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To: Holders of the Geometric Design Guide for Canadian Roads (1999)

From: Transportation Association of Canada

Subject: June 2014 Errata to the Geometric Design Guide for Canadian Roads

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The following pages contain minor corrections to the *Geometric Design Guide for Canadian Roads*.

Both the front and back of the revised page have been supplied so that you can print them 2-sided and replace the existing pages within the manual. Only the page with the June 2014 date contains information that has been changed.

If you have any questions please do not hesitate to contact the TAC secretariat.

Figure 2.2.12.2 Staging of a New Four-Lane Undivided Arterial Street

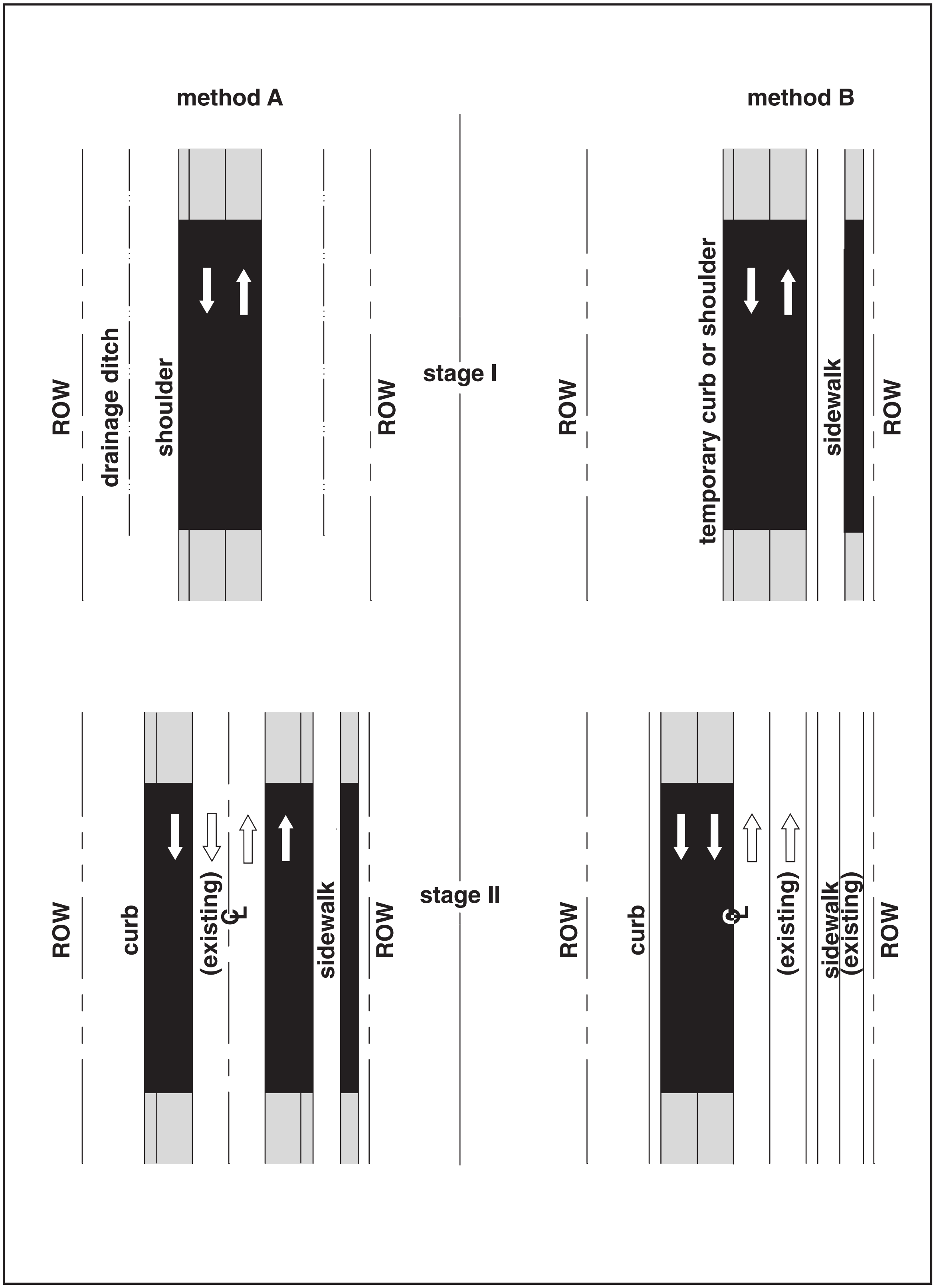
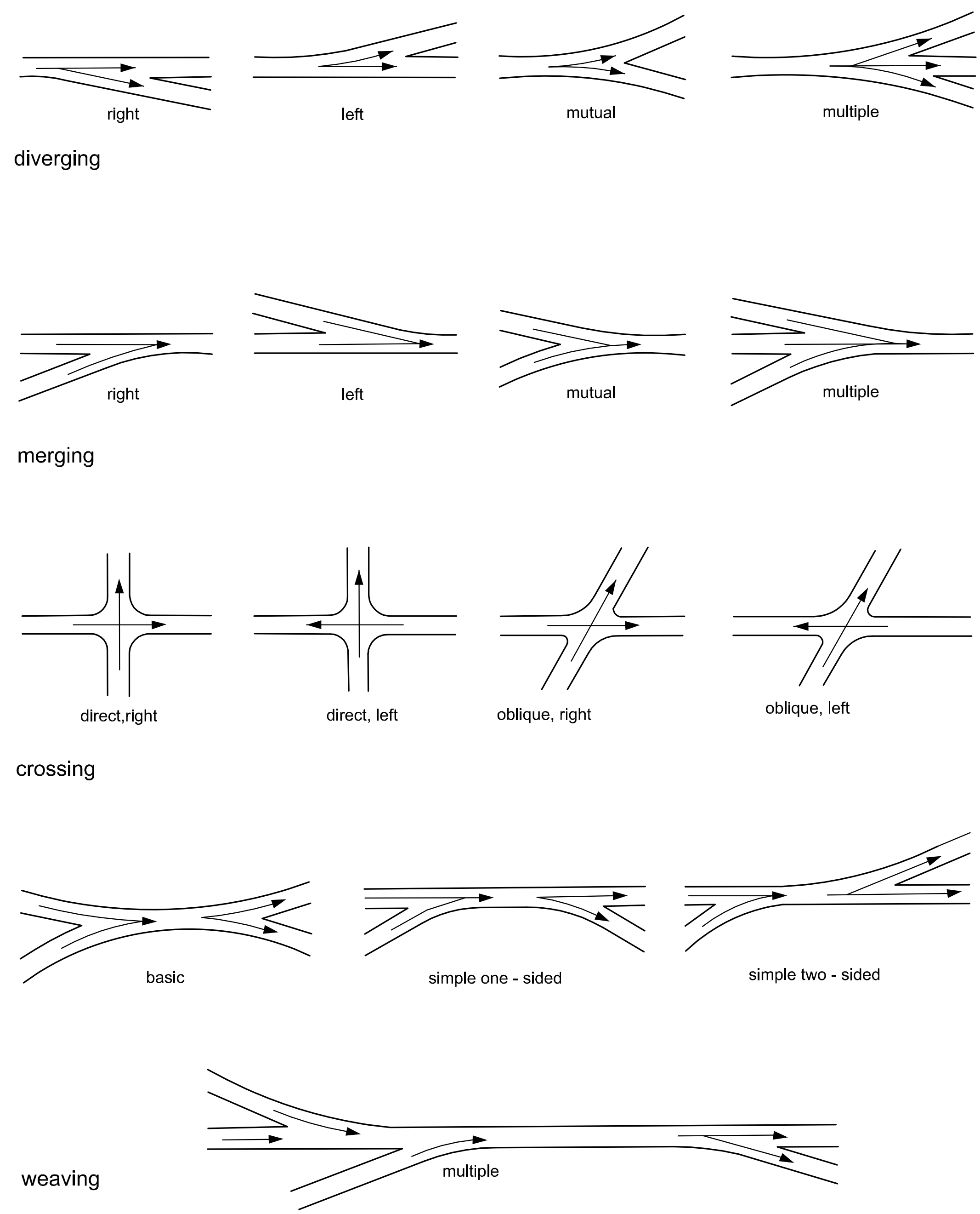


Figure 2.3.1.2 Typical Traffic Movements Within an Intersection and its Approach



Diverging and merging may be to the right, to the left, mutual or multiple.

Crossings are termed “direct” if the angle of intersection is between 70° and 110° (right-angled intersection) or “oblique” if the intersection angle is less than 70° or greater than 110° (oblique intersection).

Weaving consists of the crossing of traffic streams moving in the same direction. It is accomplished by a merging manoeuvre followed by a diverging manoeuvre. Weaving sections may be considered to be simple or multiple with a further subdivision into one-sided or two-sided weaving.

Conflicts

Every rural and urban at-grade intersection has conflict areas. One of the main objectives of intersection design is to minimize the severity of potential conflicts between all intersection manoeuvres.

A traffic conflict occurs whenever the paths followed by vehicles diverge, merge or cross.

The number of traffic conflicts at intersections depends on:

- the number of one-way or two-way approaches to the intersection
- the number of lanes at each approach
- signal control
- traffic volumes
- the percentage of right or left turns

As an example, Figure 2.3.1.3[1,6] shows conflict points for a T-intersection (three-legged) and a cross-intersection (four-legged). With the addition of a single intersection leg, the number of conflict points increases from 9 to 32. The difference in collision rates at three- and four-legged intersections is also illustrated on Figure 2.3.1.3. It is shown that as traffic volume increases, the role the increased number of conflict points at a four-legged intersection plays in collision rate, becomes more significant.[6] The designer should be cautioned, however, that the number of conflict points for offset, or split T-intersection arrangements, as shown in Figures 2.3.1.1 and 2.3.2.1, would not be 18 (2 x 9); instead the number of conflict points for this type of intersection configuration (two T-intersections) would likely be larger than at a single cross-intersection with 32 conflict points.

The conflict areas are divided into two categories:

- major conflict areas where head-on, right-angle or rear-end collisions may occur
- minor conflict areas where sideswipe collisions may take place

Illustrations of traffic conflict areas are shown in Figure 2.3.1.4.[1] It should be noted that the 90° T- and cross-intersections have the smallest conflict areas in comparison to the skewed cross-intersection and the multi-legged intersection which have the largest.

Channelized intersections with auxiliary lanes further reduce the conflict area size and the number of vehicles passing through the same intersection point by separating traffic movements into definite paths of travel using pavement markings and islands. For further information on channelized intersections, see Section 2.3.6.

In urban environments especially, conflicts can also occur between vehicles and pedestrians, and vehicles and bicyclists. Vehicles typically conflict with pedestrian crossing manoeuvres. Vehicles can conflict with any bicycle manoeuvre. The 90° T- and cross-intersections are the most straightforward intersections for pedestrian and bicycle manoeuvres, channelization may increase vehicle/pedestrian conflicts as pedestrians attempt to cross the turning roadway.

Prohibited Turns

Prohibited turns can be discouraged by designing tight or extended curb returns which make it difficult to achieve these turns. Channelization is also used to restrict or prevent prohibited, undesirable or wrong-way movements. In and limitations. When a design is incompatible with the attributes of a driver, the chances for driver error increases. Inefficient operation and collisions are often a result.[3]

In general, traffic volume is the most significant contributor to intersection collisions. Typically, as traffic volumes increase, conflicts increase, and therefore the number of collisions increase.[5] Severity of collisions varies only slightly among rural, suburban and urban intersections; the percent of severe collisions is approximately 5% higher for rural intersections.[5]

Other elements related to intersection collision rates include geometric layout and traffic control.[3] As previously noted, traffic control measures are not addressed in this document. The relationship of specific geometric elements and safety is described below:

Type of Intersection

In rural settings, four-legged intersections typically have higher collision rates than T-intersections (three-legged) for stop and signal controls.[7]

In urban settings, very little difference in collision rates between four-legged and T-intersections was found for low volume intersections (Average Daily Traffic under 20 000); however, for larger volumes, the four-legged intersection was found to have the higher collision rate.[8]

Sight Distance

In both an urban and a rural setting, studies have shown that the collision rate at most intersections will generally decrease when sight obstructions are removed, and sight distance increased.[3]

Channelization

In a rural environment, it was found that left-turn lanes would reduce the potential of passing collisions.[9]

In an urban setting, it was found that multi-vehicle collisions decrease when lane "dividers" (raised reflectors, painted lines, barriers or medians) are used; however the use of left-turn lanes was not considered effective as a collision countermeasure but was considered effective as a means of increasing capacity.[8]

Cross Section

Safety considerations for cross section elements, such as lane width, are addressed in Chapter 2.2.

2.3.1.7 Intersection Spacing Considerations

Both rural road and urban road network spacing is often predicated on the location of the original road allowances prior to urban development. The systems of survey employed in the layout of original road allowances vary from region to region across Canada. As rural areas urbanize, the development of major roads generally occurs along these original road allowances, and consequently road networks vary from region to region. As examples, the land survey system in Ontario has created a basic spacing between major roads of 2.0 km, whereas the land survey system in the prairie provinces has resulted in a 1.6 km grid.

As development occurs, this spacing is often reduced. In areas of commercial or mixed use development, the traffic generated by employment and retail shopping may result in a reduced arterial spacing. In downtown areas, this spacing could be reduced further as determined by the traffic needs and the characteristics of the road network.

The spacing of intersections along a road in both an urban and rural setting has a large impact on the operation, level of service, and capacity of the roadway. Ideally, intersection spacing along a road should be selected based on function, traffic volume and other considerations so that roads with the highest function will have the least number (greatest spacing) of intersections (the relationship of road classification and the preferred functional hierarchy of circulation is described in Chapter 1.3 of this Guide). However, it is often not always possible to provide ideal intersection spacing, especially in an urban setting. As such, the following should be considered:

Arterials

Along signalized arterial roads, it is desirable to provide spacing between signalized intersections consistent with the desired traffic progression speed and signal cycle lengths. By spacing the intersections uniformly based on known or assumed running speeds and appropriate cycle lengths, signal progression in both directions can be achieved. Progression allows platoons of vehicles to travel through successive intersections without stopping. For a progression speed of about 50 km/h and a cycle length of 60 s, the corresponding desired spacing between signalized intersections is approximately 400 m. As speeds increase the optimal intersection spacing increases proportionately. Further information on the spacing of signalized intersections is provided in the Subsection 2.3.1.7.

A typical minimum intersection spacing along arterial roadways is 200 m, generally only applicable in areas of intense existing development or restrictive physical controls where feasible alternatives do not exist. The 200 m spacing allows for minimum lengths of back to back storage for left turning vehicles at the adjacent intersections.

The close spacing does not permit signal progression and therefore, it is normally preferable not to signalize the intersection that interferes with progression along a major arterial. Intersection spacing at or near the 200 m minimum is normally only acceptable along minor arterials, where optimizing traffic mobility is not as important as along major arterials.

Where intersection spacing along an arterial does not permit an adequate level of traffic service, a number of alternatives can be considered to improve traffic flow. These include: conversion from two-way to one-way operation, the implementation of culs-de-sac for minor connecting roads, and the introduction of channelization to restrict turning movements at selected intersections to right turns only.

On divided arterial roads, a right-in, right-out intersection without a median opening may be permitted at a minimum distance of 100 m from an adjacent all-directional intersection. The distance is measured between the closest edges of pavement of the adjacent intersecting roads.

In retrofit situations, the desired spacing of intersections along an arterial is sometimes compromised in consideration of other design controls, such as, the nature of existing adjacent development and the associated access needs.

Collectors

The typical minimum spacing between adjacent intersections along a collector road is 60 m.

Locals

Along local roads, the minimum spacing between four-legged intersections is normally 60 m. Where the adjacent intersections are three-legged a minimum spacing of 40 m is acceptable.

Cross Roadway Intersection Spacing Adjacent to Interchanges

The upper half of Figure 2.3.1.6 indicates the intersection spacing along an arterial crossing road approaching a diamond interchange. The suggested minimum distance between a collector road and the nearest ramp, as measured along the arterial cross road, is 200 m (dimension A_c on Figure 2.3.1.6). In the case of an arterial/arterial cross road intersection, this minimum offset distance from the ramp is normally increased to 400 m (dimension A_a on Figure 2.3.1.6). The same dimensions apply to arterial cross roads approaching parclo-type interchanges as shown on the lower half of Figure 2.3.1.6.

Ramp Intersection Spacing at Interchanges

The upper half of Figure 2.3.1.6, as well as Figure 2.3.1.7, illustrate the suggested and minimum intersection spacing and lane configurations on the cross road at a typical diamond interchange. The two different channelization treatments illustrate the following

2.3.2 ALIGNMENT

2.3.2.1 Design Speed

The following is a discussion of design speed as it pertains to intersections. Chapter 1.2 presents discussion on roadway design speed.

Rural

In a rural environment, the design speed of the major roadway is used for the main intersection approaches to determine taper lengths, deceleration and acceleration lengths, and other geometric features specific to traffic on the major roadway.

Design speed is typically not reduced at rural intersections where drivers are accustomed to long periods of uninterrupted travel. Inattentive drivers should be alerted to the fact that an intersection is ahead and should have enough time to react accordingly by providing adequate deceleration and acceleration lengths, etc. for the design speed.

Urban

In general, it is desirable to maintain the design speed of a roadway as it passes through an intersection, particularly for a roadway where the traffic has or may have the right of way through the intersection. Examples of this situation are:

- an intersection controlled by traffic signals or which may be controlled by signals in the future
- a major road crossing a minor road where the minor roadway has a stop or yield control, and the major roadway is not controlled
- an uncontrolled intersection

For an urban roadway controlled by a yield sign at an intersection, approach speeds in the order of 25 km/h are common. A suitable design speed for such an approach roadway within the zone of the intersection would be 35 km/h.

Where traffic on a minor roadway is, and will likely always be, controlled by a stop sign at an intersection, the design speed of the minor roadway can be reduced through the intersection area. As a basic requirement, it is important to provide sufficient sight distance for the design vehicle to safely depart from the stopped position and make the desired manoeuvre through the intersection.

If a design speed equal to or greater than the existing posted speed cannot be achieved through an intersection, changes to the posted speed, the implementation of speed advisory signing or similar treatment should be considered. Sound judgement is called for in selecting the design elements that meet the expectations of the driver.

2.3.2.2 Horizontal Alignment

Intersections are ideally located on tangent sections. Location of intersections on curves is not desirable due to decreased visibility, increased conflict potential for vehicles crossing the major roadway, and complications with roadway superelevation and pavement widening on curves. Intersections on curves are discussed further in Subsection 2.3.2.5.

It is desirable that intersecting roads meet at, or nearly at, right angles.

The benefits of a 90° angle of an intersection are:

- reduced size of conflict area (see Figure 2.3.1.4)
- improved driver visibility
- more favourable condition for drivers to judge the relative position and relative speed of an approaching vehicle and to decide when to enter or cross the major road
- reduced length of time of a crossing manoeuvre
- general decrease in severity of collisions (collisions occurring at an impact angle of

90° are generally less severe than those occurring at angles of greater than 90°)[1]

While crossing at 90° is preferable in most cases, it is occasionally necessary and even advantageous to skew the crossing (for example, to favour a heavier turning movement). However, angles less than 70°and greater than 110° are typically not desirable. For example, at a skewed T-intersection with an angle less than 70° certain undesirable conditions exist because of the flat angle of entry. Vehicles which do stop are standing in a position that affords poor visibility for the driver to judge the speed and the distance of approaching vehicles on the major roadway. Also, for a skew right, vehicles leaving the major roadway to enter the minor roadway with a right turn are encouraged to do so at high speeds and for a skew left, drivers tend to cut the corner at higher speeds, thereby travelling in the opposing lane for a considerable distance and creating a safety concern.[1]

Particular consideration should be given to maintaining an angle of skew within 10° of right angle (i.e. between 80° and 100°), when any of the following conditions exist:

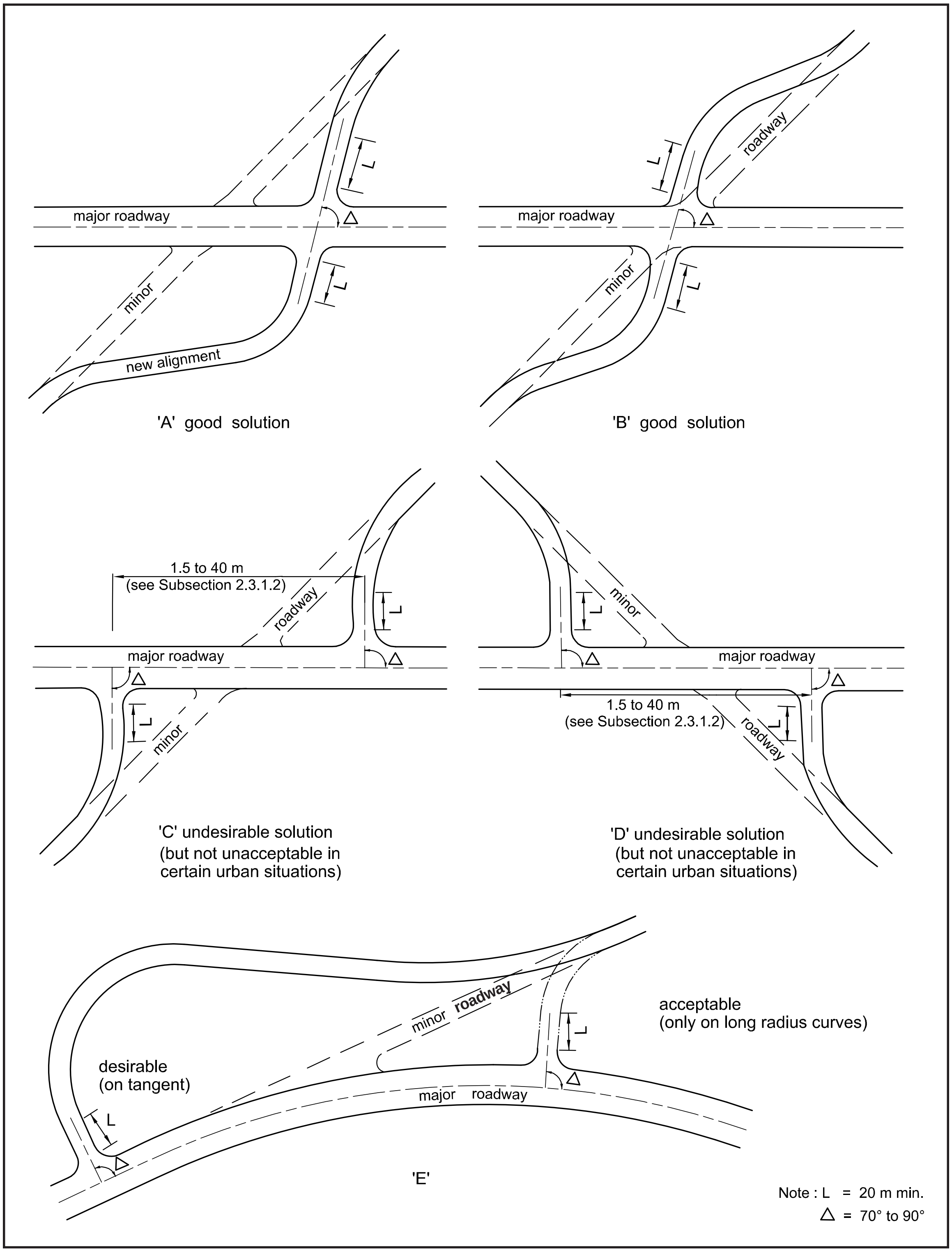
- two minor roadways with design hour volume (DHV) greater than 200 v/h (on both roadways) intersect
- minor roadway with DHV greater than 200 v/h intersecting with a major road
- two major roads intersect
- either of the intersecting roadways has more than two basic lanes
- sight distance is at a minimum
- design speed on either intersecting roadway for through traffic is greater than 80 km/h[1]

In the case of existing roads that intersect between 70° and 80° (or 110° and 100°) with no collision or performance concerns, a realignment to 80° (or 100°) may not be cost effective.

The practice of realigning roads intersecting at acute angles in the manner shown in Figure 2.3.2.1 (A and B) is beneficial. Ideally, the curves used to realign the roads would avoid a decrease in operating speed along the realigned roadway. The practice of constructing short radii horizontal curves on minor roadway approaches to achieve right-angle intersections may be acceptable but not necessarily desirable in the urban and rural settings. These curves result in increased lane infringements because motorists tend to drive flatter curves by encroaching on a portion of the opposite lane. Also, the traffic control devices at the intersection may be obscured resulting in the need for the installation of advanced warning signing.[11]

It should be noted that although examples C and D on Figure 2.3.2.1 provide poor network continuity, both examples may be acceptable alternatives. If implemented, suitable physical barriers or other obstructions should be placed across the former right of way of the minor road. These visual obstructions are desirable to alert the driver on the minor road that the road is realigned and is no longer on continuous tangent through the intersection. Assuming a four-lane undivided arterial road, the split T-intersection arrangement, example C (offset-right), introduces back-to-back left turns on the major roadway, which are generally undesirable unless left-turn auxiliary lanes can be provided. This layout, however, has the advantage of requiring the driver, wishing to cross the major road, to select a gap in only the traffic approaching from the left, and then make a conventional right turn followed by a left-hand merge manoeuvre to reach the left-turn auxiliary lane. However, if no left-turn lane is provided, vehicles travelling along the minor roadway may hold up traffic while waiting for a gap to turn left. With example D (offset-left), the turns introduced on the major roadway by the minor roadway crossing manoeuvres are right turns only, which minimize the impact on through traffic on the major roadway. However, the driver attempting to cross on the minor roadway is required to select coincidental gaps in the traffic streams from both directions on the major roadway. Moreover, the driver is required to make right-hand merge manoeuvres on the major

Figure 2.3.2.1 Examples of Realignment of Intersections



roadway which may be more hazardous. In conclusion, either example C or D may be acceptable solutions in urban areas. The traffic conditions and opportunity to incorporate auxiliary lanes are important considerations in assessing the merits of each. Where significant through volumes exist or are expected along the minor roadway crossing the major roadway, the split T-intersection realignments, examples C and D, are generally considered less desirable than the types of realignments shown as examples A and B on Figure 2.3.2.1.

Where the major road is curving and a minor road constitutes an extension of one tangent, realigning the minor road is advantageous, as shown on example E of Figure 2.3.2.1, to guide traffic onto the main roadway and improve the visibility at the point of intersection. This practice may have the disadvantage of adverse superelevation for turning vehicles and may require further study when curves have high superelevation slopes and when the approach roadway has adverse grades and a sight distance restriction due to the grade line.[11]

A suggested tangent length ‘L’ of 20 m or greater on the minor road is shown on all examples on Figure 2.3.2.1. The designer should ensure that the tangent length is long enough to provide adequate sight distance and to adjust the minor roadway cross-slope from the curve to the intersection.

For a realigned road, the original roadway pavement should be removed and appropriate landscaping used to eliminate visual distractions for drivers and to minimize potential for the driver to perceive that the roadway continues straight.

In developed areas realignments of this nature may not be feasible due to the constraints of existing buildings or high property values. If excessive collision rates are experienced and geometric changes are not feasible, it may be advantageous to restrict or eliminate the more hazardous turns. As a result, other improvements at adjacent intersections may be needed to suitably accommodate the altered travel patterns. Signalizing the intersection may also be considered. However, possible adverse effects, such as delays on the major roadway should be taken into account.

2.3.2.3 Vertical Alignment and Cross-Slope

<u>Cross-Slope:Major/Minor Roadway Intersection</u>

Profiles at intersections are designed in consideration of the expected operating conditions including speed, major traffic flows and sight distance. The profiles of the major roadway at a major/minor roadway intersection are normally not adjusted significantly to match those of the minor cross roadway. It is normally the gradient on the intersecting minor roadway that is adjusted through the introduction of suitable grades and vertical curves prior to the intersection, as shown on Figure 2.3.2.2, in such a way as not to reduce the sight distances. In certain conditions, however, reducing the normal cross-slope (typically 2%, see Chapter 2.1) on the major roadway to about 1% may assist in smoothing the profile of the minor roadway as it crosses the major roadway. Cross-slopes can be adjusted to 0.5% to 3.0% without affecting the efficient operation of traffic along the major roadway in order to enhance the smooth movement of minor roadway traffic through the intersection. Cross-slopes less than 0.5% are avoided due to potential drainage problems. In other conditions, removing the normal crown of the major roadway and using the normal cross-slope rate continuously across the pavement may better match the vertical alignment of the minor roadway. These concepts are illustrated on Figures 2.3.2.2, 2.3.2.3[1] and 2.3.2.4[1]. Changes from cross-slope to cross-slope should be as gradual and smooth as possible (see Chapter 2.1).

<u>Cross-Slope: Major Road/Major Roadway (or two roadways of equal classification)</u>

Where two major roadways (or two roadways of equal classification) intersect, the profiles of each are often adjusted in an approximately equal manner through the intersection area. Thus the cross-slopes of both major roadways can be adjusted to a minimum of 0.5% to provide an equally smooth ride along each

2.3.6.5 Traffic Islands

General

An island is a defined area between traffic lanes for control of vehicle movements in intersection areas or for pedestrian refuge. Islands may be raised areas or may be painted. In rural areas the two most desirable and commonly used treatments are the raised island with mountable curbs and the painted island. In urban areas barrier curbs are used to protect pedestrians and to reduce the risk of vehicles striking poles, etc.

Delineation and approach end treatment is critical to good channelization design. Island delineation can be divided into the following types:

Curbed Islands

This type can be applied universally and provides the most positive traffic delineation. Mountable curbs should be used in most cases. In rural areas where curbs are not common, this treatment is often limited to islands of small to intermediate size. Pedestrian refuge islands are usually protected with barrier curb.

Painted Islands

This type of island is generally designed in urban or suburban areas where speeds are low and space is limited. Application of this type of island may be considered in rural areas in advance of raised median island, where maintenance and snow removal make curbs undesirable, and where high approach speeds (urban or rural) make a curb a potential hazard. However, snow accumulation can obliterate pavement markings.

Non-Paved Areas Formed by Pavement Edges

This type of island is usually used for larger islands at rural intersections where there is sufficient space and/or where added expense of curbs may not be warranted or may pose a traffic hazard. This island type may be supplemented by delineators on posts, other guide posts, a mounded earth treatment or appropriate landscaping.

Temporary Island Installations

This type is usually constructed of asphalt curbing, precast bumper curbing or sand bags[1]. Such islands would typically be used in construction work zones.

Islands are grouped into three functional classes which are illustrated on Figures 2.3.6.2[1], 2.3.6.3[1] and 2.3.6.4[1] and are described below:

Directional

Directional islands control and direct traffic movements. They guide the driver into the proper channel for the intended route. Directional islands are of many shapes and sizes, depending upon conditions and dimensions. A common form is one of triangular shape to separate right-turning traffic from through traffic.

Divisional

Divisional islands, also called raised median islands, are introduced at intersections, usually on approach legs, to separate streams of traffic travelling in the same or opposite direction. These islands are particularly advantageous in controlling left turns at skewed intersections and at locations where separate channels are provided for right-turning traffic.

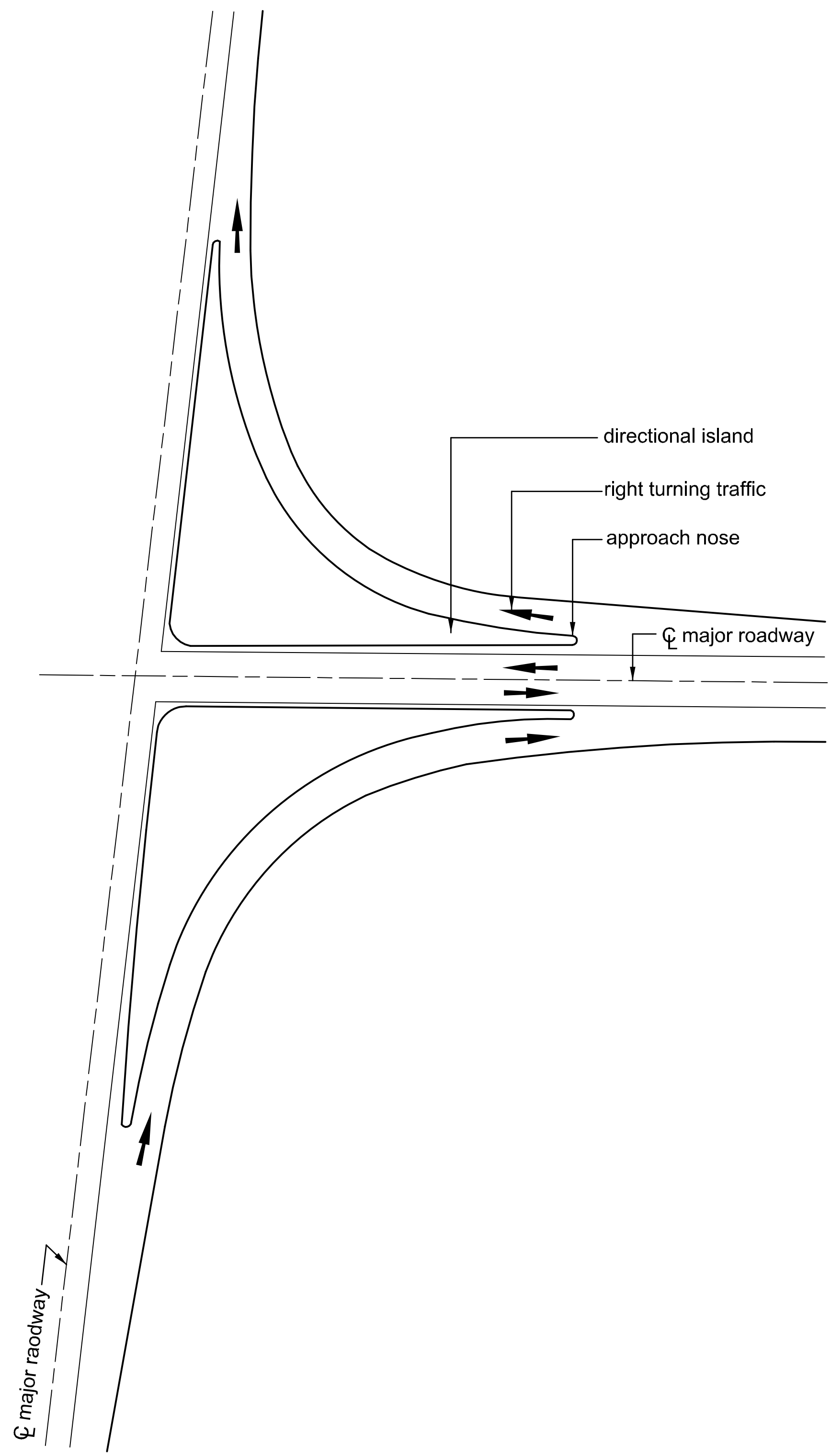
Two types of divisional islands are commonly used:

- opposing divisional islands (for T-intersections)
- offset divisional islands (for cross-intersections)

These islands are shown on Figures 2.3.6.5[1] and 2.3.6.6.[1]

Where the roadway is on a tangent, reverse curve alignment is necessary to introduce dividing islands. In rural areas where speeds are high, reversals in alignment should have radii of at least 2000 m. A median on an approach leg may

Figure 2.3.6.2 Directional Islands[1]



be regarded as a divisional island in the vicinity of the intersection.

Refuge

Refuge or pedestrian islands are typically constructed of barrier curb and are used to protect and aid pedestrians crossing a roadway or loading and unloading transit riders. In congested areas, refuge islands also expedite vehicular traffic flow by permitting vehicles to proceed without waiting for pedestrians to cross the entire roadway.

In studying the need for refuge islands, consideration is given to width of pavement, proximity of traffic signals, right- and left-turning movements at intersections, sight distances and any other factors that might have a bearing on the proposed installation. No refuge or loading island should be placed where it will be separated by fewer than two traffic lanes from an adjacent curb, edge of pavement or other island.

When designing an island the designer should consider that its location and configuration may result in a hazard to the travelling public. It is undesirable to introduce curbed islands in the centre of a high-speed road as they are considered hazardous objects. However, depending on the cross section of the roadway, it often becomes necessary, at signalized intersections, to place signal poles and islands in the medians; in these cases barrier curbs should be used.

Shape

Directional islands are typically triangular in shape and are positioned within the intersection in consideration of the tracking requirements of the turning vehicles. The dimensions and exact shape of directional islands are a function of:

- the corner radii and associated tapers
- the angle of the intersection
- the design vehicle turning path

Divisional islands are normally elongated in shape with edges parallel to the opposing adjacent travel lanes. Divisional islands are often configured to provide a protected left-turn lane at an intersection approach.

Refuge islands for pedestrians vary in relation to the pedestrian volumes and needs, the width of the crosswalks, the intersection layout and design constraints such as available right of way.

Size

Islands are usually sufficiently large to command attention. The smallest island that is normally considered is one that has an area of 6 m^2. Larger islands are required to accommodate requirements such as wheelchair ramps. Where pedestrian refuge is required, a minimum island size of 10 m^2 is preferred to accommodate the curb-cuts and ramps as well as pedestrian storage. Island size greater than the minimum are advantageous for clearly defining the desired travel paths, for the effective placement of traffic signs, traffic control poles and utilities and for pedestrian refuge and ramps.

Divisional islands introduced at rural intersections on high-speed roads are preferably at least 30 m long. Divisional islands in urban areas are preferably not less than 1.5 m wide and 4 m long.

Where short islands are unavoidable they are preceded by visibly roughened pavement, raised bars or markings. When situated in the vicinity of a high point in the roadway profile or at or near the beginning of a horizontal curve, the approach end of the island should be extended so as to be clearly visible to approaching drivers.

Approach End Treatment

Where there are no curbs on the through roadway approaching an island, the minimum offset to the edge of a curbed island (i.e. raised island) is 0.5 to 1.0 m.

Where the approach roadway has a mountable curb, a similar curb on the curbed island could be located at the edge of the through lane where there is sufficient length of curbed island to effect a gradual taper from the nose offset. Non-mountable curbs should be offset from the through travelled way edge, regardless of the size of the curbed island, to avoid a sense of lateral restriction to drivers.[11]

These details are illustrated in Figures 2.3.6.7 and 2.3.6.8.

The approach end of an island is designed to be conspicuous to approaching drivers and should be clear of vehicle paths, physically and visually, so that drivers will not veer away from the island. The approach nose is always offset with respect to the island edge. Where feasible, the total nose offset should be 1.0 to 2.0 m from the normal edge of the through pavement and 0.5 to 1.0 m from the pavement edge of a turning roadway. This is also achieved by a gradual widening of the auxiliary lane pavement.

Where the shoulder is carried through the intersection, the island may be placed at the outer shoulder's edge. Where speeds are high and the island is preceded by an auxiliary lane, it is desirable to offset the nose of large islands 0.5 to 1.0 m outside the shoulder's edge.

Figure 2.3.7.2 Yield Taper at Channelized Intersection, Major Roadway to Minor Roadway[1]

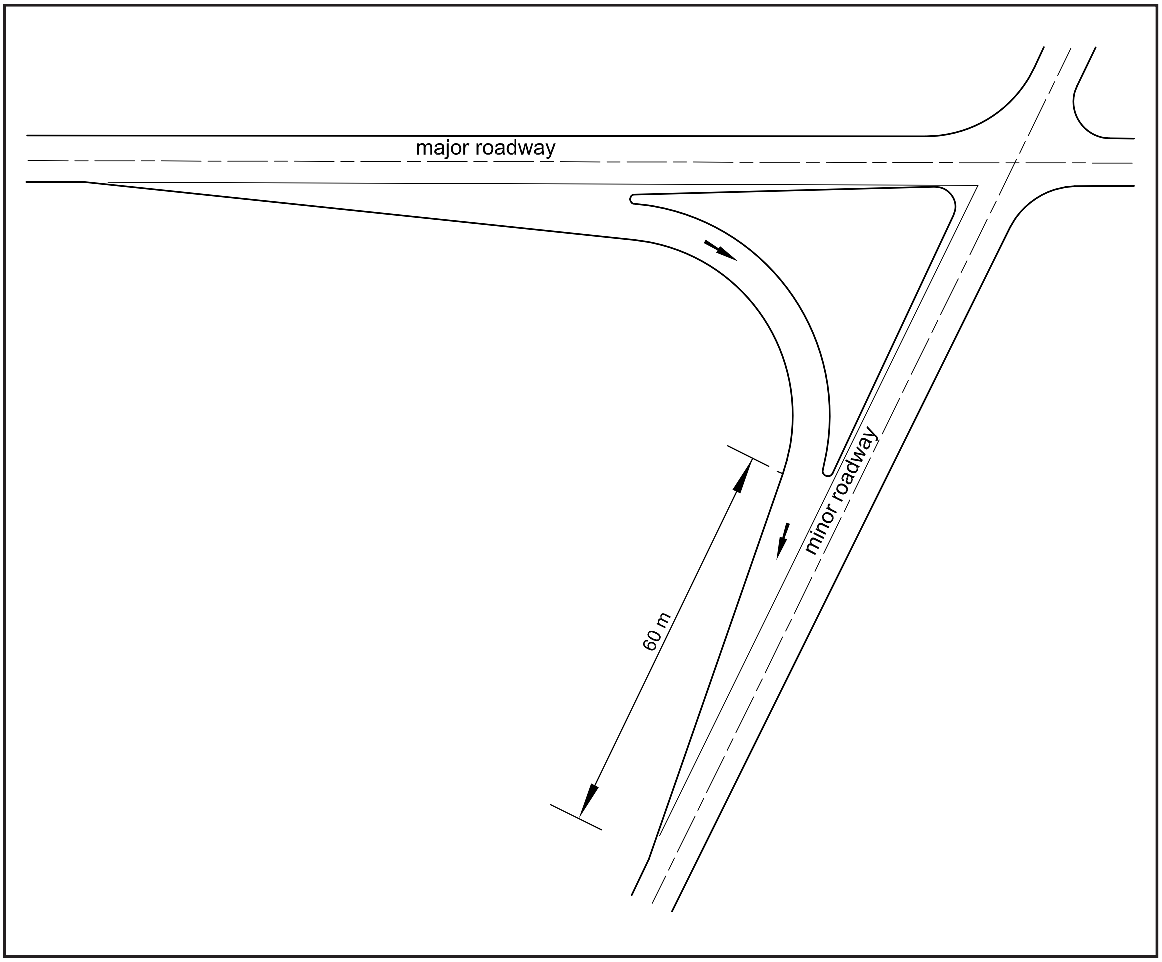
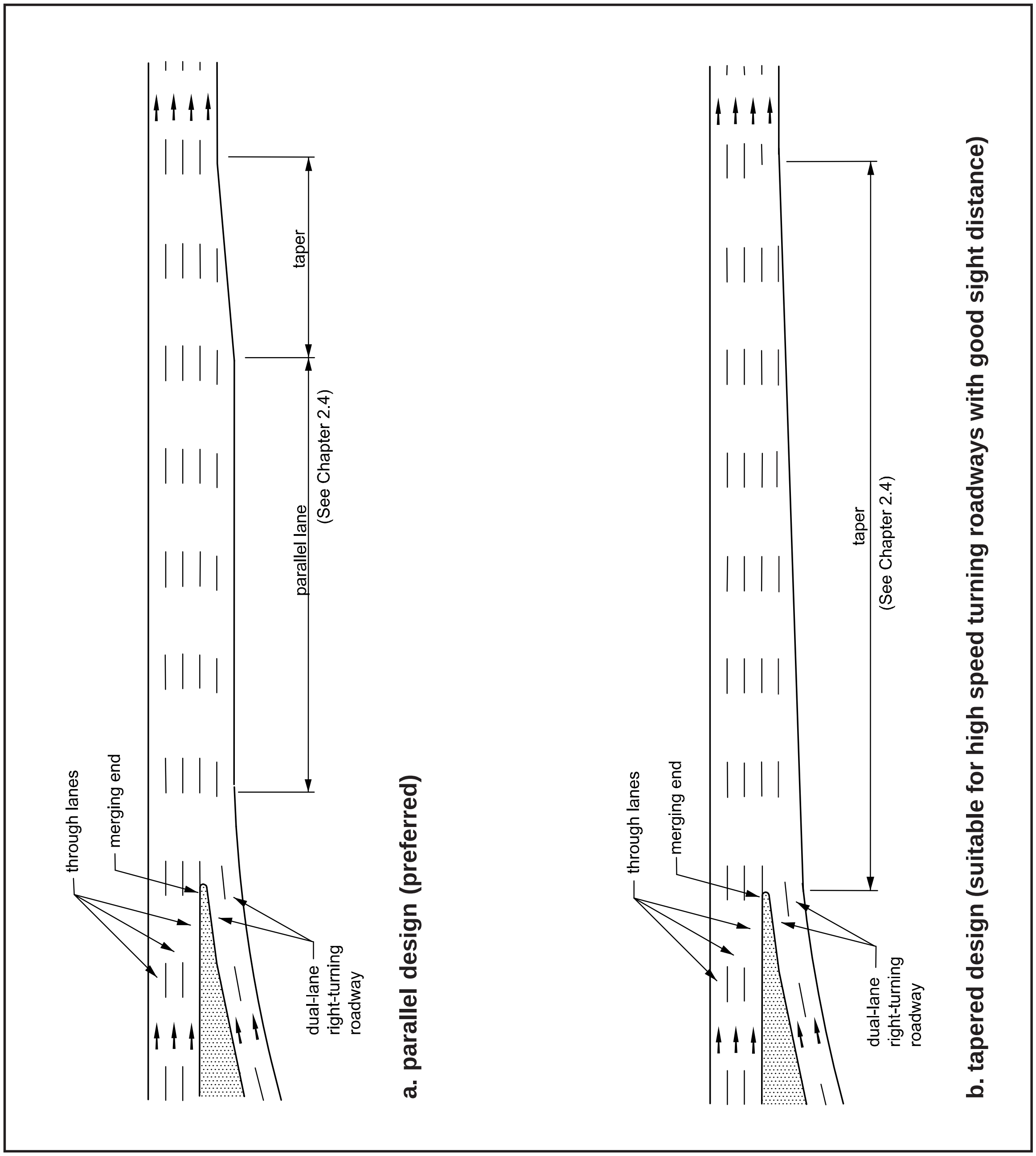


Figure 2.3.7.3 Lane Drop, Dual Lane Right-Turning Roadway



during unsaturated flow conditions. Additional storage length must be provided for larger design vehicles.

The minimum storage length that should be provided is 15 m (see Safety Warrants, Subsection 2.3.8.2).

The Runout Lane

The runout lane terminates the bypass lane on the far side of the intersection. The width of the parallel section of the runout lane is the same as that of the bypass lane. The taper length varies with the design speed and is the same as that applied to the acceleration lane (see Chapter 2.4). The runout lane is shown on Figures 2.3.8.2 and 2.3.8.3.

Left-Turn Lanes on Both Approaches

Two types of left-turn lane designs are applicable:

- opposing left-turn lanes, see Figure 2.3.8.5[1] (a)
- adjacent left-turn lanes, see Figure 2.3.8.5[1] (b)

a) Opposing left-turn lanes

The opposing left-turn lanes design is a desirable treatment for new construction of unsignalized intersections in rural areas. This configuration reduces the probability of head-on collisions as this configuration has the advantage of enabling drivers making simultaneous left turns to see past each other's vehicle and therefore, this design contributes to the ease and safety of left-turn movements. Visibility of approaching vehicles, however, can be reduced with larger vehicles in the left-turn lane. This treatment could also be applied to urban intersections where left-turn lanes are required.

b) Adjacent left-turn lanes

The provision of adjacent left-turn lanes is not generally recommended due to the potential for collisions caused by visibility problems for left-turning vehicles. Visibility problems result from the presence of vehicles in adjacent left-turn lanes.

Adjacent left-turn lanes can be designed where the intersection is located on or at the base of a steep down grade. The provision of an unobstructed runout lane can help a driver avoid conflicts in adverse weather conditions when encroachment in the opposing left-turn lane may be a safety concern.[1]

Partially Shadowed and Shadowed Turn Lanes

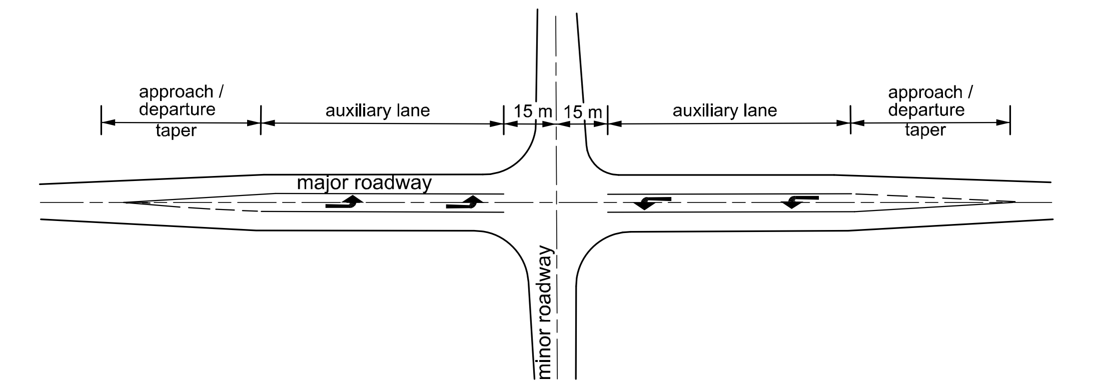
Figure 2.3.8.6 provides examples of minimum designs for flared intersections providing a left-turn area for four-lane roadways in rural areas. In these examples, the approach/departure and bay tapers are combined. This type of layout is often referred to as a partially-shadowed turn lane. In this design, deceleration of the turning vehicles is typically initiated while the vehicle is within or partially within the through lane. The turn lane area is not as well defined or protected as is a left-turn lane with a painted bay taper and/or an introduced median. Overhead signing may be desirable.

Figure 2.3.8.7 illustrates a left-turn lane with a painted approach and bay taper median area. The raised divisional island shown is optional but, where space permits, is desirable to assist in delineating the through and turn lanes. This type of design is commonly known as a shadowed turn lane. The design parameters defined in Tables 2.3.8.1 and 2.3.8.2 should be used to define the geometry of a shadowed left-turn lane.

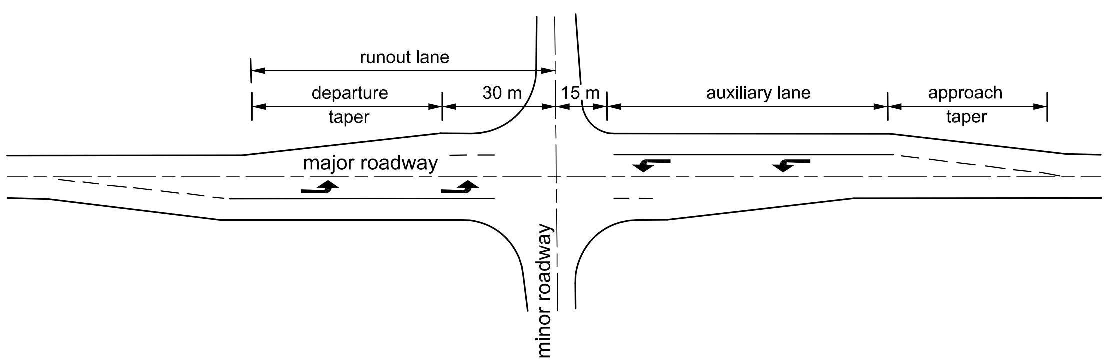
Introducing Raised Median

The ideal manner of widening the roadway to introduce a median is to widen gradually over the length of a large radius on a main line horizontal curve. However, since most intersections occur on tangent alignments, it is often necessary to use other methods, three of which are illustrated on Figure 2.3.8.7. The Figure illustrates the geometry of the approach departure tapers needed to introduce a raised median and provide a protected left-turn auxiliary

Figure 2.3.8.5 Left-Turn Lanes in Two Directions[1]



(a) opposing left-turn lanes



(b) adjacent left-turn lanes

lane. The lane, median and gutter widths shown are typical and vary in accordance with cross section requirements.

The raised median, protecting the left-turn area, is effective in clearly defining the through vehicle paths and the left-turn storage area in all weather conditions. Also, if accesses exist in close proximity to the intersection, the raised median reduces the type and number of turning-vehicle conflicts within the zone of the intersection. However, in instances where the length available for the left-turn auxiliary lane may not be sufficient to store all the left-turn vehicles during peak periods, it is advantageous to use a painted rather than a raised median area in advance of the left-turn lane. In this case, the painted median area can be used to provide additional storage during occasional peak traffic periods, reducing the problem of left-turning vehicles blocking the through lanes.

The approach and departure taper designs are a function of the design speed of the roadway. For high-speed roads (design speeds >70 km/h), the importance of using a gradual taper cannot be over emphasized. Refer to Table 2.3.8.1 for approach and departure taper geometry with design speed.

The characteristics of each of the three methods of introducing a median, as shown on Figure 2.3.8.7, are described in the following paragraphs.

Method “A” illustrates the geometry for a median introduced totally to the left of the roadway centreline. A lateral shift is not required for the traffic approaching the intersection. For this condition to occur on both approaches to a single intersection, the centrelines of the approach roadways must be offset from each other. Although this is a desirable means of introducing a median, it is a rare case, occurring only where excess right of way is available, where the roadways are not centred within the right of way, or where the rights of way are offset appropriately across the intersection. In this method, only the lanes leaving the intersection are required to taper back to the normal undivided roadway cross section. The departure taper typically commences at the beginning of the parallel lane portion of the left-turn lane, to minimize the median length.

Method “B” shows the centreline continuous through the intersection and the roadway widened symmetrically. In this method, the departure taper is continued beyond the approach taper, enabling the nose of the introduced median to be on the left side of the roadway centreline on the approach. The geometry results in a longer median length than that created by Methods “A” or “C”.

Method “C” is similar to Method “B” in that the roadway is widened symmetrically about the centreline. The departure taper commences near the beginning of the parallel lane portion of the left-turn lane to reduce the median length. The approach nose to the median is centred on the roadway centreline.

Divided Roadway

Figure 2.3.8.8 illustrates a typical layout of a left-turn lane and a right-turn lane along a divided roadway. The right-turn lane layout is also applicable to undivided roadways.

Left-Turn Slip-Around Treatment at T-Intersections

A left-turn slip-around can be introduced on a two-lane roadway at T-intersections under the following conditions:

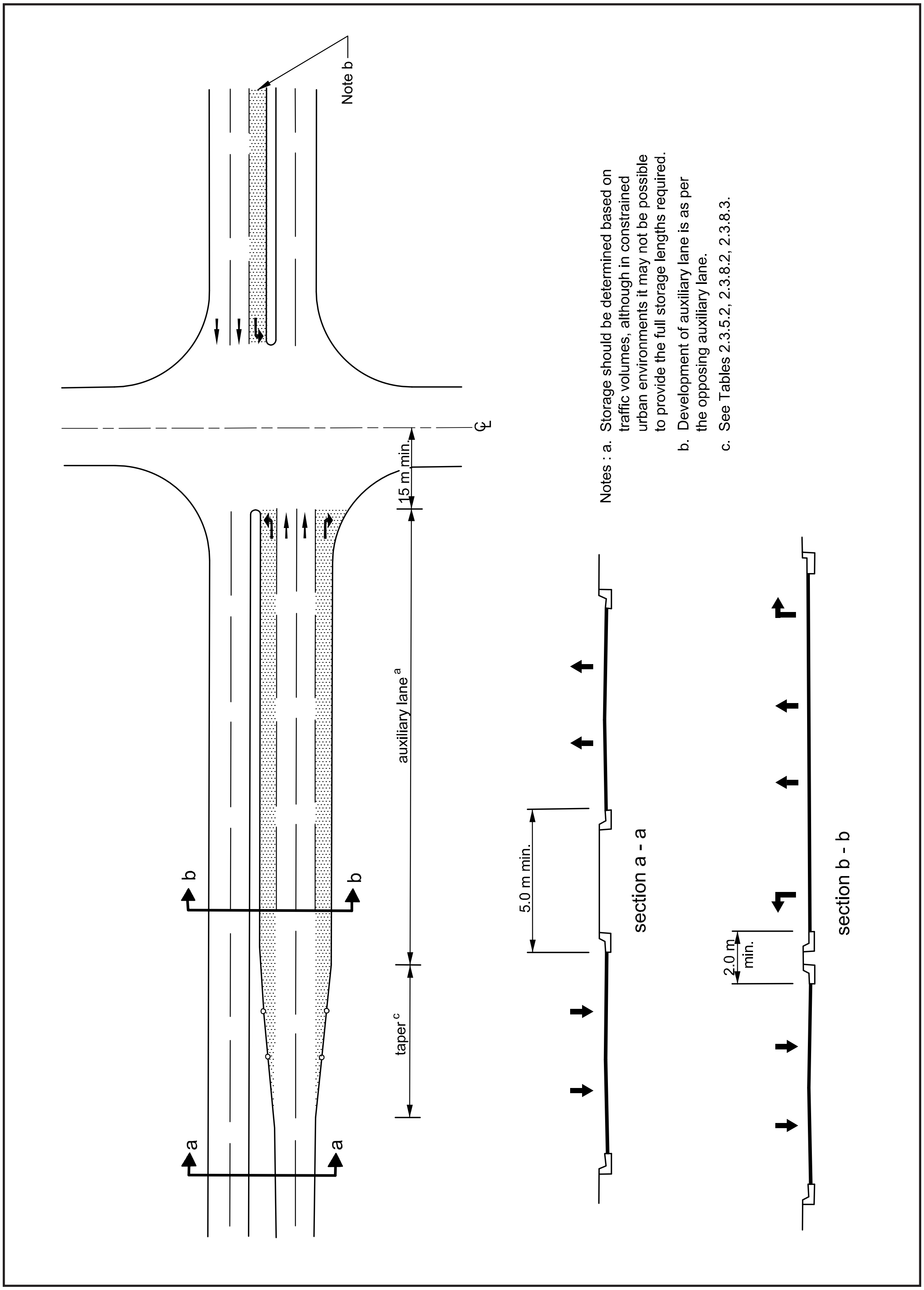
- where the left-turning volumes do not warrant a full left-turn lane but are sufficient to potentially affect through traffic

- where through vehicles bypassing occasional left-turning vehicles throw gravel from the shoulder onto the roadway

The slip-around design is comprised of an auxiliary lane and tapers at each end, as shown in Figure 2.3.8.9[1]. See Subsection 2.3.8.3 for taper lengths.

Usually the slip-around design is not applied on four-lane undivided roadways; however, where the left-turn lane is not warranted and turning vehicles impede the through traffic, the slip-around has its merit.

Figure 2.3.8.8 Turning Lane Design, Raised Median



2.3.9 TRANSITION BETWEEN FOUR-LANE ROADWAY AND TWO-LANE ROADWAY AT INTERSECTIONS

2.3.9.1 Undivided Roadways

The lane arrangement for the transition from a four-lane to two-lane roadway, and conversely from two-lane to four-lane roadway, is illustrated in Figure 2.3.9.1[1]. The typical taper lengths for diverging and merging values are shown in Table 2.3.9.1[1], as well as the design domain for parallel lane length 'A' beyond the intersection.

Special consideration is given to the merging operation by providing increased taper lengths, since it is recognized that merging is more critical when drivers, missing the warning signs, may be surprised by the sudden lane drop. Length 'A' is needed for signing purposes.

2.3.9.2 Divided Roadways

Principles similar to those used for undivided roadways are employed in the initial design stages of a divided control access roadway, see Figure 2.3.9.2[1].

Figure 2.3.9.1 Transition Between Undivided Four-Lane Roadway and Two-Lane Roadway at an Intersection[1]

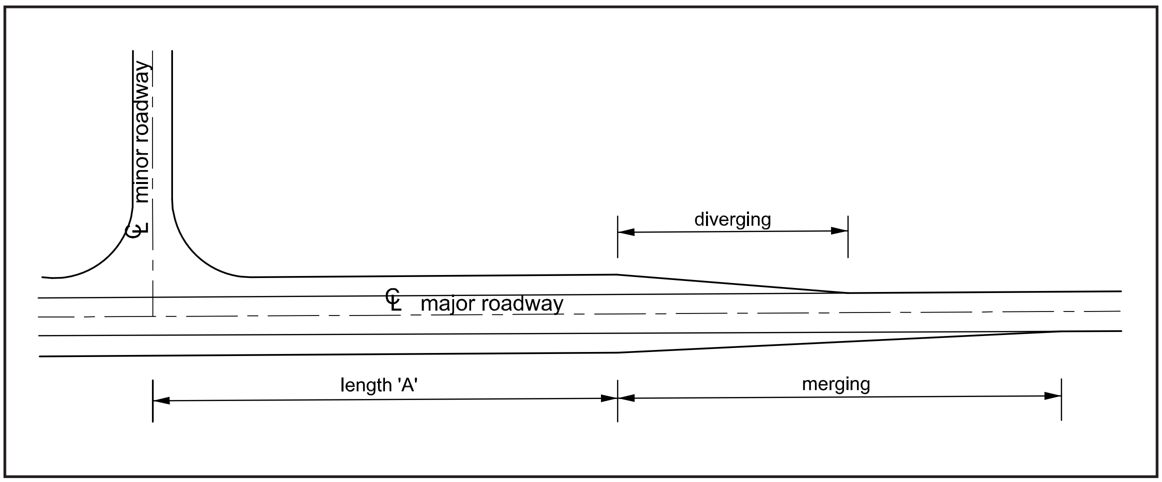


Table 2.3.9.1 Parallel Lane and Taper Lengths for Transition between Undivided Four-Lane Roadway and Two-Lane Roadway[1]

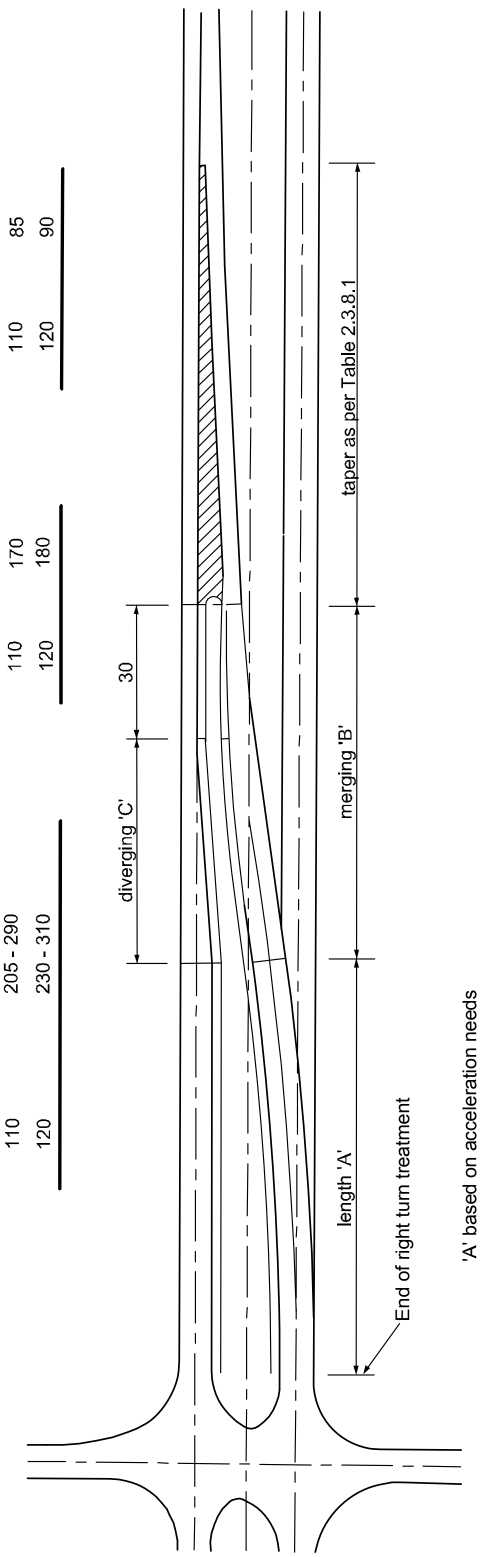
Design Speed (km/h)	Length 'A' Design Domain (m)	Merging Taper (m)	Diverging Taper (m)
50	80 – 150	85	40
60	100 – 175	100	50
70	120 – 195	115	60
80	140 – 215	130	70
90	160 – 240	145	75
100	180 – 265	160	80
110	205 – 290	170	85
120	230 - 310	180	90

Figure 2.3.9.2 Transition between Four-Lane Divided and Two-Lane Roadway Merge[1]

length 'A'	
design speed (km/h)	design domain (m)
50	80 - 150
60	100 - 175
70	120 - 195
80	140 - 215
90	160 - 240
100	180 - 265
110	205 - 290
120	230 - 310

merging 'B'	
design speed (km/h)	taper (m)
50	85
60	100
70	115
80	130
90	145
100	160
110	170
120	180

diverging 'C'	
design speed (km/h)	taper (m)
50	40
60	50
70	60
80	70
90	75
100	80
110	85
120	90



taper form, L_a, is measured from the end of the ramp curve to the point at which the auxiliary lane is 3.5 m wide. Acceleration lengths, L_a, are measured from the end of the ramp controlling curve. Measurement of L_t and L_a is illustrated in Figure 2.4.6.1.

The length of an entrance terminal is based on three factors in combination as discussed in Subsection 2.4.6.2. They are:

- merging with the through traffic
- control speed of the ramp proper
- manner of acceleration

The merging speed with the through traffic is assumed to be the range of operating speeds used in Chapter 1.2.

The control speed of the ramp proper at the upstream of the entrance terminal is included in the range of ramp design speeds in Table 2.4.6.1. The speed change lane lengths corresponding to the ramp control speeds, which are governed by the design speed of the turning roadway curve, are shown in Table 2.4.6.5.

The manner of acceleration assumes an increase of speed based on the acceleration of passenger cars tested in the U.S.[3,14]

Where acceleration lanes are on grades steeper than 3%, the length shown in Table 2.4.6.5 should be adjusted by the appropriate grade factor in Table 2.4.6.3.

The length of an entrance terminal also depends on the relative volumes of through and entering traffic. Longer entrance terminals (i.e. the higher values of the design domain in Table 2.4.6.5) are desirable on higher volume roads to enable entering traffic to merge with through traffic safely and conveniently.

Trucks and buses require longer acceleration lanes than passenger cars. Where a substantial number of large vehicles entering the road is expected, longer acceleration lanes are appropriate.

Research has shown that safety can be increased on acceleration lanes with increased length, especially for high speed facilities.

Where the entrance terminals occur on a crest curve, sight distances to the lane drop may be affected, longer acceleration lanes will then be required as discussed later in the 'Sight Distance' Subsection.

Entrance Ramp Transition Curve Criteria

In entrance ramp design, a spiral is introduced in the vicinity of the bullnose between the ramp controlling curve and the entrance curve or taper to effect a smooth transition. Acceleration starts at the beginning of the spiral, and usually continues beyond the spiral on the ramp terminal section. The radius of the spiral increases so as to accommodate the increasing speed of the vehicle accelerating. The spiral parameter needs to be small enough to provide a sufficiently rapid rate of increase in radius to match the acceleration of the vehicle. On the other hand the spiral parameter needs to be sufficiently large to ensure that the comfort, superelevation and aesthetic criteria are met. The spiral parameter, can be selected from the range given in Table 2.4.6.6.

Table 2.4.6.6 Spiral Parameter for Entrance Ramp Transition Curves

Ramp Controlling Curve Speed (km/h)	Design Domain of Spiral Parameter (m)
40	50-80
50	65-130
60	85-140
70	110-280
80	125-360

Sight Distance at Entrance Terminals

At entrance terminals, the driver is looking for a gap in the traffic in the adjacent lanes in order to effect a lane change and merge. A driver therefore has to look back to find an appropriate gap. This view is best provided by maintaining the vertical alignment of the ramp in the vicinity of the nose at elevations similar to, or above, those of the through road. If the ramp is significantly lower, the driver might have some difficulty effecting a safe merge. If the ramp is higher, the driver normally has good visibility unless the view is obscured by a traffic barrier or other visual obstruction.

A driver begins accelerating from the ramp controlling circular curve some distance before the nose, usually in the vicinity of the beginning of the spiral curve. At this point, the driver looks for a gap in the stream of traffic in the adjacent lane. The line of sight is taken to be at 120° from the direction of travel and the object to be seen is taken to be in the centre of the adjacent lane, 1.0 m above the pavement surface. This is illustrated in Figure 2.4.6.4.

To allow the driver to make a merging manoeuvre safely, ideally he requires a view of the entire speed change lane at the nose as illustrated on Figure 2.4.6.4. The driver may not have this view if the speed change lane occurs on a crest curve, in which case the vertical alignment should be adjusted so as to shift the crest curve away from the speed change lane. If this is not feasible, either the speed change lane should be lengthened or the crest curve should be flattened to provide, preferably, decision sight distance to the end of the taper as discussed in Chapter 1.2.

2.4.6.5 Ramp Terminal Spacing

Successive ramp terminals on freeways/ expressways or within an interchange are spaced to allow drivers to make decisions in sufficient time to make safe manoeuvres.

In the case of successive exits, the distance is based on the provision of adequate signing. In the case of successive entrances, the length is based on the merging manoeuvre length required for the first entrance.

An entrance followed by an exit terminal creates a weaving condition, and is discussed in Chapter 2.1.

The distance between an exit followed by an entrance needs to be sufficient to allow a vehicle on a through lane to prepare for the merge ahead after passing the exit nose.

Figure 2.4.6.5 shows the minimum values for ramp terminal spacing based on design speeds. Additional distances may be required to ensure signing requirements are met.

2.4.6.6 Safety and Design Overview

The fundamental principle of an interchange is the movement of vehicles through the interchange in the safest, most efficient manner possible. The ability of an interchange to accommodate drivers in this manner is closely related to the efficiency with which the information is provided to the driver and with the degree to which driver expectancy is met at the interchange.

Interchanges present the motorist with a complex set of decisions that require quick evaluation and action. Designers can reduce drivers' stress at interchanges by keeping the alignment simple and direct, maintaining design consistency, providing sight distances greater than the minimum stopping sight distances, and using above minimum design criteria for other geometric elements.

Collisions on ramps and connecting roads generally increase with traffic volume and with decreasing curve radius.[7] It also appears that upgrade exit ramps have lower collision rates and thus it is preferable, from a safety view point, for the connecting road to pass over the freeway or higher speed road. The use of collector lanes for high volume interchanges enhance safety, especially where loop ramps are used[7]. The use of a collector introduces an intermediate-speed facility between the freeway and the off-ramp thereby encouraging speed slow-down prior to entering the off-ramp.

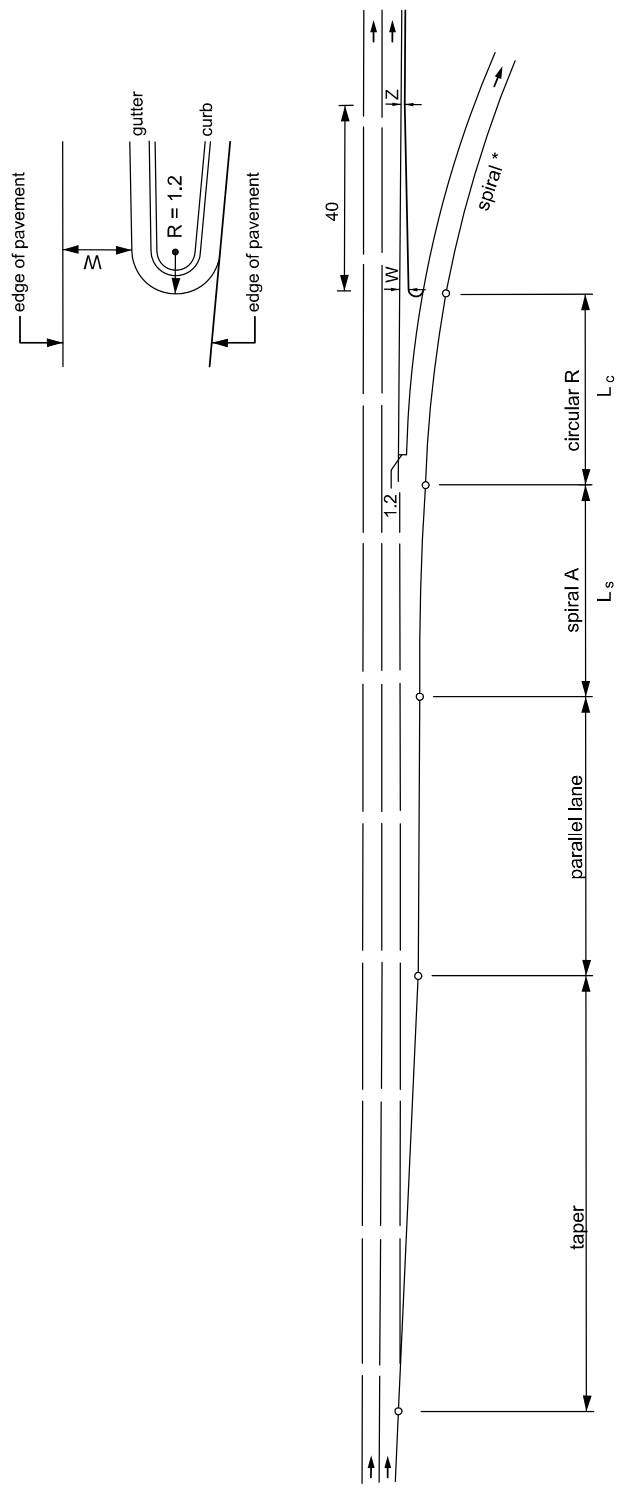
One of the key issues related to interchange design involves heavy truck incidents at interchanges. In general, tight radius curves on ramps and short speed change lanes cause problems with heavy trucks. Truck incidents on interchange ramps generally involve loss of control leading to rollover or jack-knife. Recent

2.4.8 TYPICAL INTERCHANGE DESIGN FEATURES

Examples of typical designs for ramp terminals, both tapered and parallel, for exits and entrances, are shown in Figures 2.4.8.1 to 2.4.8.7, followed by examples of at-grade intersections of ramps with crossing arterial roads for various interchange types in Figures 2.4.8.8 to 2.4.8.12.

These designs should be regarded as typical rather than “standard”, and are for the guidance of the designer. Rigid adherence to these designs may produce unsatisfactory operation in some cases. Dimensions are typical and variations are required to suit local conditions of alignment, grade, profile, traffic volume, traffic mix and local physical and environmental features. Additional detailing may also be required.

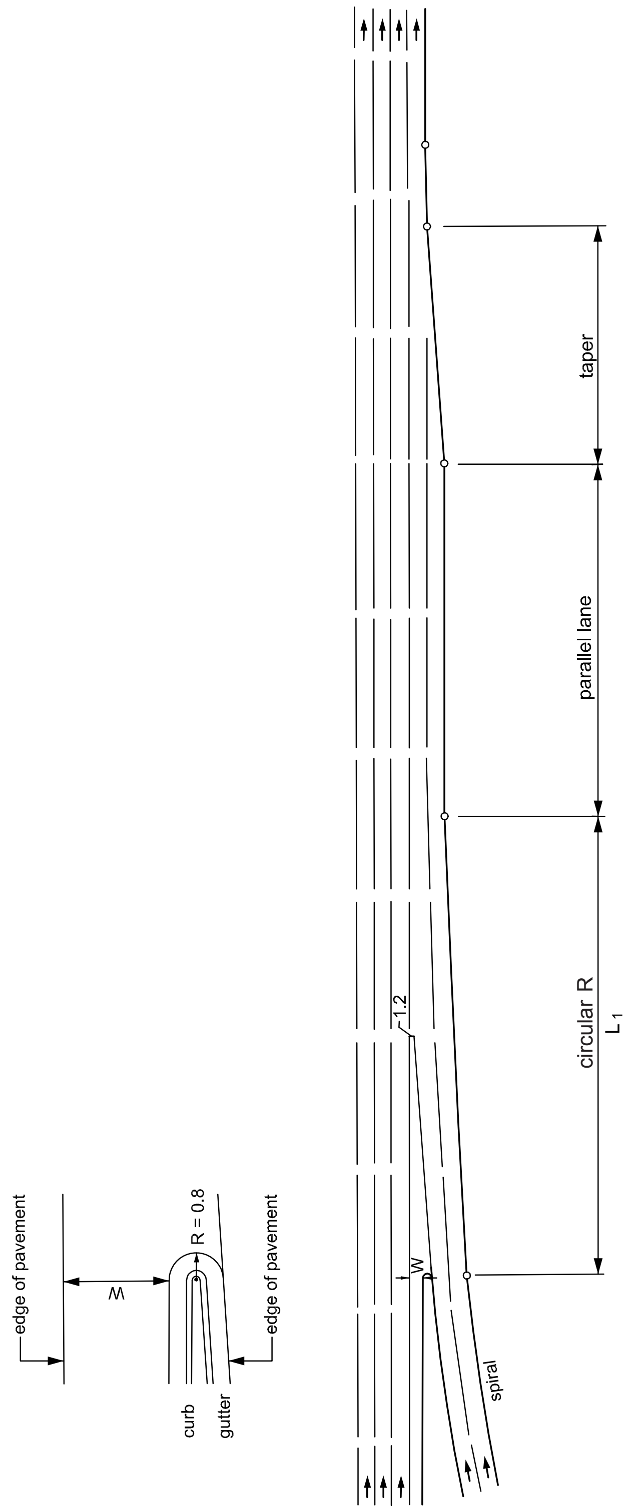
Figure 2.4.8.1 Typical Design Exit Terminal Parallel Single Lane



class	main line design speed (km/h)	taper (m)	parallel lane (m)	transition A	transition L_s (m)	transition R	transition L_c (m)	W Offset (m)	Z Offset (m)
RCU RAU RAD	100	85	20	125	45	350	40		normal shoulder width
	120	95	60	125	45	350	40		
RFD UFD	80	70	20	0	0	1000	120	3.5	
	100	85	60	0	0	1500	150	3.5	
	120	95	80	0	0	2000	170	3.5	
	130	100	90	0	0	3000	210	3.5	

* spiral parameter determined by design speed and radius of turning roadway

Figure 2.4.8.6 Typical Design Entrance Terminal Parallel Two Lane

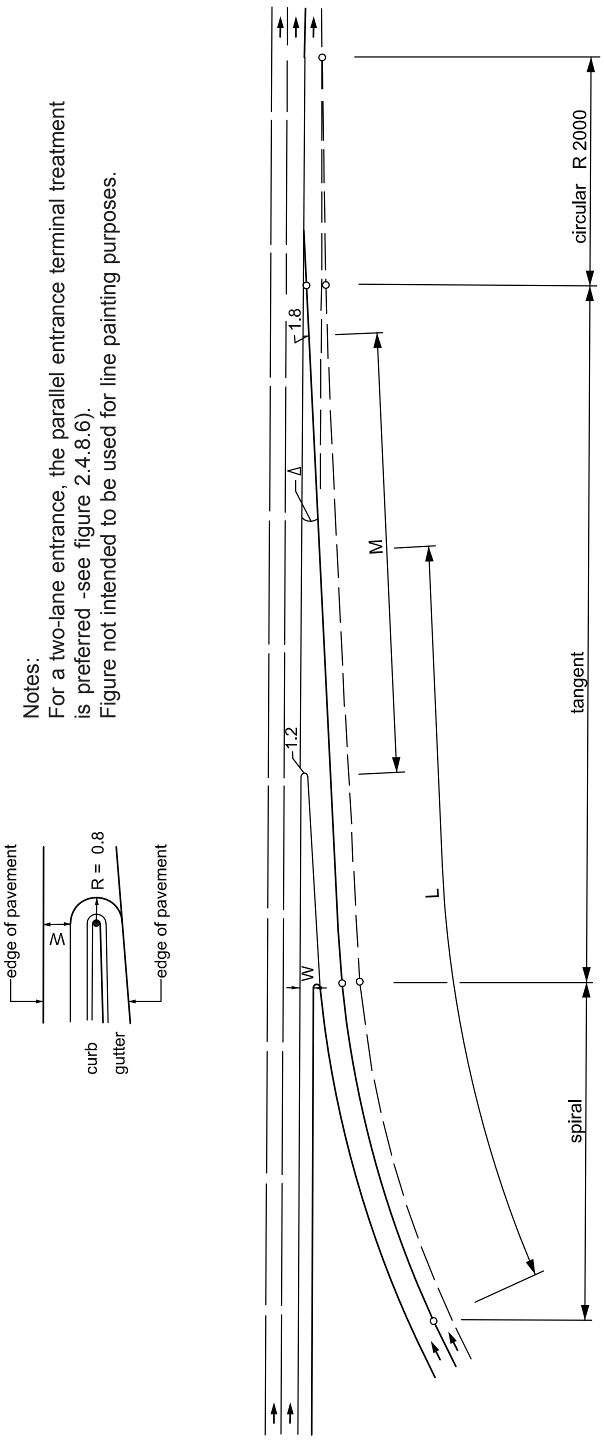


class	main line design speed (km/h)	W Offset (m)	circular R: R (m)	circular R: L_1 (m)	parallel lane (m)	taper (m)
UAD	100	0	2000	135	210	85
RFD UFD	80	3.0	2000	135	25	70
	100	3.0	3000	165	125	85
	120	3.0	4000	190	280	95
	130	3.0	5000	215	335	100

UCU 60 AND UCU 80 values use tapered design, see Figure 2.4.8.7

Figure 2.4.8.7 Typical Design Entrance Terminal Tapered Single and Two Lane

Notes:
For a two-lane entrance, the parallel entrance terminal treatment is preferred -see figure 2.4.8.6).
Figure not intended to be used for line painting purposes.



class	main line design speed (km/h)	Δ	M (m)	W (m)	L (m) ramp design speed (km/h) 40	50	60	70	80
RCU RAD UAD	100	1°-30'	172	0.75	330	290	230	-	-
	120	1°-15'	206	0.75	500	470	430	360	-
RCU RAD UCU UAU UAD	60	2°-30'	103	0	60	20	-	-	-
	80	2°-00'	129	0	170	140	90	-	-
RFD UFD	80	1°-30'	172	3.0	170	140	90	-	-
	100	1°-15'	206	3.0	330	290	230	-	-
	120	1°-00'	258	3.0	500	470	430	360	-
	130	1°-00'	258	3.0	-	550	520	460	380

3.1.3 THE CLEAR ZONE CONCEPT

3.1.3.1 Overview

A highway design with a forgiving roadside recognizes that drivers do occasionally run off the road and that serious collisions will be reduced if a reasonable recovery zone, free of obstacles, is provided. If the obstacles cannot be removed from the recovery zone, they need devices to protect vehicles that might collide with them. This practice has been embodied in a concept which is known as the Clear Zone, and it represents the minimum recovery area which should be provided for a given design situation.

The knowledge gained during more than two decades of experience with the forgiving highway concept, and, specifically, the clear zone, now enables engineers to estimate their safety impact more precisely. This experience forms the basis for the types of collision prediction models discussed earlier.

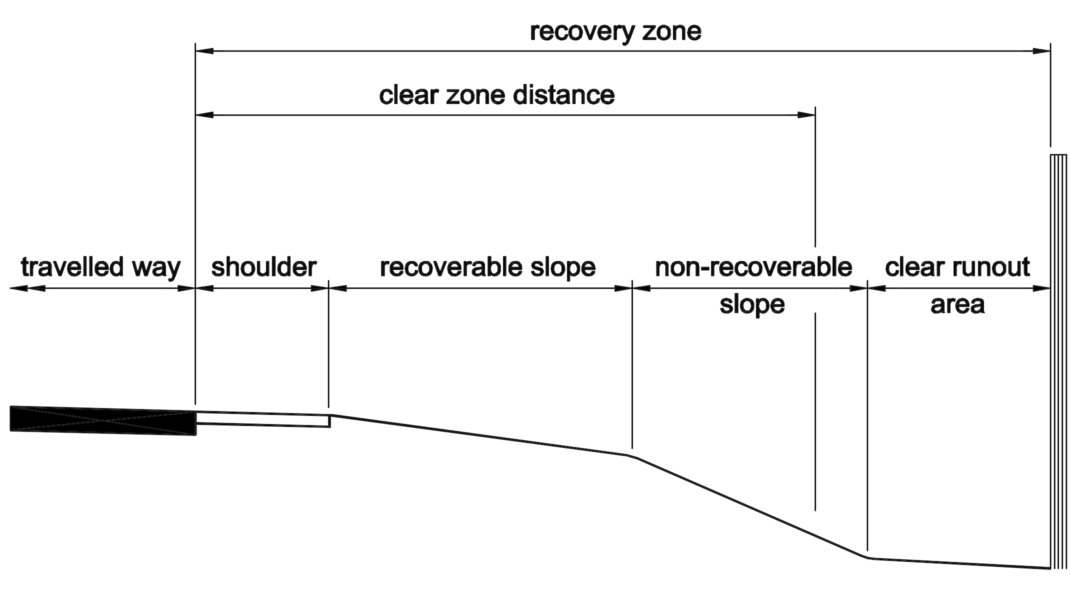
3.1.3.2 Elements of the Clear Zone

The clear zone falls within an area called the recovery zone. The recovery zone is the total unobstructed traversable area available along the edge of the road, and by convention it is measured from the edge of the closest travel lane. The recovery zone may have recoverable slopes, non-recoverable slopes and a clear run-out area.

Figure 3.1.3.1 illustrates the clear zone concept in the context of the roadside recovery zone.

Recoverable slopes are those on which a driver may, to a greater or lesser extent, retain or regain control of a vehicle. A non-recoverable

Figure 3.1.3.1 Roadside Recovery Zone



Note: If the clear zone distance ends on a non-recoverable slope a clear runout area is required. It is desirable that the cler runout area be greater than or equal to Clear Zone Distance - (Shoulder Width + Recoverable Slope)

slope may be traversable, but a vehicle will continue to the bottom. A clear runout area is located at the toe of a non-recoverable slope, and is available for safe use by an errant vehicle. There is also provision for a smooth transition between slopes to allow for the safe passage of vehicles.

The clear zone is the total, fixed-object-free area available to the errant vehicle. The design domain for the clear zone width has been found to depend on traffic volume and speed, road geometry, embankment height, side slope and environmental conditions such as snow, ice, and fog. The wider the clear zone, the less the frequency and severity of collisions with fixed objects. However, there is a point beyond which any further expenditure to move or protect the fixed objects is not warranted because the marginal risk reduction is too small.

3.1.3.3 Factors Influencing the Clear Zone Design Domain

When originally introduced, the clear zone concept dictated a single value and was based on limited observations taken from a research facility context. The concept was formally introduced in the 1974 version of the AASHTO report entitled Highway Design and Operational Practices Related to Highway Safety where the authors noted:

"...for adequate safety, it is desirable to provide an unencumbered roadside recovery area that is as wide as practical on a specific highway section. Studies have indicated that on high-speed highways, a width of 9 metres or more from the edge of the travelled way permits about 80 percent of the vehicles leaving a roadway out of control to recover…" [7]

The last portion of this statement requires emphasis. Provision of the recommended clear zone does not guarantee that all vehicles will not encroach further than the recommended clear zone distance. Quite the contrary, the clear zone principle embodies the explicit fact that some substantial portion of the vehicles which encroach will go beyond the clear zone itself, as illustrated in Figure 3.1.3.2.

Early after its introduction, it became apparent that a single value of 9.0 m for the clear zone distance was not always appropriate. Steeper embankment slopes tended to increase vehicle encroachment distances. Conversely, on low-volume or low-speed facilities, the 9.0 m distance was excessive and could seldom be justified. As a result, as the concept evolved, design practice moved to a variable clear zone distance definition and a better understanding of the wide range of factors which influence the limits of its design domain was gained.

In this Guide, the concepts reflected in the 1996 AASHTO Roadside Design Guide have been retained. Where sound, factual research was available, the application of the concepts has been modified to better conform to Canadian conditions and practice as appropriate. In this context, the clear zone design domain reflects the influence of:

- design speed
- traffic volumes
- the presence of cut or fill slopes
- the steepness of slopes
- horizontal curve adjustments

Although a clear and unambiguous guide to appropriate limits to, and adjustments for, the design domain of the clear zone is provided in Subsection 3.1.3.4 of this chapter, designers must recognize the limitations of the underlying work which provides the basis for this definition. In discussing the set of curves it uses to define its variable clear zone recommendations, AASHTO provides a thoughtful caution to designers:

"…the numbers obtained from these curves represent a reasonable measure of the degree of safety suggested for a particular roadside; but they are neither absolute nor precise. In some cases, it is reasonable to leave a fixed object within the clear zone; in other instances, an object beyond the clear zone distance may require removal or shielding. Use of an appropriate clear zone distance amounts to a agency normally has specific clearance requirements which are to be honoured. In many cases, it is desirable to relocate the overhead utility underground to avoid the conflict, while improving the aesthetics of the street right of way.

With respect to street lights, it is desirable to examine the blocking effect of the future mature tree canopies on the illumination levels intended for the roadway and the pedestrian areas. Strategic spacing, consideration of tree canopy form, and pruning of trees relative to the luminaries is often sufficient to avoid significant problems for the roadway illumination. It is desirable to position trees midway between streetlight poles and to prune the lower branches so that unobstructed light reaches a point a minimum of 1.8 m above the mid-span points as illustrated on Figure 3.3.4.1.[4] It is also desirable to select trees with thin, permeable canopies to reduce the needs of pruning. Separate pedestrian style lighting may be required to provide the levels of illuminance necessary for the safety and security of the pedestrian area.

For the climatic conditions in most Canadian urban centres, it is important not to provide a dense tree cover adjacent to pedestrian areas. The warmth provided by the sun is generally beneficial for pedestrian comfort in temperate climates. The strategic placement of deciduous trees is effective in providing shade protection during hot summer afternoons while allowing the sun to provide warmth during winter months.

Tree spacing and location are dependent on a variety of factors including:

- desired visual affect
- species of tree
- physical constraints, such as utilities, lighting, and underground structures
- vehicle/vehicle and vehicle/pedestrian sight line requirements

Each streetscaping project is normally assessed on the basis of the existing conditions and constraints toward identifying the most effective planting plan.

Tree grates are normally provided for trees planted within a hard surfaced pedestrian area. Their use maximizes the available pedestrian travel space while allowing proper gas exchange at the air/soil contact zone. Tree grates are typically manufactured using durable concrete or cast-iron materials. It is important to provide surface drainage away from the tree trunk to assist in minimizing the intrusion of roadway salt and other harmful materials into the soil and root system. Raised curbs around each tree pit may be effective in limiting salt intrusion but are more restrictive to pedestrian travel than grates which are flush with adjacent sidewalks. Tree or other grates not flush with the sidewalk or with openings greater than 13 mm in diameter may pose a hazard for persons with reduced mobility, and are normally located laterally beyond the line of travel and clear sidewalk width.

Appropriate vegetation can be selected for use on embankment and cut slopes to effectively create soft aesthetics, reduce maintenance and increase slope stability.

3.3.4.3 Vehicular Traffic Considerations

The location and configuration of vegetation are determined so as to maintain the sight lines required at street intersections and other pedestrian crossing areas. Sight distance requirements are discussed in Chapter 2.3 - Intersections. Shrubs less than 1.0 m in height and trees with canopies providing at least 2.4 m of vertical clearance may be considered within an intersection sight triangle. Hedges, high shrubs and coniferous trees which block sight lines are avoided in these critical areas. Generally, it is desirable to eliminate, or at least restrict, the type and amount of vegetation within the critical sight triangles at intersection areas to maintain pedestrian and vehicular safety.

The locations of traffic signs, particularly regulatory and warning signs, and traffic signals are normally co-ordinated with the planting layout. Vegetation at locations that may block the driver’s view of traffic signs and signals are avoided.

When creating a tree planting plan, consultation with the adjacent property owners and business operators is desirable. It may be desirable not to block important or interesting buildings from the view of the passing vehicular traffic. Certain buildings may be equally or more important to the visual quality and character of the street than planted vegetation.

Trees with trunk diameters greater than 150 mm at maturity are considered fixed objects. Groups of small trees or shrubs closely spaced may have the same effect as a single large tree. Therefore, for larger trees and tree groups, it is advisable to locate trees in accordance with the clear zone guidelines, based on design speed, from the edge of the travel lane (existing or future) to the tree trunk, as outlined in Chapter 3.1. Permitted locations for trees are often a matter of local policy, but it is generally desirable to avoid having large trees in close proximity of vehicular travel lanes, such as within boulevards less than 2.0 m and medians less than 4.5 m in width. When parking is provided along an urban street where streetscaping is employed, the parking area generally provides a suitable buffer between the traffic lanes and the boulevard trees and other fixed objects, and therefore the curb to fixed object dimension is less critical.

A minimum setback of 750 mm from the curb face to the tree trunk face is generally desirable in all cases. This provides a suitable minimum clearance for passengers to open a vehicle door and exit/enter reasonably unimpeded, reduces the frequency of splashed salt and other harmful materials onto the tree trunk and minimizes the intrusion of root growth into the road subgrade.

3.3.4.4 Roadside Treatments

The selection of the most appropriate roadside area treatments is influenced by a number of factors including:

- the total curb to property line (roadside) width available
- the clear sidewalk width required to accommodate the anticipated pedestrian characteristics and volumes
- the nature and characteristics of the adjacent land use
- the volume, speed and type of vehicular traffic along the adjacent roadway
- the location of overhead and underground utilities

Generally, four options are available to the designer as illustrated in Figure 3.3.4.2.[5] Each landscaping project is assessed on its individual characteristics. It may be advantageous on certain projects to implement combinations of options to suit varying land uses, vehicular traffic and parking conditions, and the physical constraints; combination of options may be more visually stimulating in making the motorists more aware of the driving environment and thus enhancing safety. Where a change is made from one option to another, it is important to design the pedestrian route transitions to be obvious and unobstructed.

A description and typical application of the four options are outlined by the following:

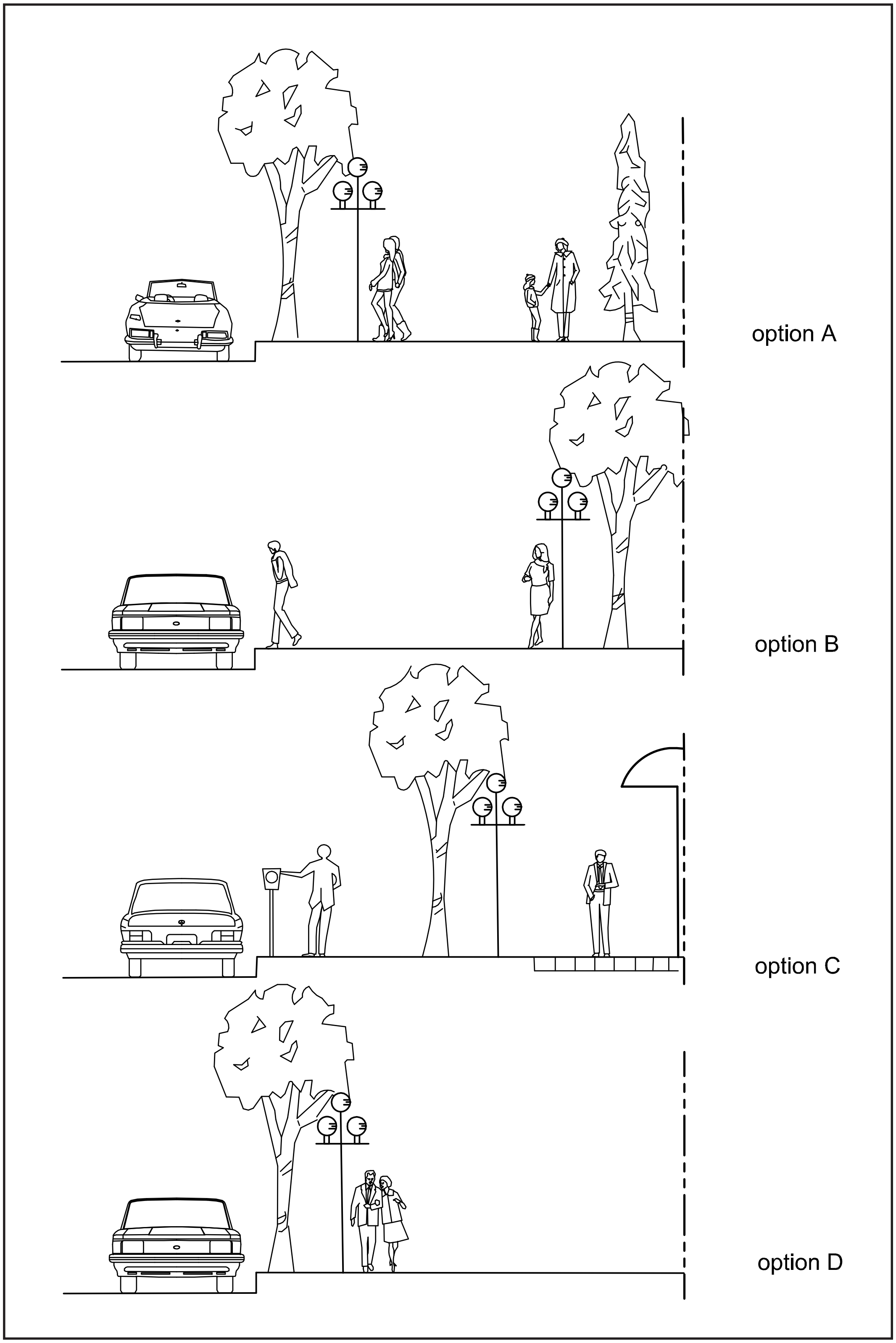
<u>Option A – Boulevard and Border Vertical Features</u>

This treatment is particularly beneficial where wide expanses of paved areas exist on either side of the roadside. An example is a pedestrian area between a multi-lane road and a parking area for a regional shopping centre. The vertical features and the created enclosure effectively buffer the pedestrian from both the busy road and the adjacent land use. To provide an appropriate pedestrian scale, the ratio of pedestrian area width to height of the vertical features is normally in the range of 1:1 to 1:2.

<u>Option B – Border Vertical Features Only</u>

With this option, a buffer is introduced only between the pedestrian area and the adjacent development and therefore provides a physical separation between the pedestrian area and the adjacent land uses. Common applications are along off-street parking areas and adjacent to industrial land uses, where large and unsightly areas are visible to the pedestrian. The aesthetics of residential land uses may also be improved by this style of treatment. This arrangement may also be the only feasible option

Figure 3.3.4.2 Roadside Streetscaping Alternatives[5]



where overhead utility lines exist along the roadway curb and the width of the roadside precludes Option C. If there is a high level of movement between a roadway parking lane and the pedestrian area, or where future roadway widening is planned, Option B may be advantageous. This option also provides the best visibility, between the vehicle driver and the pedestrian, where pedestrians are expected to cross the roadway.

<u>Option C – Vertical Features Centre of Roadside</u>

The most common use of this concept is along a street with relatively tall buildings and busy commercial activity at street level. The vertical features help to scale down the adjacent buildings to the pedestrian level. The centre features create separate pedestrian areas along the adjacent commercial space and along the curb. This treatment is beneficial where on-street parking to sidewalk activity level is expected to be high, and can be used effectively where future roadway widening is planned. The minimum total roadside width is normally 6.0 m for this option to be functional.

<u>Option D – Boulevard Vertical Features Only</u>

This option is generally used where there is a need to buffer the pedestrian area from a busy roadway. The adjacent land use is typically such that a continuous exposure from the pedestrian area is desirable or at least not objectionable. Examples of such land uses are continuous retail spaces with display windows or an interesting park space or recreational activity area. The vertical features adjacent to the roadway are normally positioned in accordance with the clear zone guidelines provided in Chapter 3.1.

In commercial areas, it is common practice for the entire roadside width to be hard surfaced, from the curb to the right-of-way limit, and often beyond, where buildings are set back from the property line. Narrow grass strips in commercial areas are costly to maintain and are subject to damage from sand and salt intrusion, snow removal, and pedestrian and bicycle traffic.

A number of different materials, including concrete, impressed concrete, asphalt, concrete pavers, brick, stone, and asphalt pavers, can be used effectively to hard surface the boulevard and border areas. For a streetscaped roadside, it is generally preferable to use plain materials, such as concrete or asphalt, for the boulevard and border areas. Decorative materials, such as concrete pavers and brick, are most effectively used to delineate the edge of pedestrian area or within the pedestrian area to provide route continuity and to enhance the pleasure of, and interest in, walking along the street.

3.3.4.5 Median and Outer Separation Treatments

Narrow medians and outer separations, 2.0 m or less in width, are normally hard surfaced due to the difficulty in maintaining narrow strips of grass. Concrete or asphalt materials are typically used to surface the narrow median or outer separation areas. The use of decorative materials, such as concrete pavers, stone or brick, for median and outer separation areas is generally of less benefit as compared to roadside treatments. Pedestrians are appreciative of the decorative detail and therefore, if funds are limited, it is usually more cost-effective to use these materials in the pedestrian areas rather than the median and outer separation areas. However, decorative medians and outer separations are of visual benefit to passing motor vehicle occupants, cyclists and adjacent property owners and businesses.

For medians and outer separations approximately 2.0 m to 4.5 m in width, grass is typically the most common surface treatment. Where these cross section elements are wider than 4.5 m, the use of shrubs and trees, together with grass, are common landscape treatments. In the vicinity of intersections or pedestrian crossings, it is important to keep the sight triangles free of obstructions. Low shrubs, less than 1.0 m in height, and trees with high canopies, providing more than 2.4 m of vertical clearance, can often be used without significantly interfering with sight lines. Potential problems with street lights should be avoided as discussed in Subsection 3.3.4.2.

3.4.5 ALIGNMENT ELEMENTS

The alignment elements in the following paragraphs are generally applicable to bike paths. Other classifications of bikeways are designed for motor vehicle traffic and those standards are adequate for bicycles, with the exception of stopping sight distance. Stopping sight distance is greater for bicycles than motor vehicles, particularly in the case of steep downgrades, and should be considered in the designation of bike lanes and bike routes.

3.4.5.1 General Approach

As for any transportation facility, there is a responsibility to generate a collision free design. The standards and practices for bikeways that follow are intended to assist designers to meet this responsibility. However, the bicycle is a distinct vehicle which is often used in locations of substandard geometrics. In such cases, providing suitable warning signs along bikeways is a significant consideration in maintaining safety.

3.4.5.2 Design Vehicles

The suggested dimensions of a bicycle to be used in the design of bikeways are:

- length, 1.75 m
- width at pedals, 400 mm
- height to lowest pedal position, 100 mm
- width at handlebars, 800 mm
- height to handlebars, 1.25 m
- height to top of seated riders, 2.0 m

Desirable bikeway widths for design are as follows:

- one-way, 1.20 m to 1.60 m
- two-way, 2.20 m to 2.60 m

3.4.5.3 Design Speed

The speed at which a cyclist travels is dependent on several factors, including the type and condition of the bicycle, the purpose of the trip, the condition and location of the path, the speed and direction of the wind, and the physical condition of the cyclist. Paved bike paths are designed for a selected speed that is at least as high as the preferred speed of the faster cyclists. In general, a minimum design speed of 30 km/h is used; however, when the downgrade exceeds 4%, or if strong tailwinds prevail, a design speed of 50 km/h is advisable.

On unpaved paths, where cyclists tend to ride more slowly, a lower design speed of 25 km/h can be used or where the grades or the prevailing winds dictate, a higher design speed of 40 km/h can be used. Since bicycles have a higher tendency to skid on unpaved surfaces, horizontal curvature design should take into account lower coefficients of friction.

3.4.5.4 Stopping Sight Distance

Minimum stopping sight distance for bicycles is the distance required to bring a bicycle to a controlled full stop. It is a function of the cyclists' perception and brake reaction time, the initial speed of the bicycle, the coefficient of friction between the tires and the bikeway surface and the braking capability of the bicycle. The stopping sight distance is given by the expression:

$$SSD = 0.694V + \frac{V^2}{255(f + g/100)} \qquad (3.4.1)$$

Where:

	SSD	=	stopping sight distance (m)
	V	=	design speed (km/h)
	f	=	coefficient of friction
	G	=	grade (% up grade is positive and down grade is negative)

The expression is based on a perception-reaction time of 2.5 s. Table 3.4.5.1 illustrates minimum stopping sight distance for a range of speeds from 10 to 50 km/h and grades up to 12%. For two-way facilities, the values for the descending direction control the design. Coefficient of friction (f) is taken to be 0.25 for paved surfaces, which accounts for the poor wet weather braking characteristics of many bicycles.[2]

Table 3.4.5.1 Minimum Stopping Sight Distance for Bicycles (Paved Surface, Wet Conditions)

Grade (%)	Minimum Stopping Sight Distance (m) Design Speed (km/h)								
	10	15	20	25	30	35	40	45	50
12	8	13	18	-	-	-	-	-	-
10	8	13	18	24	-	-	-	-	-
8	8	13	19	25	32	-	-	-	-
6	8	13	19	25	32	40	-	-	-
4	8	13	19	26	33	41	49	-	-
2	8	14	20	26	34	42	51	61	-
0	9	14	20	27	35	44	53	63	74
-2	9	14	21	28	36	45	55	66	77
-4	9	15	21	29	38	47	58	69	81
-6	9	15	22	30	39	50	61	73	86
-8	9	16	23	32	42	53	65	68	92
-10	10	16	24	34	44	53	70	84	100
-12	10	17	26	36	48	61	76	92	110

Notes: For the purposes of measuring stopping sight distance the height of eye is normally taken to be 1.37 m and the height of object zero, to provide for impediments to bicycles at pavement level, such as potholes.

For selection of design speed, refer to Subsection 3.4.5.3.

3.4.5.5 Horizontal Alignment

Radius and Superelevation

The minimum radius of a circular curve for a bikeway is a function of bicycle speed, superelevation, and coefficient of friction. These variables are related by the expression:

$$R = \frac{V^2}{127(e+f)} \quad (3.4.2)$$

Where: R = radius (m)

V = design speed (km/h)

e = superelevation (m/m)

f = coefficient of lateral friction

This relationship is used to determine the minimum design radius for given design speeds. For most applications and conditions, the superelevation rate will range from a minimum of 0.02 to 0.05 m/m. The coefficient of lateral friction used for design of paved bikeways varies from 0.3 at 25 km/h to 0.22 at 50 km/h. For the design of unpaved surfaces, lateral friction factors are reduced to 50% of those of paved surfaces. Table 3.4.5.2 gives coefficient of lateral friction and minimum radius for a range of design speeds based on superelevation rates of 0.02 and 0.05 m/m.

Where curve radii less than those in Table 3.4.5.2 are used, or superelevation is unavailable, warning signs in advance of the curve are appropriate.

Lateral Clearance on Horizontal Curves

Lateral clearance to obstructions on the inside of horizontal curves is based on the need to