuge island outward to occupy the median shoulder. This would provide pedestrians with a larger space and better visibility.

On divided roads where there is a risk of vehicles using pedestrian crossings for U-turns, a possible solution is installation of bollards over the width of the pedestrian path at intervals not exceeding 2m.

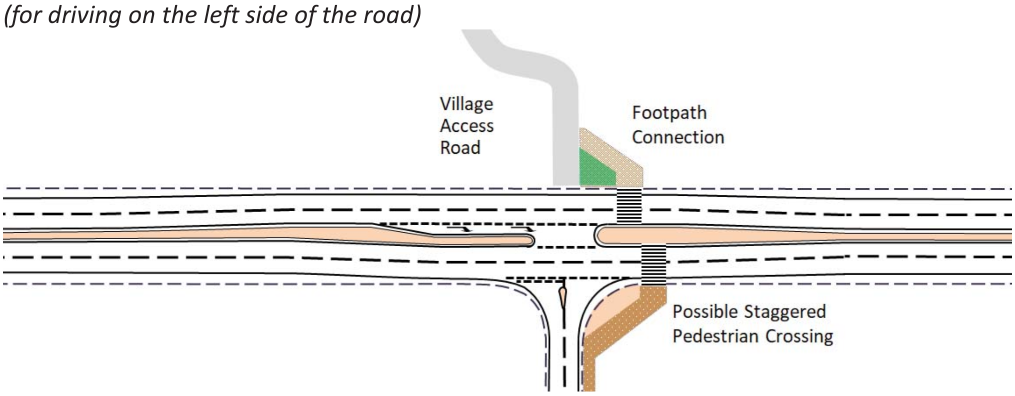
A typical pedestrian crossing on Class I roads with staggered layout is illustrated in ***Figure 5.2.4.3***.

FIGURE 5.2.4.3 PEDESTRIAN CROSSING ON CLASS I ROADS

(for driving on the right side of the road)



(for driving on the left side of the road)



2.5 Pedestrian Fences

Pedestrian fences are physical separation provided to:

- highlight crossing points
- encourage crossing at right angle
- prevent pedestrians crossing Class I roads between designated crossings
- guide pedestrians towards footbridges or underpasses
- divert pedestrians away from intersections and road sections not suitable to cross
- avoid pedestrians spilling onto the road
- serve as a handrail

Pedestrian fences may be provided to prevent pedestrians spilling onto the road at exits of town halls, tourist sites, religious places, schools etc.. where there may be a momentary surge of pedestrian flows. At school exits, pedestrian fences may be provided to guide students towards a crossing or pick-up point.

Another important function of pedestrian fences is their use as parapets over steep side slopes, sheer drops, water bodies and along bridges.

Avoidance of Excessive Use

If long lengths of pedestrian fences are installed without adequate crossing facilities, pedestrians may attempt to cross the road indiscriminately at accesses and median openings or else climb over pedestrian fences or median safety barriers. Sections of fences may even be removed by local residents. These could lead to serious safety problems if drivers travelling at high speeds do not expect crossing pedestrians.

Overuse of pedestrian fences may result in severance, obstructed view and degradation of streetscape and landscape. They may also unnecessarily restrict loading and unloading activities and force pedestrians to walk on the road. A subtle balance has to be achieved in conjunction with traffic calming. More attractive pedestrian fences, whether in simplistic or decorative patterns, should be encouraged.

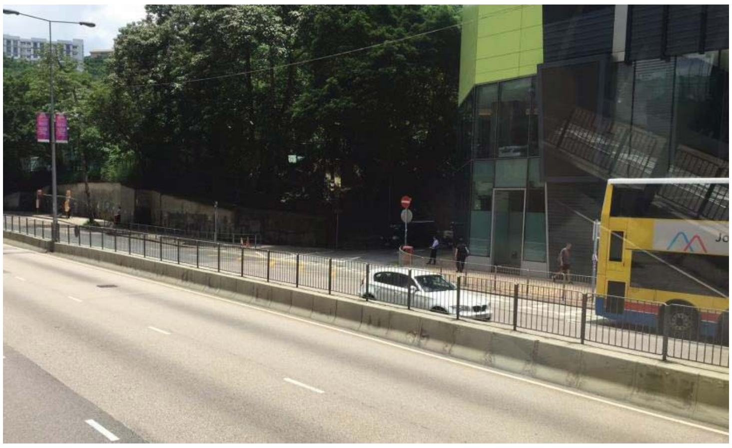
General Requirements

Where pedestrians are channelised onto a crossing facility, pedestrian fences should have a nominal length of 15m with adjustment to suit site conditions. In the vicinity of grade-separated crossings, fences may need to be erected along footpaths over a long distance in order to encourage their usage. For divided roads, pedestrian fences may be erected along the median alone to prevent pedestrians from crossing the roads other than at designated crossing points. This is illustrated in ***Figure 5.2.5.1***.

FIGURE 5.2.5.1 PEDESTRIAN FENCE WITH ANTI-CLIMB DESIGN *(driving is on the left side of the road)*

Pedestrian fences may be substituted by safety barriers, planters or other aesthetically pleasing design, provided these achieve the same purpose. In high risk situations, standard safety barriers may need to be supplemented with additional fences, as shown in ***Figure 5.2.5.2***.

FIGURE 5.2.5.2 PEDESTRIAN FENCE ON TOP OF SAFETY BARRIER *(driving is on the left side of the road)*



Fence Design

The design of panels of pedestrian fences should minimise the risk of entrapment of the head or limbs of a child through gaps. Any openings or gaps in the panel should either:

- not allow passing of a 110mm diameter rigid sphere; or
- allow passing of a 230mm diameter rigid sphere

If whole or part of a panel essentially consists of vertical infill bars, the width of any gaps between infill bars should not exceed 110mm. The minimum height of pedestrian fences should be 1.0m. They may need to be raised to 1.3m or even higher in extraneous circumstances e.g. over a railway.

An increased height of pedestrian fence may also be needed where there is a high incentive for pedestrians to cross a divided road with heavy or high speed traffic. Additionally the fence should not contain any traversable gaps. Such gaps constitute a very high risk as drivers do not expect any crossing activities.

Visibility

Pedestrian fences could have an adverse effect on the visibility at pedestrian crossings and intersections (***Figure 5.2.5.3***). This is due to support posts and vertical bars appearing to be a solid wall when viewed at a shallow angle. The problem is aggravated if the road is on a curve and around a crest profile.

High visibility pedestrian fences are based on slim horizontal bars rather than vertical bars (***Figure 5.2.5.4***). They should be adopted around pedestrian crossings, intersections and median openings. They should also be used for any short lengths of fences and in the vicinity of their termination.

FIGURE 5.2.5.3 POTENTIAL MASKING OF WAITING AREA AT A CROSSING
(driving is on the left side of the road)

FIGURE 5.2.5.4 HIGH VISIBILITY PEDESTRIAN FENCE AT A CROSSING
(driving is on the left side of the road)

Passive Safety

Pedestrian fences are generally inappropriate where traffic speeds exceed 70km/h and should not be used to substitute safety barriers. When collided by a vehicle, there should be minimum risk of detachment of horizontal rails which may penetrate into a vehicle or dislodgement of components as projectiles. In particular, top rails with rigidity substantially higher than other members of the fence panel should not be permitted unless there is remote likelihood of vehicles colliding with the fence.

For the safety of pedestrians and slow vehicle users, pedestrian fences should be free of sharp edges and corners.

3 SLOW VEHICLE FACILITIES

3.1 General Requirements

Slow vehicle facilities are road facilities provided for the exclusive use of slow vehicles. It is important that they function as a network without missing links. Short-cuts are often desirable especially if these are free from vehicle traffic.

Slow vehicle network should be planned with an understanding of land-use related to the spatial distribution of villages, towns, schools, cultivation, industrial areas etc. Origins and destinations of trips should be established and preferably quantified.

Depending on the local circumstances, slow vehicles may include a combination of the following vehicle types which have travel speeds generally not exceeding 30km/h.

- Bicycles
- Electric bicycles (E-bikes)
- Low powered motorcycles
- Tricycles/Trishaw
- Electric tricycles
- Motor tricycles
- Agricultural vehicles
- Animal drawn vehicles
- Animal herds

The composition of slow vehicle types may change over time. For example, bicycle traffic may become substituted by electrical bicycles. In some rural areas, electric tricycles may be the dominant type of slow traffic. Sections of Asian Highway routes may be recreational and tourism routes frequented by cyclists.

Bicycles and electric bicycles may share the same facilities provided that adequate width and capacity design are accommodated. These facilities should not be used for motorcycles or motor tricycles as their speeds could be significantly higher.

Slow vehicle facilities consist of slow vehicle routes and slow vehicle crossings. In some circumstances, slow vehicles may share the road with other road-users including motor vehicles or pedestrians. These may also form part of the slow vehicle facilities.

Main Design Parameters

Design parameters given for bicycles are deemed suitable for electric bicycles with appropriate adjustments. The basic design requirements are given in ***Table 5.3.1.1***.

TABLE 5.3.1.1 KEY DESIGN PARAMETERS FOR BICYCLE ROUTES [24]

Function of Slow Traffic Facility	Deign Speed	Minimum Stopping Sight Distance[1]	Minimum Dynamic Stopping Sight Distance [2]	Minimum Radius	Minimum Radius around intersection
Trunk	30 km/h	35 m	65 m	25 m	4 m
Local	20 km/h	25 m	45 m	15 m	4 m

1. Add 50% if path is not paved or downhill gradient >5%
2. This is sight distance cyclists require to feel safe and comfortable

The gradient of slow vehicle facilities for bicycles normally is preferably less than 3% and limited to 7%. At increasing gradient between 3% and 5% over extended distance, additional precautions such as intermediate flat sections and safer roadside should be incorporated. Where gradient exceeds 5%, the design should be a ramp with regular landings. For approach to intersections or underpasses with gradients exceeding 5%, speed control should be considered.

Crossfall for bicycle tracks should be limited to 2.5% without superelevation.

Slow vehicle facilities should have an even surface for the comfort and safety of users, in particular bicycles and electric bicycles.

It is generally undesirable to provide ironworks such as gully gratings, manhole covers and similar features which could become slippery when wet. This is particularly the case for bicycles and motorcycles. Gully gratings should

Visibility Distance

At crossing paths of bicycles and slow traffic, adequate visibility should be maintained. The requirement is given in ***Figure 5.3.1.1*** and ***Table 5.3.1.2***.

FIGURE 5.3.1.1 VISIBILITY REQUIREMENTS FOR SLOW VEHICLES [24]

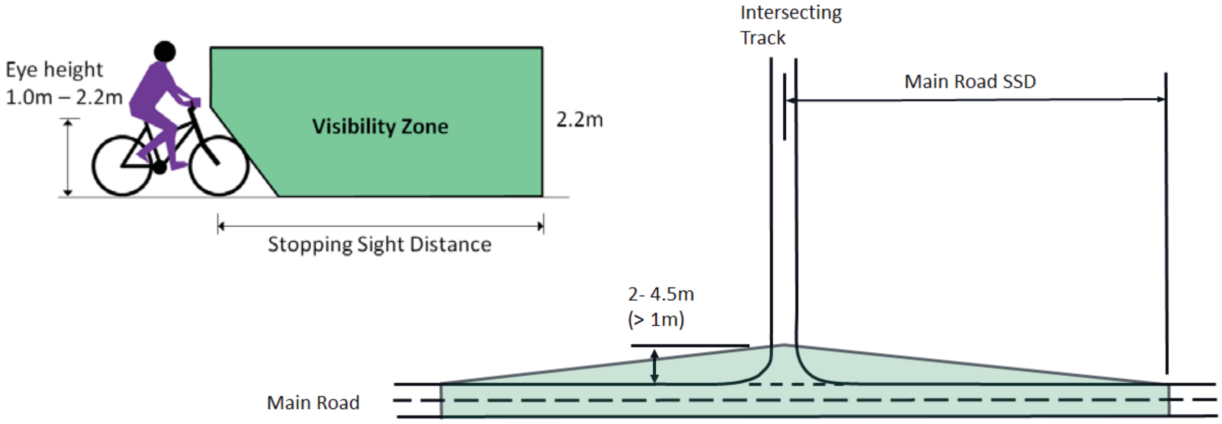


TABLE 5.3.1.2 RECOMMENDED VISIBILITY DISTANCE FOR SLOW VEHICLES [25]

	Crossing Width	Crossing Time (s)	85 Percentile Traffic Speed (km/h)				
			30	50	70*	80*	100* #
Recommended Values (m)	4m	4.2	45	100	180	205	
	5m	4.5	45	105	185	210	
	6m	4.9	50	110	190	220	
	7m	5.1	50	115	200	225	
	8m	5.5	55	120	205	235	
Absolute Minimum Values (m)			35	70	120	150	215

* Additional traffic calming is recommended

\# only appropriate for occasional cyclists and slow vehicles, crossing cyclists should be advised to dismount

Horizontal Clearance

Horizontal clearance should be provided along the edge of slow vehicle facilities to enhance the comfort and safety of users. The requirement is illustrated in ***Table 5.3.1.3***.

TABLE 5.3.1.3 HORIZONTAL CLEARANCE [24]

Feature	Minimum Clearance (m)
Low upstand <50mm high without sharp edges	Nil
Kerb heights 50mm-150mm	0.20*
Continuous features =<1.2m high	0.25*
Isolated objects of any heights- sign post, lighting columns, cabinets etc.	0.25*
Continuous features >1.2m high	0.5*
Bridge parapet of any heights	0.5*

* added to the width of the facility or provided as a verge

Slow vehicle tracks should be separated from the running carriageway by a strip not less than 0.5m. If the track lies along a road with speed limit of 70km/h or above, the separation should be increased to 1.5m. For main road speed limit of 80km/h or above, safety barriers for vehicles should be provided adjacent to the slow vehicle track.

Forgiving Roadside

To further enhance the safety of slow vehicle occupants in the event of a crash, a forgiving roadside should take into account:

- errant slow vehicles colliding with aggressive roadside objects or walls
- slow vehicle occupants falling over steep side slopes, drops or into water bodies
- falling cyclists or motorcylists impacting onto objects or ground features

The roadside of slow vehicle lanes or tracks should be free from aggressive features which may aggravate the consequences if a slow vehicle crashes onto the roadside. This is illustrated in ***Figure 5.3.1.2*** and ***Figure 5.3.1.3***. Features which require particular attention include drainage facilities, lighting columns, traffic signs, subway headwalls, bridge piers etc..

FIGURE 5.3.1.2 BICYCLE-FRIENDLY GULLY GRATING

FIGURE 5.3.1.3 ROADSIDE HAZARDS ALONG A BICYCLE TRACK *(cycling is on the left side of the road)*

Roadside safety risks may be reduced with a widened verge free of aggressive objects or ground profiles, especially at sharp bends and on downhill gradients. If hazardous features cannot be relocated, consideration should be given to covering them with protective pads.

Equipment to regulate access and to slow down bicycles should be passively safe. Self-restoring frangible bollards are preferred to rigid metal or concrete bollards.

Fences for bicycles should be adopted to channelise users towards crossings and to prevent them falling off bridges and side slopes. New bicycle fences on bridges should be at least 1.4m high. A safety barrier may be considered to separate slow vehicles from vehicle traffic at high speeds.

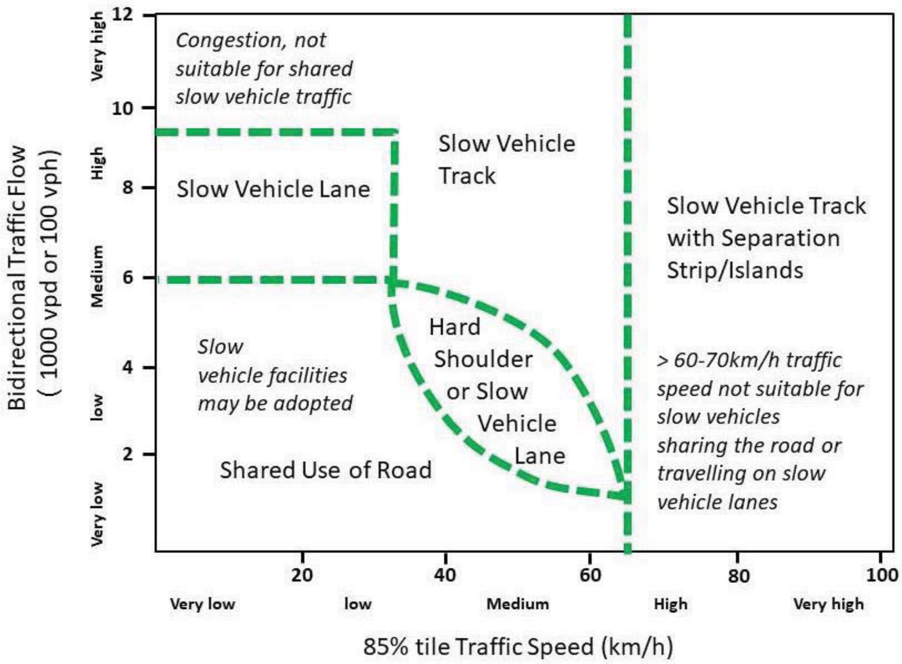
3.2 Slow Vehicle Routes

Slow vehicle routes consist of the following categories:

- Slow vehicle lanes - facilities on the carriageway
- Slow vehicle tracks - facilities associated with but physically separated from a carriageway
- Slow vehicle paths - facilities independent of a carriageway
- Slow vehicle crossings

The choice of facilities should be based on traffic volume and traffic speeds according to ***Figure 5.3.2.1***.

FIGURE 5.3.2.1 SUITABILITY OF SLOW VEHICLE ROUTES [24]



The main principles are:

- Shared use of road where traffic speed is less than 30km/h and traffic volume is low
- Slow vehicle lane is a possibility at low traffic speeds and high traffic volume or moderate traffic speeds and low traffic volume
- Slow vehicle track is necessary at high traffic volume or high traffic speeds

If there are substantial difficulties in providing a slow vehicle track, a slow vehicle lane should still be provided wherever feasible. Traffic speeds should be reduced to appropriate levels where slow vehicles are present alongside vehicle traffic.

Where a bypass is constructed, slow vehicles are ideally diverted to the old road. This includes roads of traffic volume not exceeding 1,000 veh/day and traffic speeds do not exceed 60km/h. At higher traffic flows, up to 4,000 veh/day, additional measures are needed to increase the awareness of vehicle drivers.

Slow Vehicle Lanes

A typical slow vehicle lane is bounded by a solid line marking with coloured surfacing as shown in ***Figure 5.3.2.2***. ***Table 5.3.2.1*** gives the recommended lane widths for slow vehicle lanes. It may be desirable to provide some forms of physical segregation.

FIGURE 5.3.2.2 BICYCLE LANES *(driving is on the right side of the road)*

TABLE 5.3.2.1 SLOW VEHICLE LANE WIDTHS

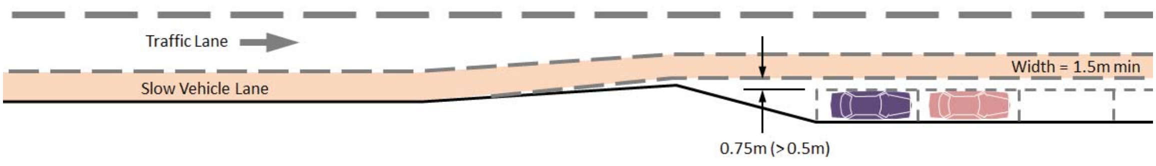
	Main Types of Slow Vehicles		
	Bicycles	Electric Bicycles	Electric Tricycles
Preferred (m)	2.5	2.75	2.75
Desirable Minimum (m)	2.0	2.5	2.5
Absolute Minimum (m)	1.5	2.0	2.0

* including low power motorcycles
** tricycles overtaking tricycles assumed to be infrequent

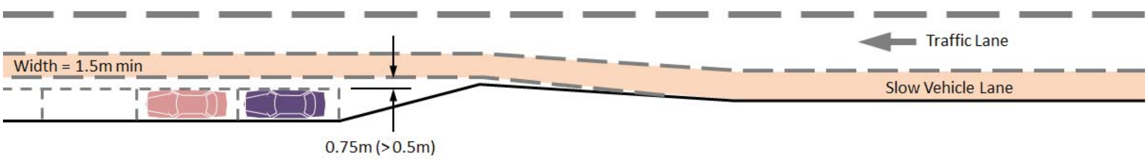
Slow vehicle lane width may be reduced to 1.75m to optimise the distribution of road width. If the prevailing traffic is bicycles, a width of 1.5m and exceptionally 1.25m would be acceptable provided that the path is free from gravels, debris or hazardous gully gratings.

It is not advisable to provide roadside parking space alongside slow vehicle lanes. If parking spaces are required, a lateral separation of 0.75m to 1.0m (0.5m minimum) should be provided to minimise the risk of opened doors intruding into the slow vehicle lane. This is shown in ***Figure 5.3.2.3***.

FIGURE 5.3.2.3 ADVISORY SLOW VEHICLE LANES ALONGSIDE ROADSIDE PARKING AREA
(for driving on the right side of the road)

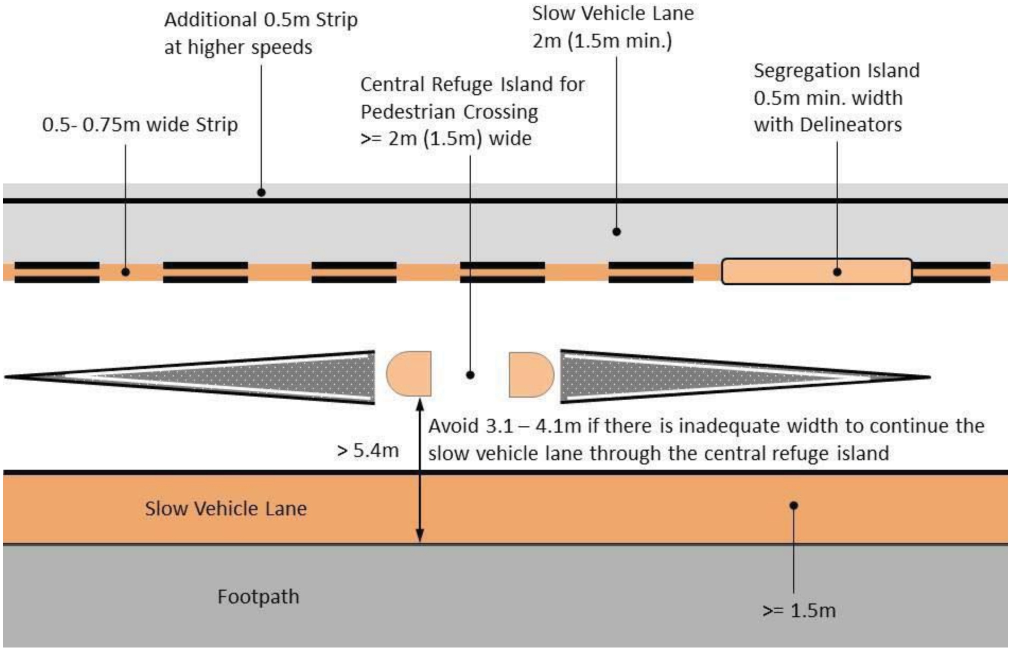


(for driving on the left side of the road)



Traffic islands may be needed for pedestrian crossings, slow vehicle crossings, traffic calming or protected turn lanes. In all these circumstances, it is necessary to ensure continuity of the slow vehicle lane and to provide adequate space for a heavy vehicle and a slow vehicle to pass in parallel. This is illustrated in ***Figure 5.3.2.4***.

FIGURE 5.3.2.4 SLOW VEHICLE LANES AT CENTRAL REFUGE [24]



In principle, the width of the slow vehicle lane should be maintained at 2m with a minimum width of 1.75m. It could be desirable to widen the edge line to 0.5m wide. The width of the through traffic lane should be 3.1m to 3.5m such that the combined width of the vehicle lanes and slow vehicle lane lies between 5.1m and 5.6m. These values correspond to traffic speed between 30km/h and 50km/h.

Alternatively, it would be desirable to provide a segregated island for the slow vehicle lane. In this case, the width of the slow vehicle lane should be based on the type of slow vehicles. A minimum width of generally 1.75m is advisable.

Slow Vehicle Tracks

Slow vehicle tracks should be physically separated from the carriageway by:

- paved verge
- unpaved verge
- segregation island
- plantings

One-way slow vehicle tracks are generally provided along one side of the road. A segregated bicycle lane is illustrated in ***Figure 5.3.2.5***. Two-way slow vehicle tracks can be provided on one side or both side of the road.

FIGURE 5.3.2.5 SEGREGATED BICYCLE LANE *(driving is on the right side of the road)*

The recommended widths of one-way and two way slow vehicle tracks are given in ***Tables 5.3.2.2*** and ***5.3.2.3*** respectively.

TABLE 5.3.2.2 RECOMMENDED ONE-WAY SLOW VEHICLE TRACK WIDTHS

	Main Types of Slow Vehicles		
	Bicycles	Electric Bicycles	Electric Tricycles
Preferred (m)	2.5m	2.75m	3.0m
Desirable Minimum (m)	2.0m	2.5m	2.5m
Absolute Minimum (m)	1.5m	2.0m	2.0m

TABLE 5.3.2.3 RECOMMENDED TWO-WAY SLOW VEHICLE TRACK WIDTHS

	Main Types of Slow Vehicles		
	Bicycles	Electric Bicycles	Electric Tricycles
Preferred (m)	3.0m	3.5m	3.5m
Desirable Minimum (m)	2.0m	3.0m	3.0m
Absolute Minimum (m)	1.75m	2.5m	2.5m

Slow vehicle tracks intended for two-way traffic of electric bicycles or low powered motorcycles should be at least 3m in width. Otherwise, unidirectional tracks are preferred.

Segregated islands should have a width not less than 0.5m. They may be intermittent with regular gaps for access.

Kerbs should have a passively safe profile for slow vehicles with a preferred height of 50mm. If a larger kerb height is adopted, an edge line or additional margin should be considered.

A transition should be provided at the interface between a slow vehicle lane and slow vehicle track. An example is given in ***Figure 5.3.2.6***.

FIGURE 5.3.2.6 TRANSITION FROM BICYCLE LANE TO BICYCLE TRACK *(driving is on the right side of the road)*

Slow Vehicle Paths

Existing tracks and village roads should be encouraged to form an attractive network avoiding slow vehicles to use the main road. Some of these could be closed to vehicle traffic or else measures are incorporated to discourage access. The use of bollards, self-closing gates and chicanes could be considered.

The following opportunities should be identified around Asian Highway routes:

- Along rivers and canals
- Linking existing routes used by local inhabitants
- Providing new shortcuts
- Reuse of obsolete roads, bridges and railways

Upgrading of the Asian Highway Network often requires realignment or rerouting. The possibility of reusing abandoned sections of roads should always be evaluated. This is illustrated in ***Figure 5.3.2.7***.

FIGURE 5.3.2.7 REUSE OF AN OLD BRIDGE FOR SLOW VEHICLES *(driving is on the right side of the road)*

Service Road

Where there is a regular travel demand of a mix of local traffic and slow vehicle types along Asian Highway routes, a service road should be considered. This situation is illustrated in ***Figure 5.3.2.8***.

Depending on usage and space availability, the width of service road could be in the range of 5.0m to 8.5m for unidirectional traffic. Service roads may also be beneficial to accommodate frontage activities on urbanised sections.

FIGURE 5.3.2.8 SERVICE ROAD

(for driving on the right side of the road)

(for driving on the left side of the road)

Signing and Delineation

Bicycle facilities are preferably signed to formalise their usage. Appropriate signage includes:

- Start/end of compulsory cycle track
- Cycle track markings (***Figure 5.3.2.9***)
- Demarcation of cycle track and pedestrian footpath

Bicycle symbol marking should be repeated

- after every intersection
- at 50-100m intervals on urbanised sections
- at 500-750m intervals outside built-up areas

FIGURE 5.3.2.9 SYMBOL FOR BICYCLE FACILITIES

Cycle lanes should be separated from the carriageway by an edge line marking. For cycle lanes between 2m and 2.5m in width, a continuous edge line marking is generally appropriate. For cycle lanes less than 2m in width, it is preferable to adopt a dotted edge line marking.

For cycle lanes exceeding 2m in width, it may be desirable to widen the edge line to further emphasize the exclude vehicle traffic. Other options include the use of frangible bollard or railings to segregate slow vehicles.

To further emphasize the exclusive nature of slow vehicle lanes, consideration may be given to the use of coloured surfacing e.g. red or green. The colour of surfacing should be consistently used. Coloured surfacing may be continuously applied or partially applied at intersections. Coloured surfacing should only be extended along a crossing facility if slow traffic has priority and the speed of approach traffic is kept slow.

On two-way cycle tracks, centreline markings should be provided.

Edge lines are not normally required if the edge of slow vehicle path is well defined. They may be considered at high speeds.

To alert slow vehicles on the approach to hazards such as sharp bends, intersections, pedestrian crossings etc., it would be desirable to provide visual traffic calming measures including coloured surfacing, “SLOW” markings etc..

Combined Pedestrian and Bicycle Facilities

Slow vehicles and pedestrians often share the same route. As such, facilities for both road-users should be planned together.

Bicycles and pedestrians may readily share the same paths if their combined density does not exceed 100 pedestrians/hour/metre width. For a combined path 3m in width, combined density of 300 is generally acceptable.

Combined paths are not appropriate if they are frequented by electric bicycles or tricycles. In this case, physical segregation should be provided. Such physical segregated may be in the form of a kerb with a raised footpath, a line marking or a verge. There should be adequate deterrence for slow vehicles intruding onto the pedestrian footpath.

Intersection among Slow Vehicle Tracks/Lanes/Paths

Intersections among slow vehicles should be adequately treated, especially if there is a high traffic volume of slow vehicle at elevated speed. In general, priority intersections are sufficient with appropriate signing, markings and provision of visibility. Where slow vehicle traffic volume is high, additional features including turning lanes may be considered.

Slow Vehicle Parking and Stopping Facilities

It is highly undesirable that slow vehicles are stopping on slow vehicles facilities, on the carriageway and around intersections. Adequate parking or waiting facilities should be available. If it is not possible to relocate slow vehicles around intersections on urbanised sections, traffic speed should be substantially reduced to accommodate for possible conflicts.

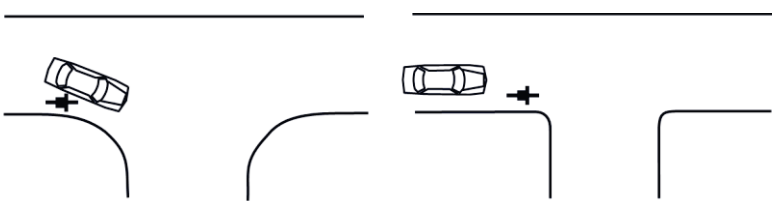
3.3 Slow Vehicle Crossings

There are two main categories of slow vehicle crossings- those crossing a side road and those crossing a main road. Each slow vehicle crossing should be carefully addressed to minimise any potential safety problems.

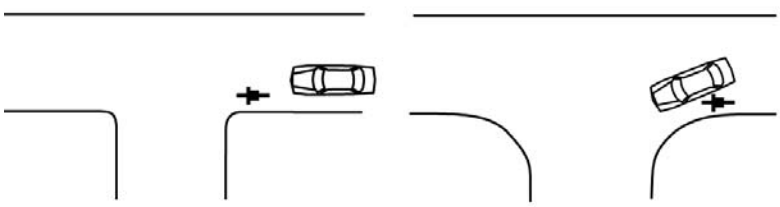
Intersection between Slow Vehicle Track and Side Roads

Drivers of nearside-turning vehicles, particularly large vehicles, may fail to see cyclists travelling straight ahead. For this reason, it is advisable to adopt smaller corner radii for minor intersections, accesses and intersections within urbanised sections where such conflicts are frequent. This is illustrated in ***Figure 5.3.3.1***.

FIGURE 5.3.3.1 PREFERENCE FOR TIGHTER SIDE STREET CORNER [26]
(for driving on the right side of the road)



(for driving on the left side of the road)



Where small corner radius is not desirable, bicycle lanes or tracks crossing T-intersections or busy accesses should be set back away from the main road by 4 to 8m. Crossings may be provided without setback for side roads with light traffic. These are illustrated in ***Figures 5.3.3.2*** and ***5.3.3.3*** respectively. It is desirable to provide a speed table at side road crossings.

FIGURE 5.3.3.2 SLOW VEHICLE CROSSING FOR MORE BUSY SIDE ROAD [27]

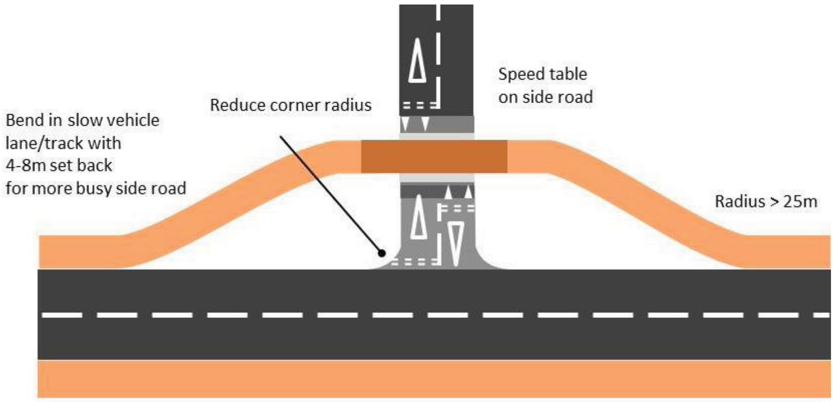
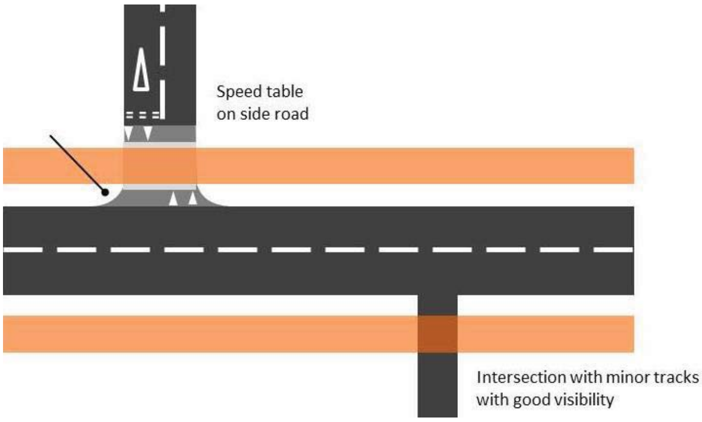


FIGURE 5.3.3.3 SLOW VEHICLE CROSSING FOR SIDE ROAD WITH LIGHT TRAFFIC [27]



Where main road slow vehicles have right of way, two sets of give-way markings should be provided on the side road. This is illustrated in ***Figure 5.3.3.4***.

FIGURE 5.3.3.4 MARKINGS AT A BICYCLE CROSSING
(ref: Google Street View, driving is on the right side of the road)

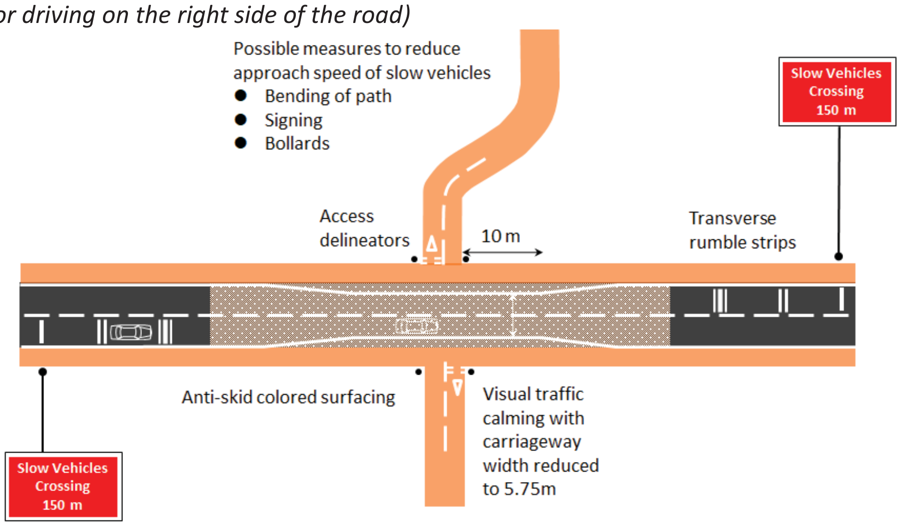
Intersections between Slow Vehicle Track and Main road

Where a slow vehicle track crosses the main road, slow vehicles should be required to give way to main road traffic. The speed limit of the main road should not exceed 60km/h and effective speed reduction measures for main road traffic are always required.

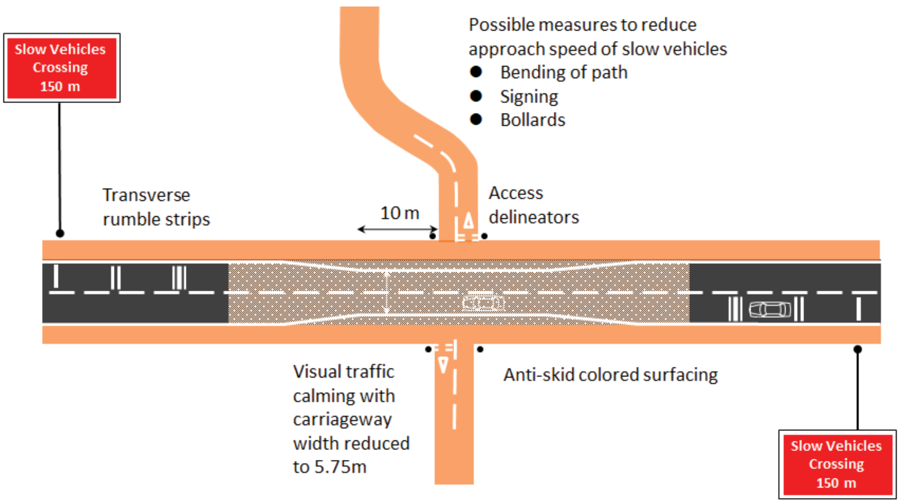
For intersections with relatively low traffic volume on the main road (600 veh/hour), measures should target at both main road traffic and slow vehicle traffic. Specific informatory signs are recommended to warn approach drivers of the nature of crossing traffic. A possible scheme is illustrated in ***Figure 5.3.3.5***.

FIGURE 5.3.3.5 SLOW VEHICLE CROSSING [27]

(for driving on the right side of the road)



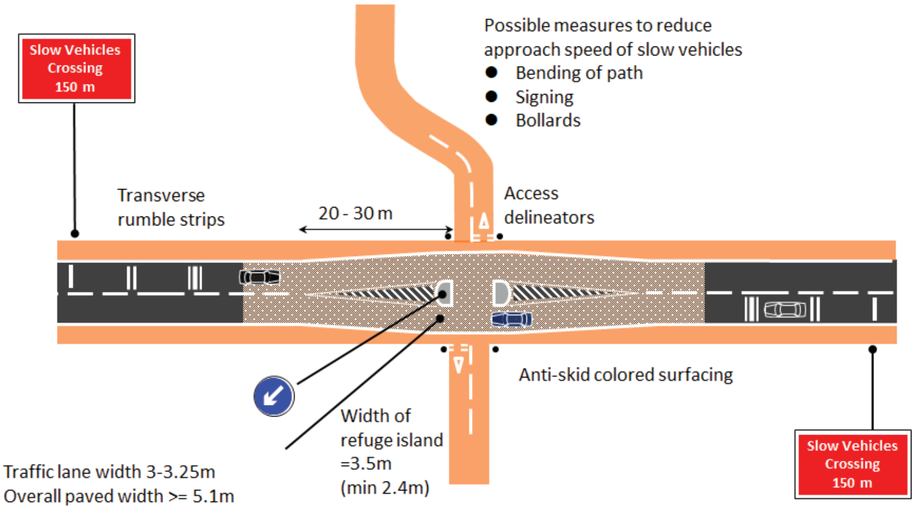
(for driving on the left side of the road)



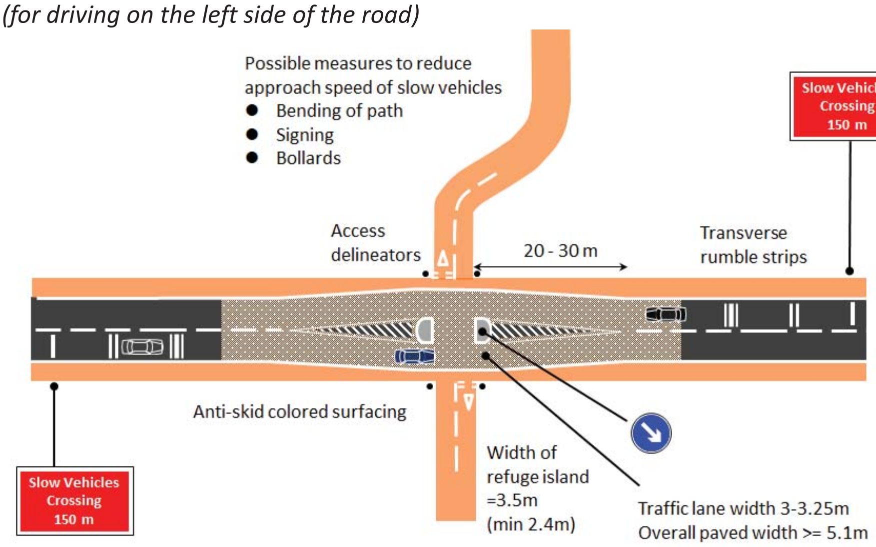
For intersections with relatively high traffic volume on the main road (600-1,000 veh/hour), considerations should be given to the provision of a central refuge island to facilitate slow vehicles to cross in two steps. This is shown in ***Figure 5.3.3.6***. Such islands should be wider than 3.5m to accommodate the prevailing crossing vehicles. The island should have adequate visibility distance and are readily identifiable by main road drivers.

FIGURE 5.3.3.6 SLOW VEHICLE CROSSING WITH CENTRAL REFUGE ISLAND [27]

(for driving on the right side of the road)



(for driving on the left side of the road)



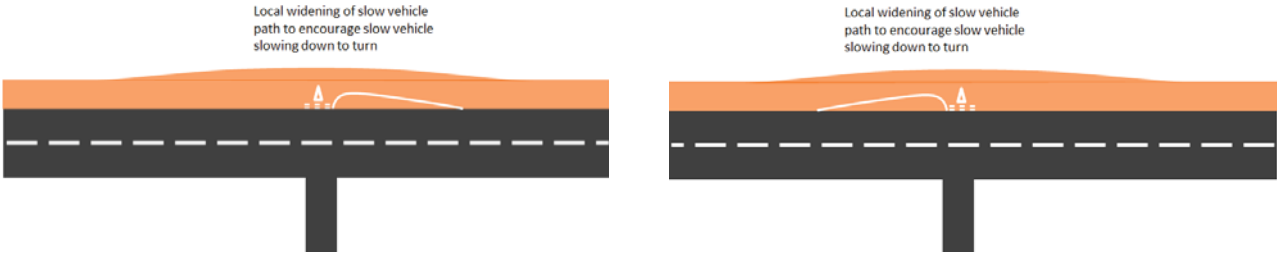
At still higher traffic flow (1,200 veh/hour) on the main road, the waiting time for slow traffic increases to 10 seconds even with a refuge island. At very high traffic flow (1600 veh/hour), it will be necessary to introduce traffic signals or other measures to facilitate crossing movements.

For main roads with busy traffic or traffic speeds exceeding 60km/h, cyclists should be advised to dismount prior to crossing the road.

Where there are frequent offside turning bicycles or slow vehicles, it is advisable to modify the layout as an intersection such that crossing is at right angle. This is illustrated in ***Figure 5.3.3.7***.

FIGURE 5.3.3.7 SLOW VEHICLE CROSSING TURNING POCKET

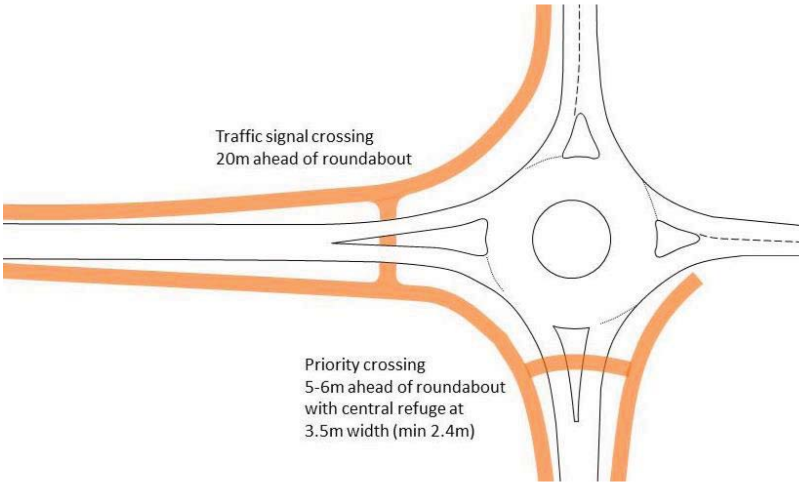
(for driving on the left side of the road) *(for driving on the left side of the road)*



Roundabouts

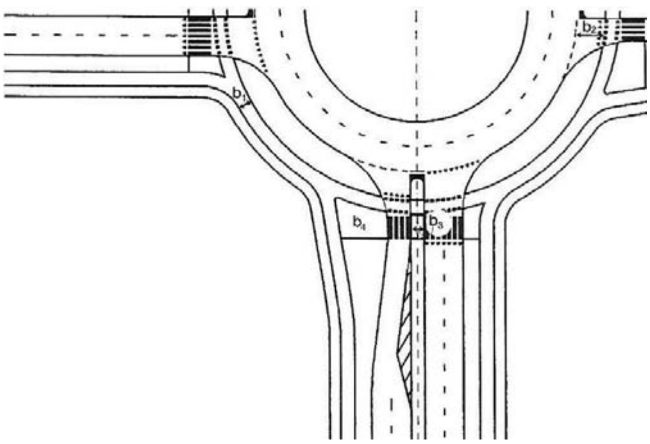
Single lane compact roundabouts are generally appropriate for mixed usage of main road traffic and slow vehicles. For two-lane roundabouts alongside Class I roads, slow vehicles should be routed through segregated tracks with crossings on the approaches. This is illustrated in ***Figure 5.3.3.8***.

FIGURE 5.3.3.8 SLOW VEHICLE CROSSING AT ROUNDABOUTS



Furthermore, two-lane roundabouts should be designed with features to discourage high speeds at entries and exits. It would be advisable to narrow down the exit lane to single lane, unless the crossing is signalised. This is illustrated in ***Figure 5.3.3.9***. This approach is also appropriate for single lane roundabouts with heavy traffic or higher traffic speeds.

FIGURE 5.3.3.9 PEDESTRIAN AND BICYCLE CROSSINGS AT A TWO-LANE ROUNDABOUT [25]



Grade-separated Facilities for Slow Traffic

Grade-separated crossings should be adopted on Class I roads and roads with high traffic speeds or traffic volumes. They may be provided in the following forms:

- Overpass
- Underpass
- Passage underneath viaducts or bridges
- Passage along river underneath bridge crossings

Underpasses and passages underneath viaducts or bridges are preferred to overpasses except where the latter is favoured by topography. Underpasses are desirably level or slightly depressed, with some raising of the highway on embankments. The design of underpasses should take into account visibility, personal security and passive safety. There should be no sharp bends on the approach and inside the facility.

Intersections between Slow Vehicles and Pedestrian Paths

Where a slow traffic track intersects a footpath and where pedestrians need to cross a slow vehicle track, the priority should be clearly established. It is advisable to route a slow vehicle track or lane behind a bus stop to avoid the need for slow vehicles taking evasive actions.

Where pedestrians need to cross a slow vehicle track at bus stops or in the vicinity of intersections, measures should be provided according to the slow traffic volume and speeds. Such measures should aim at raising awareness of both slow vehicle users and pedestrians, and may include:

- Refuge islands separating opposing slow vehicles
- Narrowing features
- Speed tables
- Rumble markings

It is advisable to adopt flushed or slightly raised kerbs for any refuge islands. Delineation of these islands or narrowing features should be based on flexible and self-restoring bollards with little potential in aggravation of injuries to an errant road-user. To further increase the conspicuity of crossing areas, coloured surface may be considered (***Figure 5.3.3.10***).

Adequate visibility should be provided at conflict areas between slow vehicles and pedestrians.

FIGURE 5.3.3.10 PEDESTRIAN CROSSING ON A BICYCLE TRACK USING SELF-RESTORING PASSIVELY SAFE BOLLARDS *(cycling is on the left side of the road)*

3.4 Dedicated Motorcycle Facilities

Where mass flow of commuting motorcycles travelling at higher speeds i.e. up to and beyond 60km/h, accounts for a significant proportion of the traffic, consideration should be given to the provision of dedicated motorcycle facilities in the form of exclusive motorcycle lanes or non-exclusive motorcycle lanes (***Figure 5.3.4.1***).

FIGURE 5.3.4.1 EXCLUSIVE MOTORCYCLE LANE (LEFT) AND NON-EXCLUSIVE MOTORCYCLE LANE (RIGHT) *(Ref: iRAP) (driving is on the left side of the road)*

Justification for dedicated motorcycle facilities may be established on the following basis [28]:

- Total volume of traffic: at or near saturation
- Percentage of motorcycles: 30%
- Motorcycle crashes: >5 per km per year
- Density of intersections and direct frontage accesses: <30 per km

Design Considerations

Design considerations for motorcycle lanes are similar to those for slow vehicles. Since motorcycles using these facilities generally travel at higher speeds and in mass flow, they are not suitable for the shared use of slow vehicles such as bicycles and electric bicycles.

Table 5.3.4.1 provides typical design parameters for motorcycle lanes.

TABLE 5.3.4.1 TYPICAL DESIGN PARAMETERS [28]

	Types of Motorcycle Lanes	
	Exclusive	Non-exclusive
Length	> 5km	
Lane width (m)	3.0m	2.0m*
Paved shoulder (m)	0.5m (forming part of lane width)	0.75m on traffic side 0.5m on roadside

* <2.5m to avoid usage by other vehicles

Exclusive motorcycle lanes will need to be planned with an elaborated suite of infrastructure, namely grade-separation intersections, lighting and signage systems. There should be no at-grade intersections and pedestrian crossings. Personal security will need to be addressed where facilities are located in quiet areas, underneath grade-separated interchanges and in underpasses.

Non-exclusive motorcycle lanes, on the other hand, require special treatments where they are in conflict with at-grade intersections, direct frontage accesses or bus stops.

Motorcycle lanes should be clearly signed to exclude all other traffic. As far as practical, the roadside of motorcycle lanes should have clear zones free from aggressive roadside features constituting a hazard for errant motorcyclists. This is particularly important at curves and other locations where falls are more likely.

Motorcycle Shelters

Motorcycle shelters are facilities to enable motorcyclists having a rest and finding shelter during rainstorms. In general their use is limited to access-controlled roads with or without motorcycle lanes.

Roadside areas underneath intersecting bridges often attract motorcyclists to seek shelter. These locations should therefore be designed with adequate paved shoulders. They are also candidates for the provision of motorcycle shelters if additional space is available beyond the shoulder.

The following facilities should be considered at motorcycle shelters:

- Shelter structure on a platform
- Paved motorcycle parking spaces
- Merging and diverging lanes
- Toilets, benches and garbage bins
- Lighting and drainage systems
- Vehicle restraint systems
- Lightning protection at exposed locations

Motorcycle shelters should have good visibility on the approach and at the intersection with the main road. They should be supported by entrance signing, advance signing and information about available shelters further ahead.

4 TRAFFIC CALMING

4.1 General Requirements

Any existing and future built-up areas directly traversed by the main road should be identified and categorised according to population and intensity of activities. Adequate traffic calming is then formulated through these built-up areas and their peripheries.

Speed limits are applied according to the following rules

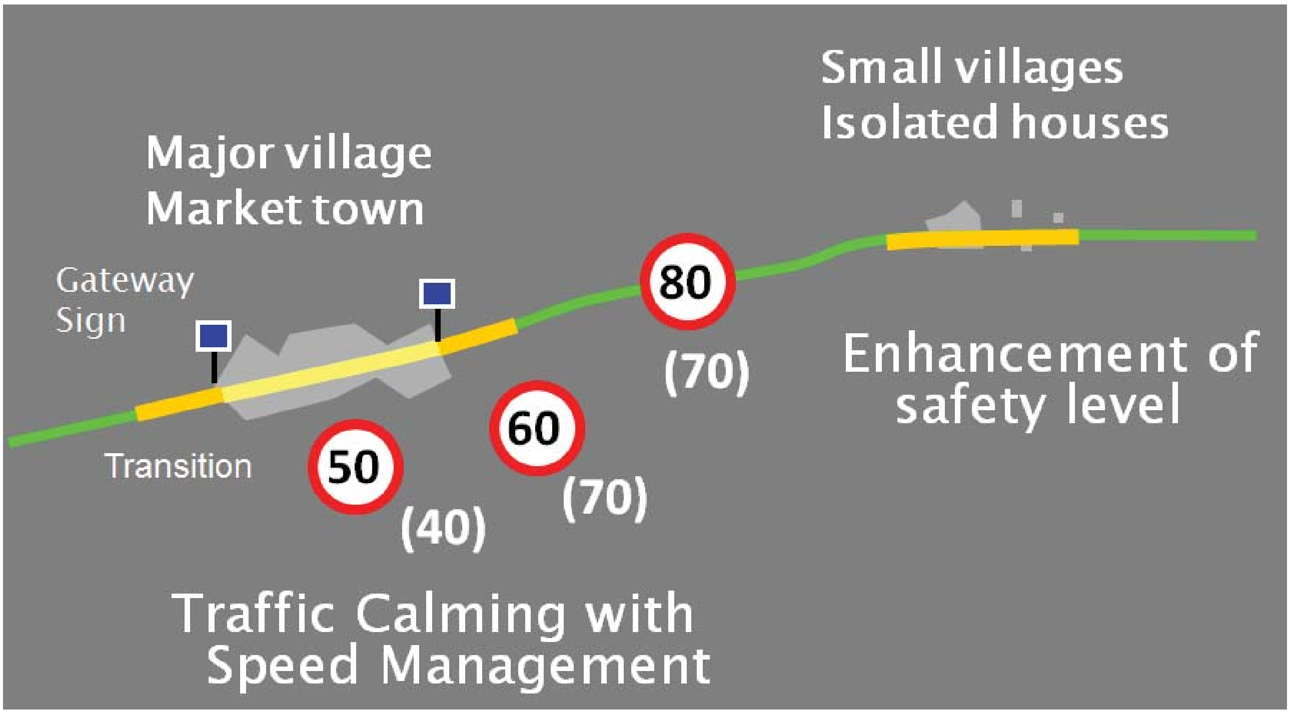
- 50 km/h (40 km/h)– village and towns
- 60 km/h (50 km/h)– peripheral zones

All built-up area should have a gateway sign showing the name of the settlement. Such signs are located to coincide with the commencement of buildings and not necessarily the administrative boundary. A sign is also needed to mark the end of the built-up area.

Along road sections at the periphery of built-up areas, visual or audio-tactile traffic calming measures are preferred. This may be supported by gentle physical speed reduction measures. A range of physical speed reduction measures may be adopted at the gateway and within the built-up area.

Figure 5.4.1.1 illustrates the general approach and typical scenarios of traffic calming schemes respectively.

FIGURE 5.4.1.1 GENERAL APPROACH OF TRAFFIC CALMING SCHEMES



Ribbon Developments

These are elongated built-up areas along a highway over a significant distance, sometimes in the order of kilometres. Customized traffic calming schemes will need to be formulated to sustain lower speeds and to provide safe crossing opportunities for pedestrians. Ribbon developments should be avoided through planning regulations as they could constitute significant safety risks.

Urbanised Sections of Class I Roads

Multi-lane Class I roads generally have high traffic speeds and heavy traffic volume. Direct passage through built-up areas could cause severance to communities with serious safety problems. This is illustrated in ***Figure 5.4.1.2***.

FIGURE 5.4.1.2 CLASS I ROAD TRAVERSING A BUILT-UP AREA *(driving is on the right side of the road)*

In general, Class I roads should bypass built-up areas. Otherwise, the road should be converted as an urban street with traffic calming. In addition to redistribution of the road cross-section and provision of pedestrian and slow vehicle facilities, the following features will be desirable:

- Reduced speed limit at 40 to 50km/h
- Reduced traffic lane width
- Reduced number of traffic lanes with preferably one lane per direction at crossings
- Signalisation of intersections and crossings
- Kerb extension at pedestrian crossings
- Intersections with protected offside turn lane
- Adequate visibility at intersections and crossings
- Provision of overpasses or underpasses for pedestrians and slow vehicles

4.2 Visual Traffic Calming

Visual traffic calming is a collection of techniques to slow down traffic without physically altering the road and pavement construction. The principle is to influence drivers' perception of the road environment, road width and the associated safety risks. A merit of visual traffic calming is that it is generally more economical and acceptable to stakeholders.

The use of visual traffic calming requires a careful evaluation of the environmental context with a holistic approach. To be effective, however, additional physical measures may still be required. The effectiveness has to be monitored and adjustments are made if necessary.

The techniques often involve visual illusion and creation of a certain degree of uncertainty. These are divided into the following categories:

- Gateway, Signing and Delineation
- Streetscape and landscaping
- Special pavement
- Road markings

General Considerations

The road environment of urbanised sections should be distinctly different from free-flow highway sections. There should be strong visual treatments using both engineering and non-engineering measures, to incite drivers to reduce speed and adopt appropriate behaviour.

Accordingly, a smooth road alignment and features or equipment associated with high speed traffic should be avoided. If the urbanised section consists of a long straight section, it is advisable to provide interruptions at intervals not exceeding 200m. Such interruptions may be limitation of excessive forward visibility, reassignment of cross-section, pedestrian crossings, pedestrian refuge islands, speed humps etc..

Gateway, Signing and Delineation

Gateways should be located to coincide with the start of buildings which is not necessarily the administrative boundary. The fundamental provision is a gateway sign displaying the name of the built-up area at the entrance and exit. The entrance sign is preferably integrated with a gateway feature or decorations which gives drivers a strong perception of the start of an urbanised section.

Gateway signs are desirably legally defined to indicate built-up areas and the default speed limit. Otherwise, separate speed limit signs should be erected. For urbanised sections of extended length, speed limit markings may be adopted as repeaters.

Where a lower speed limit is not adopted but reduced traffic speed is desirable locally, “SLOW” markings may be adopted in conjunction with warning signs indicating “Pedestrians”, “Children” or “Village” etc. Non-standard signs with soft messages and graphics may also be adopted to supplement more formal measures.

Streetscape and Landscaping

The appearance of footpaths, crossings, lighting columns, bus stops etc. are important visual hints for the presence of pedestrians and local activities. These may be reinforced by the presence of postal collection boxes, refuse bins, benches etc.

Well-conceived and attractive streetscape and landscaping constitute the collection of non-engineering “natural traffic calming” measures. Landscaping comprising trees, shrubs, flowers and associated street furniture is desirable from the perspective of amenity, and could contribute to speed reduction through optical narrowing of the road and in conjunction traffic calming measures. A notable change in landscaping design is also desirable for highway traffic entering the peripheral zone of an urbanised section.

Drivers are more likely to associate pedestrians and local activities with important buildings, plazas, town halls, worship places, markets, landmarks, shopping streets etc. These may be further accompanied by historic artifacts, decorations, fountains, memorials etc. on the roadside. Traffic calming schemes would be most effective if designed in conjunction with these features.

Figure 5.4.2.1 illustrate the alteration of a main road with a heavy emphasis of streetscape and landscaping design. Likewise ***Figure 5.4.2.2*** illustrates traffic calming based on low-cost visual effects. Designs should be based on traffic calming principles take into account local cultures, climate, materials, funding and maintenance. A degree of participation by local communities could help to foster a sense of ownership which is important to sustain major traffic calming schemes.

Figure 5.4.2.1 Traffic Calming with Attractive Streetscape on a Main Road
(driving is on the right side of the road)

Figure 5.4.2.2 Traffic Calming Treatments through a Built-up Area
(driving is on the right side of the road)

Special Pavement

This measure makes use of a change in the colour, pattern or texture of the pavement to incite a change of drivers' behaviour. Examples include:

- Coloured surfacing in buff, red or other colours
- Stone pitched paving

Coloured surfacing alone is inadequate to slow down traffic. A better effect can be obtained with appropriate patterns and texture. Considerations should also be given to skid resistance of the materials and implications on two wheel vehicles.

Road Markings

Standard design of road markings is not always desirable along urbanised sections as this tends to give the impression of the continuation of the highway. In some circumstances, it may be beneficial to deliberately remove centreline markings in conjunction with narrowing measures. This is illustrated in ***Figure 5.4.2.3***. By creating a sense of uncertainty, drivers could become more alert.

FIGURE 5.4.2.3 TERMINATION OF CENTRELINE MARKINGS ON AN URBANISED SECTION

(driving is on the right side of the road)

Road markings with the intention of speed reduction include:

- Transverse bar markings
- Edge markings visual narrowing
- Central Hatching (***Figure 5.4.2.4***)
- Dragon teeth markings (***Figure 5.4.2.5***)
- Optical speed bar markings (***Figure 5.4.2.6***)
- Diamond markings (***Figure 5.4.2.7***)

Speed reduction markings have a wide application for urbanised sections as well as free-flow sections of undivided and divided roads. For these latter applications, they are mainly used on the approach to hazards including:

- Sharp curves
- Intersections on both main road and side road approaches
- Tunnels and toll plazas
- Urbanised section

FIGURE 5.4.2.4 CENTRAL HATCHING WITH COLOURED SURFACING *(driving is on the left side of the road)*

FIGURE 5.4.2.5 DRAGON TEETH MARKINGS *(ref: iRAP, driving is on the left side of the road)*

FIGURE 5.4.2.6 OPTICAL SPEED BARS *(ref: FHWA, US, driving is on the right side of the road)*

FIGURE 5.4.2.7 DIAMOND MARKINGS *(driving is on the right side of the road)*

4.3 Vertical Speed Control Devices

Vertical speed control devices are raised areas on the pavement forcing drivers to slow down their vehicles. These devices fall into four main types

- Speed bump
- Speed hump
- Speed table

- Speed cushion

Speed bumps are generally narrow units, being products in rubber or construction in concrete or asphalt with a raised top up to 60mm high. They are intended to slow down traffic to 10km/h or below.

Speed humps are sinusoidal device over an extended width enabling traffic to pass through at higher speeds ranging from 30km/h to 60km/h.

Speed tables (***Figure 5.4.3.1*** and ***Figure 5.4.3.2***) are trapezoidal devices over an extended width enabling traffic to pass through at higher speeds ranging from 30km/h to 60km/h. They consist of a flat top and approach ramps.

FIGURE 5.4.3.1 SPEED TABLE OF GENTLE PROFILE

(driving is on the right side of the road)

FIGURE 5.4.3.2 SPEED TABLE AT THE CORE AREA OF AN URBANISED SECTION

(driving is on the right side of the road)

Speed cushions (***Figure 5.4.3.3***) are pillow-like raised areas laid over the centre of a traffic lane. Smaller vehicles have to partially ride over the device at reduced speed. Bicycles and slow vehicles may travel unimpeded on the side while larger vehicles can straddle across the device.

FIGURE 5.4.3.3 SPEED CUSHION *(driving is on the right side of the road)*

Applications

Vertical deflection speed control devices should be encouraged in the following situations:

- Within towns and villages
- Service areas, notably those on Primary class roads
- Road sections where pedestrians aggregate e.g. tourist sites

The following applications are possible:

- Over a main road
- Over a side road joining a main road
- Over an intersection

Speed bumps should not be used on the main road but may be acceptable for direct frontage accesses or minor side roads as an interim measure. Installations should be not less than 12m from the intersection

The use of speed tables at three village sites along a national highway in Bangladesh has resulted in drastic reduction of casualties and fatalities [29] [30]. These speed tables form part of a comprehensive traffic calming scheme in conjunction with education initiatives.

Dimensions

Figure 5.4.3.4 and ***Table 5.4.3.1*** illustrate alternative speed hump and speed table profiles for a variety of speed levels appropriate for main roads. These designs are relatively gentle and are deemed to be suitable on main road with heavy vehicles as well as bicycles or motorcycles.

Speed humps and speed tables should be located on straight sections and straddle across both the carriageway and the slow vehicle lane.

FIGURE 5.4.3.4 SPEED HUMPS FOR DESIGN SPEEDS BETWEEN 20KM/H AND 60KM/H [25]

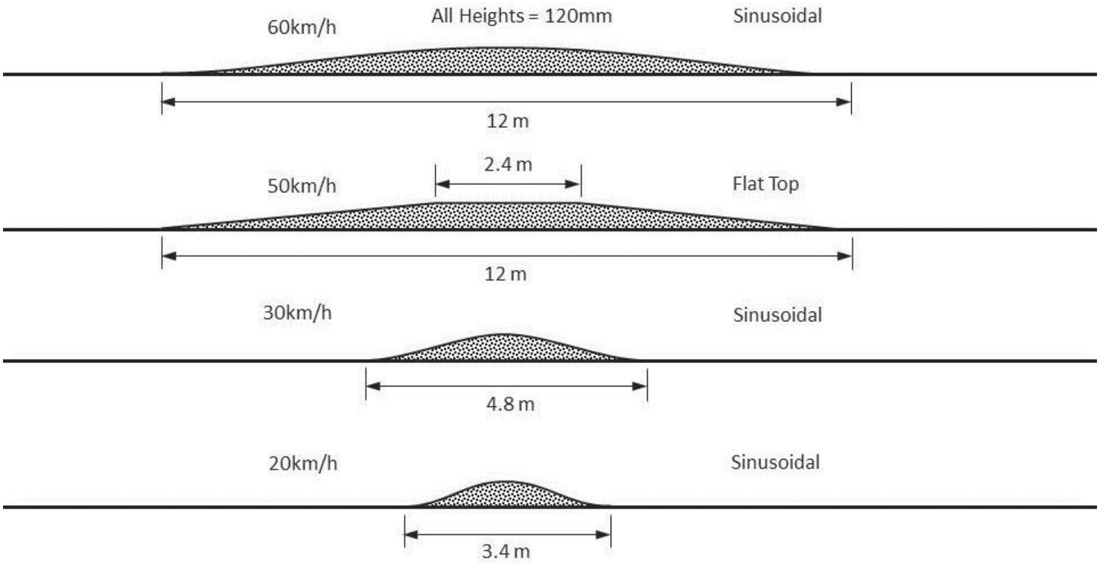


TABLE 5.4.3.1 ALTERNATIVE DESIGN PARAMETERS OF SPEED TABLES

Approach speed	<50km/h	<50km/h	<30km/h*
Height	75mm	50mm	100mm
Ramp gradient	5% (3.3%)	5% (3.3%)	7%
Length of plateau top	8-15m (<30m)	8-15m (<30m)	8-15m (<30m)

( ) optional value with high percentage of heavy vehicles
* suitable for lower class roads and core areas of towns or villages

Relationship with Pedestrian Crossings

The width of pedestrian crossings is generally in the order of 3m to 5m. Pedestrian crossings may be located on or in between speed tables. Where traffic flow is heavy and speed is around 30km/h, pedestrian crossings on speed table are particularly attractive if there is already a footpath. Where traffic flow is heavy and speed is around 40 to 50km/h, pedestrian crossings may be located between speed tables. Where traffic flow is moderate and speed is low with busy pedestrian activities, pedestrian crossings may not be required.

On roads with high approach traffic speeds, it is advisable to locate the first speed table at least 75m downstream of the start of 50km/h speed limit. Speed tables may be repeated at 100 to 200m intervals within urbanised sections.

The profile of speed humps will need to be based on approach speed and intended passing speed. Speed table with uniform sloping ramp is particularly recommended due to their simple profile. Approach ramps of 3% to 7% are generally appropriate. On roads frequented by heavy vehicles or buses, approach ramp gradient should be in region of 3% to 5%. Speed humps also need to be friendly for bicycles and two-wheelers.

Signing and Delineation

Drivers should be alerted of the presence speed humps in order to adequately slow down on the approach. Suitable measures include transverse rumble strips, speed limit and traffic signs for speed humps. Example of traffic signs are illustrated in ***Figure 5.4.3.5***.

FIGURE 5.4.3.5 TYPICAL SIGNING FOR VERTICAL SPEED REDUCTION FACILITIES

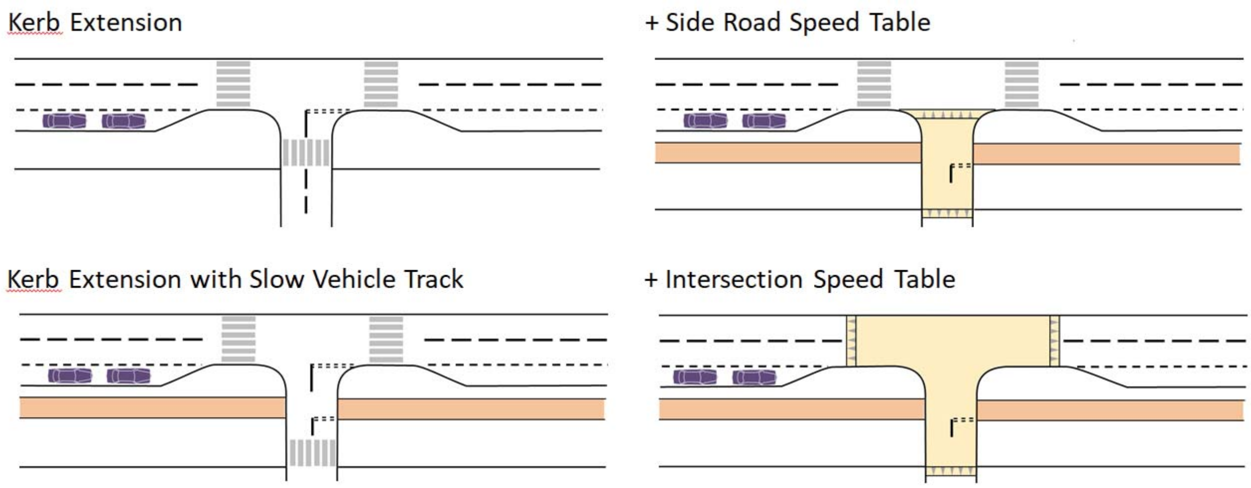
4.4 Kerb Extension

Kerb extension is the local physical extension of the kerbline which narrows down the carriageway. The narrower road and possibly reduced number of traffic lanes slows down traffic and make it easier for pedestrians to cross the road. Another benefit is improvement to the conspicuity and visibility of crossings. An example of kerb extension is illustrated in ***Figure 5.4.4.1***.

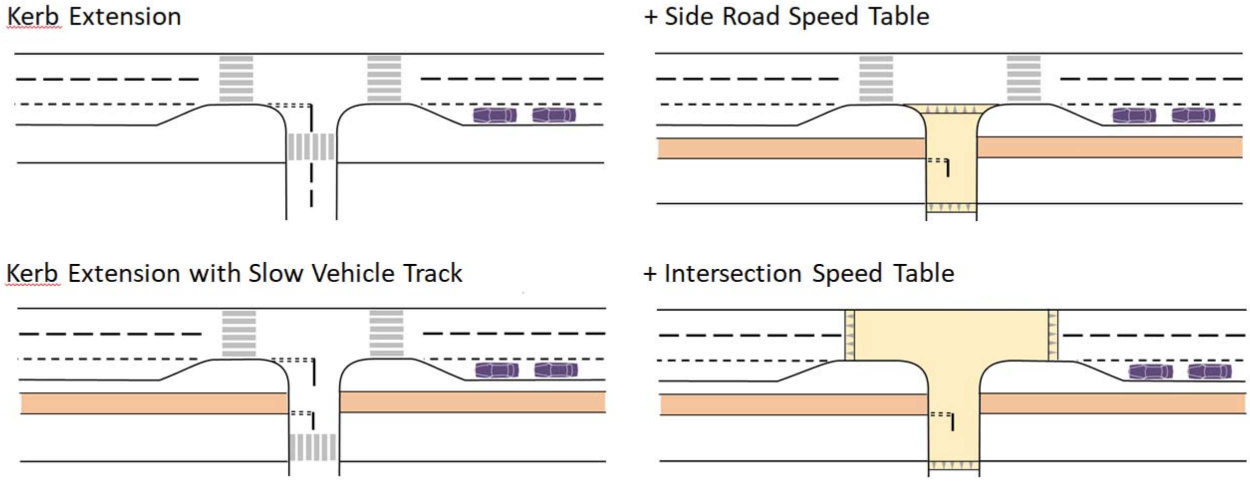
FIGURE 5.4.4.1 KERB EXTENSION AT A PEDESTRIAN CROSSING
(driving is on the left side of the road)

Kerb extension may be provided on the main road, the side road, or both. They are suitable at intersections as well as standalone crossings. Slow vehicle routes at kerb extensions will need to be treated to maintain continuity and to manage any conflicts. ***Figure 5.4.4.2*** illustrates alternative designs of kerb extension at an intersection.

FIGURE 5.4.4.2 KERB EXTENSION AT INTERSECTIONS
(for driving on the right side of the road)



(for driving on the left side of the road)



Kerb extension should be conspicuous and visible at night, especially if the narrowing is substantial. They should only be provided on urbanised sections where traffic speeds have been reduced.

4.5 Traffic Calming Schemes

A traffic calming scheme is a comprehensive design to slow down traffic to levels compatible with the needs and safety of all road-users. The scheme also aims to raise awareness among all road-users to share the road in harmony. A sound traffic calming scheme helps drivers to recognise the rationale to reduce their speeds and adapt their behaviour.

Extensive engagement with stakeholders is necessary to gain the support of local communities and regular road-users. Consideration should also be given to the involvement of an interdisciplinary professional team.

The degree of traffic calming should be commensurate with the level of local activities and safety risks. Each urbanised section should be studied individually to establish the desired level of traffic speeds and traffic calming. Traffic calming provisions and design should be reasonably consistent within an urbanised section and along a particular route.

It is often desirable to adopt lower speed limits through urbanised sections. To be effective, speed limit should be self-enforcing with a clear change of road condition. In many circumstances, however, additional traffic calming measures including physical devices are necessary to ensure that the speeds of all vehicles are reduced and sustained.

Table 5.4.5.1 is a summary of typical traffic calming measures and their suitability for the various road sections. Traffic calming schemes are formulated with a collection of measures which can be based on engineering facilities or non-engineering facilities. The best results are often obtained with a mix of visual and physical measures.

TABLE 5.4.5.1 TRAFFIC CALMING MEASURES

	Approach Zone	Peripheral Section	Urbanised Section	Core Zone
Visual Measures				
Speed Limit changes	Possible stepwise reduction	Necessary	Necessary	Desirable
Transverse rumble strips	Desirable	Optional	Not advisable due to noise	Not advisable due to noise
Gateway Sign	-	-	Needed for larger built-up areas	-
Coloured Surfacing	Not needed	Optional	Optional	Optional
Warning Signs	Possible	Desirable	Optional	Optional
“SLOW” Markings	Possible	Optional	Optional	Possible
Enforcement cameras for red light jumping, speeding or both	Possible	Possible	Desirable	Possible
Physical measures				
Reassignment of cross-section	Not needed	Highly desirable	Highly desirable	Highly desirable
Vertical speed reduction	Not advisable	Not advisable	Desirable	Highly desirable
Chicanes	Not advisable	Not advisable	Optional at boundary	
Stone pitched pavement	Not advisable	Not advisable	Optional	Optional
Non-engineering Measures				
Special landscaping	Not needed	Desirable	Highly desirable	Highly desirable
Streetscape design	Not needed	Optional	Highly desirable	Highly desirable

Route-wide Planning

Traffic calming schemes on Asian Highway routes should be planned on a route-wide basis. The first step consists of :

- Step 1 Identification of the location of cities, towns, villages and other facilities where there are interactions between traffic and local activities
- Step 2 Definition of the urbanised sections, peripheral zones and core areas
- Step 3 Undestanding of the nature and needs of local activities, with quantification or description if possible
- Step 4 Collection of traffic data including volume and speed profile
- Step 5 Proposed design of traffic calming schemes to harmonise between traffic and local activities
- Step 6 Optimisation on a route-wide basis

Cities

Where Asian Highway routes traverse a city as at-grade arterial roads, they should have the image of urban roads or streets rather than highways. In principle, all urban roads are subject to speed limit of 50km/h with intensive treatment to balance the need between traffic flow and local activities. Sections of the road may need to have grade-separated crossings for pedestrians and slow traffic.

The periphery of cities could extend for significant distance where provisions for pedestrians and slow vehicles are minimal. Concurrently traffic speeds are high as drivers are not adapted to a change of the road environment. Such urbanised sections should be subject to adequate traffic calming in conjunction with adequate crossing facilities.

Large Villages and Towns

This category of urbanized sections is frequently encountered along the highway network. It is not limited to settlements and commercial areas, but also industrial areas with frequent pedestrians and slow vehicles.

Where the character of a highway largely remains, drivers will not have a good reason to substantially slow down and adapt their behaviour. This is particularly the case if the approach is a Class I road. For this reason, a strong change in road character is necessary. Furthermore, road space should be fairly shared among all road-user groups.

Traffic calming schemes should be developed on the following basis:

- Gateway signs clearly defining the start and end of the urbanized section
- Change of road character to a street
- Creation of a distinct boundary, possibly using roundabouts
- Minimisation of the space for traffic
- Assignment of space for pedestrians and slow vehicles
- Provision of crossing facilities

Urbanised sections may consist of thriving core areas, being high streets or intersections with intense commercial activities. These would be candidates for integrated traffic calming and streetscape projects.

Scattered Settlements

This category of settlements is highly diversified ranging from isolated houses to small villages. They normally does not qualify as built-up areas. Depending on circumstances, speed limit may be retained or moderately reduced to the 60- 70km/h level for small villages and sections with scattered houses.

A variety of measures may be applied to promote safety, including:

- Minor sign showing the name of the village
- Warning signs e.g. “Pedestrians”
- Footpaths or at least stabilised verges
- Covering of open ditches
- Improvement of conspicuity and visibility at accesses and crossings
- Visual traffic calming

- Transverse rumble strips

Tourist Areas

Tourist areas along Asian Highway routes include formal sites and informal sites. While formal sites are generally provided with parking facilities, vehicles may still overflow onto the main road during peak periods. At informal sites where there are known attractions or scenery, drivers may opt to park onto the shoulders. Where tourist activities are known with potential hazardous traffic conditions or conflicts between pedestrians and traffic, the road section should be subject to traffic calming treatments.

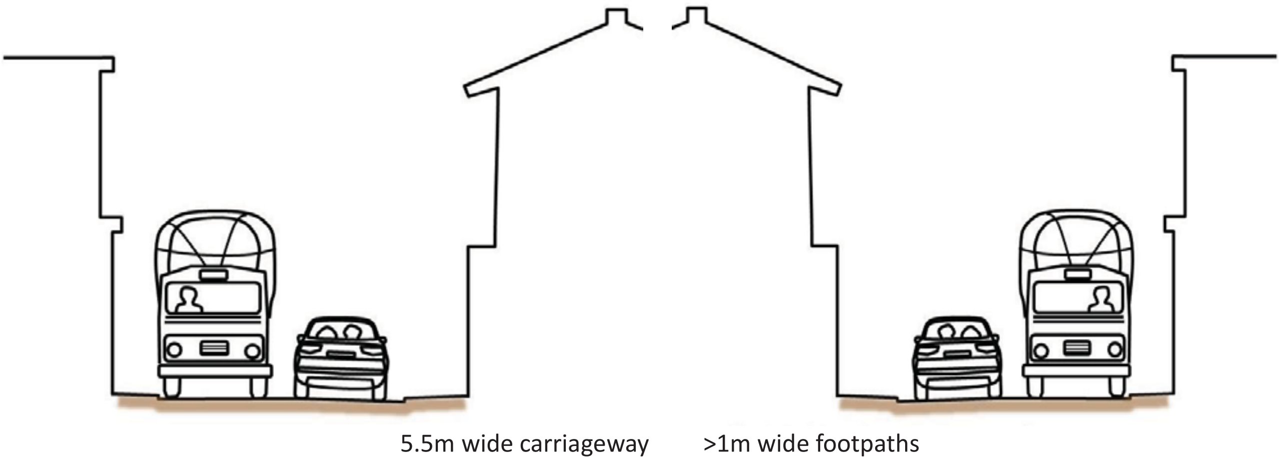
Narrow Urbanised Sections

Urbanised sections with very narrow cross-sections through villages are priority candidates for improvements including construction of bypasses. This is illustrated in ***Figure 5.4.5.2***. In the interim they will need to be specially treated using a combination of measures, including:

- Speed limit of 30 or 40 km/h for mixed and shared road usage
- Adequate visibility at crossings
- Providing narrow, intermittent footpaths and refuges for pedestrians and slow vehicles

FIGURE 5.4.5.2 NARROW ROAD SECTION THROUGH VILLAGES

(for driving on the right side of the road) *(for driving on the left side of the road)*



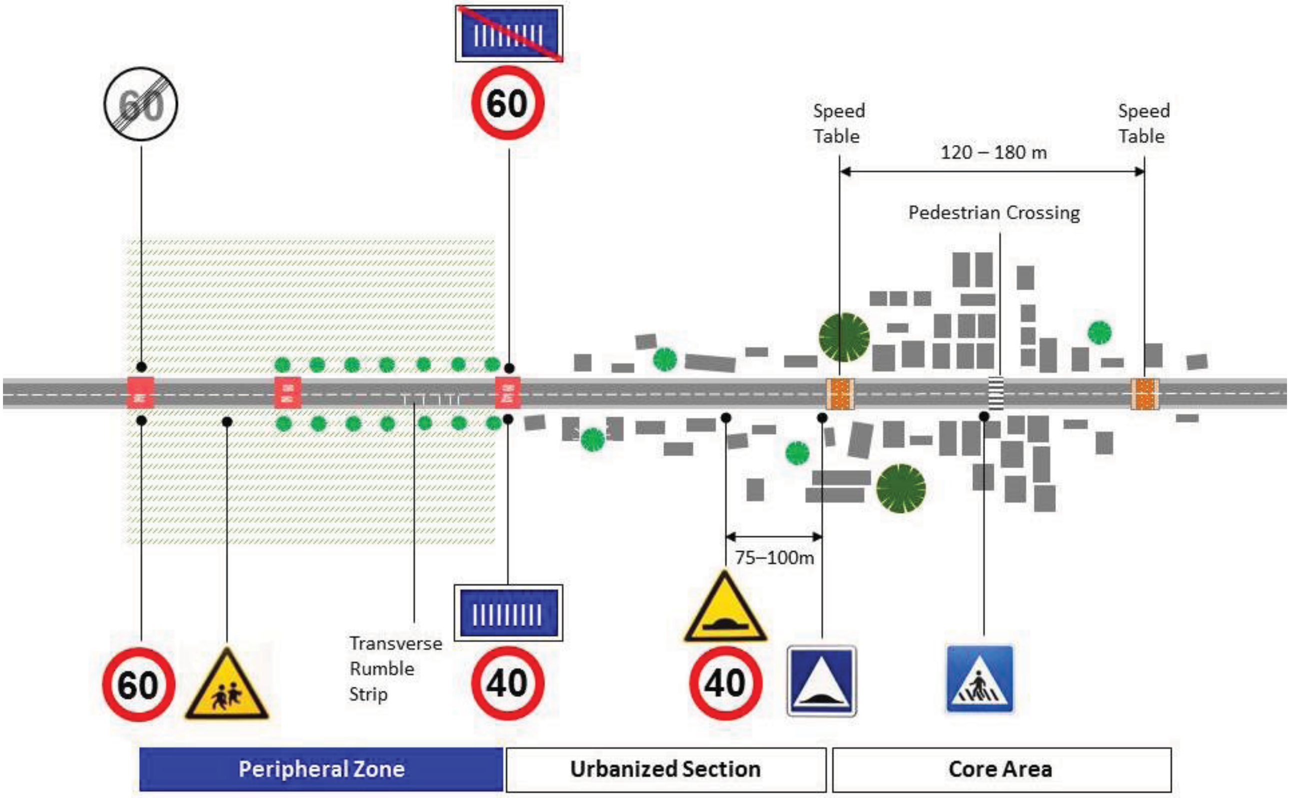
Traffic Calming Schemes

A typical traffic calming scheme for an urbanised section through a village is illustrated in ***Figure 5.4.5.3***. This is based on the differentiation of an approach zone, a peripheral zone and an urbanised section with a core area.

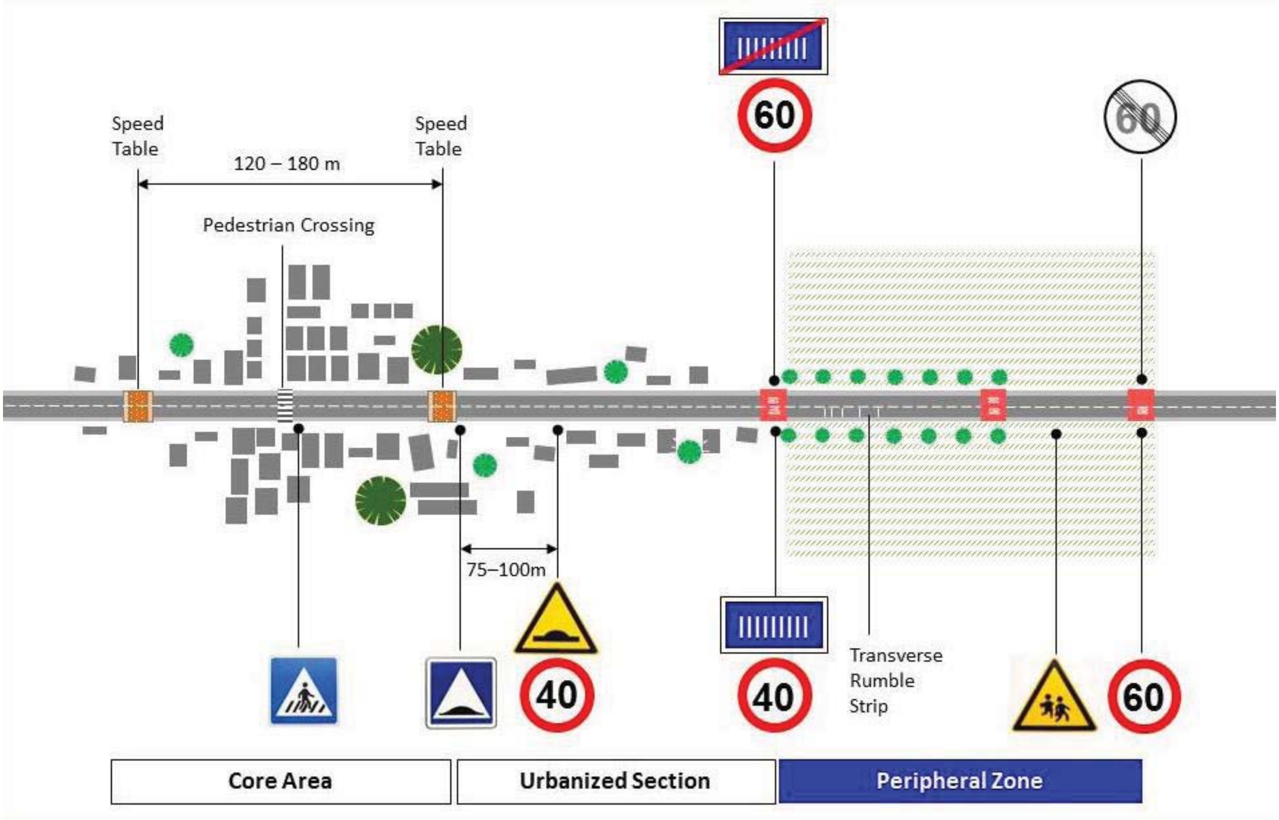
Individual villages and towns may be inter-related with abundant pedestrians or slow vehicles using the main road. Traffic calming schemes will then need to cover an extended stretch of the main road. It may be necessary to designate stretches of road between built-up areas as peripheral sections with reduced speed limit and traffic calming treatments.

FIGURE 5.4.5.3 TYPICAL TRAFFIC CALMING SCHEME THROUGH A BUILT-UP AREA

(for driving on the right side of the road)



(for driving on the left side of the road)



PART 6 DELINEATION, PAVEMENT MARKINGS AND ROAD LIGHTING

1 OVERVIEW

Delineation facilities assist drivers, particularly in high speed traffic, to see the road clearly. Adequate delineation is crucial for driving in dark hours and during adverse weather conditions including rain, fog, snow etc.

This chapter addresses measures to assist drivers to better visualise and recognise:

- the general road alignment ahead
- the edge of the road
- traffic lanes, centrelines and changes in cross-sections
- the presence of curves
- the presence and layout of intersections, crossings and traffic islands
- roadside hazards

Most of the measures are based on retro-reflective materials for night time performance. Reliability of delineation may be enhanced with multiple measures e.g. line markings in conjunction with raised pavement markers.

In addition to delineation facilities, other measures, inter alia, visual contrast in paving materials, reflective paints and landscaping features, should be adopted to increase the conspicuity of the road layout and road features.

Road lighting enables road-users to see clearly the road environment and other road-users, but it is more costly in terms of provision and maintenance. For this reason, they are recommended along Asian Highway routes on the basis of needs, with priority given to built-up areas and intersections with elevated night time usage and special road sections such as tunnels and bridges.

2 DELINEATION

2.1 Chevron Signs

Chevron signs are traffic signs with one or more chevron symbols pointing to the left or the right (***Figure 6.2.1.1***). They are installed on the outside of sharp curves to alert and guide drivers.

FIGURE 6.2.1.1 CHEVRON SIGNS

Chevron signs are provided on the outside of sharp curves which:

- require approach traffic to reduce speed substantially
- are not conspicuous due to an open landscape
- are not clear due to presence of intersections or tangential features
- have poor visibility
- have a history of collisions related to loss of control

Chevron signs should be used as part of a curve signing system based on the severity of curves in terms of required speed reduction as well as clarity and visibility. The system should consist of a number of levels, for example:

- Level 1: Alignment delineators only
- Level 2: Curve warning sign
- Level 3: Curve warning sign and one double chevron sign
- Level 4: Curve warning sign and single chevron sign along the entire curve

Sign Face

The colour of chevron signs may be in the combination of black and white, black and yellow or blue/green/red and white as long as they can be recognised at a distance. Chevron signs should be 600 to 900mm in height depending on design speed. The sign face should be made with retroreflective materials and may be enhanced with a yellow border, flashing lights or embedded light-emitting elements.

Double or triple chevrons may be used on chevron signs. However, chevron signs should not be mounted one above the other to avoid ambiguity with the resultant graphics.

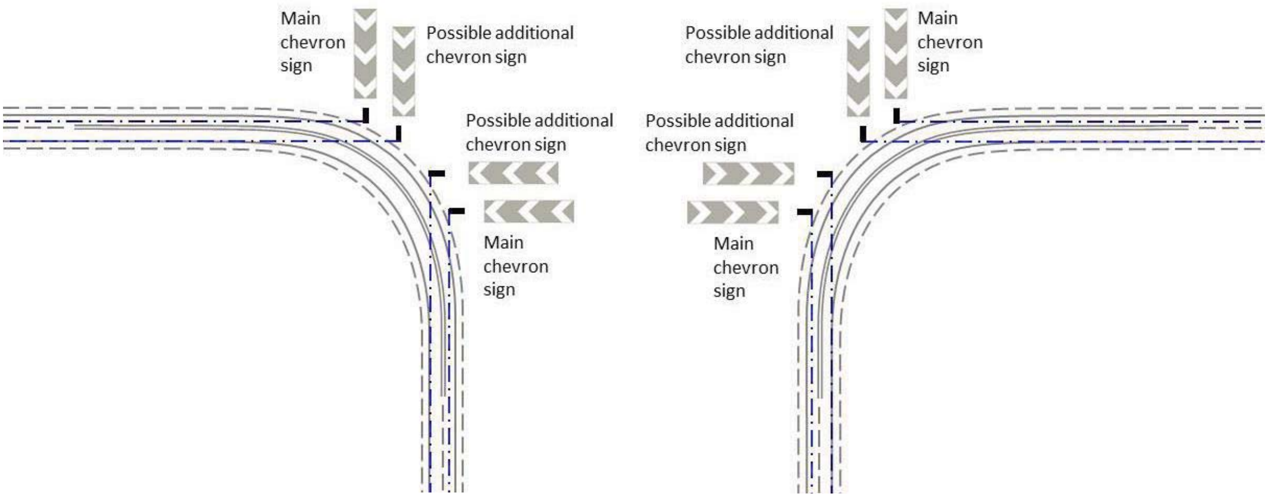
On divided roads with narrow medians and where additional emphasis of the sharp curve is warranted, chevrons may be painted directly onto concrete safety barriers.

Positioning

Chevron signs should be clearly visible to drivers approaching a curve (***Figure 6.2.1.2***). On roads without lighting, they should be aligned to face drivers at an angle slightly more than 90° to avoid causing glare. The mounting height from the bottom of the sign should be between 1m and 1.5m above the road surface. This may need to be increased if the curve is located after a crest profile.

FIGURE 6.2.1.2 POSITIONING OF CHEVRON SIGNS

(for driving on the right side of the road) *(for driving on the left side of the road)*



If chevron signs are needed along the median, adequate space should be reserved for their installation. To avoid chevron signs impairing the forward visibility for opposing traffic, the median may need to be widened or else a higher mounting height is adopted.

Where chevron signs are provided along the entire curve, the formula may be adopted:

$$S = 1.65 \sqrt{(R-15)}$$

where S = Distance between signs (m)
R = Radius of the curve (m)

Chevron signs should also be installed along transition curves at intervals = 2* S. The intervals should be further verified to ensure that at least 3 signs are visible on the approach and within the curve.

On curves which are not guarded by a safety barrier, mounting poles for chevron signs should be passively safe. Flexible design should be considered there are regular motorcycles travelling at high speeds.

2.2 Delineators

Delineators generally consist of reflectors or retroreflective strips attached to ground-mounted posts or reflectors mounted directly onto safety barriers or retaining walls. They are particularly beneficial for roads without road lighting and where the performance of road markings is unsatisfactory. Delineators are classified according to ***Table 6.2.2.1***.

TABLE 6.2.2.1 CATEGORIES OF DELINEATOR

Category	Function
Alignment Delineator	Highlighting road alignment and curves
Access Delineator	Demarcating accesses and intersections
Lane Delineator	Separating opposing traffic or slow traffic
Hazard Marker	Highlighting roadside hazards
Diverge Gore Delineator	Highlighting diverge gores on high speed roads

Alignment delineator may be integrated with mileage markers which display mileage at 100m intervals.

The appearance and colour of different categories of delineators should be distinctly different and consistently applied according to their functions.

Delineators are normally provided as vertical posts with an overall height between 1m and 1.3m. They should consist of reflectors and are clearly visible at night time. The reflector should be mounted more than 0.8m above the road surface to minimise masking by plants. A higher mounting level is required in areas susceptible to heavy snow.

Delineators should be frangible or flexible for passive safety. To reduce maintenance needs, self-restoring delineation posts are encouraged at high impact sites and on high speed roads.

Alignment Delineator

Alignment delineators should be used on road sections with increased risks of an errant vehicle leaving the road such as zones of narrowing or lane reduction and merging or diverging areas. They are also recommended on straight sections where delineation by line markings is unsatisfactory and road lighting is not provided. Typical delineators are illustrated in ***Figure 6.2.2.1***.

FIGURE 6.2.2.1 ALIGNMENT DELINEATORS *(driving is on the right side of the road)*

They are generally mounted on circular, square or quadrangle posts. Alternatively reflectors may be directly attached to safety barriers or retaining walls. Reflectors on safety barriers should be set back from the traffic face. For mounting onto retaining walls, protruding fixtures should not constitute a safety hazard upon impact.

Reflectors should enable a delineator to be clearly visible 300m ahead when illuminated by a high beam light in clear conditions. They should have a size equivalent to at least 75mm or 100mm diameter and are mounted at heights in the order of 800mm to 1200mm irrespective of the mounting method. The recommended colour is white with a black colour area surrounding the reflector. ***Table 6.2.2.2*** provides a guide to the spacing of alignment delineators.

TABLE 6.2.2.2 **SPACING OF ALIGNMENT DELINEATORS** *(ref: VicRoads Guide)*

Curve Radius (m)	Spacing (m)	
	Outside of curves	Inside of curves*
< 100	6	12
100- 199	10	20
200- 299	15	30
300- 399	20	40
400- 599	30	60
600- 799	40	60
1200- 1199	60	60
1200- 2000	90 **	90 **
> 2000 and Straight	150 #	150 #

* Position to match delineator on opposite side

** Adopt 60m in areas susceptible to fog

Adopt 75m in areas susceptible to fog and 90m where low beam light is used, adopt 90m where wire rope safety barriers are used

Delineators for sharp curves should be substituted by larger and taller design at closer spacing to highlight the hazard. This is illustrated in ***Figure 6.2.2.2***.

FIGURE 6.2.2.2 **ALIGNMENT DELINEATORS FOR SHARP CURVES** *(driving is on the right side of the road)*

Access Delineator

Access delineators are provided at direct frontage accesses and intersections to highlight their presence and position. This is illustrated in ***Figure 6.2.2.3***. They are not required for major intersections and roundabouts where the layout is clearly defined. They are not necessary on urbanised sections where lighting is provided.

FIGURE 6.2.2.3 ACCESS DELINEATORS

At least one access delineator is required on each side of an access. For larger intersections, it is desirable to install two or more units to reveal the layout. A possible colour scheme is white with a red colour retroreflective strip wrapping around the post.

Hazard Markers

Hazard markers are used to alert drivers of roadside hazards with the risk of frontal collisions. An example is illustrated in ***Figure 6.2.2.4***. They are needed if the hazard cannot be readily treated.

FIGURE 6.2.2.4 HAZARD MARKERS AHEAD OF A CULVERT *(driving is on the right side of the road)*

Hazard markers preferably have a rectangular sign face in stripes. They may be preceded by alignment delineators guiding approach traffic to avoid the hazard.

Additionally, it could be desirable to apply reflective paints in white colour or strips of yellow and black colour directly onto the hazard e.g. ending of bridge parapet or drainage structures. If the hazard presents relatively low risk, painting alone may substitute the hazard marker.

Lane Delineator

Lane delineators are circular flexible posts installed along centrelines of undivided roads. They are also appropriate for installation over narrow traffic islands separating opposing traffic lanes, slow vehicle lanes or parking areas. They should be 70cm or more in height for conspicuity.

The main purposes of lane delineators are

- Deterrence of corner cutting along curves
- Deterrence of overtaking on straight sections or curves
- Prevention of wrong-way traffic
- Highlighting the presence of traffic islands

Where the interface of an undivided road and a divided road lies on a curve, it may be beneficial to provide a section of lane delineators to reduce the risk of wrong way driving. Similar usage may be applied ahead of traffic islands located within a curve.

Lane delineator may be used along both straight sections and curves to deter overtaking in addition to solid line markings. This is shown in ***Figure 6.2.2.5***.

FIGURE 6.2.2.5 CENTRELINE DELINEATORS

Diverge Gore Delineator

Diverge gores are generally delineated by chevron road markings and raised pavement markers without the need for delineators. However, it could be desirable to provide delineators on the approach to serve as an additional buffer zones for diverge gores which:

- are located on curves
- have poor visibility
- have a high risk of collisions

Delineators for diverge gores may be of a distinct colour or based on lane delineators. They should be flexible and are preferably self-restoring. This is shown in ***Figure 6.2.2.6***.

FIGURE 6.2.2.6 DELINEATORS AT DIVERGE GORES *(driving is on the right side of the road)*

2.3 Anti-Glare Systems

Anti-glare systems are facilities to limit the glare of headlights from opposing vehicles or other external light sources. They can be provided in the following forms:

- Manufactured net using expanded metal
- Manufactured plate typically in synthetic resin
- Hedges
- Earth embankments
- Raised concrete safety barriers

Anti-glare systems should be considered on Primary class and Class I roads without road lighting in the following situations:

- Median less than 9m in width
- Heavy night time traffic
- Low standard horizontal curves and sag curves
- Opposing traffic at a different level smaller than 2m
- Existence of a parallel road with opposing traffic
- Near tunnel portals where tunnel tubes are at close proximity
- Glare from other light sources

At intersection, median openings and pedestrian crossings, anti-glare systems have to be terminated well in advance to satisfy visibility requirements.

General Requirements

Anti-glare systemss are designed to block visibility between drivers and the front headlights of opposing vehicles. They are based on the eye-height of drivers and the height of front lights in ***Table 6.2.3.1***.

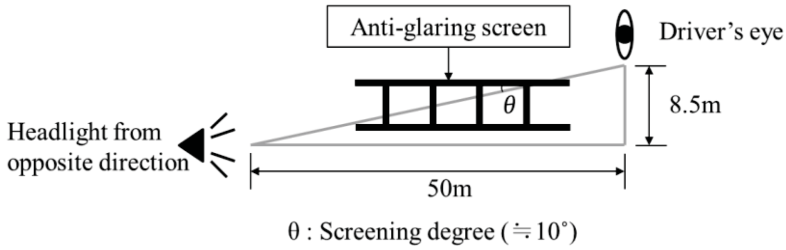
TABLE 6.2.3.1 DESIGN PARAMETERS FOR ANTI-GLARE FACILITIES

Vehicle Type	Observer eye-height	Height of front lights
Large vehicle	2.0m*	1.05m
Small vehicle	1.05m	0.6m

* up to 2.45m depending on vehicle fleet

It is generally sufficient to provide screening from opposing headlights between zero and 10 degrees. This is illustrated in ***Figure 6.2.3.1***.

FIGURE 6.2.3.1 SCREENING ANGLE FOR ANTI-GLARE SYSTEM *(ref: Standards of Korea)*



The height of anti-glare systems is generally in the order of 1,400mm above the pavement. The width of anti-glare screen is in the range of 80 to 250mm at a spacing of 0.5m to 1.0m.

For hedges, the spacing of trees should be based on the effective width of tree crowns. It is desirable to alternate between screens or nets and hedges.

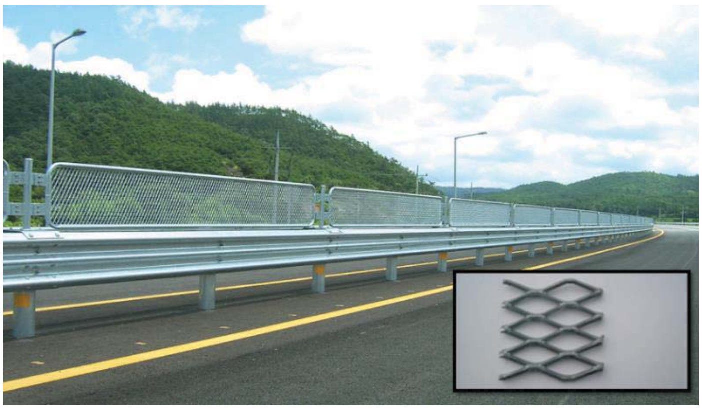
Anti-glare screens should be able to shield opposing traffic headlamps at an angle not less than 8 degrees. On horizontal and vertical curves, the minimum angle should be increased to the range of 8 to 15 degrees.

Anti-glare facilities on curves should not result in unacceptable forward visibility required for the prevailing operating speeds of traffic. Otherwise, the median has to be adequately widened.

Anti-glare screens or nets should not be made of reflective materials. They may be attached onto safety barriers without compromising their normal safety function. Typical designs are illustrated in ***Figures 6.2.3.2 and 6.2.3.3***.

FIGURE 6.2.3.2 SAFETY BARRIER MOUNTED ANTI-GLARE SCREENS *(driving is on the right side of the road)*

FIGURE 6.2.3.3 SAFETY BARRIER MOUNTED ANTI-GLARE NETS *(driving is on the right side of the road)*



The use of hedges should take into account the adequacy of space for planting and maintenance. Preference should be given to species which are strong, slow growing, have few falling leaves and require little maintenance. An example is shown in ***Figure 6.2.3.4***.

FIGURE 6.2.3.4 HEDGES AS ANTI-GLARE SYSTEM *(driving is on the right side of the road)*

Raised concrete median safety barriers may be considered if screens or nets are susceptible to damage and additional containment level is also desirable. This is illustrated in ***Figure 6.2.3.5***.

FIGURE 6.2.3.5 1270MM HIGH CONCRETE SAFETY BARRIER AS ANTI-GLARE SYSTEM
(driving is on the right side of the road)

3 PAVEMENT MARKINGS

3.1 Line Markings

Line markings are materials laid on road pavement for the control, warning, guidance or information of road users. Longitudinal line markings are especially useful to delineate the road alignment, define the cross section of the road, separate opposing traffic, guide traffic through intersections and avoid obstructions. In this way they provide continuous information to drivers to negotiate the road and keep within the limit of their desirable lateral position.

In addition, line markings are used for the following regulatory purposes:

- Overtaking restriction
- Designation of paved shoulder and laybys
- Designation of bicycle or slow traffic lane
- Designation of areas where traffic should not enter

Line markings are used for the delineation of edge lines, lane lines, centrelines and intersections. Centrelines may be omitted for narrow roads with a width less than 5.5m. They may be omitted where specifically forming part of the traffic calming strategy in towns and villages.

Double line instead of single line centreline should be encouraged on undivided roads, in particular Class II roads.

For overtaking, mix solid and dotted lines should be encouraged where overtaking sight distance is adequate in one traffic direction. Alternatives are long dotted lines or double dotted lines to discourage but not to fully prohibit overtaking.

At interchanges on Primary class and Class I roads, closely spaced dotted lines should be adopted to demarcate acceleration lanes, deceleration lanes, lane drops and weaving sections.

General Requirements

The function of road markings relies on their performance in terms of visibility (***Figure 6.3.1.1***). Consideration should be given to high reflectivity markings for improved night time brightness by incorporating tiny glass beads. Additionally, wet performance may be improved with larger glass beads or raised profile markings.

FIGURE 6.3.1.1 LINE MARKINGS OF GOOD NIGHT TIME PERFORMANCE

Important performance parameters of road markings include the followings:

- Retroreflectivity for night time traffic
- Luminance factors for daytime driving
- Skid resistance

Additionally, road marking materials should be controlled for the followings:

- Luminance factor after UV ageing
- Chromaticity
- Maximum thickness of 5mm

The skid resistance of road markings is important particularly for bicycles and motorcycles. In principle, it is not recommended to lay large areas of markings at curves and where braking is required.

Any outdated markings should be effectively removed, especially if they can mislead a vehicle travelling on an opposing lane or stopping too late into crossings or intersections.

Visibility of Line Markings

The requirements for forward visibility mainly address objects or vehicles at specified heights above the carriageway. It is equally important for drivers to be able to see clearly line markings on the road. Such requirements are given in ***Table 6.3.1.4***. The visibility of give-way or Stop lines is particularly important if the need for stoppage may not well perceived on the approach.

TABLE 6.3.1.3 RECOMMENDED VISIBLITY DISTANCE FOR LINE MARKINGS

		Visibility Distance (m)					
Design Speed (km/h)	Requirements	120	100	80	70	60	50*
Longitudinal Markings- Edge Lines, Lane Lines	3s of Travel Distance	100	83	67	58	50	42
Give-way/Stop Lines and Pedestrian Crossings	SSD	295	215	150	120	90	70

Edge Markings

Edge lines are used to define the edge of the carriageway. They should be provided outside built-up areas for Primary class and Class I roads on both the nearside and offside. The nearside edge line is marked as the paved shoulder where this is provided.

For existing routes not delineated by edge lines, priority for retrofit could be given to:

- roads where the edge of the verge is not well defined
- sections susceptible to fog, mist and heavy rain
- along undivided roads with heavy traffic
- at sudden change of cross-sections
- on the approach to curves
- on the approach to narrow bridges

Edge lines may be omitted on

- within built-up areas
- on roads with lighting or clearly defined edges
- on road sections with speed limit of 60km/h or below

Edge lines are generally continuous solid line.

Speed Limit (km/h)	W (m)
=< 70	0.15- 0.2
>= 80	0.2- 0.375

Colour : White

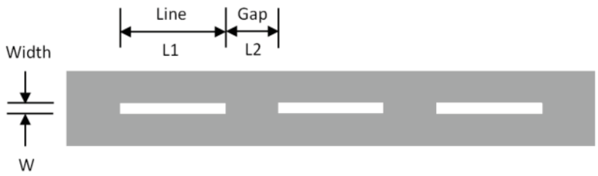
Shoulder edge line may consist of additional marks or a long line marking (20m) with gaps (6m) at regular intervals. Such features serve as a marker for drivers to maintain a safe distance with vehicles in front (***Figure 6.3.1.2***). Edge lines may also be dotted as an advisory edge of the carriageway.

FIGURE 6.3.1.2 GAPS ON SHOULDER EDGE LINES SERVING AS MARKERS

Continuous edge markings may have an adverse effect on pavement surface drainage, especially around superelevation transition areas with flat sections. At these locations, the thickness of edge line markings should be limited to 3mm with possible gaps.

Lane Lines

Lane lines should be provided to separate vehicles proceeding in the same direction. These markings generally consist of a short marking and a long gap.



Speed Limit (km/h)	L1 of Marking (m)	W (m)	L2 (m)
=< 60	1	0.1- 0.15	5
>= 70	2	0.1- 0.15	7

Colour : White

Centreline Markings

Centreline markings should be provided to separate opposing traffic. They may be omitted if the width of the carriageway is less than 5.5m. Centreline markings are important for the regulation of overtaking through the systematic application of the following marking types:

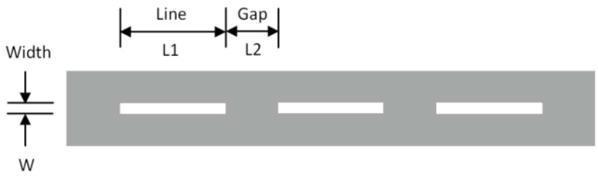
- Dotted lines
- Warning lines
- Single solid lines
- Double solid lines
- Dotted and solid line

Speed Limit (km/h)	W1 (m)	W2 (m)
All	0.1 - 0.15	0.1 – 0.175

Colour : White or Yellow

Warning Lines

Warning line markings are used to substitute lane lines or centrelines where crossing of the line marking is discouraged. They may be adopted on the approach to intersections, along curves and on short overtaking sections. They generally consist of a long marking and a short gap.



Speed Limit (km/h)	L1 (m)	W (m)	L2 (m)
=< 60	4	0.1 – 0.15	2
>= 70	6	0.1 – 0.15	3

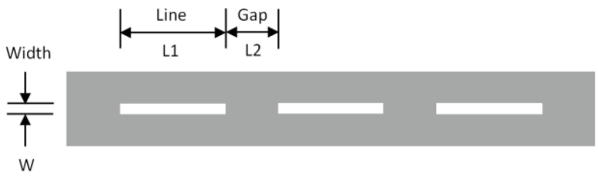
Colour : White or Yellow

Grade-separated Intersections

At grade-separation intersections, the following markings should be used to define merging and diverging areas as well as lane drops.

- Acceleration/Deceleration lane and Lane drop markings
- Weaving sections
- Merge and diverge chevron markings

These markings should be dotted lines at close spacing which have an appearance distinctly different from lane lines. Accordingly a larger width is also desirable. The use of these markings for a lane drop diverge is illustrated in ***Figure 6.3.1.3***.



Length of Marking (m)	Width of Marking (m)	Length of Gap (m)
3	0.5	3
1	0.3	3
1	0.3	1

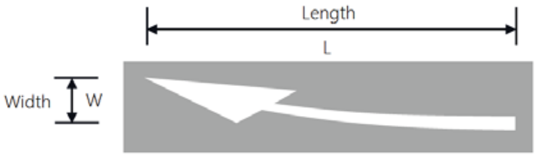
FIGURE 6.3.1.3 LANE DROP MARKINGS *(driving is on the right side of the road)*

Curly Arrow Markings

Curly arrows are used to advise drivers to move towards the side of the carriageway where the arrow is pointing to. They have multiple applications including:

- Prompting drivers to merge on an acceleration lane
- Prompting drivers to merge where the number of traffic lanes is reduced
- Advising overtaking drivers to return to their normal travel lane

Curly arrow markings are in the form of a curving arrow. An oblique arrow version may be used where traffic merges. Typical uses of curly arrow markings are illustrated in ***Figure 6.3.1.4*** and ***Figure 6.3.1.5***.



Speed Limit (km/h)	L (m)	W (m)
50	6	0.7
>=60	9	1.05

FIGURE 6.3.1.4 CURLY ARROW MARKINGS AHEAD OF TERMINATION OF OVERTAKING ZONE
(driving is on the right side of the road)

FIGURE 6.3.1.5 CURLY ARROW MARKINGS FOR LANE REDUCTION

(driving is on the right side of the road)

Markings for Merging Areas, Diverging Areas and Traffic Islands

Chevron markings are used at merging and diverging areas to separate traffic proceeding in the same direction. They consist of chevron marks bounded by two edge lines. The chevron symbol should be pointing towards approach drivers.

Hatched markings are used on the approach to traffic islands or medians which separate opposing traffic. They consist of hatched lines bounded by two edge lines Hatched lines should be slanting towards approach traffic.

Worded Markings

Worded markings are generally adopted to reinforce traffic signs and directional signs (***Figure 6.3.1.6***). They may be selectively used for the following purposes:

- Speed limit markings
- "SLOW" marking in conjunction with warning signs
- Vehicle type restriction
- Route number guidance
- Directional guidance

Worded markings should be simple as long messages contribute to sign clutter and are difficult to read. They are generally designed by elongation of equivalent signage fonts at a ratio of about 3:1.

FIGURE 6.3.1.6 WORDED MARKINGS FOR ROUTE GUIDANCE
(driving is on the left side of the road in this photo)

3.2 Wide Centreline Markings

These are centreline markings of enhanced width (***Figure 6.3.2.1*** and ***Figure 6.3.2.2***). They are provided to:

- separate opposing traffic on undivided roads
- deter or discourage vehicles from overtaking
- reduce the risk of head-on collisions between opposing vehicles
- discourage high traffic speeds
- facilitate provision of turn lanes
- facilitate provision of pedestrian refuge islands

Wide centreline markings are appropriate for:

- Class II roads with speed limit of 80km/h or above.
- Sharp curves on Classes II or III roads
- Crest summits with inadequate overtaking visibility
- Climbing lanes or overtaking sections
- Divided roads with one carriageway constructed for two-way traffic
- Tunnels with bidirectional traffic
- Undivided carriageway on loops of grade-separated intersections
- Sections of roads where there is a history of crashes related to overtaking

They are recommended as an interim measure to discourage or restrict overtaking on Class II roads with heavy traffic i.e. >12,000 veh/day, prior to capacity improvements or upgrading to Class I roads.

FIGURE 6.3.2.1 WIDE CENTRELINE MARKINGS IN DOUBLE DOTTED LINES
(driving is on the right side of the road)

FIGURE 6.3.2.2 WIDE SOLID CENTRELINE MARKINGS WITH COLOURED SURFACING INFILL
(driving is on the right side of the road)

Speed Limit (km/h)	W1 (m)	W2 (m)
All	0.1 - 0.15	0.7 – 0.8

Colour : White or Yellow

Wide centrelines may be provided as dotted lines on both sides to indicate that drivers may overtake when safe. They may also be provided with single-sided dotted lines to indicate that drivers may overtake from one side only when safe.

Cross-section of Road

Table 6.3.2.1 gives the values for road cross-sections with wide centrelines. It is generally appropriate to adopt reduced lane widths of 3.25m which may be further narrowed down to 3.0m.

TABLE 6.3.2.1 CROSS-SECTION WITH WIDE CENTRELINE MARKINGS [31]

Element	Nominal Values*	Variations
Lane Width	3.25m	Lane width may be reduced to 3.0m or increased to 3.5m
Paved Shoulders *2	2.0m	Normal minimum 1.75m Acceptable minimum 1.5m
Wide Centreline	1.0m	Normal minimum 0.8m Acceptable minimum 0.6m
Wide Centreline with Median Barrier	2.0m	1.5m

* exclusive of curve widening which should always be provided

Other Considerations

Where there is an increased risk of overtaking collisions, consideration should be given to installation of a median safety barrier. This may be a wire-rope safety barrier or any other double face safety barriers. Installation of such safety barriers is subject to the following criteria:

- Overall width of paved surface in one direction should be 6m and at least 5.75m

- Adequate visibility at intersections and crossings for pedestrians or slow traffic should be provided
- Appropriate end treatment for the median safety barriers

It is advisable to install longitudinal rumble strip or raised rib markings in conjunction with wide centrelines. The middle gap of wide centrelines is preferably infilled with hatched marking or coloured surfacing.

The introduction of wide centrelines should be accompanied by publicity programmes to explain their purpose and rules to follow.

On existing roads with narrow bridges, wide centrelines should be terminated by a taper to become normal centrelines 30m or more ahead of the narrow section.

3.3 Raised Pavement Markers

Raised pavement markers (also known as road studs or cat eyes) are discrete markers inserted onto the pavement along edge lines and lane lines for delineation of the road layout. They are generally equipped with a reflector in glass or plastic. Their retro-reflective property reveals the road alignment under the headlights of approach traffic.

Raised pavement markers are desirable to supplement line markings on Primary class roads and Class I roads. They are also recommended for use on other classes of roads with speed limit of 70km/h or above and without lighting.

They are desirable to improve visibility at night, in adverse weather and where road markings are susceptible to dusts and blackening. The added benefit is their tactile function when ridden over by vehicles.

Raised pavement markers are particularly useful to emphasize curves or on road sections with increased safety risk, including:

- undivided multi-lane Class 1 roads
- transition zones with changes in the number of traffic lanes
- transition from divided road to undivided road
- interchange diverges, merges and weaving sections
- intersections with turn lanes
- tunnels and approaches
- narrow bridges and approaches

In general, raised pavement markers should be installed on the outside of edge lines or shoulder lines. On undivided roads, raised pavement markers should be provided along centrelines. On divided roads, they may be omitted over lane lines. They should not be used at locations which could cause a hazard to pedestrians, cyclists and motorcyclists.

General Requirements

Raised pavement markers should conform to EN1463 (EU) or equivalent national standard. Markers may be depressible or non-depressible. They may be embedded, surface-bonded with adhesives or anchored by shear pins. The maximum height above the pavement surface should be 20mm and up to 25mm for depressible markers.

Raised pavement markers should be unidirectional on divided roads and bidirectional on undivided roads. Bidirectional markers may be used to deter wrong-way driving at critical locations.

A good quality road surface is required for installation. Markers should not be provided over pedestrian crossings and at stop lines as they could be slippery.

Colour and Spacing

Raised pavement markers should be in different colours to indicate different line marking types. Their spacing is related to speed limit, curve radius and the need to highlight the road conditions. The casing should have a neutral colour such as natural metallic finish, white or black. They may have the same colour of the reflector if used for unidirectional traffic.

A possible scheme is illustrated in ***Table 6.3.3.1*** but the precise distance should be adjusted to tie in with the length of markings and gaps in national standards.

TABLE 6.3.3.1 EXAMPLE OF RAISED PAVEMENT MARKER PROVISIONS [5]

Line Marking	Colour	Spacing		Direction
		Speed Limit		
		=<60km/h	>=70km/h	
Double line (opposing traffic)	White	4.5m		Bidirectional
Centreline (opposing traffic)	White	12m (6m)	18m (9m)	Bidirectional
Lane lines:	White	12m	18m	Unidirectional
Warning lines:	White	6m	9m	Unidirectional/Bidirectional
Undivided roads edge line	Red	12m (6m)	18m (9m)	Unidirectional*
Divided road hard shoulder	Red	18m [9m]		Unidirectional
Divided road central reserve	Amber			Unidirectional
Acceleration/Deceleration lane/lane drop	Green	8m		Unidirectional
Chevron markings	Red	3m		Unidirectional

( ) centreline on wide roads or multi-lane roads
* placement adjacent to approach traffic direction only
[ ] curves <450mR and where there are problems of fog, mist or dazzles from headlights

Active Raised Pavement Markers

These are light-emitting versions which could be beneficial at selective locations where enhanced delineation is considered necessary. This may include sharp curves with a history of repeated crashes with runaway vehicles.

3.4 Rumble Strips

A rumble strip is an installation on the pavement consisting of indentations which generate an audio-tactile effect to alert drivers when it is driven over. There are two types of rumble strips, namely longitudinal rumble strip and transverse rumble strip.

Longitudinal rumble strips provide an effective warning to road users who may stray away from their travel paths due to fatigue, inattention, errors in judgement or poor visibility in rain or fog. If not corrected in time, this could lead to the vehicle crashing onto the roadside or colliding with a stopped vehicle on the shoulder. Rumble strips are particularly beneficial in a rural environment and may be installed along:

- Edge lines and shoulder lines
- Centrelines and wide centre lines
- Chevron markings preceding a diverge gore
- Hatched markings preceding a traffic island

Transverse rumble strips may be formed from:

- Transverse bar markings of decreasing intervals

- Discrete groups of transverse bar markings

Applications

While rumble strips are recommended as a preventive measure, they may be selectively applied as remedial measure at road sections prone to crashes.

Centreline rumble strips are recommended:

- for undivided Classes I or II roads with speed limit of 80km/h or above
- at and on the approach to curves
- in conjunction with wide-centrelines

Edgeline rumble strips should be specified as follows:

- on all Primary class roads
- access-controlled Class I road with speed limit of 80km/h or above
- Undivided Classes I, II roads with speed limit of 80km/h or above

The following longitudinal rumble strip types may be used:

- Raised markings
- Milled-in type
- Rolled-in type
- Audio-tactile Line Markings (Raised rib markings)

Audio-Tactile Line Markings (Raised Rib Markings)

This marking is laid by installing extruding molten thermoplastic material as raised bars along the edge line or shoulder line markings. It is recommended that the width of the traffic lane is maintained at 3.5m with a minimum of 3.3m. The level of audio and tactile performance is determined by the spacing and height of the raised bars. Typical dimension is given in ***Table 6.3.3.2***.

TABLE 6.3.3.2 TYPICAL DIMENSIONS OF AUDIO-TACTILE LINE MARKINGS [5]

Width	same as width of markings
Length	50mm
Height	8mm (Roads with bicycles and pedestrians) 11mm (Primary class roads without bicycles
Spacing	200mm - 500mm

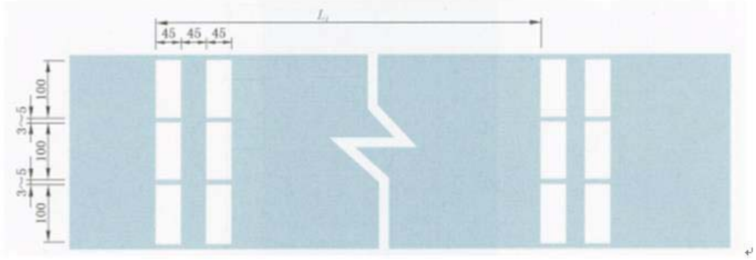
Transverse Rumble Strips

Transverse rumble strips are grooves or raised markings installed perpendicular to the road. Each unit may consist of several grooves or raised markings. The units are repeated at regular or progressively smaller intervals.

The main purpose of transverse rumble strips is to reduce traffic speeds and raised awareness on the approach to intersections, roundabouts, pedestrian crossings and urbanised sections etc.. They are also useful on the approach to sharp curves, tunnels and toll plazas on free-flow sections of single and ro roads. They should be used in conjunction with traffic signs unless the hazard is self-explaining.

Typical dimension and layout of rumble strips are illustrated in ***Figure 6.3.3.1***.

FIGURE 6.3.3.1 TRANSVERSE RUMBLE STRIPS *(ref: Highway Design Standard of China)*



General Precautions

The height of rumble strips, whether raised or depressed should be controlled to no more than 12mm for the safety of bicycles and motorcycles. If bicycle lanes are provided on the shoulder, a clear travel path of at least 1.2m should be available from the rumble strip.

In areas susceptible to freezing temperature, ice formation over the grooves is a concern for rumble strips of milled-in or rolled-in types.

Ice formation is also a concern for audio-tactile markings if the longitudinal gradient on any parts of the road is less than 0.67%, including superelevation transition areas. This may be alleviated by creating gaps of 100mm to 150mm width on the markings at approximately 36m to facilitate pavement surface drainage [5].

Rumble strips can be a nuisance when installed in the vicinity of residence or facilities sensitive to noise or vibration. For this reason, they should not be used within 200m of sensitive receivers.

4 ROAD LIGHTING

Road lighting should be provided as a priority:

- within built-up areas and their peripheries
- for road sections with sub-standard alignment
- for road sections with heavy traffic at night time
- for road sections with regular pedestrians or slow traffic at night time
- for grade-separated pedestrian or slow vehicle facilities
- at major interchanges or intersections with heavy traffic at night time
- through tunnels, long bridges and their immediate approaches
- at toll plazas and immediate approaches to ports or border control points

GENERAL REQUIREMENTS

The recommended luminance performance of road lighting is given in ***Table 6.4.1.1***.

TABLE 6.4.1.1 RECOMMENDED LUMINANCE PERFORMANCE

Category	Average Luminance Level L (cd/m^2)	Overall Uniformity Ratio U_0	Longitudinal Uniformity Ratio U_1	Road Categories
1	1.5	0.4	0.7	Primary class and Class I roads Roads with speed limit >= 70km/h
2	1.0	0.4	0.5	Other rural or urban roads
3	0.5	0.4	0.5	Connecting roads of less importance

L: Average luminance over a defined area of the road surface viewed from a specified observer position
U_0: Ratio of the minimum to average luminance of a defined area of the roadway
U_1: Ratio of the minimum to the maximum luminance along a longitudinal line drawn through the observer position

Lighting for main carriageways should be luminance based to achieve a bright road surface, with acceptable uniformity and glare, against which vehicles, pedestrians and other objects appear in silhouette. Main carriageways are:

- mainline of Primary class, Classes I, II or III roads
- slip roads and free flow link roads at grade-separated intersections and interchanges
- hard shoulders wider than 1 m
- hatched areas and chevron markings

Lighting for conflict areas should be illuminance based. Conflict areas are：

- At-grade intersections and approaches
- Circulatory carriageways and approaches of roundabouts
- Grade-separated intersections and interchanges
- Toll plazas including taper zones
- Pedestrians and slow vehicle crossings

The design of road lighting should be based on the reflection characteristics of the road surface in order to obtain the optimum quality and quantity of illumination.

Road lighting should be designed in conjunction with any bridges, noise barriers, tree plantings, overhead signs and signals and any other overhead utilities to minimise shadow patches. Safe working clearances should be maintained between lighting and overhead power lines.

Continuity of Coverage

If road lighting is provided along the mainline of a section of road, any at-grade intersections, grade-separated intersections and interchanges within or at either end of the mainline lit section should also be lit.

If road lighting is not provided along the mainline of a road, any grade-separated intersections may be:

- unlit
- partially lit at conflict points with local roads
- fully lit with lighting on the mainline through the intersection and on the slip roads

At the end of a lit section on the mainline of a road, grade-separated intersections may be:

- partially lit, with mainline lighting terminated just beyond the diverge gore of the slip roads connecting to the lit section, lighting continuing along the full length of those slip roads, and the slip roads connecting to the unlit side of the intersection remaining unlit
- fully lit, with lighting on the mainline extended through the intersection and on the slip roads

Lighting on slip roads, link roads and auxiliary lanes should extend to the end of the taper, and the mainline lighting should continue for a further distance at least 1.5 times the SSD.

For at-grade intersections of any type, including off-line elements of partially lit grade-separated intersections, lighting should not terminate closer to the conflict point than indicated as follows:

- 1.5 times the Desirable Minimum Stopping Sight Distance on the major road at a priority intersection
- the peak traffic queuing distance on the approach to a give way or stop line
- the distance required to illuminate any curve at the end of an exit slip road or the beginning of an entry slip road

There should not be an unlit gap of less than four times the SSD between lit sections.

For service areas on Primary class and Class I roads where the mainline is lit, the slip roads should also be lit. For service areas where the main carriageway is not lit the slip roads may be lit but lighting should commence as far as possible away from the mainline to avoid misleading guidance for mainline traffic.

Passive Safety

Lighting columns are considered aggressive roadside features. At traffic speeds above 60km/h, they should not be located on the outside of sharp curves, traffic islands and diverge gores without road restraint systems. On Primary class roads and other roads with traffic speeds exceeding 80km/h, lighting columns should always be guarded by safety barriers with appropriate working widths.

On urbanised sections and where traffic speeds are less than 60km/h, lighting columns should be avoided at vulnerable position. In general, they are erected without road restraint systems but should be set back from the outer edge of paved shoulders or kerblines by at least 0.6m.

From the safety perspective of maintenance, lighting columns are preferably installed on the roadside in comparison to the median of Primary class roads.

PART 7 ROAD SIGNAGE

1 TRAFFIC SIGNS

1.1 General Requirements

Traffic signs should be homogeneous, visible at a distance day and night and understandable at a glance. Symbolic signs should be adopted wherever practical.

Traffic signs should be consistently in terms of provision criteria, size and mounting arrangement. Non-standard signs may be used to address particular traffic management and road safety functions. If adopted, they should be designed with particular attention to details and size. The proliferation of non-standard traffic signs should be strictly regulated.

The use of traffic signs should be planned and optimised on a route-wide basis. Excessive use of traffic signs should be avoided as this is likely to result in an overload of information for drivers. Additionally, signs at close distance are likely to obscure one another.

Positioning

The positioning of traffic signs should be based on the following criteria:

- Advance distance for warning signs
- Location where regulatory signs apply

To ensure optimum reading conditions and visibility, warning signs should be positioned ahead of significant bends. In particular, placement on the inside of bends should be avoided.

Combination of Signs

The number of traffic signs on a single assembly should be limited to two, excluding supplementary plates. Stop signs and give-way signs should not be mounted on the same post as a warning sign.

Sign combinations, excluding speed limit terminal signs, which may be mounted together should be placed in the following order from top to bottom:

- Stop or give-way or any triangular warning sign
- speed limit repeater signs
- other circular signs
- rectangular signs

Sign posts erected on footways should not result in an unobstructed path less than 1000mm to allow the passage of wheelchairs.

All combination of signs should be carefully evaluated that the message is clear and ambiguity is unlikely.

Mounting

Traffic signs should be mounted on roadside verges,footpaths or traffic islands at the following mounting heights:

- 1.5m- 2.3m (>= 0.9m) on free-flow rural sections
- 2.1m- 2.3m where pedestrians are present

Erection of sign posts over the carriageway, paved shoulders and areas of hatched markings should not be permitted.

Mounting heights should be adjusted to avoid obscuring due to parapets, safety barriers or other features.

Traffic signs are preferably mounted on the roadside but overhead mounting may be desirable in the following circumstances:

- Where there are four or more traffic lanes in one direction
- Where there is inadequate roadside space
- Where traffic signs are likely to be obscured due to trees, noise barriers, fences etc.

Size, Visibility and Positioning

Recommended parameters are given in ***Table 7.1.1.1***.

TABLE 7.1.1.1 KEY PARAMETERS FOR PROVISION OF TRAFFIC SIGNS [32]

Approach Traffic Speeds (km/h)	Height of Warning Signs (mm)	Minimum Visibility Distance (m)	Distance from the Hazards (m)
=< 30	600	45	45
30 – 50	600	60	45
50 - 65	750 (600)	60	45 – 110
65 – 80	900 (750)	75	110 – 180
80 – 100	1200 (900)	90	180 – 245
> 100	1200 (1500)	105 (120)	245 - 305

( ) alternative values

1.2 Warning Signs

Warning signs are traffic signs which warn drivers of hazardous situations ahead so that they will adapt their behaviour and reduce speeds accordingly.

Warning signs should be sited in advance of the associated hazards at distance commensurate with the approach speeds. The precise position will need to take into account optimum visibility and coordination with other signs in the vicinity.

Warning signs should be used sparingly and consistently along a route. Excessive use will reduce their values with adverse safety implications.

Where appropriate, distance indicators should be used to inform drivers of the position of the hazard.

If the hazard is encountered over a prolonged section of the road, it is desirable to install a supplementary plate indicating the length of the hazard.

Warning signs may be used in conjunction with "SLOW" or similar message displayed on supplementary plates or worded markings. They may be used together with longitudinal rumble strips to further reinforce the message for drivers to reduce speed.

Table 7.1.2.1 is a list of warning signs frequently required.

TABLE 7.1.2.1 LIST OF MAJOR WARNING SIGNS

Sign group	Variations	Road safety function
Bend warning signs	• Bend to right/left • Consecutive bends	Remind drivers of sharp bends ahead
Gradient warning signs	• Uphill/downhill gradients	Remind drivers of steep gradients ahead
Permanent change in road conditions	• Road narrowing • Two-way traffic • Two-way traffic on main road • Tunnel ahead	Remind drivers to adapt to changes in cross-section, road environment or opposing traffic
Transient change in road conditions	• Slippery roads • Uneven roads • Risk of ice and packed snow • Rock falls • Traffic queues likely	Remind drivers of possible obstructions
Intersection/traffic control ahead	• Give-way/Stop ahead • Merging ahead • Crossroad ahead • T-intersection ahead • Staggered intersection ahead • Traffic Signals ahead • Roundabout ahead	Remind drivers of intersections and their types
Headroom restriction	• Headroom restriction ahead • Weight restriction ahead	Remind drivers of reduced headroom or weight restriction for bridges
Pedestrians and Slow Traffic	• Pedestrians on roads, • Pedestrian crossings, • Children • Bicycle crossings • Bicycles on roads • Speed humps	Remind drivers on the presence of pedestrians, slow traffic and traffic calming measures
Animals	• Specific animal warning signs	Remind drivers of potential animals and types on or crossing the road

1.3 Regulatory Signs

Regulatory signs should be provided to indicate requirements, restrictions and prohibitions on Asian Highway routes. The meaning of these signs should be legally defined in national or local traffic law. ***Table 7.1.3.1*** is a list of frequently used regulatory signs.

TABLE 7.1.3.1 LIST OF MAJOR REGULATORY SIGNS

Sign group	Variations	Road safety function
Speed limit	• Speed limits • Speed limit for certain vehicles • Speed limit ends • Speed limit zones • Speed checks	Speed limit system and enforcement
Stop	• Stop • Give-way	Intersection control
Turning restriction	• Keep right/left • No right/left turn • Turn right/left	Limiting movements at intersections
Usage restriction	• No entry • No motor vehicles • No pedestrians • No bicycles	Prevention of wrong-way traffic Restriction of pedestrians and bicycles etc. into special road sections
Expressway/Express Road	• Expressway/Express road starts • Expressway/Express road ends	Defining roads where expressway regulations apply
Stopping restriction	• No stopping • No parking • Loading/unloading restrictions	Restriction of stopped vehicles and activities on major roads
Vehicle size restriction	• Height limit • Length limit • Weight limit	Restriction of vehicle size entering a route
Goods vehicle diversion	• Goods vehicles route • Goods vehicle lane restriction	Forming part of a goods vehicles management strategy
Lane usage	• Bus lane • Cycle track • Pedestrian footpath	Defining specific usage of lanes and tracks
Traffic calming zones	• Village name sign • Speed limit zone	

1.4 Supplementary Signs

Supplementary signs are traffic signs used to further define the conditions which apply to a warning sign or regulatory sign. ***Table 7.1.4.1*** is a list of frequently used supplementary signs.

TABLE 7.1.4.1 LIST OF MAJOR SUPPLEMENTARY SIGNS

Sign group	Variations	Associated Traffic Signs	Road safety function
Distance ahead	• Distance in metres • Distance in km	Regulatory signs, warning signs	Providing drivers with better information about hazards or regulations ahead
Extent	• Distance in metres • Distance in km	Regulatory signs, warning signs	Providing drivers with better information about extent of hazards or regulations ahead
Type of vehicles	• Lorries • Vehicles longer than a certain length	Regulatory signs, warning signs	Defining the applicable type of vehicles
Time period	• Day of week • Time of Day • School hours • When raining	Regulatory signs, warning signs	Defining the time period applicable to regulatory signs and possibly warning signs

1.5 Informatory Signs

Informatory signs consist of a collection of standard signs and special signs giving advice or information to drivers about unusual road conditions, hazards or presence of enforcement cameras. They are also used for road safety reminder signs for fatigue driving, drink driving, use of mobile phone while driving etc..

The design of informatory signs should be simple, attractive and readily understandable. The use of non-standard informatory signs should be regulated to maintain consistency of the signing system.

Mileage Signs

Mileage signs are used for the purpose of asset management, maintenance and emergency response. The recommended maximum spacing is 500m. On Primary class road their preferred spacing is 100m. Mileage markers should indicate route numbers and mileage and are preferably fabricated in retroreflective materials. The displays should be facing both sides of a road including divided roads. The sign should be passively safe.

1.6 Advertisement Signs

These are signs which do not have a function related to traffic control and road safety. They are often provided for commercial purposes but sometimes non-commercial publicity. They could range from billboards on massive overhead structures, bridge-mounted signs to more modest roadside signs.

The main concerns for advertisement signs are:

- Distraction to drivers
- Impairment of visibility of intersection
- Impairment of visibility of traffic signs and directional signs
- Passive safety

Prominent advertisement signs, whether within or outside the right-of-way, should therefore be avoided and minimised along Asian Highway routes, especially where there is a high demand of driving tasks at high speeds. Less dominating advertisement signs may be acceptable where they do not constitute a significant problem.

-

2 DIRECTIONAL SIGNS

2.1 General Requirements

Directional signing is an integral component of the road infrastructure with important functions of route guidance and road safety. The quality of directional signs has direct implications on urban streetscape and rural landscape.

Despite the popularity of GPS-based route guidance systems, directional signing remains necessary to provide essential on-road information for drivers to navigate through the road network. Directional signs also serve as markers for critical manoeuvres on high speed roads.

Uncertainties could lead to erratic behaviour among drivers such as abrupt lane changing, stopping, U-turning or reversing. This in turn could lead to side-swipes, rear-front collisions, loss of control and collisions onto the roadside. Drivers losing track in their travel contribute to substantial unnecessary travel distance, thereby increasing road safety risks.

A sound directional signing system requires sound planning from the network and route-wide perspectives. Incorrect information, late availability of information, lack of continuity and overcrowded sign faces could undermine the performance of directional signing and become safety problems.

Key Requirements

Directional signing should satisfy the following criteria:

- There should be adequate information for route guidance but excessive information or sign clutter should be avoided.
- Signs should be provided with advance distance commensurate with approach traffic speeds, number of traffic lanes and complexity of the intersection.
- Information should be accurate and correct in terms of sign format, route number, colour, destinations, traffic lane configurations etc.
- Information should provide continuous guidance without breakage.
- Signs for similar intersections should be consistent in terms of positioning, sign face graphics, mounting arrangements etc.
- Signs should be easily readable with good visibility and are understandable at a glance.

2.2 Master Plan

Destination Hierarchy

A hierarchy of destinations may be defined according to population, economic importance and traffic generation. A typical hierarchy system consists of the following levels:

Level 1	Major and metropolitan cities
Level 2	Important cities and towns, major airports
Level 3	Smaller towns, city districts
Level 4	Major local destinations (railway terminals, hospitals, landmarks etc.)
Level 5	Other local destinations (parking, community centres etc.)

Control Destinations

Control destinations are key destinations of value for orientation. In general they are major cities and may include destinations beyond country borders. For Primary class roads and other major roads, control destinations should be designated at the national level. They may also include special destinations such as ports, border control points, important bridge crossings and tunnels etc.

City Districts

Districts should be defined according to administration boundaries and the road network, taking into account understanding by drivers. Other than specific district names, it is often desirable to adopt the format “[City Name] South”, “[City Name] Centre” etc. at exits of Primary class roads.

Local Destinations

White colour signs are desirable for signing local destinations. These include hospitals, railway stations, parking, smaller towns, minor districts, landmarks, town centres etc. Clear guidance for their selection has to be formulated. Common local destinations may be presented in symbols.

Route Numbers

Route numbers are generally defined for national roads, provincial roads, county roads etc. Primary class roads may be designated by route number exclusively denoting expressways.

Route number of Primary class roads and other major roads or ring roads may be signed as destinations. This helps to alleviate the burden of signing, especially in urban areas and for early guidance from remote locations.

Similarly, special road infrastructure such as international tunnels and major bridge crossings may be signed as destinations on directional signs.

Direction towards a Route

Where a grade-separated intersection leads to only one direction of a Primary class road, route numbers should be displayed in conjunction with the appropriate destination name or compass direction i.e. North, South, East and West.

To avoid confusion, it is necessary to distinguish the display of route numbers indicating:

- that drivers are already on or joining the route
- the direction leading to the route from more remote locations

Exit Numbers

Exit numbers should be assigned and displayed on Primary class roads and possibly other access-controlled roads. The numbering system should be formulated on a long-term route-wide basis. Exit numbers need not be assigned for interchanges between Primary class roads.

Symbols

The use of symbols is desirable as long as they are readily understood by all drivers including those coming from other countries. Symbols are desirable to indicate the followings:

- Airports
- Ports and docks
- Industrial zones
- Hospitals
- Border crossing points
- Parking areas, rest areas
- Railway stations
- Park and Ride facilities
- Filling stations
- Service area facilities- toilet, refreshments, restaurants, information, lodgings, repair shops etc.
- Vehicle types- goods vehicles, articulated vehicle, buses, cars, motorcycles
- Expressway/Express Road symbol
- Tourist attractions symbols- viewpoints, picnic sites etc.

Given their widespread applications in the road network, it is desirable to enhance the quality of symbol graphics. It is also advisable to contain the majority of symbols within a square of standard size. This is illustrated in ***Figure 7.2.2.1***.

FIGURE 7.2.2.1 SYMBOLS ON DIRECTIONAL SIGNS

Signing Rules

1. Priority is given to major destinations of high hierarchy. Major local destinations may be signed on a selective basis.

2. Once a destination is displayed on a directional sign, it should be displayed on all downstream signs until the destination is reached. The destination may be substituted by destinations of a lower hierarchy.

3. Forward direction displayed on directional signs should consist of at least one control destination.

4. On the immediate approach to a control destination, the next control destination should start to appear.

5. Control destination of an intersecting route may also be displayed as a forward destination.

6. Guidance should be provided in the catchment area of a Primary class road which may be based on a circle up to 30km in radius in rural areas

7. On the approach to a main road, priority is given to the display of more remote control destinations rather than nearby destinations

2.3 Sign Types and Formats

Sign Types

There are three principal types of directional signs:

- Advance Direction Signs : Signs provided ahead of an intersection giving information about forthcoming routes, destinations, intersection types and traffic lane configurations

- Direction Signs : Signs provided at an intersection guiding drivers to negotiate through the intersection

- Confirmatory Signs : Signs provided after an intersection confirming the route and the associated destinations and distance

At major intersections, all three types of signs should be provided. At minor intersections, confirmatory signs may be omitted after the intersection. For less important destinations, it may be acceptable to provide only one directional sign if approach speed is less than 50km/h and the intersection has good visibility on the approach.

Colour Scheme

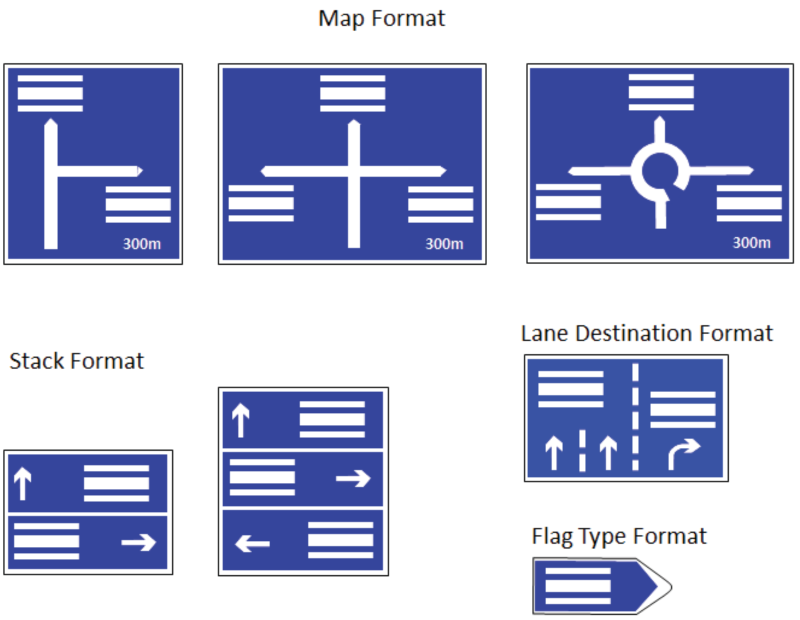
It is beneficial to adopt the following colour scheme system for directional signs to distinguish roads or destinations at different hierarchies.

- Green: Expressways, express roads
- Blue: Other roads
- White: Local destinations
- Yellow: Temporary directional signs
- Brown: Tourist directional signs

Sign Formats

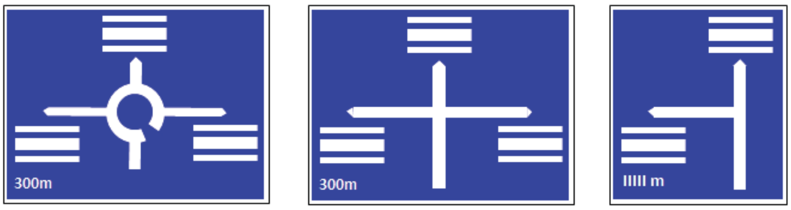
Appropriate sign formats for at-grade intersections are illustrated in ***Figure 7.2.3.1***.

FIGURE 7.2.3.1 SIGN FORMATS FOR AT-GRADE INTERSECTIONS
(for driving on the right side of the road)

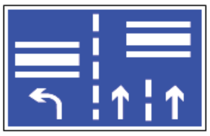


(for driving on the left side of the road)

Map Format

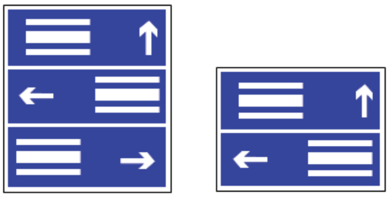


Lane Destination Format



Flag Type Format

Stack Format



Usage of these formats is given in ***Table 7.2.3.1***.

TABLE 7.2.3.1 SIGN FORMATS AND SIGN TYPES FOR AT-GRADE INTERSECTIONS

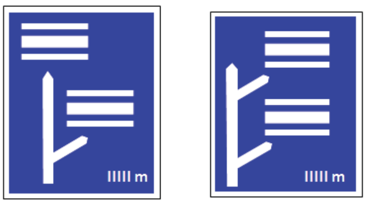
	Advance Direction Sign	Direction Sign
Map Format	✓	X
Stack Format	✓	✓
Lane Destination Format	✓	X
Flag Format	X	✓

Appropriate sign types for grade-separated intersections are illustrated in ***Figure 7.2.3.2***.

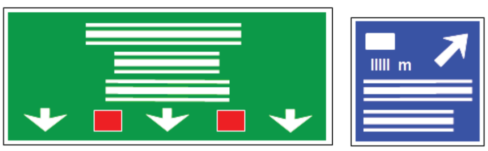
FIGURE 7.2.3.2 SIGN FORMATS FOR GRADE-SEPARATED INTERSECTIONS

(for driving on the right side of the road)

Map Format

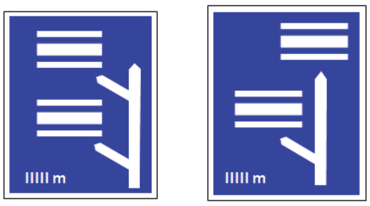


Overhead Format

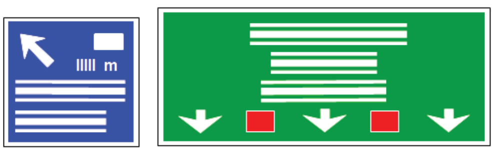


(for driving on the left side of the road)

Map Format



Overhead Format



Usage of these formats is given in ***Table 7.2.3.2***.

TABLE 7.2.3.2 SIGN FORMATS AND SIGN TYPES FOR GRADE-SEPARATED INTERSECTIONS

	Advance Direction Sign	Direction Sign
Rectangular Overhead Format	✓	✓
Map Format	✓	X
Stack Format	✓	✓*
Lane Destination Format	✓	X
Flag Format	X	✓

Confirmatory Signs

Confirmatory signs should display the current route number, destinations ahead and associated distances. The selected destinations should consist of one or more control destinations of value for orientation and possibly other major destinations. Off-route destinations and the route number of an intersecting Primary class road may be signed. Destinations may be listed from top to bottom or vice versa according to their proximity. A typical confirmatory sign is illustrated in ***Figure 7.2.3.3***.

FIGURE 7.2.3.3 TYPICAL CONFIRMATORY SIGN

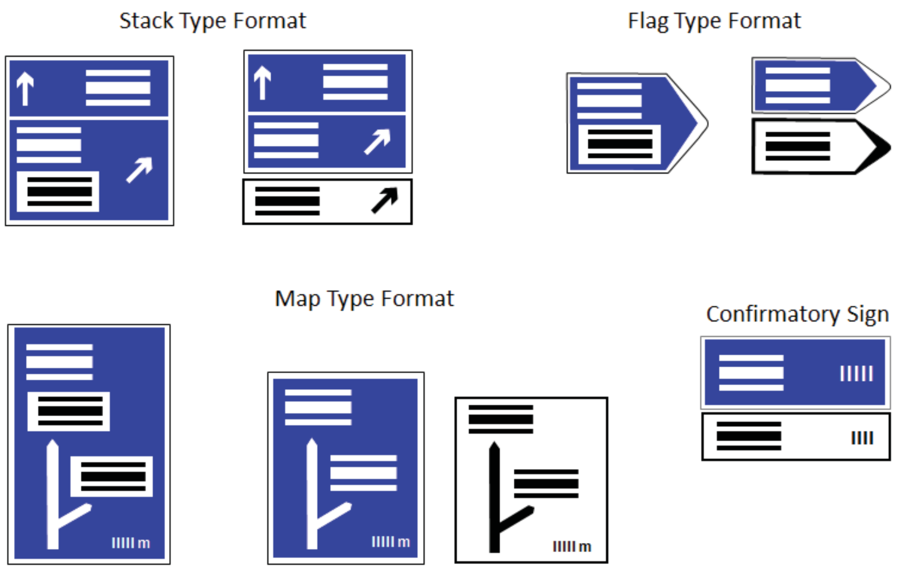
On rural sections of Primary class roads where intersections are spaced far apart, it is often desirable to indicate the distance to the next exit. This sign may be standalone or mounted onto the same assembly of the main confirmatory sign.

Incorporation of Local Destinations

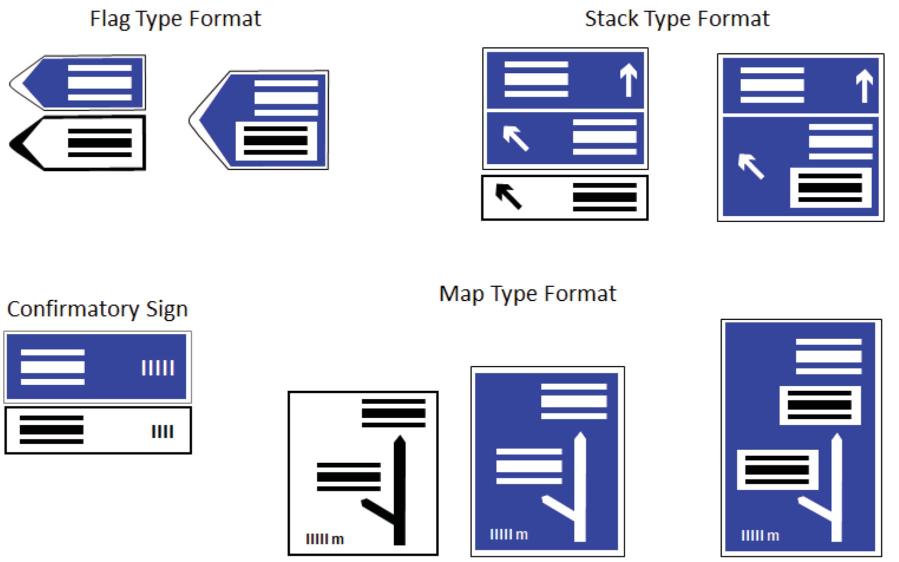
Where local destinations are signed in the white colour format, they may be incorporated into directional signs with a white patch. Alternatively, local destinations may be provided as separate panels on the same sign assembly in the stack or flag format. This is illustrated in ***Figure 7.2.3.4***.

FIGURE 7.2.3.4 SIGNING OF LOCAL DESTINATIONS IN WHITE COLOUR FORMAT

(for driving on the right side of the road)



(for driving on the left side of the road)

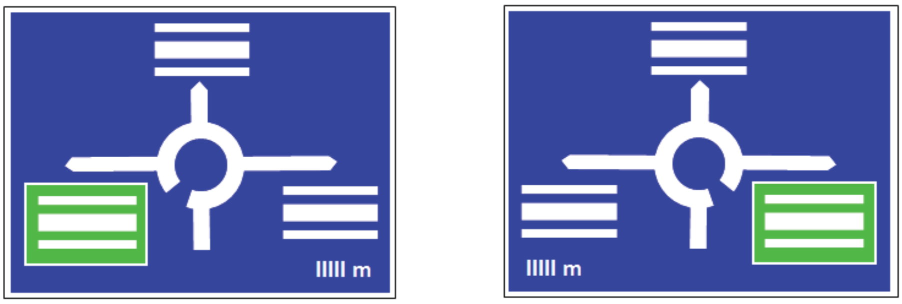


Direction to Expressways

Where an expressway is signed in the green colour format, a green panel may be incorporated into directional signs on the approach. This is illustrated in ***Figure 7.2.3.5***. Alternatively, separate panels may be adopted in the stack or flag format.

FIGURE 7.2.3.5 SIGNING TOWARDS AN EXPRESSWAY

(for driving on the right side of the road) *(for driving on the left side of the road)*

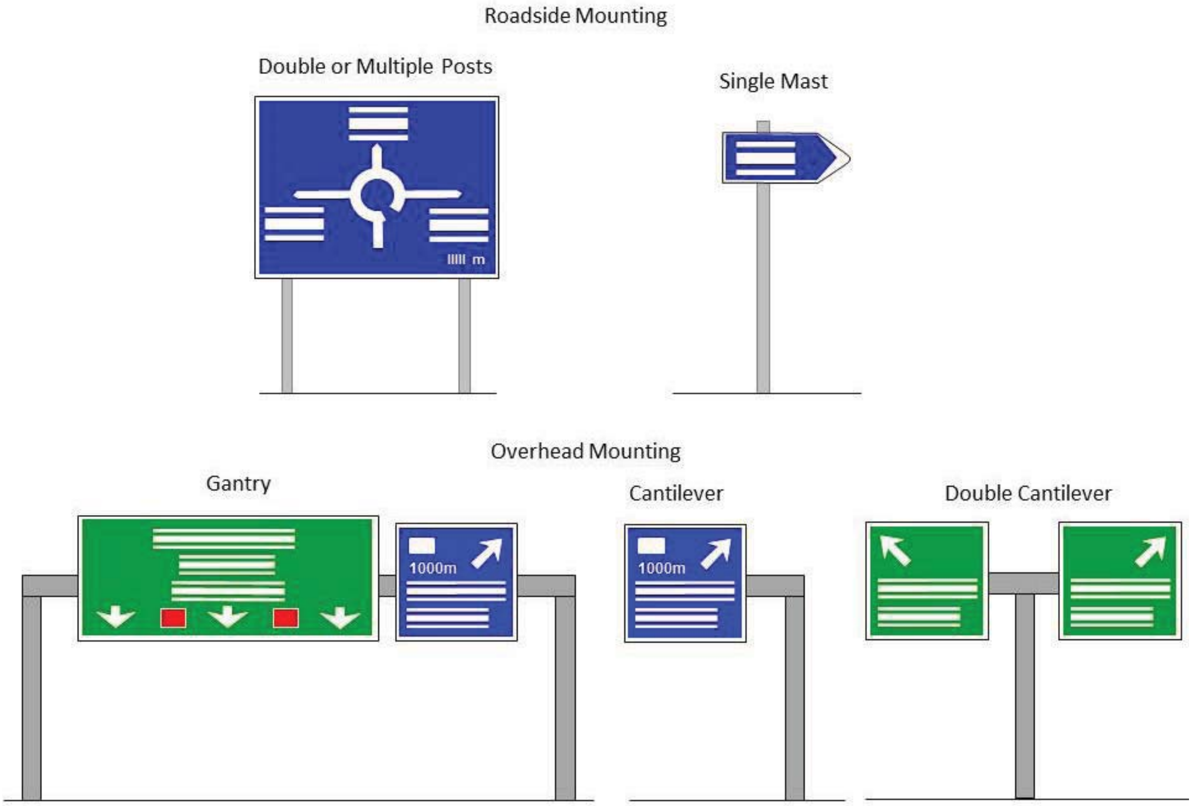


2.4 Mounting Forms

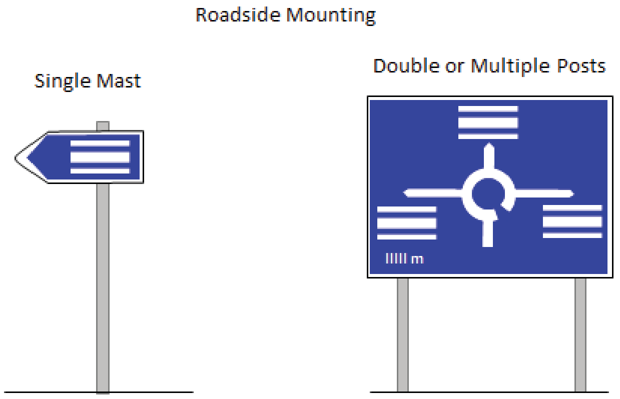
Directional signs may be mounted on the roadside or overhead. This is illustrated in ***Figure 7.2.4.1*** and ***Table 7.2.4.1***.

FIGURE 7.2.4.1 MOUNTING FORMS OF DIRECTIONAL SIGNS

(for driving on the right side of the road)



(for driving on the left side of the road)



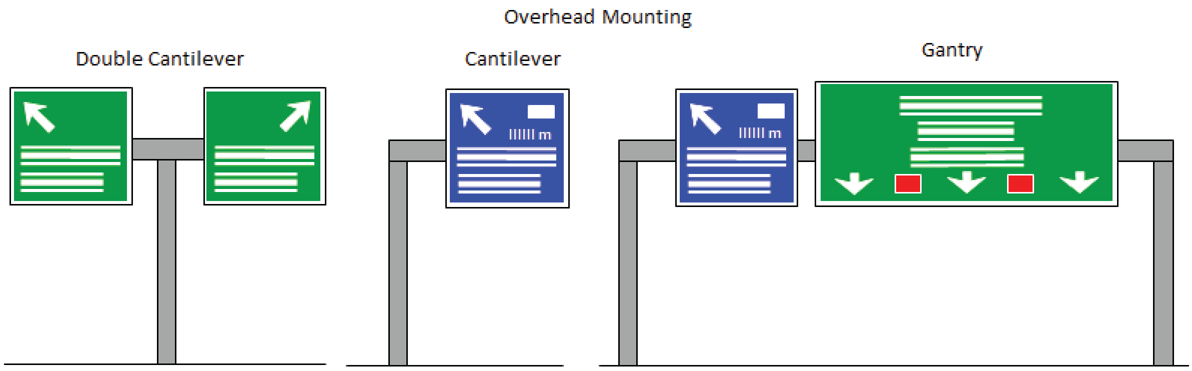


TABLE 7.2.4.1 MOUNTING FORM OF DIRECTIONAL SIGNS

Mounting Form	Characteristics	Remarks
Roadside	Side-mounted signs over the verge with mounting height in the order of 1.5m and 2.5m	Generally appropriate for all types of roads with adequate roadside space
Cantilever	Overhead signs partially over the carriageway	Generally more economic for medium size directional signs
Gantry	Overhead signs spanning over the carriageway	Appropriate for larger signs, heavy traffic, traffic lanes >=3 and lane drops
Double Cantilever (Butterfly)	Overhead signs over the carriageway on both sides at diverge gores	Not recommended unless approach speed is low or crash cushions are installed

The suitability of mounting forms for various sign formats is given in ***Table 7.2.4.2***.

TABLE 7.2.4.2 MOUNTING FORMS AND SIGN FORMAT

Sign Format	Roadside	Overhead		
		Gantry	Cantilever	Double Cantilever
Map	✓	#	#	X
Stack	✓	#	#	X
Lane destination	✓	✓	✓	X
Flag type	✓	X	X	X
Rectangular	X	✓	✓	✓

acceptable

Directional signs may also be mounted onto intersecting bridges or other structures. Other alternative or innovative mounting solutions may be justified for unusual circumstances.

Mounting Height

Roadside signs are generally mounted at 1.5m to 2.5m above the ground surface. Overhead signs including cantilevers, gantries and double cantilevers should be mounted not less than 5m above the ground surface. Mounting height up to 5.5m should be considered where the legal height of vehicles reaches 4.6m. Adequate mounting height for overhead sign structures is required since they are susceptible to damage or collapse upon impact by an overheight vehicle.

Consistency of Mounting Forms

Sign formats and mounting forms should, as far as practical, be consistently applied along a route.

Roadside mounting is generally appropriate for Classes II and III roads. It is also appropriate for Primary class roads and Class I roads in the following situations:

- Less important intersections
- Number of traffic lanes per direction =< 2
- Low volume of heavy vehicles

Overhead mounting is generally appropriate for Primary class roads and Class I roads in the following situations:

- Important intersections and interchanges
- Number of traffic lanes per direction >= 3
- High volume of heavy vehicles
- Where roadside visibility is unsatisfactory
- Where mounting is dictated by road structures including viaducts and noise abatement facilities etc..

Overhead mounting in the form of cantilevers may be adopted for advance direction signs and confirmatory signs on Classes II and III roads if roadside mounting is severely constrained by roadside conditions such as lack of verges, trees-lined roadside and frequent obstructions.

2.5 Positioning and Visibility

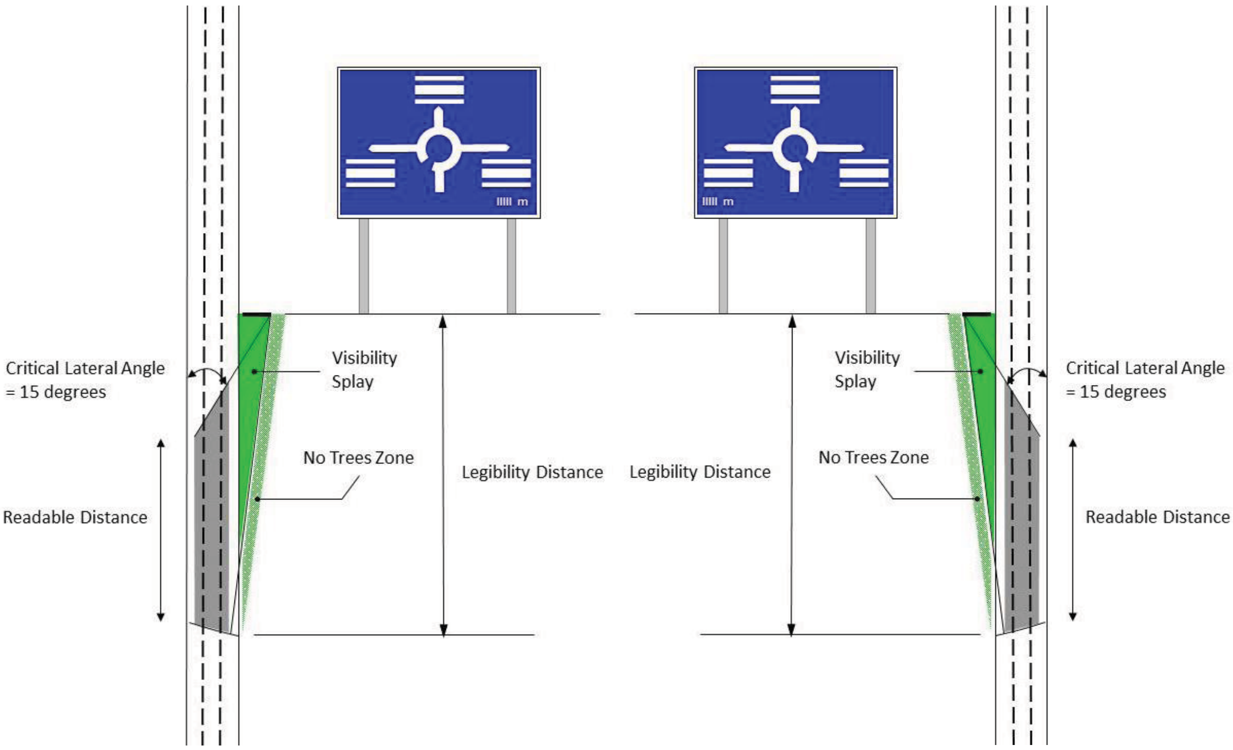
Directional signs should be positioned at vantage locations so that drivers can recognise their presence well ahead and are able to read the information at ease. In case of intersections in the proximity of one another, there should be no ambiguity as to which intersection the sign is referring to.

The roadside may need to be locally widened to accommodate the sign, the mounting structure, safety barriers and visibility splays.

Directional signs are read by drivers moving at speeds. The effective reading time is usually small, in a matter of seconds. This has fundamental implications of sign face design and positioning. ***Figure 7.2.5.1*** illustrates the general considerations for a roadside direction sign.

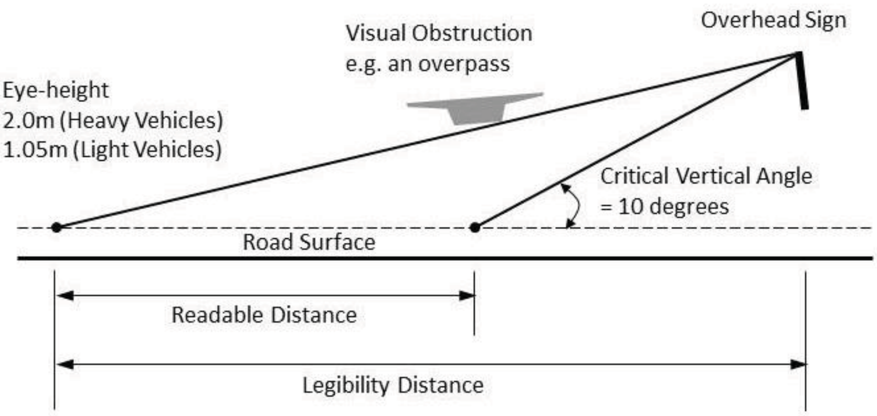
FIGURE 7.2.5.1 READABLE TIME FOR A ROADSIDE DIRECTIONAL SIGN

(for driving on the right side of the road) *(for driving on the left side of the road)*



Overhead directional signs are susceptible to obscuring by overpasses and tree crowns. This is illustrated in ***Figure 7.2.5.2***.

FIGURE 7.2.5.2 READABLE TIME FOR AN OVERHEAD DIRECTIONAL SIGN



Positioning in Relation to Alignment

The position of directional signs should take into account both horizontal and vertical alignments.

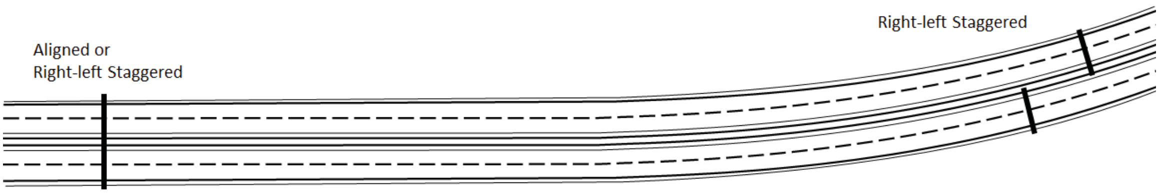
Advance direction signs are preferably positioned on straight sections with a straight approach. This is particularly the case for gantry directional signs with arrows pointing to individual traffic lanes.

It is generally appropriate to position roadside advance direction signs on the outside of a large radius curve. It is also suitable to position gantries or cantilevers on the outside or inside of large radius curves with an open view on the approach. To avoid obscuring, advance direction signs should not be positioned after a significant crest profile.

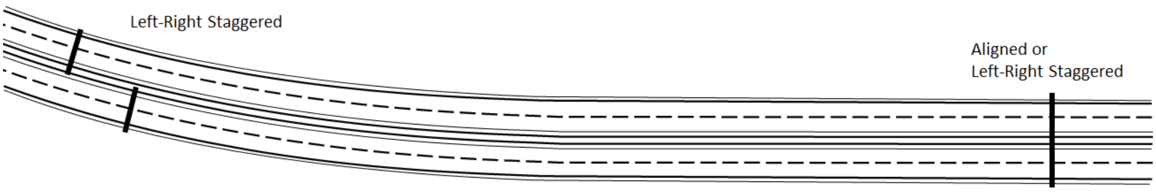
For optimum visual effect, gantries in the proximity serving different directions on a divided road should be aligned or staggered. This is illustrated in ***Figure 7.2.5.3***.

FIGURE 7.2.5.3 APPROPRIATE POSITIONING OF GANTRIES IN THE PROXIMITY ON DIVIDED ROADS

(for driving on the right side of the road)



(for driving on the left side of the road)



Obscuring

Obscuring may be an isolated problem or systematic issues. To alleviate the problem, the visibility of directional signs should be coordinated with the design of other road infrastructure components such as cut slopes, overpasses, landscaping, noise barriers, equipment etc.

To avoid obscuring and overloading of information, directional signs should be spaced well apart. Smaller traffic signs should not be positioned within the visibility splay in front of roadside directional signs.

Sign clutter

Signs closely spaced from each other contribute to sign clutter. Besides overloading drivers with information, downstream signs may be obscured by upstream signs.

The spacing between gantry signs is ideally 300m or more. Smaller spacing down to 200m may be used occasionally if necessary.

Passive Safety

Mounting structures of directional signs have major implications on roadside safety. The following approaches are recommended:

- Diverge gores should be free of mounting structures unless crash cushions are widely in use
- Safety barriers should be provided where speed limit is 70km/h or more
- Passively safe mounting structures should be adopted if safety barriers are not provided and speed limit is 70km/h or more

2.6 Signing Schemes

It is desirable to provide directional signs at all intersections in the following sequence:

- Advance Direction Sign
- Direction Sign
- Route Confirmatory Sign

At grade-separated intersections, a final advance direction sign should be provided at or in the vicinity of the commencement of a deceleration lane.

The precise positioning of directional signs should be based on optimisation of visibility and reading conditions, as well as the need to maintain adequate spacing between other signs.

Advance Direction Signs

Advance direction signs should be provided for all major intersections. Their needs for minor intersections and direct frontage accesses should be determined on a case-by-case basis. ***Table 7.2.6.1*** is a general guidance for their provision.

TABLE 7.2.6.1 PROVISION OF ADVANCE DIRECTION SIGNS

Road Class	Typical Speeds km/h	Advance Direction Sign	
		Minimum Numbers	Advance Distance
Primary class	100- 120	2*	1000m- 2000m
Class I (access-controlled)	80- 110	2*	500m- 1000m
Class I	60- 80	1	200m- 500m
Class II	60- 80	1	100m- 300m
Class III	50- 60	1	50m- 200m
Urbanised sections	40- 50	1	50m-150m

* in addition to the final advance direction sign for direct diverge layout

Additional advance direction signs, possibly commencing at a more upstream location, may be provided for important intersections and where there are multiple traffic lanes.

Positioning Details

Directional signs in the vicinity of weaving sections should be positioned to provide timely directional information for merging traffic to select traffic lanes.

In the vicinity of a direct merge, they should be positioned 150m to 250m downstream of the merging taper to minimise distraction for merging traffic.

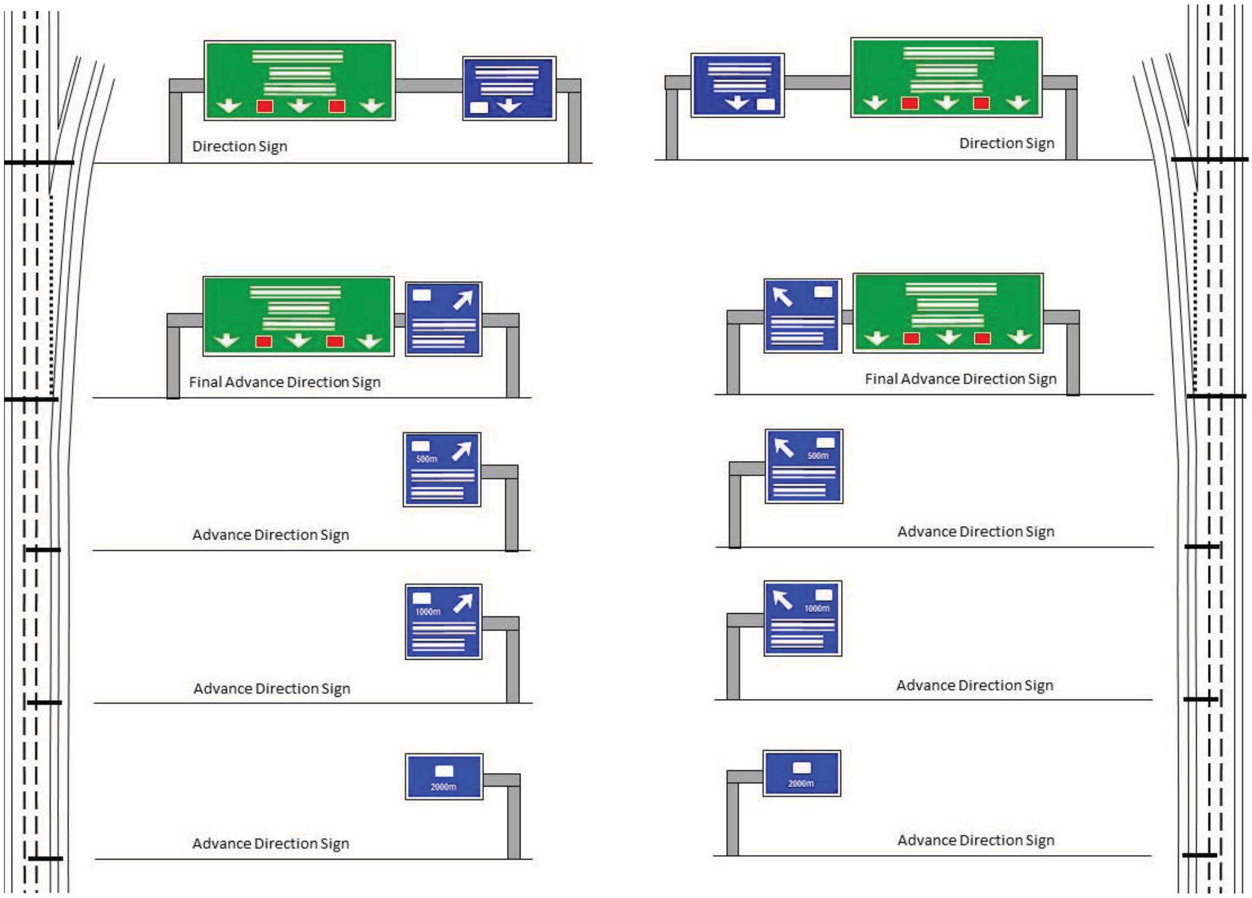
Grade-separated Intersections

The recommended directional signing sequence for direct diverges may be based on overhead signs or roadside signs. This is illustrated in ***Figure 7.2.6.1***. Overhead signs are recommended for:

- interchanges connecting two Primary class roads
- important exits
- roads with three or more traffic lanes per direction
- roads with a high volume of heavy vehicles

FIGURE 7.2.6.1 TYPICAL DIRECTIONAL SIGNING SCHEME FOR DIRECT DIVERGE

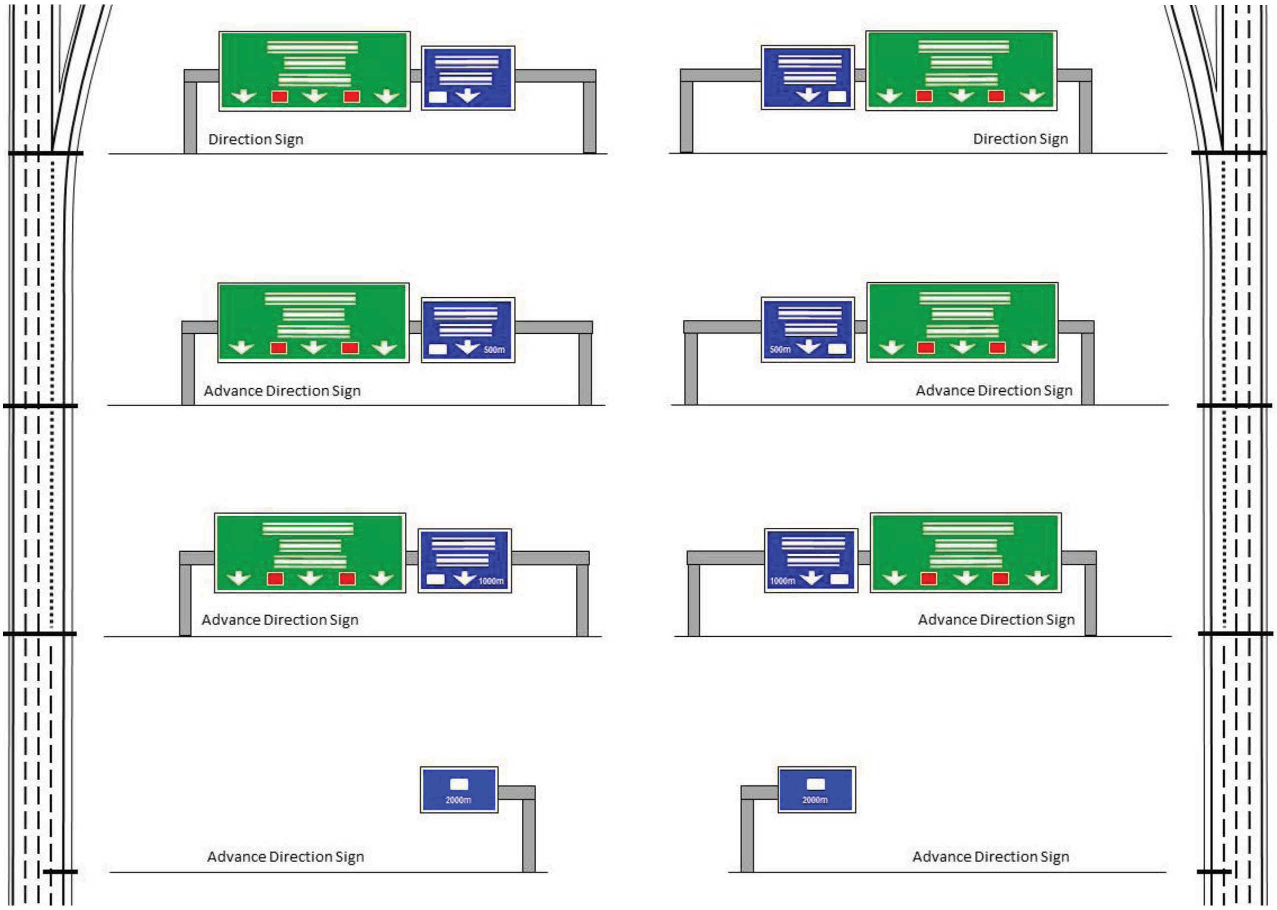
(for driving on the right side of the road) *(for driving on the left side of the road)*



The recommended directional signing sequence for lane drops is based on overhead signs as illustrated in ***Figure 7.2.6.2***.

FIGURE 7.2.6.2 TYPICAL DIRECTIONAL SIGNING SCHEME FOR LANE DROPS

(for driving on the right side of the road) *(for driving on the left side of the road)*



Weaving Sections

Weaving sections may be in a variety of layouts and adaptation of signing sequence will be required. Directional signs should guide drivers to get into or stay on the correct traffic lane at an early stage. The recommended directional signing sequences for typical weaving sections are illustrated in ***Figures 7.2.6.3*** and ***7.2.6.4***.

FIGURE 7.2.6.3 TYPICAL DIRECTIONAL SIGNING SCHEMES FOR WEAVING SECTIONS

(for driving on the right side of the road) *(for driving on the right side of the road)*

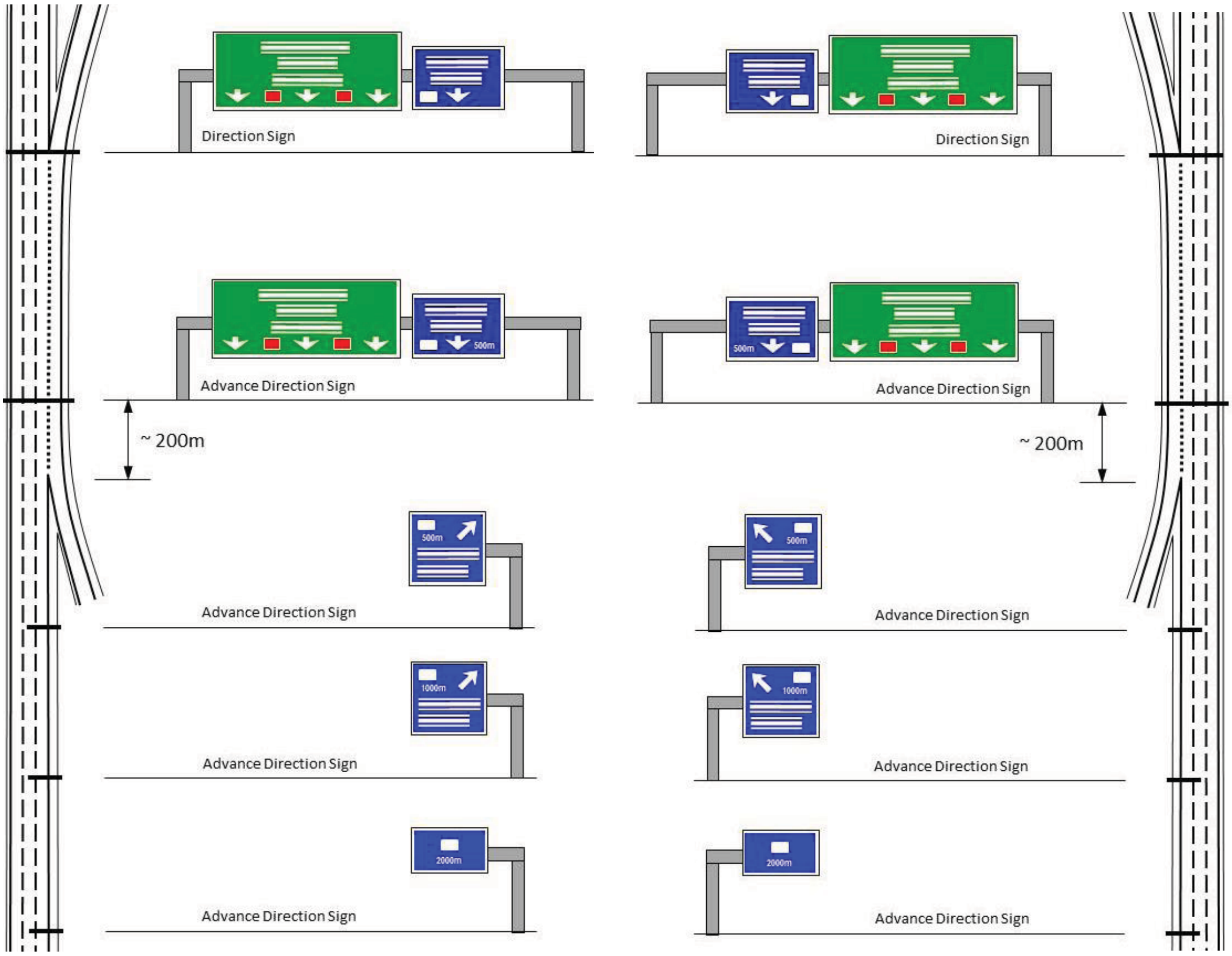
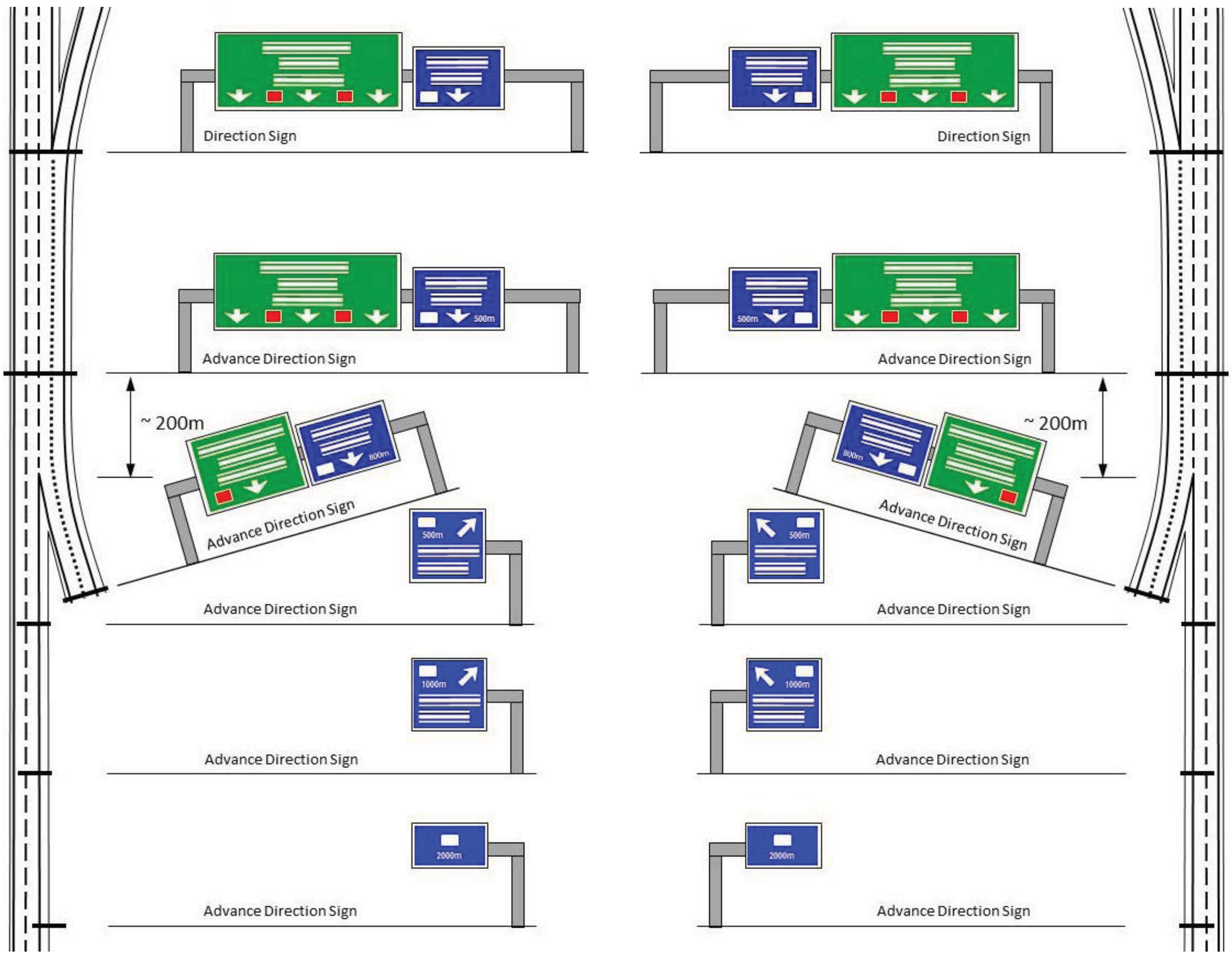


FIGURE 7.2.6.4 TYPICAL DIRECTIONAL SIGNING SCHEME FOR AN ASYMMETRICAL WEAVING SECTION

(for driving on the right side of the road) *(for driving on the right side of the road)*

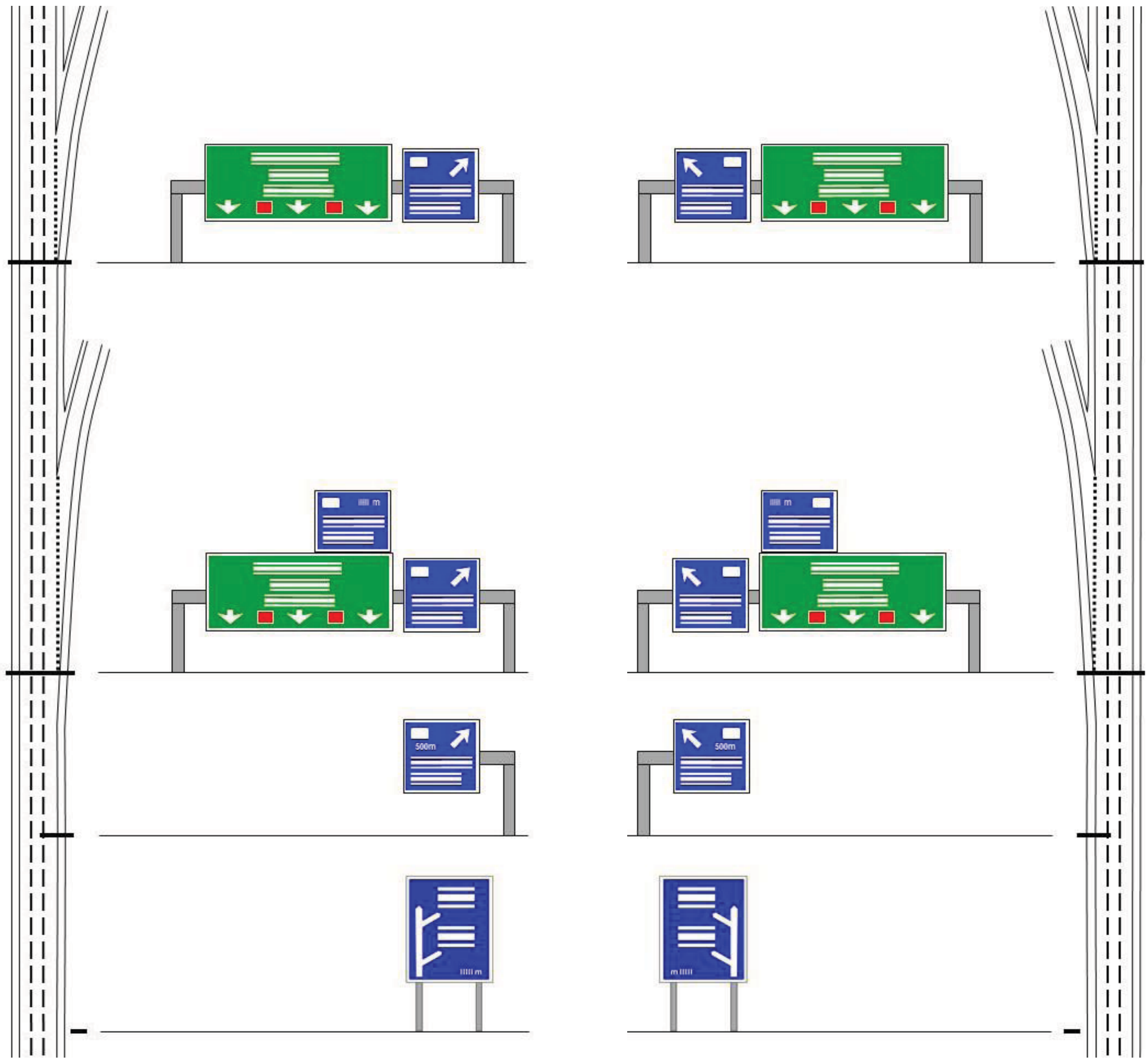


Successive Diverges

Where two or more diverges are located in proximity, it is important to provide adequate advance guidance and to clearly distinguish the exits. This is illustrated in ***Figure 7.2.6.5***.

FIGURE 7.2.6.5 TYPICAL DIRECTIONAL SIGNING SCHEME FOR SUCCESSIVE DIVERGES

(for driving on the right side of the road) *(for driving on the right side of the road)*

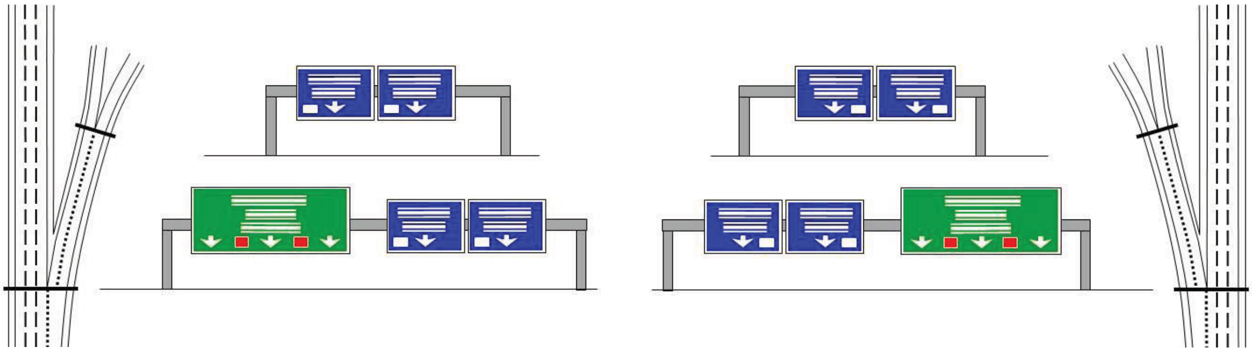


Secondary Diverges

Where a diverge is followed by further branches, it is important to provide timely advance guidance and to clearly distinguish the exits. This is illustrated in ***Figure 7.2.6.6***.

FIGURE 7.2.6.6 TYPICAL DIRECTIONAL SIGNING SCHEME FOR SECONDARY DIVERGES

(for driving on the right side of the road) *(for driving on the right side of the road)*



Confirmatory Signing

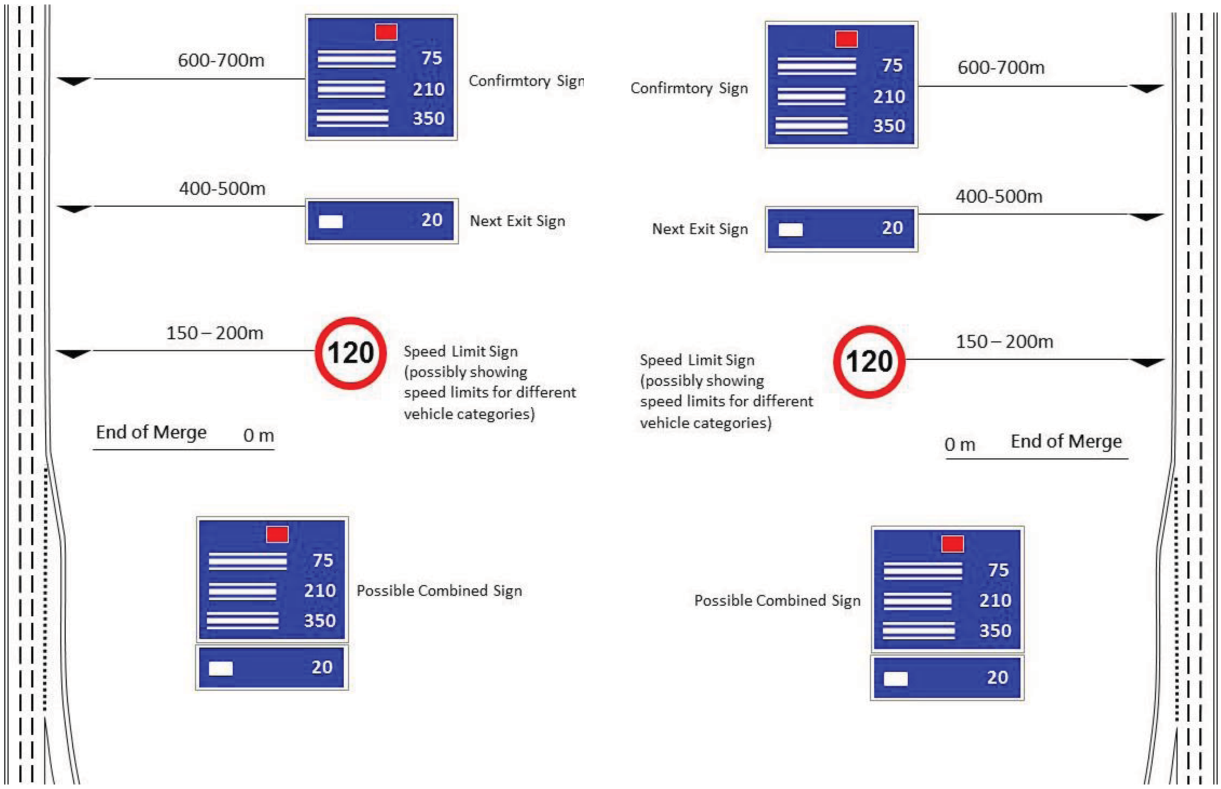
Confirmatory Signs are provided:

- downstream of a merge (***Figure 7.2.6.7***)
- at intervals of 5 to 10km
- after a long tunnel or a series of tunnels
- after a mainline toll plaza
- after a major urbanised section

If grade-separated intersections are in close proximity, confirmatory signs should be provided downstream of the last entrance or exit. Confirmatory signs should not be provided within a weaving section alongside an auxiliary lane and are not normally required along an urbanised section.

FIGURE 7.2.6.7 CONFIRMATORY SIGNS AFTER A MERGE

(for driving on the right side of the road) *(for driving on the left side of the road)*



Service Areas Signing

It is recommended that a separate sequence of directional signs is provided for service areas and filling areas. Their positioning should be coordinated with directional signs for intersections and interchanges. On Primary class and Class I roads, and possibly other classes of roads, it is advisable to indicate the available facilities and distance ahead for at least two upcoming service areas.

Class I Roads

Signing schemes for access-controlled Class I roads should follow the same principles for Primary class roads. These may be based on less advance signs, reduced advance distance and less use of overhead gantry signs.

Grade-separated Intersections in Urban Areas

Grade-separated intersections are often very closely spaced and may have complex layouts. The road network may also consist of frequent flyovers, viaducts, tunnels and underpasses.

Signing schemes for these roads should provide clear guidance with the following characteristics:

- Less number of advance signs and smaller advance distance
- Sign face showing multiple exits ahead (***Figure 7.2.6.8***)

- Optimised use of different sign formats and mounting structures

FIGURE 7.2.6.8 INFORMATION SIGNS AHEAD OF A GROUP OF INTERSECTIONS

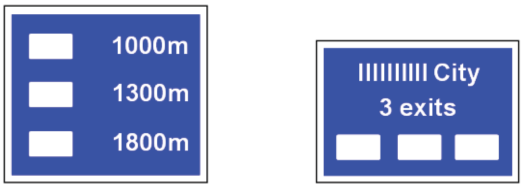
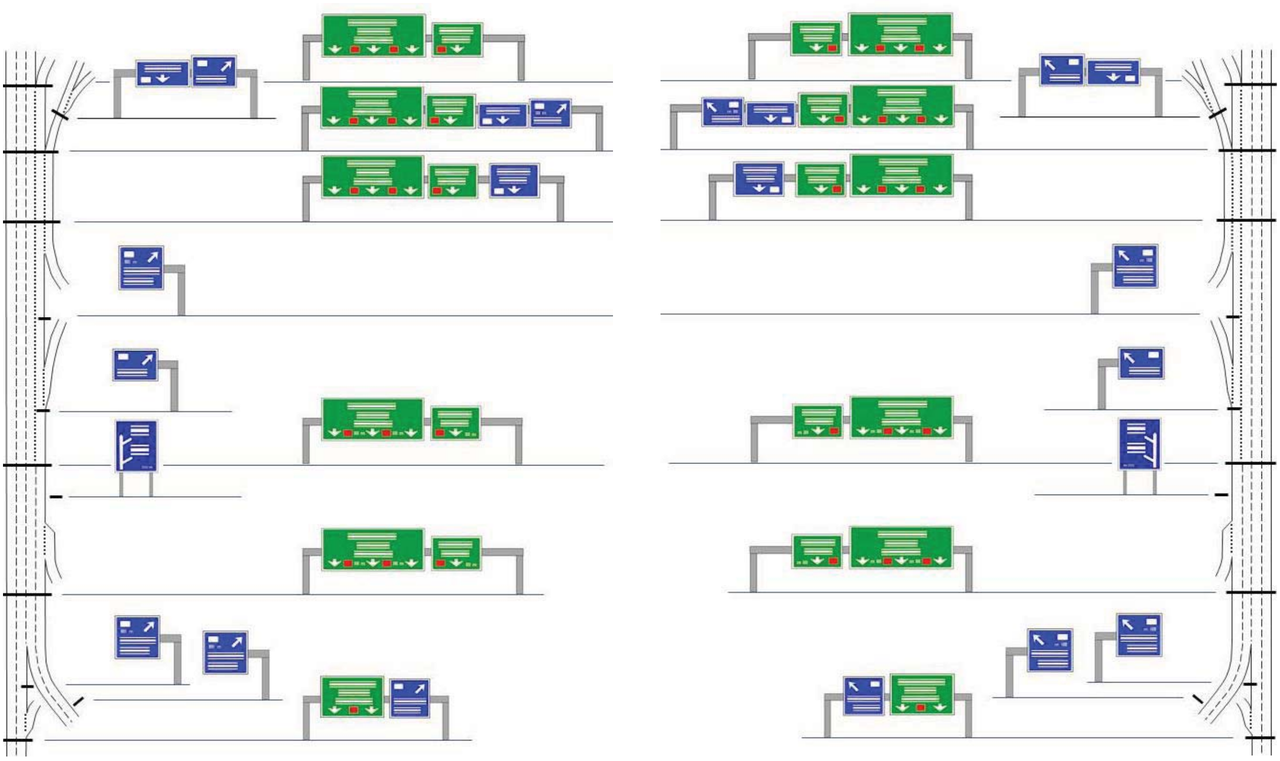


Figure 7.2.6.9 illustrates the optimisation of directional signing for multiple successive intersections.

FIGURE 7.2.6.9 SIGNING SCHEME FOR MULTIPLE SUCCESSIVE INTERSECTIONS

(for driving on the right side of the road) *(for driving on the left side of the road)*

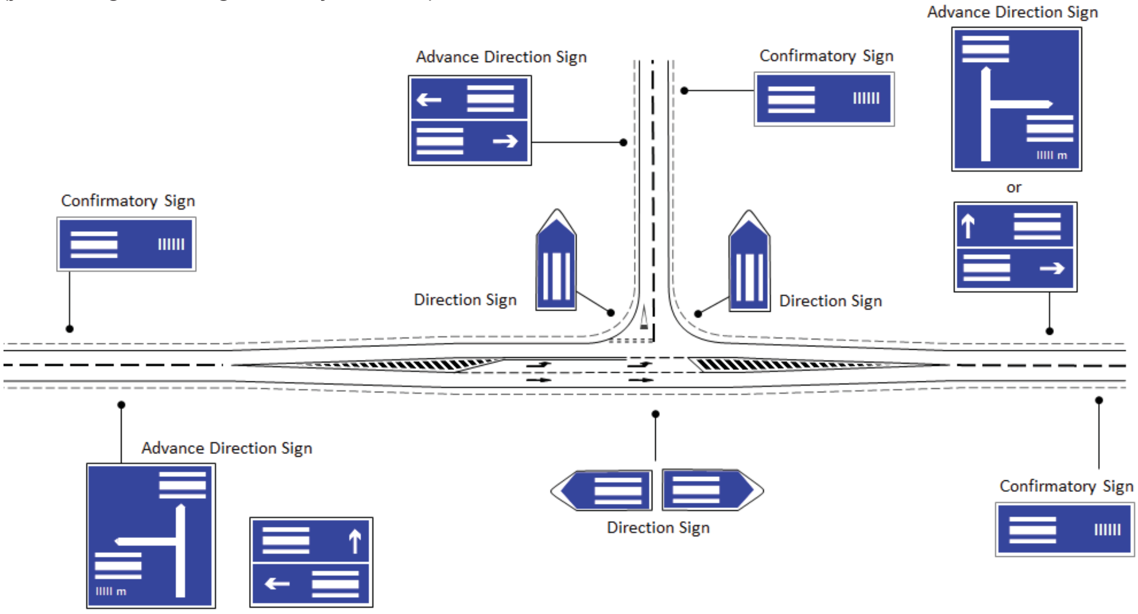


At-grade Intersections

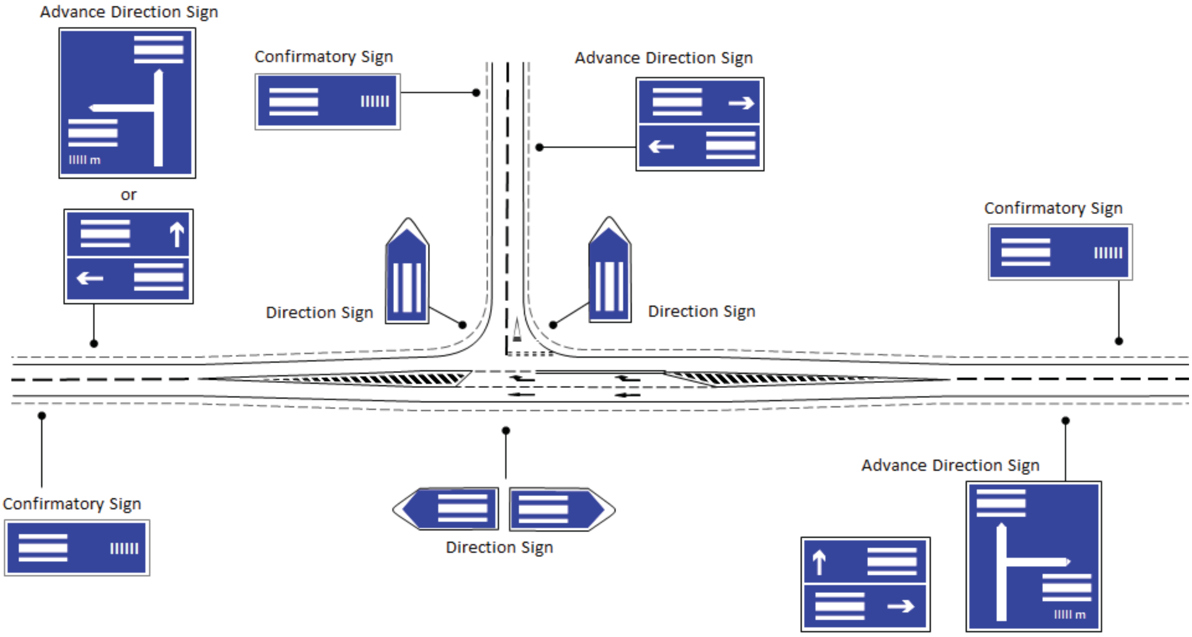
A typical directional signing scheme for priority intersections is illustrated in ***Figure 7.2.6.10***.

FIGURE 7.2.6.10 TYPICAL DIRECTIONAL SIGNING SCHEME FOR A PRIORITY INTERSECTION

(for driving on the right side of the road)



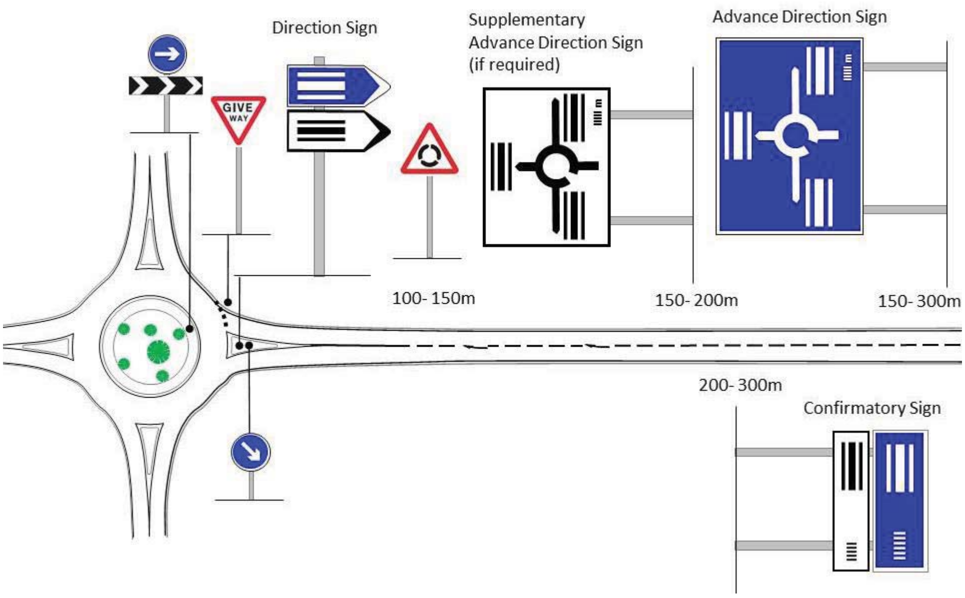
(for driving on the left side of the road)



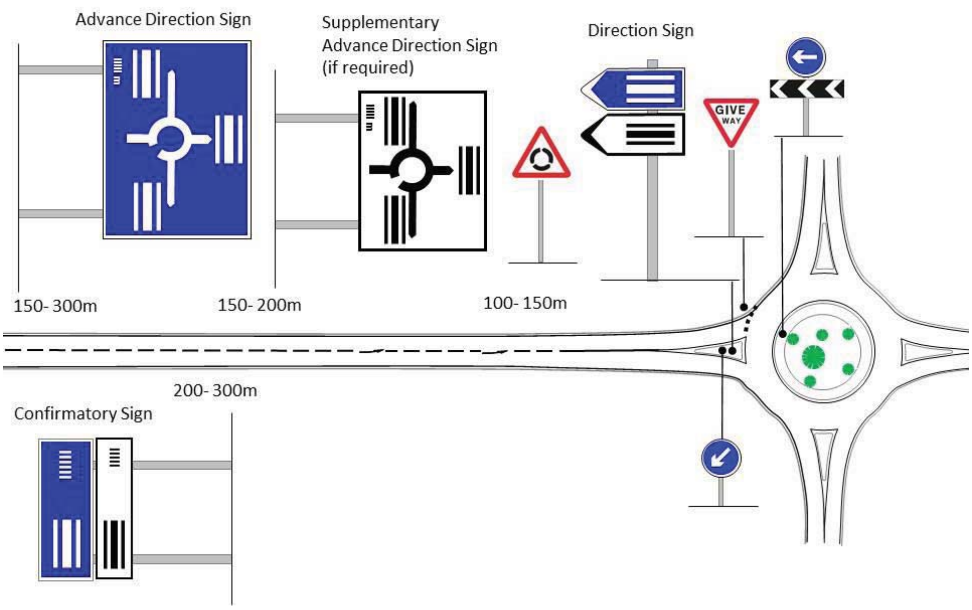
A typical directional signing scheme for roundabouts is illustrated in ***Figure 7.2.6.11***. Consideration should be given to erecting signs showing "New Roundabouts" if an existing intersection is converted as a roundabout.

FIGURE 7.2.6.11 TYPICAL DIRECTIONAL SIGNING SCHEME FOR A ROUNDABOUT

(for driving on the right side of the road)



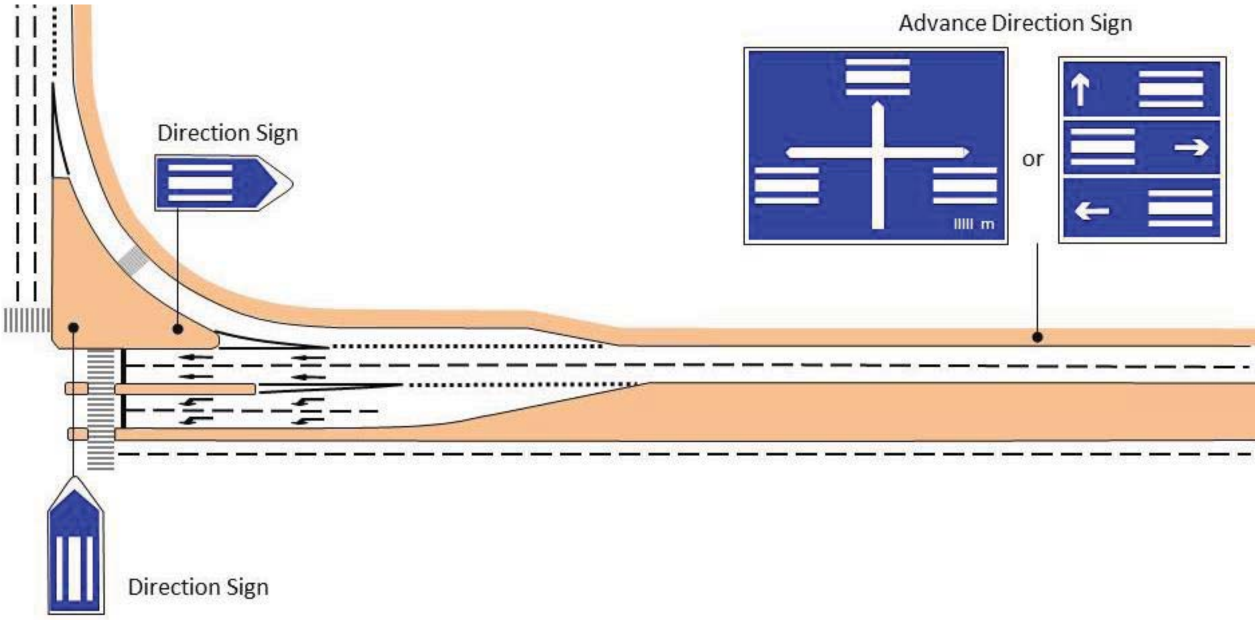
(for driving on the left side of the road)



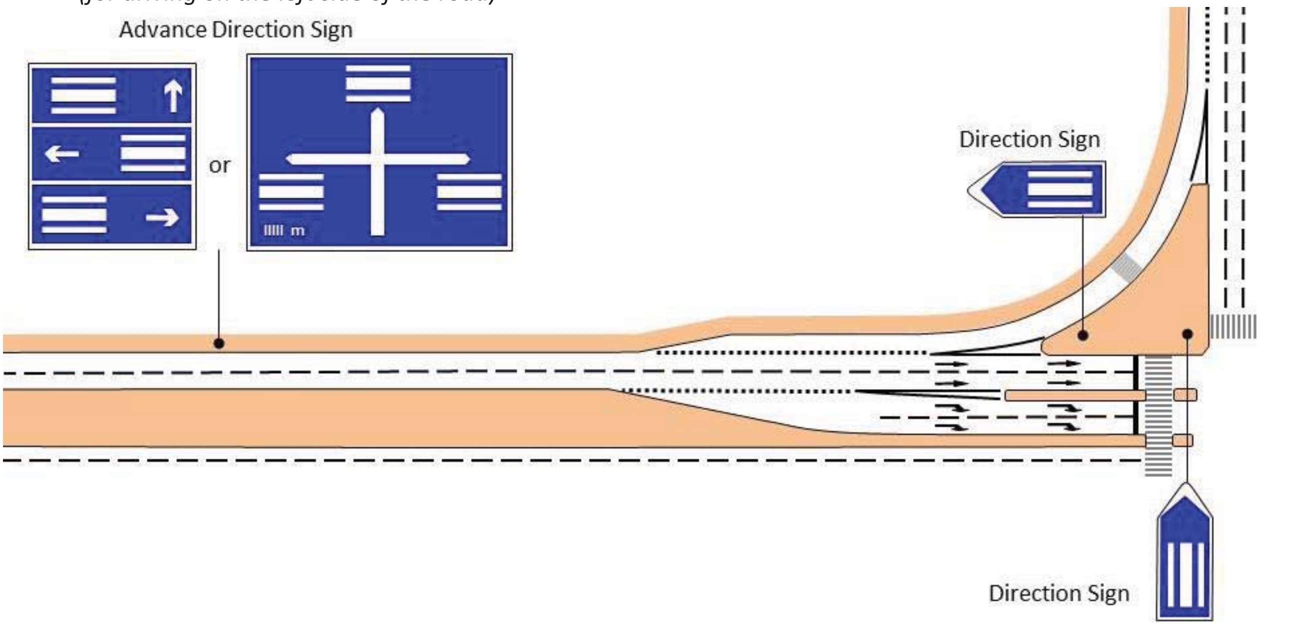
A typical directional signing scheme for signalised intersections is illustrated in ***Figure 7.2.6.12***.

FIGURE 7.2.6.12 TYPICAL DIRECTIONAL SIGNING SCHEME FOR A SIGNALISED INTERSECTION

(for driving on the right side of the road)



(for driving on the left side of the road)



Supplementary Directional Signs

Supplementary directional signs (SDS) are used to display secondary directional information which cannot be satisfactorily accommodated on the main signing sequence (***Figure 7.2.6.13***). SDS may be provided in one of the following forms:

- Separate advance direction sign ahead of the intersection
- Informatory sign in the format “follow XXX for YYY”
- Informatory sign “Follow Exit A for B”

FIGURE 7.2.6.13 SUPPLEMENTARY DIRECTIONAL SIGNS

Advance SDS should be positioned downstream of the most upstream advance direction sign and may be repeated. They may be provided as roadside signs or overhead cantilevers in stack type format, map type format or roundabout format.

SDS should not be installed at diverge gores or intersections without a corresponding advance direction sign. This is particularly important where traffic speed is high.

Coordination with Variable Signs

Remote controlled variable signs are often provided for managed expressways and special road sections such as tunnels or long bridges. Typical variable signs are given in ***Table 7.2.6.2***.

TABLE 7.2.6.2 TYPES OF VARIABLE SIGNS

Variable Sign Types	General Features	Purpose
Lane Control Signal	Signals displaying arrows or crosses above each traffic lanes	Indicating lane or road closures
Variable Speed Limit Sign	Signs displaying normal or temporary speed limit	Reducing the speed limit during incidents or planned events
Variable Directional Sign	Conventional directional signs which are fully or partially variable	Route guidance during diversion
Variable Message Signs	Sign which can display freely programmeable or limited number of messages or graphics	Multi-purpose message which may be in the format of “Event-Location-Action”

Where variable signs are adopted, the following rules should be taken into account:

- Variable signs and directional signs should be coordinated to provide a logical sequence of information for temporary traffic control
- Variable message signs advising diversions should be positioned with adequate advance distance

- Co-mounting of variable signs on directional signs should take into account compatibility of display, overloading of information, excessive height and aesthetics
- The spacing between consecutive signs should be adequate to avoid overloading of information and obscuring

2.7 Sign Face Graphics

Directional signs have to be readily understood by drivers at a glance. Sign face graphics design should be based on sound and consistent design rules covering:

- Border widths
- Spacing between texts, symbols and borders
- Order of texts and symbols placement
- Relative alignment of texts and symbols
- Overall proportion
- Positioning relative to traffic lanes

Language

Messages of directional signs on Asian Highway routes should be readily understandable by international drivers. Displays in all languages should be equally readable at the prevailing speeds of the road.

Latin letters on directional signs should be based on simple font types or specially developed font types for traffic signing purpose.

In order to accommodate long destination names and to optimise sign face designs, it is generally acceptable to adopt abbreviations. Abbreviations should be understandable and consistently applied.

Alignment and Listing Order

Where destinations are displayed in a stack of rows over one or more lanes, it is generally desirable to align them to the centre.

Where destinations are displayed in a stack of rows, one possibility is to place the nearest destination at the top and the furthest one at the bottom. However, placement in the reverse direction is also possible and has become popular in some countries.

Destinations may also be listed from left to right over one or more lanes to limit the height of overhead signs.

Text Heights

Texts on directional signs may be in capital letter for the first letter or the whole word. The design of directional signs may be based on the height of small letters or capital letters. Italic fonts may be used for secondary information, distances etc.. Typical letter heights for different road classes are given in ***Table 7.2.7.1***.

TABLE 7.2.7.1 LETTER HEIGHTS ON DIRECTIONAL SIGNS

Road Class	Typical Speeds km/h	Letter Height mm	
		Small Letter	Capital Letter
Primary class	100- 120	250, 300	350, 420
Class I (access-controlled)	80- 110	200, 250	280, 350
Class I	60- 80	150, 200	210, 280
Class II	60- 80	150, 200	210, 280
Class III	50- 60	100, 150	140, 210
Urbanised sections	40- 50	75, 90, 100, 125, 150	105, 126, 140, 175

* for overhead mounting, minimum height of small letters and capital letters are 100mm and 140mm respectively.

Local destinations in white colour format may be signed with letter heights one step smaller than that for major destinations.

Along urbanised sections of Classes I, II and III roads, smaller letter heights are generally sufficient for the reduced traffic speeds. A smaller sign will also be more compatible with urban streetscape.

Distance Indicators

Distance indicators in the form of metres or kilometres (with decimals where required if >= 1 km) should be used on advance direction signs. Distances for confirmatory signs should be in kilometres.

Arrows

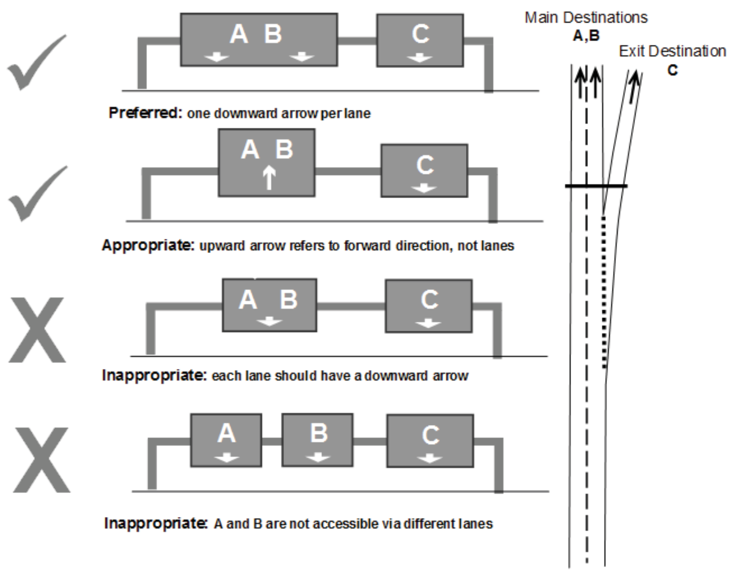
There are two meanings of arrows when used in conjunction with destinations in texts or symbols:

- to indicate the general direction
- to indicate individual traffic lanes to follow
- a mix of the above

The meaning of arrows should be well defined and consistently applied. ***Figure 7.2.7.1*** illustrates the recommended use of arrows.

FIGURE 7.2.7.1 APPROPRIATE USE OF ARROWS

(for driving on the right side of the road)



Arrows on overhead signs may point upward or downward as long as the meaning is clear. The use of lane-specific upward pointing arrows is illustrated in ***Figure 7.2.7.2***.

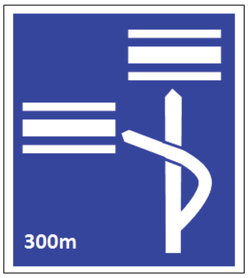
FIGURE 7.2.7.2 LANE-SPECIFIC UPWARD POINTING ARROWS *(driving is on the right side of the road)*

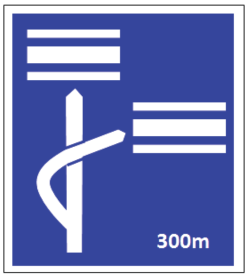
Map Symbols

Map format signs may be varied to better reflect actual intersection layout such as very sharp curves at exits. However, complex symbols are not advisable as drivers may not be able to understand the sign at a glance. This is illustrated in ***Figure 7.2.7.3***.

FIGURE 7.2.7.3 EXAMPLE OF UNDESIRABLE COMPLEX MAP FORMAT SIGN

(for driving on the right side of the road) *(for driving on the left side of the road)*





Interchange and Exit Symbols

Interchange and exit symbols are attractive and readily understandable. Examples of these symbols are illustrated in ***Figure 7.2.7.4***.

FIGURE 7.2.7.4 INTERCHANGE SYMBOL (LEFT) AND EXIT SYMBOL (RIGHT)

2.8 Directional Signing for Tourist Destinations

It is advisable to consider directional signing for tourist attractions as a separate system subordinate to the primary directional signing system which takes priority.

Directional signing for tourist attractions are categorised into:

- Tourist directional signs
- Map boards at rest areas
- Tourist itinerary signs

The following practices are recommended for the provision of tourist signing:

- Development of a hierarchy of tourist attractions and strict rules for selection
- Consistent signing schemes
- Use of brown and white colour format
- On Primary class roads or access-controlled roads, tourist directional signs are primarily provided in the map type, stack type or supplementary sign format on the roadside
- Advance direction signs for tourist attractions are always required for high speed roads
- Tourist attractions may not need to be signed if they are obviously associated with a main destination or more than 10km after an intersection.

Animation Signs

On Primary class roads and other roads traversing countryside with outstanding features of landscape, natural, historical or cultural values, animation signs may be provided along the route to break the monotony of the road and to promote appreciation by road-users. Examples of these signs are illustrated in ***Figure 7.2.8.1***.

Animation signs are not tourist directional signs. Their use should adhere to the following rules:

- high artistic quality using subdue colours, preferably brown and its variations
- simple presentation with only the name of the feature, possibly with indication of the viewing direction
- sign location is well separated from directional sign sequence
- sign location on straight sections
- Minimum spacing of 5 km

FIGURE 7.2.8.1 ANIMATION SIGNS

PART 8 TUNNELS

1 TUNNEL TYPES

Tunnels are special road sections in an enclosed environment. There are two main categories of tunnels:

- Tunnels on Primary class or Class I roads with separate tubes for unidirectional traffic
- Tunnels on Classes II or III roads in single tube for bidirectional traffic

Tunnels may exist as an isolated facility or in the form of a series of tunnels. Other road infrastructure may have some or all of the characteristics of tunnels. This includes:

- Roads with noise abatement facilities such as enclosures and barriers
- Roads underneath a deck construction

Tunnels may be classified according to their lengths:

- Very short tunnels: < 250m
- Short tunnels: 250m- 500m
- Medium tunnels: 500m- 1000m
- Long tunnels: 1000m- 3000m
- Very long tunnels： >3000m

Safety provisions should be provided in accordance with road class, tunnel type, traffic volume and vehicle composition. Tunnels exceeding 500m in length require particular attention in terms of management, operation and emergency response.

This part of the document is intended to provide fundamental guidelines on road safety for tunnel infrastructure. Ventilation, fire system, communications and control systems are not covered.

Tunnels operation is more demanding than open roads for several reasons. Incidents are more difficult to handle and could lead to prolonged delays. There is also increased risk of fire and secondary incidents. Tunnel facilities also require routine or emergency maintenance.

Incidents in tunnels are diversified and generally consist of the followings:

- Minor incidents: breakdowns, minor damage only collisions
- Major incidents: collisions involving injuries, collisions resulting in prolonged blockage
- Fire
- Spillage
- Congestion
- Flooding
- Overheight vehicles
- Unauthorised entry of animals, pedestrians, vehicles or other users

Tunnels joining two different countries, if constructed, require special arrangement in management responsibilities.

Operation Modes

To facilitate maintenance activities and emergency response for incidents, the following operation modes are required with appropriate facilities and plans:

- Lane closure
- Tunnel tube closure
- Full tunnel closure for both directions
- Single tube contra-flow traffic (if applicable)
- Diversion (if applicable)

Restrictions

Pedestrians and slow vehicles including bicycles, mopeds, low power motorcycles etc. should not be permitted inside tunnels. If these road-users have to use a tunnel, adequate facilities such as wide shoulders or raised protected walkways should be provided.

Overtaking should be strictly prohibited in bidirectional tunnels. Overtaking restriction is also advisable in unidirectional tunnels to minimise collision risks. However, it is admitted that strict prohibition of overtaking may increase the risk of rear-front collision, for example, when a small vehicle is trapped behind a slow moving heavy vehicle.

Dangerous Goods Transport

The risk of dangerous goods transport through tunnels should be evaluated and managed. The following alternatives could be considered:

- Full restriction
- Restriction of certain categories of dangerous goods
- No restriction
- No restriction with escort

The main considerations are frequency of dangerous goods vehicles, traffic volume and the tunnel design.

2 TUNNEL INFRASTRUCTURE

2.1 General Road Design

Tunnels and their approaches should have relatively generous horizontal alignment without sharp curves and steep gradients. Gradients should be limited to 3% wherever possible to limit both emissions and safety risks. Toll booths should be located at least 300m from a tunnel.

In general, interchanges should be located outside tunnel with merging or diverging lanes located at least 1.5*SSD from the tunnel portal. Particular attention should be given to the adequacy of advance directional signs if a tunnel is located within the normal directional signing sequence.

There is a trend of providing interchanges inside tunnels worldwide to reduce nuisance, save up valuable land and minimise environmental impact. Interchanges in tunnels should only be permitted with a very high standard merging and diverging lanes characterized by:

- location on gentle alignment
- very good visibility
- parallel merging layout
- buffer zones after merging
- adequate, well designed and maintained directional signs
- Enhanced delineation
- crash cushion at diverge gores

In addition, these tunnels should be equipped with sophisticated traffic control and surveillance systems.

2.2 Safety Facilities

Emergency Laybys and Cross Passages

For tunnels exceeding 1500m in length and without an emergency lane, emergency laybys should be provided at intervals not more than 1000m. They should be located on straight sections or large radius curves. Approach traffic should be able to see a stopped vehicle in the layby with visibility distance of SSD.

To reduce the risk of an errant vehicle colliding frontally with the end wall of emergency laybys, the tunnel wall or safety barrier should have a flared layout.

Cross-passages for emergency services or diversion should be provided at spacing not exceeding 1,500m for tunnels longer than 1,500m in length.

Dangerous Goods Transport

The suitability of a tunnel for the transport of dangerous goods or hazardous materials should be established on the basis of risk and availability of alternative routes. Transport under escort is also a possibility.

Adequate consideration should be given to the containment and management of spillage. If dangerous goods is permitted, the drainage system should be specially designed for the collection of flammable or toxic liquid to minimise the risk of ignition and spread of fire, liquids or vapors through the tunnel tubes or between tubes.

To avoid trapping of potentially hazardous spillage in the road pavement, it is not advisable to use porous asphalt within a tunnel.

Speed Limit

Speed limits should be signed for each tunnel or series of tunnels other than short tunnels without significant change of driving conditions. Appropriate speed limit for tunnels may be determined from an overall consideration of design speed, road alignment and operational characteristics.

Table 8.2.2.1 provides general guidance on the setting of speed limits for tunnels.

TABLE 8.2.2.1 SPEED LIMITS FOR TUNNELS

Tunnel Type	Speed Limit km/h		
	Alignment, Cross-section, Equipment and facilities		
	Favourable	Constrained	Very constrained
Primary class roads and controlled access Class I roads-rural	100 (110)	80- 90	70- 80
Primary class roads and controlled access Class I roads-urban	80 (90)	70-80	60-70
Class II or Class III roads- single tube bidirectional operation	70	60	50
Primary class roads and controlled access Class I roads-single tube bidirectional operation	70	60	50

( ) may be suitable for tunnels of very high design standard

Emergency Station

Emergency stations should be provided at every layby and at spacing not less than more than 150m. Each station should be equipped with an emergency telephone and at least two fire extinguishers.

Emergency Escape Facilities

An emergency walkway not less than 0.75m in width should be provided on either side of a tunnel tube. This requirement may be waived if:

- an emergency lane not less than 2m is provided.
- the tunnel is unidirectional and is equipped with a sophisticated surveillance and control system

Emergency exits should be provided for all new tunnels to enable a tunnel user to walk on foot and reach a safe place in the event of a fire or other serious incidents. They also provide an alternative access for emergency services to reach an incident site. The maximum spacing between emergency exits is 500m.

Emergency exits may be in one of the following forms:

- Cross-passage between tunnel tubes
- Exit to an escape tunnel system
- Exit to an outdoor area or safe location
- Shelters with an escape connection

Shelters without an exit to escape routes should not be provided.

Monotony

Monotony in long tunnels could be mitigated by:

- Tunnel walls in colours at regular intervals
- Special colour schemes
- Informatory signs showing the remaining length of the tunnel

2.3 Tunnel Approach Zone

Tunnel approach zone is the transition area between a tunnel and open roads. The zone needs to satisfy requirements for operation, maintenance, emergency response and landscaping design. Major tunnels may consist of the following facilities in this zone:

- Ventilation building and fire control point
- Management centre with parking
- Access openings for staff, vehicles and emergency
- Laybys for inspection or retention of vehicles
- Crossovers and U-turn facilities
- Facilities for surveillance and traffic control

Simplicity should be attained for tunnel approach zones from the visual perspective and in terms of facilities, accesses and staff activities. Tunnel portals on high speed roads should be visible to drivers a few hundred metres ahead.

Traffic Control Facilities

Laybys should be provided at the entrance and exit of tunnel portals for the purpose of inspection, escort and temporary parking of broken down vehicles, unauthorised vehicles or operational vehicles.

Laybys are desirably 4 to 5m wide inclusive of paved shoulders. The length should permit parking of at least one long vehicle and a tow truck.

A vehicle crossover facility should be provided for twin tube tunnels to allow for single tube contra-flow operation.

Access for Operation, Maintenance and Emergency Response

Depending on the required response time for incidents, emergency response facilities should be provided in the vicinity of one or both tunnel portals. Consideration should also be given to provision of emergency access points for the use of the police and fire service.

In principle, direct frontage accesses for facilities should be minimised at tunnel approach zones. U-turn facilities are preferably grade-separated with acceleration lanes instead of at-grade design if they are likely to be used frequently.

Adequate visibility should be provided for any accesses or U-turn facilities. They should be closed off with traffic cones or barrier gates to deter unauthorised use.

Walkways and grade-separated crossings should be provided for operational and maintenance staff to access facilities and to implement routine traffic control. Walkways and working compounds should as far as practical be located outside clear zones or guarded by safety barriers.

2.4 Roadside Safety for Tunnels

Due to the need to satisfy a variety of operational, maintenance and emergency response functions, roadside areas of tunnel tubes and tunnel approach zones are more complicated in terms of roadside safety design.

Tunnel Tube

Tunnel walls, raised walkways or safety barriers should be smooth, continuous and free of aggressive protrusions. Corners of walkway kerbs should be smooth without sharp edges which could puncture the tires of vehicles.

At the termination of emergency laybys, the tunnel wall and walkway should be tapered or equipped with crash cushions. This is illustrated in ***Figure 8.2.4.1***. Attention should also be given to the details for crossovers and cross passages inside tunnel tubes to minimise the risk of collision with the ending of walls and walkways.

Figure 8.2.4.1 Termination of Emergency Layby inside Tunnel

Tunnel Portal

Roadside areas at the interface between open road and tunnel tube should not consist of hazards which could cause an errant vehicle to stop abruptly, penetrate into a vehicle or launch the vehicle air-borne. This requirement applies to tunnel entrances and tunnel exits.

Attention will need to be given to the detailed design of transition among tunnel walls, walkways and safety barriers on the approach zone. Examples of treatments are given in ***Figures 8.2.4.2*** and ***8.2.4.3***. It is also necessary to ensure that the upper part of an errant tall vehicle will not collide with the tunnel portal of circular or arch cross-section.

The safety risks of tunnel portals may be reduced with better delineation and longitudinal rumble strips on the immediate approach.

FIGURE 8.2.4.2 SAFETY BARRIER OVERLAPPING TUNNEL ENTRANCE
(driving is on the right side of the road)

FIGURE 8.2.4.3 DOUBLE SAFETY BARRIERS AND ACCESS OPENING AT TUNNEL ENTRANCE
(driving is on the right side of the road)

Terminations of raised tunnel walkways are preferably contiguous with the approach safety barrier. Low level walkway may be flared and ramped down at a shallow angle.

At the exit portal of tunnels, safety barriers on the open road should be continuous with the tunnel wall or safety barrier systems inside the tunnel. Alternatively they may be further set back and anchored without any exposed upstream end terminals. For bidirectional tunnels and tunnels regularly operated for bidirectional flows, transitions should be designed for safety in both traffic directions.

Tunnel Approach Zone

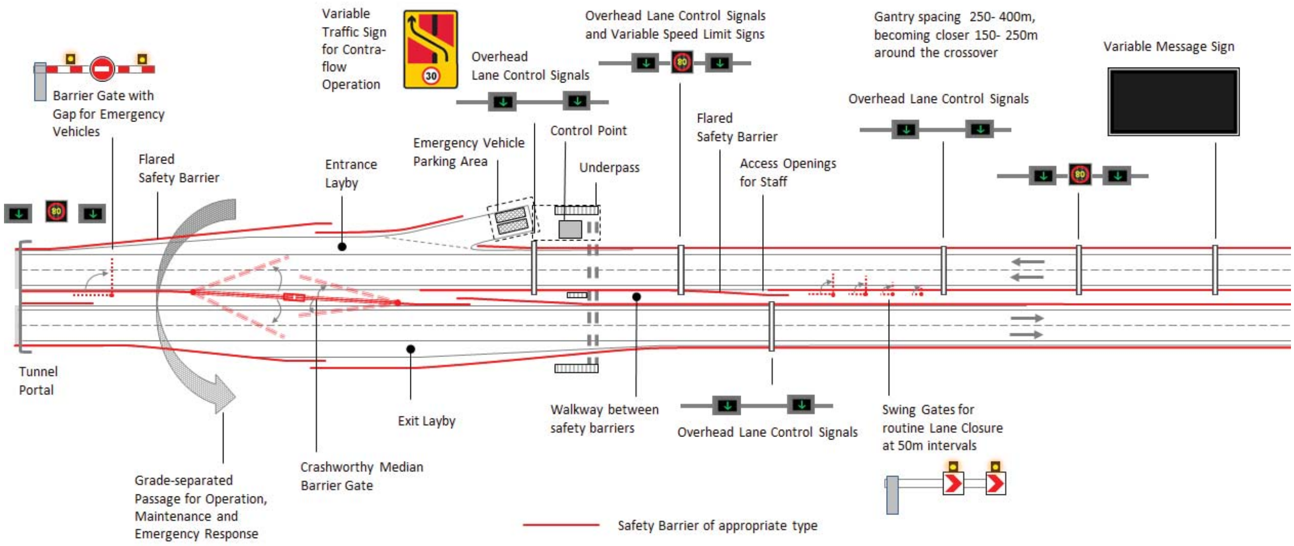
The following issues require special attention at tunnel approach zones:

- Absence of unguarded aggressive features
- Minimization of traffic islands and openings
- Provision of clear zones or crash cushions
- Continuity of vehicle restraint systems at tunnel portals
- Appropriate taper angle of safety barriers
- Crossover openings

Access openings for operational vehicles and pedestrians should be systematically provided with upstream safety barriers overlapping downstream barriers.

Figures 8.2.4.4 and ***8.2.4.5*** illustrate typical layout of tunnel approach zones integrating the needs for operation, maintenance, emergency response and roadside safety.

FIGURE 8.2.4.4 TYPICAL LAYOUT OF TUNNEL APPROACH ZONE ON A PRIMARY CLASS ROAD
(for driving on the right side of the road)



(for driving on the left side of the road)

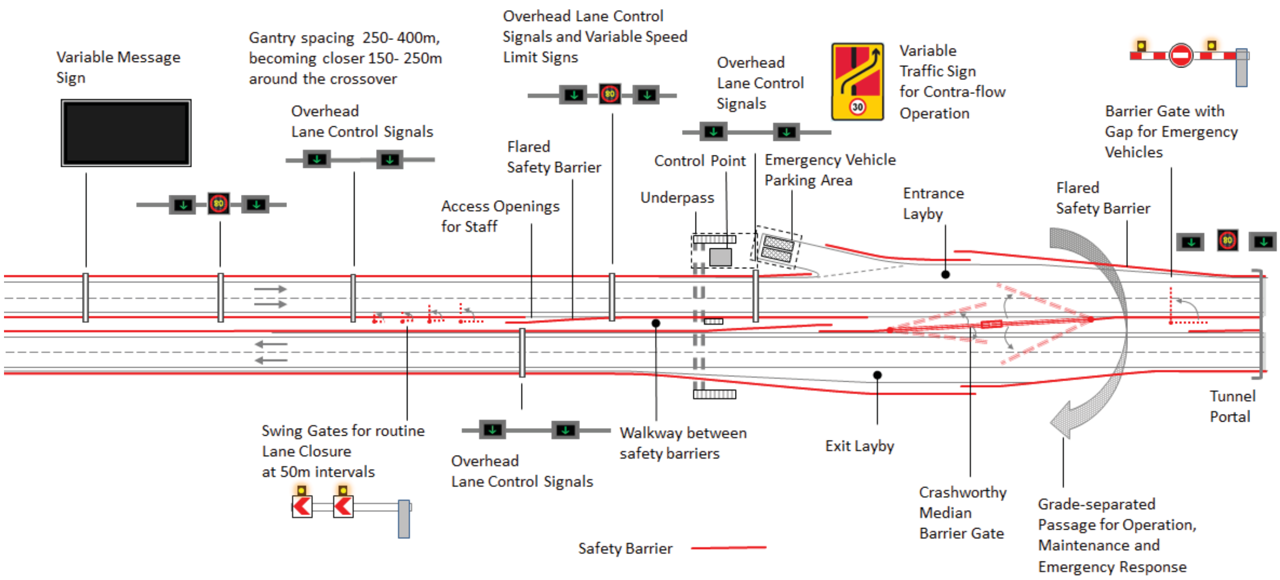
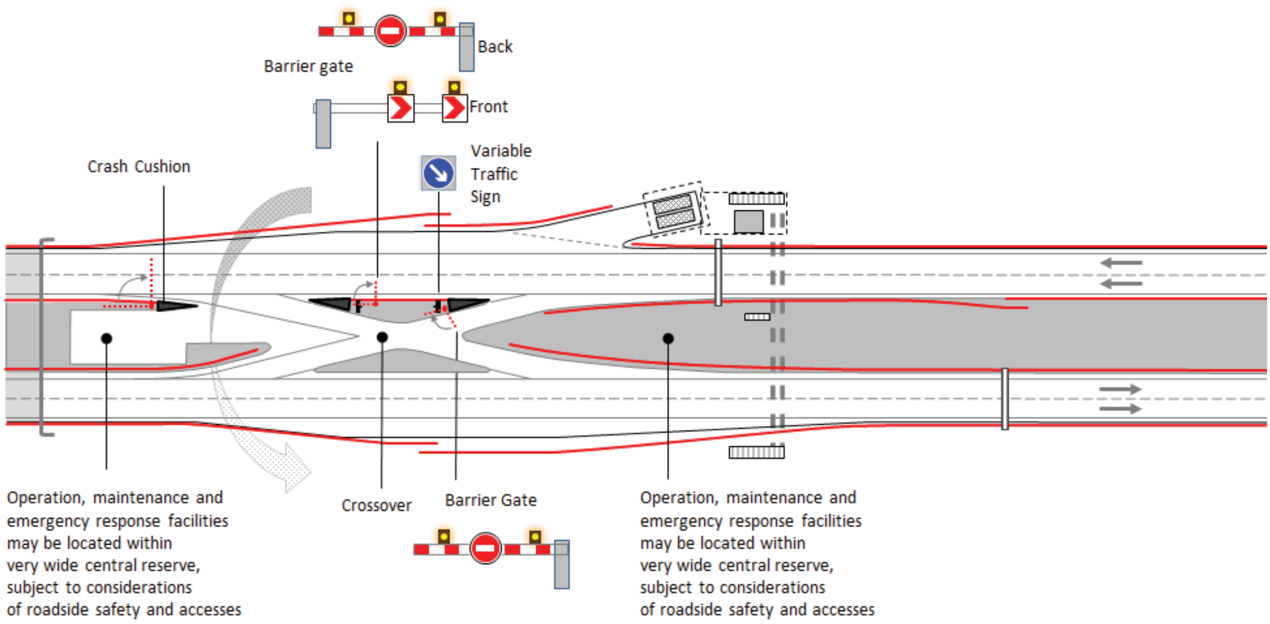


FIGURE 8.2.4.5 TYPICAL LAYOUT OF TUNNEL APPROACH ZONE WITH A WIDENED MEDIAN

(for driving on the right side of the road)



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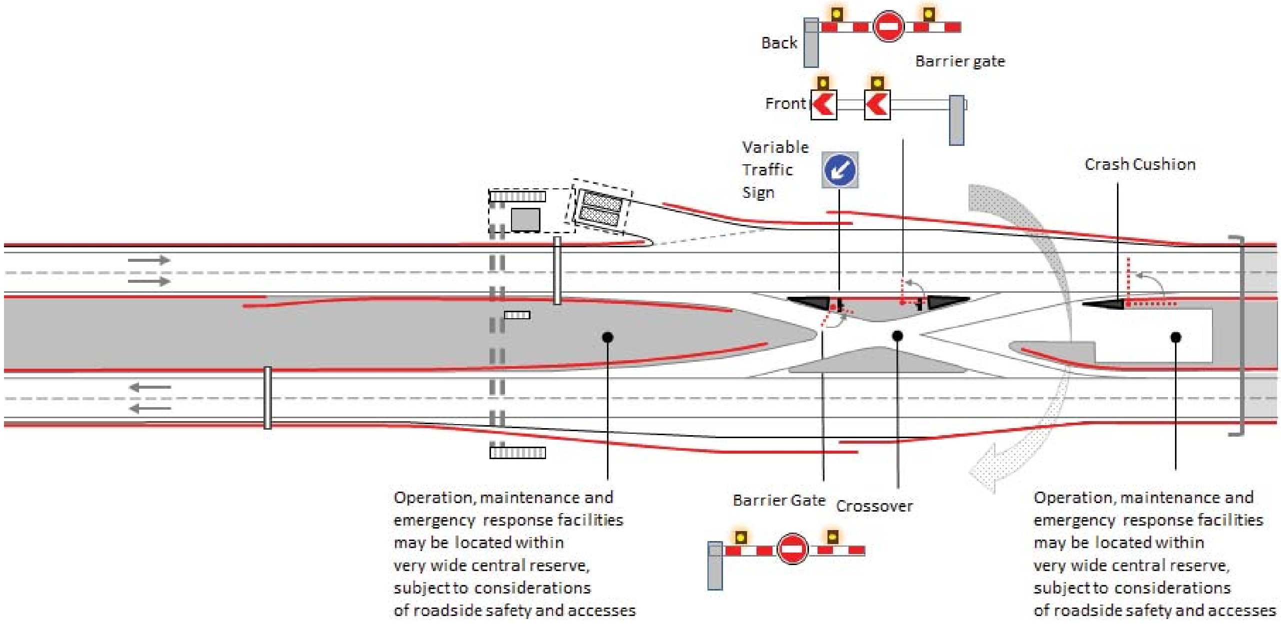


3 TUNNEL SIGNING AND LIGHTING

3.1 General Requirements

For unidirectional tunnels, lane changing should be discouraged or prohibited. For bidirectional tunnels, lane changing should be prohibited using double solid line markings. A widened centreline may be considered for additional safety.

Traffic signs and directional signs should be coordinated in positioning and information flow. They should not constitute sign clutter or overload of information.

The following traffic or informatory signs should be provided ahead of tunnels:

- Tunnel name or symbol and length
- Speed limit, and minimum speed limit if appropriate
- Turn on Radio if radio break-in system is in place
- Use low head beam lights
- Keep distance apart

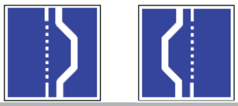
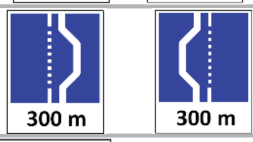
A sign giving essential information may be erected ahead of the tunnel. This is illustrated in ***Figure 8.3.1.1***. For very long tunnels, notably those longer than 3 km, it is advisable to provide informatory signs inside tunnels stating the remaining length of the tunnel every 1000m.

FIGURE 8.3.1.1 POSSIBLE SIGN DISPLAY CONTAINING ESSENTIAL INFORMATION

3.2 Emergency Signing System

An emergency signing system is required to assist road users to access emergency equipment and to evacuate a tunnel. The system should consist of self-illuminated signs fed from a separate power source. Signs should be based on graphics rather than worded messages. Essential emergency signs are given in ***Table 8.3.2.1***.

TABLE 8.3.2.1 EMERGENCY SIGNING SYSTEM [33]

Sign Type	General Requirements	Typical Design
Layby sign	At the start of layby	
Layby advance sign	200m- 300m ahead of the start of a layby	
Telephone and fire equipment	At emergency stations, mounting height at 1.2 to 1.5m	
Emergency exit signs	At emergency exits, mounting height at 1.2 to 1.5m	
Direction to emergency exits	towards both directions, mounting height at 1.2 to 1.5m	

3.3 Fixed and Variable Signing

Directional Signing

Where a tunnel is located within the directional signing sequence of an interchange, directional signs should be provided ahead of the tunnel. The provision and positioning of directional signs should take into account any restriction of lane changing within and in the vicinity of the tunnel tube.

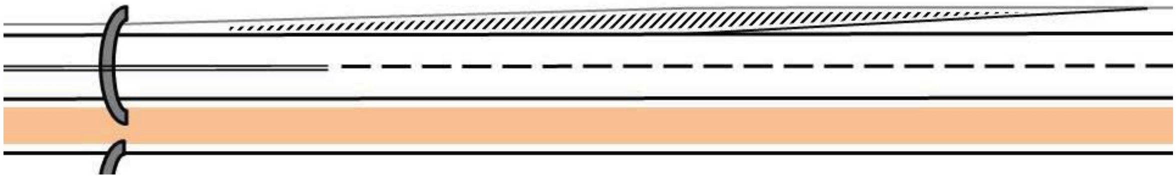
It may be desirable to install directional signs inside a tunnel tube due to presence of interchange inside or in the proximity of tunnel exits. This would require adequate headroom or roadside space. Directional signs at reduced size and simplified sign faces may be acceptable if there are severe technical or economic constraints.

Where a directional sign is installed shortly downstream of a tunnel tube, there should be sufficient distance to ensure that the sign can be properly read by drivers.

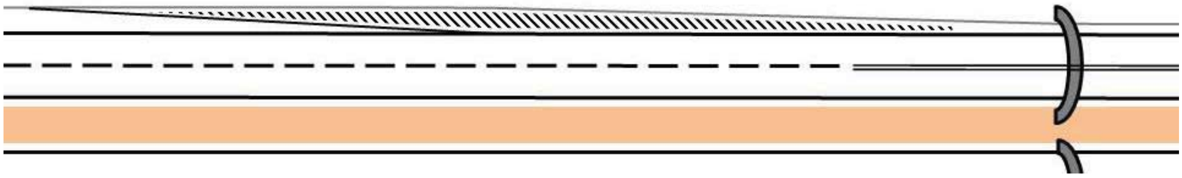
Delineation

Where a wide paved shoulder on the approach becomes a narrow shoulder inside the tunnel, narrowing should be introduced progressively in a taper. Hatched markings may also be laid as illustrated in ***Figure 8.3.3.1***. If adopted, solid lane line markings preferably commence or terminate not shorter than 20m from the tunnel portal.

FIGURE 8.3.3.1 ROAD MARKING AT NARROWING OF SHOULDERS
(for driving on the right side of the road)



(for driving on the left side of the road)



Consideration should be given to adopting a wide centerline marking to separate opposing traffic in a bidirectional tunnel tube. This is illustrated in Figure 8.3.3.2.

FIG 8.3.3.2 WIDE CENTRELINE IN A BIDIRECTIONAL TUNNEL *(driving is on the right side of the road)*

Visual guidance inside tunnels may be enhanced with reflectors or LED light sources at regular intervals along the walkway and/or the tunnel wall. This is illustrated in ***Figure 8.3.3.3***.

FIG 8.3.3.3 DELINEATION IN A UNIDIRECTIONAL TUNNEL *(driving is on the right side of the road)*

Variable Signing

Appropriate facilities are required to implement various operation modes and may include all or part of the followings:

- Traffic signals
- Lane control signals
- Variable directional signs
- Variable speed limit signs
- Variable message signs

Lane control signals will need to be double-sided for bidirectional traffic or contra-flow operation.

Messages on variable message signs may be in the form of "Event", "Location", "Action". Information about the event and location is beneficial but may be omitted if these are evident. Symbolic warning signs are also desirable as long as they are readily understood.

Useful messages for severe incidents or fire inside tunnels may include "REDUCE SPEED", "SWITCH OFF ENGINES", "EVACUATE".

Flashing lights or flashing messages could be desirable to alert drivers of fixed or variable signs.

Barrier Systems

Barrier gates should be provided to close off a tunnel tube in case of emergency or maintenance. They may be horizontally or vertically operated. In order to allow emergency vehicles to access a closed tunnel tube, a gap should be allowed on one side, in the middle or by staggering two barrier gates.

If lane closure is frequently envisaged, consideration should be given to a horizontal swing gate system on the approach.

Barrier systems should be operated in conjunction with variable message signs and lane control signals to provide sufficient warning and guidance for approaching drivers.

Barrier systems should be passively safe if collided by an errant vehicle. Their support mechanisms should be guarded by safety barriers.

3.4 Tunnel Lighting

Tunnel lighting is required to enable traffic to approach, enter, through and exit a tunnel or similar facilities smoothly and at a safety level equivalent to the adjacent open road, day and night and under all weather conditions.

Steady lighting should be provided in the interior zone of tunnels not affected by external conditions. Lighting should be provided in the following three zones for drivers to adapt to lighting conditions outside the tunnel.

- Threshold Zone: first entrance section which is brightly lit
- Transition Zone: gradual reduction to interior zone

- Exit Zone : readaptation to outside lighting which is geerally shorter in length

Lighting in these zones should be automatic with direct continuous monitoring of external ambient conditions. Adequate allowance for glare is needed for tunnels in an east-west orientation.

Flicking of lights should be avoided in the interior zones by appropriate spacing of luminaire.

Tunnel Walls

Tunnel walls and road surface should have high reflectance of diffused light to provide a high luminance background to silhouette an obstruction. The reflectance of tunnel walls should desirably exceed 0.6. but highly glossy finish is not appropriate, particularly for bidirectional traffic. Tunnel roof and wall area above 4m height should be in black or dark colour.

Tunnel lighting is largely divided into lighting at both ends and lighting inside the tunnel:

- Basic lighting: lighting with uniform brightness installed across the entire length of a tunnel to provide drivers with enough visibility at all time

- Entrance lighting: in addition to the basic lighting, lighting is installed at the entrance of a tunnel to reduce visual adaptation problems during day time. This type of lighting consists of a threshold zone and a transition zone

- Exit lighting: when necessary, in addition to the basic lighting, lighting installed at the exit of a tunnel to help drivers adapting to the high illuminance of natural lighting at the exit

- Lighting for connected roads at the entrance: lighting installed at the entrance of a tunnel helps drivers easily recognise the traffic conditions around the entrance and the changes in lane width inside and outside of the tunnel

Typical lighting profiles are illustrated in ***Figures 8.3.4.1*** and ***8.3.4.2***.

FIGURE 8.3.4.1 LIGHTING PROFILE FOR UNIDIRECTIONAL TUNNEL TUBE

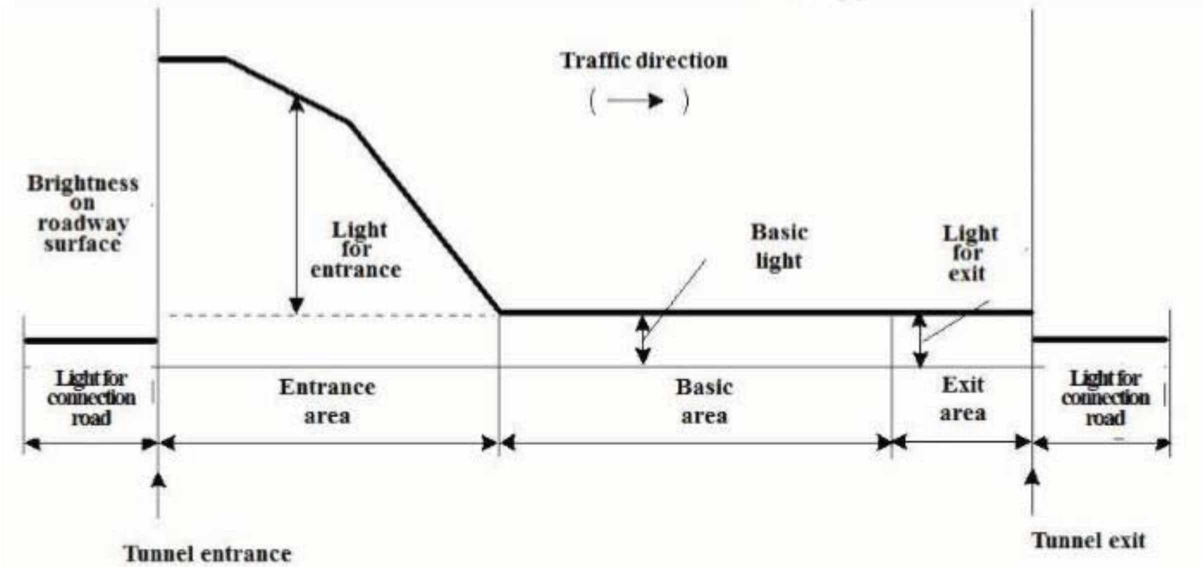
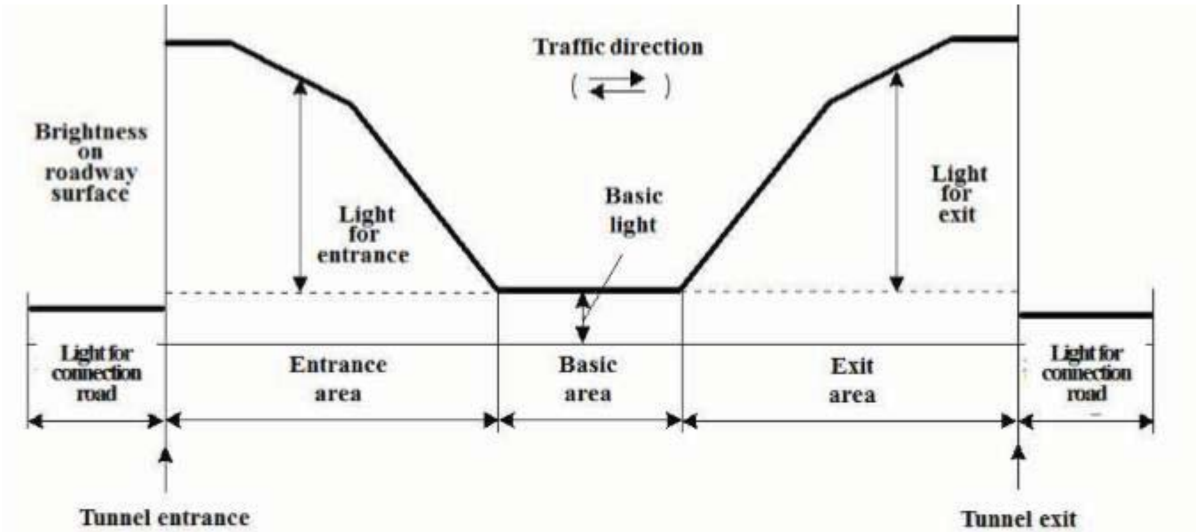


FIGURE 8.3.4.2 LIGHTING PROFILE FOR BIDIRECTIONAL TUNNEL TUBE



APPENDICES

APPENDIX 1 LIST OF REFERENCES

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APPENDIX 2 GLOSSARY

Term	Equivalent Term	Definition
Access-controlled Roads	Controlled-access Road	A high speed road restricted to motor vehicles with entry and exit movements at limited and designated grade-separated intersections
At-grade intersections		Intersections where at least one conflicting traffic stream has to stop or slow down considerably.
Built-up Area		A developed area with buildings, structures and concentration of human activities. This may include a city, a town, a village or an industrial zone
Carriageway		Part of the pavement designated for the normal use of traffic
Compact Roundabout	Continental Roundabout	Roundabout with a single traffic lane on the approach, exit and circulatory carriageway without flaring design at entries. If there are two traffic lanes, these are known as Compact 2-lane roundabouts. Three or more traffic lanes are not permitted for any part of the roundabouts.
Curves	Bend	A horizontal curve unless otherwise specified as a vertical curve
Desire Line		Travel paths likely to be taken by pedestrians or slow vehicles seeking the shortest route between two points
Directional Sign	Guide Sign	Traffic signs providing directional guidance for road-users.
Diverge Gores	Back of Nose	The physical area immediately downstream of the paved area at diverges.
Divided roads	Dual Carriageway Road	A road with two pavements physical separated by a verge, traffic island or safety barrier between opposing traffic
Emergency Services		All local services whether public or private or part of the road management which intervene in the event of an incident on the road, including the police, fire brigades and designated rescue or recovery teams.
Escape Ramp	Escape Lane	Facility with an arrester bed or net designed to slow down and stop a heavy vehicle failing to stop on a steep downhill grade
Express Road	Expressway (US)	A divided or undivided access-controlled road of high technical standard with legally defined status in a country
Expressway	Motorway, Freeway	A divided access-controlled road of very high technical standard with legally defined status in a country
Grade-separated intersections		Intersections where conflicting traffic streams are separated physically at different levels and meet via merges.
High Speed Roads		Roads with speed limit or operating speed of 70km/h or more
Horizontal clearance		Lateral separation between an object the edge of carriageway
Kerb Extension	Build-out, Bell-out	Local physical extension of the kerbline which narrows down the carriageway
Lane drop		Diverge areas where one or more traffic lanes branches off, resulting in a decrease of mainline traffic lane
Lane gain		Merge areas where one or more traffic lanes join the road, resulting in an increase of mainline traffic lane

Median	Central Reserve	The area between opposing traffic comprising the physical separation and shoulders on a divided road
Nearside	Passenger side	The right side in the direction of travel where driving is on the right side of a road, or the left side in the direction of travel where driving is on the left side of a road
Offside	Driver side	The left side in the direction of travel where driving is on the right side of a road, or the right side in the direction of travel where driving is on the left side of a road
Painted Traffic Islands		Traffic islands demarcated by line markings and/or coloured surfacing which are traversable by a vehicle without difficulties.
Parapet		Safety barrier installed on a structure including bridges and retaining walls.
Passively Safe		Objects or areas with physical characteristics which are unlikely to incur serious injuries or fatalities when colliding by or ridden over by an errant vehicle travelling at the prevailing traffic speeds.
Paved shoulder		Part of the pavement outside the carriageway not designated for the normal use of traffic
Pavement		Paved area of the road which may be readily traversed by traffic
Physical Traffic Islands		Traffic islands ed by line markings and/or coloured surfacing which in principle are traversable by a vehicle without difficulties.
Road Restraint System		A facility on one side of the road designed to prevent vehicles, pedestrians or slow vehicles from crossing to the other side.
Road Restraint System RRS		Restraint systems including VRS and fences or parapets for pedestrians
Safety Barrier	Guardrail, Safety Fence	Longitudinal VRS along the roadside or median provided for the containment of an errant vehicle in an impact
Shoulder		Part of the pavement outside the carriageway not designated for the normal use of traffic
Slow Vehicle		Traffic comprising bicycles, electric bicycles, animal-drawn carts, animal herds etc.
Street		A road in the built-up area without the characteristics of a high speed road
Traffic Calming		The promotion of favourable driving behaviour and control of vehicle speeds to be commensurate with the activities taking place along a road using specific measures
Traffic volume		Traffic movement expressed in vehicles per day or vehicles per hour, vehicles being Passenger Car Units
Undivided Road	Single Carriageway Road	A road on a single pavement without a physical separation between opposing traffic.
Urbanised Section		Section of the road traversing a built-up area with at-grade intersections or crossings and frontage activities
Vehicle Restraint System VRS		Engineering system installed on a road to provide a level of containment for an errant vehicle.
Verge	Unpaved Shoulder	Unpaved area of the shouder
Wide Centreline Marking		Centreline marking which has an overall width larger than normal, and is generally in the order of 0.6m to 1.0m but may be even wider e.g. 1.5m to 2m.