

The logo features a stylized maroon circle containing a white dashed line that curves upwards and to the right, resembling a road or a highway interchange.

QATAR HIGHWAY DESIGN MANUAL

Intersections and Interchanges

Notice:

This document is issued for the sole purpose of stakeholder engagement in advance of a stakeholder workshop to be held on 18 and 19 June 2013.

The contents of the document are draft and must not be used for any purpose other than preparation for the said workshop.

Note that the document is a work-in-progress and as such may contain inaccuracies in cross referencing, table and figure referencing and page numbering. It may also contain rough drafts of figures and could include inconsistencies and areas of text yet to be developed.

Contents

1	Type selection.....	1
1.1	Introduction	1
1.1.1	Selection Criteria	1
1.1.2	Design Objectives	1
1.2	Junction Selection	2
1.2.1	Junction types.....	2
1.2.2	Aspects affecting provision	3
1.2.3	Traffic flow and Capacity	4
1.2.4	Network Connections.....	6
1.2.5	Junction Spacing	7
1.3	Design Principles	7
1.3.1	General Principles.....	7
1.3.2	Geometric Requirements	7
1.3.3	Safety.....	11
1.3.4	Non-motorised users.....	12
2	Priority intersections	13
2.1	Introduction	13
2.1.1	Priority Intersections General	13
2.1.2	Siting of Priority Intersections	13
2.2	Priority Intersection Types	14
2.2.1	Simple Intersection.....	14
2.2.2	Ghost Island Intersections.....	15
2.2.3	Single Lane Dualling.....	16
2.2.4	Dual Carriageway Intersections.....	17
2.3	Priority Intersection Configurations.....	17
2.3.1	T-junction	17
2.3.2	Crossroads	18
2.3.3	Staggered Junction	18
2.3.4	Skew Junction	20
2.4	Design Procedure	21
2.4.1	Intersection design procedure	21
2.4.2	Choice of major/minor priority intersection	23
2.5	Design Elements	24
2.5.1	General.....	24

2.5.2	Design Speed	25
2.5.3	Gradient	25
2.5.4	Visibility	25
2.5.5	Geometric Requirements	28
2.5.6	Central Islands	33
2.5.7	Stagger Distances	39
2.5.8	Diverging Auxiliary Lanes	39
2.5.9	Merging Auxiliary Lanes and Tapers	41
2.5.10	Skew Junctions	43
2.5.11	T-Junction with Carriageway Separation	45
2.5.12	Channelizing Traffic Islands	47
2.5.13	Splitter/Right Turn Islands	50
2.6	Service Road Diverges and Merges	51
2.6.1	Service Road Provision	51
2.6.2	Service Road Junctions	52
2.7	U-Turn Facilities	55
2.7.1	General Principles	55
2.7.2	Geometric Design	56
2.8	Priority Intersections in Residential Areas	58
2.8.1	Typical Configurations	58
2.8.2	Older Residential Areas	59
2.8.3	Corner lots at Priority Intersections	59
3	Roundabouts	62
3.1	Introduction	62
3.1.1	General	62
3.1.2	Design Principles	62
3.1.3	Definitions	63
3.2	Types of Roundabouts	64
3.2.1	Normal Roundabouts	64
3.2.2	Compact Roundabouts	65
3.2.3	Grade Separated Roundabouts	65
3.2.4	Signalized Roundabouts	66
3.2.5	Double Roundabouts	66
3.3	Safety at Roundabouts	68
3.3.1	General	68

3.3.2	Two Wheeled Vehicles	70
3.3.3	Large Goods Vehicles	70
3.4	Siting of Roundabouts	70
3.4.1	General	70
3.5	Design Hierarchy	71
3.5.1	Selection of Roundabout Type and Provision for Non-motorised Users	71
3.6	Geometric Design – Circulatory Carriageway	74
3.6.1	Inscribed Circle Diameter (ICD)	74
3.6.2	Circulatory Carriageway	74
3.6.3	Central Island	75
3.6.4	Entry Deflection Islands	77
3.7	Geometric Design – Entries and exits	77
3.7.1	Roundabout entries	77
3.7.2	Roundabout Exits	86
3.8	Design – Visibility	88
3.8.1	General	88
3.8.2	Approach Visibility	88
3.8.3	Visibility of the Circulatory Carriageway	89
3.8.4	Forward Visibility at Entry	89
3.8.5	Visibility to the Left at Entry	90
3.8.6	Circulatory Visibility	91
3.8.7	Pedestrian Crossing Visibility	92
3.8.8	Visual Intrusions	93
3.9	Design – Other aspects	94
3.9.1	Crossfall and Longitudinal Gradient	94
3.9.2	Kerbing	96
3.9.3	Dedicated Right Turning Lanes	97
3.9.4	Road Markings	107
3.9.5	Lighting	107
4	Interchanges	108
4.1	Introduction	108
4.1.1	General	108
4.1.2	Definitions	109
4.2	Interchange Layouts	111
4.2.1	General	111

4.2.2	Free-flow Interchanges.....	112
4.2.3	Standard Grade Separated Interchanges	114
4.3	Design Strategy.....	116
4.3.1	General	116
4.3.2	Safety	116
4.3.3	Traffic Flows and Design Year	116
4.3.4	Urban/Rural	117
4.3.5	Junction Spacing Within the Network	117
4.3.6	Initial Information Requirements and Decisions	117
4.3.7	Design Development	118
4.4	Design Elements	120
4.4.1	Design Speed	120
4.4.2	Lane Provision and Capacity	121
4.4.3	Hard Shoulders and Hardstrips.....	122
4.4.4	Merges and Diverges at Interchanges	122
4.4.5	Slip Roads.....	130
4.4.6	Interchange Links.....	130
4.4.7	Loops.....	130
4.5	Weaving and Junction Spacing	134
4.5.1	Weaving length.....	134
4.5.2	Lane provision.....	139
4.6	Major Interchange Design	140
4.6.1	General	140
4.7	Other Design Considerations.....	141
4.7.1	Clearance and Headroom	141
4.7.2	Superelevation.....	141
4.7.3	Safety Fencing.....	142
4.7.4	Signing	142
4.7.5	Lighting	142
4.7.6	Utilities.....	142
4.7.7	Emergency Vehicles	142
4.7.8	Maintenance Provisions	143
4.7.9	Environmental Issues.....	143
5	Signal Control of Intersections	144
5.1	Introduction.....	144

5.1.1	General	144
5.1.2	Design Principles	145
5.1.3	Arrangements and Operation	147
5.1.4	Classified Traffic Counts	148
5.2	Types of Signalized Intersection.....	148
5.2.1	Layouts	148
5.2.2	Simple Crossroads	149
5.2.3	Signal-Controlled T-junctions	150
5.2.4	T-Junction on a Dual Carriageway with Median Opening (Signalized).....	151
5.2.5	Signal-Controlled Staggered Junctions.....	151
5.2.6	Signalized Roundabouts	151
5.3	Geometric Design Features.....	152
5.3.1	General	152
5.3.2	Design Speed	152
5.3.3	Visibility on the Approach to Intersections	152
5.3.4	Junction Inter-visibility Zone	153
5.3.5	Junction Inter-visibility	154
5.3.6	Corner Radii	156
5.3.7	Carriageway Widths	156
5.3.8	Entry Lanes	156
5.3.9	Storage Length	157
5.3.10	Staggered Junctions	158
5.3.11	Lane Continuity	159
5.3.12	Carriageway Widths Around Curves	160
5.3.13	Swept Path Requirements.....	160
5.3.14	Right Turn Slip Lanes	162
5.3.15	Separation Islands	164
5.3.16	Left Turning Traffic Movements.....	164
5.3.17	High Friction Surfacing (HFS).....	164
5.3.18	Location of Signals.....	165
5.4	Road Users' Specific Requirements.....	166
5.4.1	General	166
5.4.2	Specific Measures for Pedestrians	166
5.4.3	Pedestrian Refuges and Separation Islands	167
5.4.4	Crossing Places	168

5.4.5	Specific Measures for Cyclists.....	169
5.4.6	Bus Lanes	169
5.5	Signalized Roundabouts	169
5.5.1	General	169
5.5.2	Pedestrian Crossing Facilities	170
5.5.3	Geometric Design Standards	171
5.5.4	Size.....	171
5.5.5	Extent of Signal control	172
5.5.6	Methods of Signal control	172
5.5.7	Duration of Signal control.....	172
5.5.8	Geometric Modifications.....	174
5.5.9	Offside Approach Lane	174
5.5.10	Nearside Approach Lane.....	175
5.5.11	Internal Approach Lanes.....	175

Tables

Table 1.3.1 – Vehicle Classification (Sheet 1 of 2).....	9
Table 1.3.1 – Vehicle Classification (Sheet 2 of 2).....	10
Table 2.5.1 Minimum corner and curve radii and carriageway widths.....	32
Table 2.5.2 Tapers for Central Islands	35
Table 2.5.3 Deceleration Length on Single Carriageway Roads	36
Table 2.5.4 Direct Taper Length	37
Table 2.5.5 Minimum Stagger Distance for Right/Left Staggered Junctions.....	39
Table 2.5.6 Minimum Auxiliary Lane Lengths on Diverge	40
Table 2.5.7 Minimum Auxiliary Lane Lengths on Merge	42
Table 2.5.8 Channelizing Island Offset	48
Table 2.5.9 Design of Radius R_1	48
Table 2.6.1 Taper lengths for diverges at urban service road junctions	53
Table 2.7.1 Deceleration Length on Single Carriageway Roads	57
Table 2.8.1 Chamfer length at Corner Lot	60
Table 3.5.1 – Selection of roundabout types and provision for Non-motorised Users	73
Table 3.6.1 – Turning widths for compact and smaller normal roundabouts.....	76
Table 3.8.1 – Visibility Distance at Circulatory Carriageway	89
Table 3.9.1 Desirable minimum stopping sight distance on segregated right turn lane	99

Table 3.9.2 Minimum Corner and Curve Radii and Carriageway Widths.....	99
Table 3.9.3 Segregated Right Turn Lane Approach Treatments	103
Table 3.9.4 Minimum Approach and End Tapers.....	103
Table 3.9.5 Desirable Minimum Entry/Exit Taper Length Factor	103
Table 4.4.1 Design Speed of Connector Roads	120
Figure 4.4.1 Merging Diagram – Design Traffic Flows.....	125
Table 4.4.2 Geometric Parameters for Merging Lanes	125
Table 4.4.3 Geometric Parameters for Diverging Lanes	128
Table 4.4.4 Minimum Loop Radii	134
Table 4.6.1 Geometric Parameters for a Fork within an Interchange Link	141
Table 5.1.1 Minimum Visibility Distance to Primary Signals	146
Table 8.3.1 Recommended Length of Application of High Friction Surfacing	165

Figures

Figure 1.2.1 Process in determining junction selection	3
Figure 1.2.2 Junction types suitable for varying major and minor road flows	6
Figure 2.2.1 Simple Intersection	15
Figure 2.2.2 Ghost island intersection	15
Figure 2.2.3 Single lane dualling.....	16
Figure 2.2.4 Dual Carriageway T-junction with Carriageway Separation.....	17
Figure 2.3.1 Crossroads	18
Figure 2.3.2 Simple Left/Right Staggered Junction	19
Figure 2.3.6 Right/Left Staggered Junction with Single Lane Dualling.....	20
Figure 2.3.7 Simple Left-hand skew junction	21
Figure 2.4.1 Flow chart outlining design procedure	22
Figure 2.4.2 Approximate level of T-junction provision for varying traffic flows	24
Figure 2.5.1 Visibility criteria at major/minor priority intersections	27
Figure 2.5.2 Measurement of X distance on curved major road	28
Figure 2.5.3 Circular Corner Radii incorporating tapers	30
Figure 2.5.4 Design of a Compound Curve.....	31
Figure 2.5.5 Minor Road Approaches.....	32
Figure 2.5.6 Ghost island development	34
Figure 2.5.7 Physical island development	34
Figure 2.5.8 Major/minor priority intersection with a ghost island	35

Figure 2.5.10 Right/Left Stagger Junction with Ghost Island (minimum stagger length)	38
Figure 2.5.11 Auxiliary lane on Diverge	39
Figure 2.5.12 Auxiliary Lane on Merge	41
Figure 2.5.13 Merging Taper (non-standard arrangement)	43
Figure 2.5.14 Major/minor priority intersection with Skew minor road	44
Figure 2.5.15 Local grade separation T-junction	46
Figure 2.5.16 Local grade separation T-junction incorporating merge and diverge facilities.....	46
Figure 2.5.17 Local grade separation	47
Figure 2.5.18 Design of Channelizing Island	48
Figure 2.5.19 Typical urban traffic island with pedestrian refuge	50
Figure 2.5.20 Typical layout of splitter island.....	51
Figure 2.6.1 Service Road Diverge/Merge for Speeds $\geq 100\text{kph}$	54
Figure 2.6.2 Service Road Diverge/Merge for Speeds $< 100\text{kph}$	55
Figure 2.7.1 U-turn Facility	57
Figure 2.8.1 Multiple accesses joining a major road	58
Figure 2.8.2 Access Roads Consolidated Prior to Access to Through Route	58
Figure 2.8.3 Development of Chamfer at Corner Lot.....	60
Figure 3.2.1 – Normal Roundabout	64
Figure 3.2.2 – Compact Roundabout.....	65
Figure 3.2.3 – Grade Separated Roundabout.....	66
Figure 3.2.4 – Double Roundabout with Short Central Link.....	67
Figure 3.6.1 – Turning widths for compact and smaller normal roundabouts	76
Figure 3.7.1 – Geometric Design Features at Entry.....	78
Figure 3.7.2 – Average Effective Flare Length	80
Figure 3.7.3 - Entry Angle measurement on large roundabouts.....	81
Figure 3.7.4 - Entry Angle measurement at smaller roundabouts	82
Figure 3.7.5 – Determination of Entry Path Radius.....	84
Figure 3.7.6 – Determination of Entry Path Radius (on a curved approach arm with negative approach curvature).....	84
Figure 3.7.7 – Determination of Entry Path Radius (on a curved approach arm with positive approach curvature).....	85
Figure 3.7.8 – Determination of Entry Path Radius for a roundabout at a Y-junction.....	85
Figure 3.7.9 Typical Single Carriageway Exit	88
Figure 3.8.1 Measurement of Junction Approach Sight Distance on Curved Approach.....	89
Figure 3.8.2 Forward Visibility Required at Entry.....	90
Figure 3.8.3 Visibility to the Left Required at Entry (from “Give Way” Line)	91

Figure 3.8.4 Visibility to the Left Required at Entry 15m back (from “Give Way” Line)	91
Figure 3.8.5 Circulatory Visibility	92
Figure 3.8.6 Visibility Required at Entry, to a pedestrian crossing at next exit	93
Figure 3.9.1 Crossfall Design using 2:1 Ratio Circular Crown Line.	95
Figure 3.9.2 Method of Terminating Edge Strips on Single Carriageway Approach to a Roundabout	96
Figure 3.9.3 Method of Terminating Edge Strips on Dual Carriageway Approach to a Roundabout	97
Figure 3.9.4 Dedicated Approach and Exit for Segregated Right Turn Lane Approach and Exit (Design Speed $\leq 60\text{kph}$).....	101
Figure 3.9.5 Diverge / Merge Layout for Segregated Right Turn Lane with Island < 50m long	102
Figure 3.9.6 Physically Segregated Right Turn Lane with “Give Way” on Exit	102
Figure 3.9.7 Example of Calculation of Entry/Exit Taper Lengths (1.5m wide island less than 50m long, 70kph approach design speed)	104
Figure 3.9.8 Termination of Taper Hatching at Physical Island.....	105
Figure 4.2.1 – 2-level Cyclic Interchange.....	112
Figure 4.2.2 – Full Cloverleaf Interchange	113
Figure 4.2.3 – Half Cloverleaf Interchange.....	113
Figure 4.2.4 – Trumpet Junction	114
Figure 4.2.5 – Diamond Junction.....	114
Figure 4.2.6 – Grade Separated Roundabout	115
Figure 4.2.7 – Single Point Junction (Signal Controlled At-grade element)	115
Figure 4.3.1 – Flow Chart Showing the Intersection / Interchange Design Process	119
Figure 4.4.2 Merging Layout A – Parallel Merge	125
Figure 4.4.3 Merging Layout B – 2 Lane Parallel Merge (refer to clause 4.4.10)	125
Figure 4.4.4 Merging Layout C – Lane Gain.....	126
Figure 4.4.5 Merging Layout D – Lane Gain with Parallel Merge	126
Figure 4.4.6 Merging Layout E – 2 Lane Gain	126
Figure 4.4.7 Diverging Diagram – Design Traffic Flows	128
Figure 4.4.8 Diverging Layout A – Auxiliary Lane Diverge.....	129
Figure 4.4.9 Diverging Layout B – 2 Lane Parallel Diverge	129
Figure 4.4.10 Diverging Layout C – Lane Drop	129
Figure 4.4.11 Diverging Layout D – Lane drop at Parallel Diverge	129
Figure 4.4.12 Diverging Layout E – 2 Lane Drop	130
Figure 4.4.13 Types of Loop	132
Figure 4.4.14 Examples of Loop Combinations	133

Table 4.5.1 – Diverge and merge distances for weaving length calculations	135
Figure 4.5.1 Weaving Length Measurement – Auxiliary Lane Layouts	136
Figure 4.5.2 Weaving Length Measurement – Lane Gain/Lane Drop	136
Figure 4.5.3 Weaving Length Measurement – Lane Gain Only	136
Figure 4.5.4 Weaving Length Measurement – Lane Drop Only	136
Figure 4.5.5 Definition of Distance B at two lane merge	136
Figure 4.5.6 Definition of Distance E at two lane diverge	137
Figure 4.5.7 Weaving Length Diagram for Urban Roads	138
Figure 4.5.8 Terms used in Weaving	139
Figure 4.5.9 Example of link road interchange	140
Figure 4.6.1 Development of Taper at Fork (to be reversed for RHD)	141
Figure 5.1.1 Example of a Small Signal-Controlled T-Junction	147
Figure 5.2.1 Crossroads	150
Figure 5.2.2 Example of a Small Signal-Controlled T-Junction	150
Figure 5.2.3 T-Junction with Dual Carriageway with Median Opening (Signalized Only)	151
Figure 5.3.1 Visibility Requirements on Approach to Intersection	153
Figure 5.3.2 Junction Inter-visibility Zone (without crossings)	153
Figure 5.3.3 Junction Inter-visibility Zone (with crossings) (to be reversed for RHD)	154
Figure 5.3.4 Major Obstruction to Inter-visibility (to be reversed for RHD)	155
Figure 5.3.5 Mitigation of Major Obstruction to Inter-visibility (to be reversed for RHD)	155
Figure 5.3.6 Right Turn Approach Lane (to be reversed for RHD)	156
Figure 5.3.7 Left Turn Approach Lane (to be reversed for RHD)	157
Figure 5.3.8 Ghost Island Layout (to be reversed for RHD)	157
Figure 5.3.9 Stagger Distance and Reservoir Length (to be reversed for RHD)	158
Figure 5.3.10 Lane Continuity Through Junction Inter-visibility Zone (to be reversed for RHD) ...	160
Figure 5.3.11 Examples of Swept Paths (to be reversed for RHD)	161
Figure 5.3.12 Setting Back “Stop” Lines (to be reversed for RHD)	161
Figure 5.3.13 Localised Widening at T Junction (to be reversed for RHD)	162
Figure 5.3.14 Right Turn Slip Lane (without Taper) (to be reversed for RHD)	163
Figure 5.3.15 Right Turn Slip Lane (with Taper) (to be reversed for RHD)	163
Figure 5.3.16 Locating Secondary Signals (to be reversed for RHD)	165
Figure 5.4.1 Pedestrian Refuge (to be reversed for RHD)	167
Figure 5.4.2 Pedestrian Crossing Facilities on Separation Island	168
Figure 5.5.1 Junction Control Area	171
Figure 5.5.2 Example of Large Signalized Roundabout with Partial, Direct Signal Control	173

Figure 5.5.3 Signalized Roundabout with Indirect Signal Control.....	174
Figure 5.5.4 Provision of Additional Offside Approach Lane (to be reversed for RHD)	175
Figure 5.5.5 Provision of Additional Nearside Approach Lane (to be reversed for RHD)	175
Figure 5.5.6 Improvement to Internal Queuing Lanes (to be reversed for RHD)	176

1 Type selection

1.1 Introduction

1.1.1 Selection Criteria

Junctions are a critical element of the highway transport system. The highest level of delay, collisions and vehicle emissions are generally concentrated at junction locations and it is therefore vital that appropriate junction strategy and selection is implemented in the design.

A junction's key purpose is to enable the safe and efficient transfer of traffic streams through the junction from one link to another. The selection of the most appropriate junction type requires consideration of a number of factors, the most significant including road classification, traffic flows and capacities and safety. It is essential when selecting junction types that the numerous factors are addressed in the decision making process.

Key considerations in the design of road junctions are that:

- The majority of serious injury road accidents occur at junctions;
- The capacity of the road network largely depends on the capacity of the junctions, particularly in urban areas;
- Conflict between pedestrians and vehicles are greatest at junctions.

Junctions may be between roads of similar functional classification, or roads of varying functional classification. Junctions between varying functional classifications must be given particular consideration to ensure that the interface is appropriate. An example would be a Local Access linking to a Freeway that would be inappropriate due to the excessive variation in traffic flows, traffic speeds and purpose. Information on appropriate connections within the highway network is provided in Part 1 – Highway Strategy and Route Classifications.

1.1.2 Design Objectives

The design objectives for junctions should be to achieve the following:

- Safe passage with minimization of accident incidence and severity;
- Minimized congestion and delay;
- Minimized fuel consumption, air pollution and noise.

Collision risk should be minimized and the design should attempt to reduce the severity of accidents as far as practical.

Safe and convenient passage for non-motorised users is necessary, especially in urban situations.

Capacity should be adequate for the situation, designed to accommodate the necessary level of traffic with a view to achieving compatibility with the overall delays and levels of service on approach roads, particularly the mainline approaches. Relatively small delays at junctions can accumulate over relatively short periods of time to significant levels in economic terms, particularly for heavily used urban situations. Care must therefore be exercised when assessing what would be an acceptable delay at a particular junction location.

The nature of traffic flow through junctions, with increased stopping and starting, makes these locations important in assessing fuel consumption, associated air pollution and noise nuisance. Again, this is of particular significance at highly trafficked urban locations.

For large junctions where capital expenditure is high, an economic appraisal may be necessary to demonstrate that the capital costs of the scheme are justified by the economic benefits derived.

1.2 Junction Selection

1.2.1 Junction types

Various junction types are available for use at intersecting roads. The basic junction forms to be considered include the following:

- Priority intersection – A priority intersection is an at-grade junction where the minor road terminates at the major road. Traffic control may be controlled by “Give Way” or “Stop” signs and markings. Priority intersections may take various layout forms, depending on the number of links and their configuration. These are further discussed in Section 5.
- Roundabouts – A roundabout is an at-grade intersection incorporating a circulatory carriageway around a central island located at the intersection. Roundabouts provide higher capacity than priority intersections by reducing conflicts between opposing flows. Roundabouts are further discussed in Section 6.
- Grade-separated interchanges – This junction type removes the principal vehicle conflict by the provision of grade separation between the intersecting roads, and is suitable for higher vehicle flows. The intersecting roads are joined by connector roads, which merge and diverge from the principal routes through parallel lanes and tapers. Grade separated interchanges are further discussed in Section 7.
- Signal-controlled junctions – Traffic signal control may be applied to various forms of junctions. Signal control is most commonly applied to standard at-grade intersections but may also be incorporated within roundabouts and grade separated interchanges. Signal control is further discussed in Section 8.

In addition to the standard junction types defined for intersecting roads, other facilities may be provided, including pedestrian crossings and median gaps for U-turns. While these do not offer alternative road intersection options, they must be considered in similar terms to assess safety and potential delay.

1.2.2 Aspects affecting provision

In selecting the most appropriate junction type for a particular location, the designer is required to consider a wide range of aspects which will affect the decision making process. Figure 1.2.1 outlines the typical process and range of aspects to be addressed in determining the junction selection.

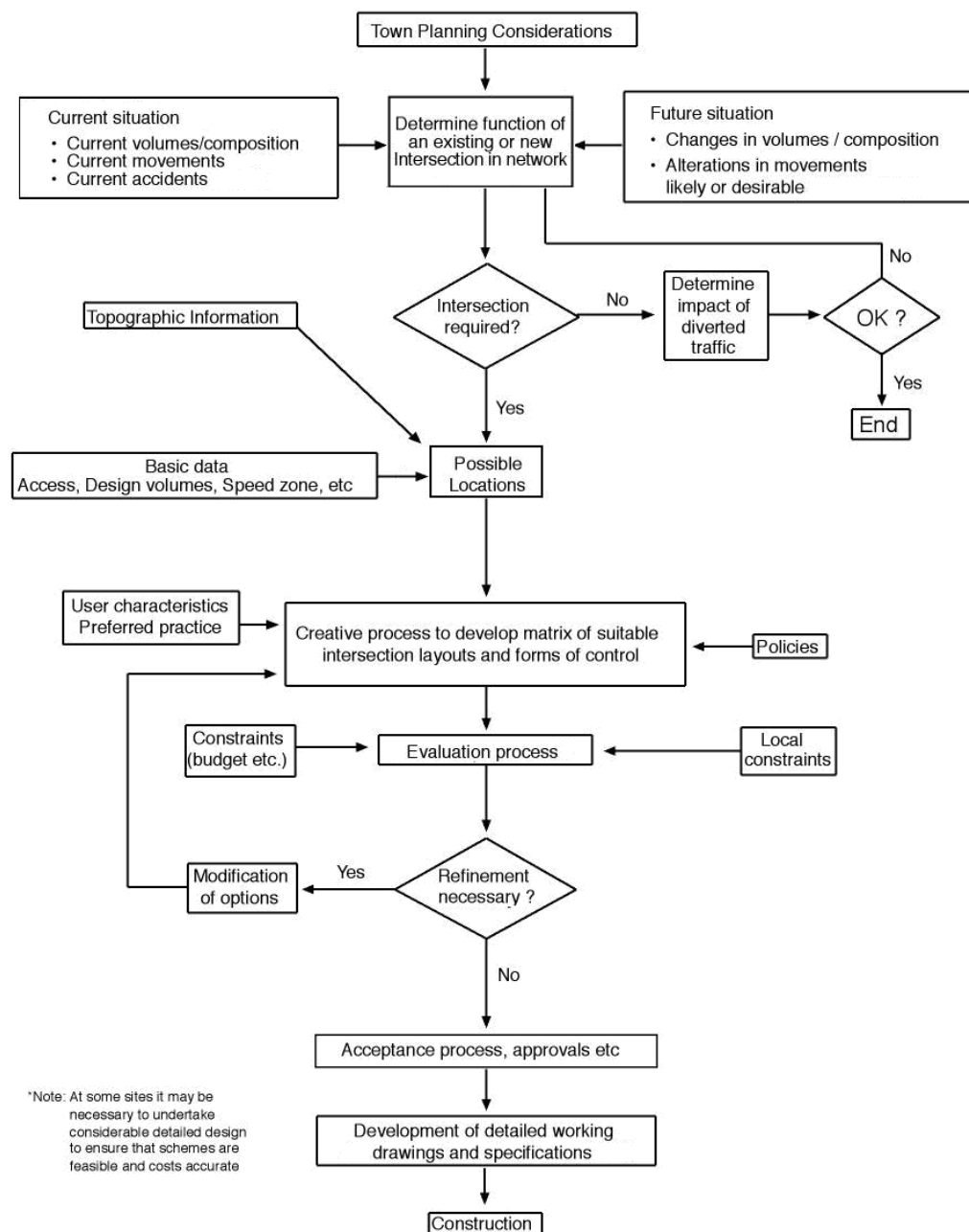


Figure 1.2.1 Process in determining junction selection

The designer is required to identify the function of the junction and the status of each link which forms a part of it. The following should be determined:

- the function of each leg;
- conflict points with non-motorised transport modes;
- whether each leg should be incorporated within the junction.

In doing so, the network consequences on motor vehicles, pedestrians, cyclists, public transport and freight should be examined, to assess the impact of:

- not providing an intersection;
- deleting an intersection leg;
- banning a motor traffic movement;
- not providing for or allowing a pedestrian, cyclist or public transport movement.

The output from this step is a series of decisions about:

- which movements or legs should form the intersection (if any);
- the function of each leg in the road hierarchy;
- the movements which should have priority.

With the composition of the intersection defined and the function of each leg clarified, the current situation must be quantified at the likely site(s). Basic data that should be collected includes:

- topography at the site(s);
- land use, access points to properties and special site constraints (e.g. the location of public utilities, awnings and balconies, trees, monuments, property boundaries, buildings, and drainage structures including pipes);
- compilation and analysis of crash data for the most recent five-year period (for example);
- the current traffic (including bicyclists and pedestrians);
- special network functions existing, or proposed, such as freight routes and bus routes;
- values of economic factors (e.g. operating and delay costs, rates for construction and maintenance work;
- property values, utility adjustment costs) to be used in the analysis stage;
- budget limits;
- special constraints (e.g. political commitments, flood levels).

1.2.3 Traffic flow and Capacity

A critical factor in junction selection is the traffic flow and the predicted future traffic demand. Before any detailed evaluation can be made it is important to obtain the best estimate of all the relevant traffic flows and turning movements for the junction.

In situations where this data is not readily available it will be necessary to undertake traffic surveys, or use traffic modelling to predict the likely traffic flow levels.

The composition and turning movements of traffic will influence the geometric layout adopted. Predicted future traffic flows are required to:

- Enable the design to be tailored to provide sufficient capacity to meet the future traffic flow demands;
- Enable a decision to be made to constrain the traffic flows at the given location for a particular reason;
- Identify the need to allow for current or future junctions.

For the road network to operate efficiently, new junctions must have sufficient capacity to accommodate this design flow. It is not possible to ensure at the time of design that a new junction has sufficient capacity indefinitely. Instead, new and improved junctions shall be designed on traffic levels predicted to occur in the Design Year, typically 20 years after the opening of the schemes, to ensure that they are free of congestion for a reasonable period.

Predicted traffic flows shall be based on the existing, observed traffic flows factored up to model the Design Year flows. All intersections and interchanges shall be designed using the peak hour flows. The use of peak hour flows will model the worst case for traffic congestion. Of particular importance to junction design is the volume of traffic undertaking each turning manoeuvre. All predicted traffic volumes and turning volumes for the Design Year shall be agreed with the Roads Authority.

The form that a junction takes is greatly influenced by the volume of traffic predicted to pass through it. All junction layouts will need to be analysed to ensure they have sufficient capacity. This analysis should be carried out using an approved standard software package (e.g. ARCADY for roundabouts, PICADY for priority intersections, VISUM for traffic control and wider network modelling).

Figure 1.2.1 illustrates broadly the typical level of flows of major and minor road traffic that can be handled by particular types of junctions. This is a generalized figure, which is a reasonable first guide as to the type of junction which should be planned. Specific site circumstances, however, will have a significant influence on junction selection, and the design must be consistent with local circumstances and the functional classifications of the roads within the junction.

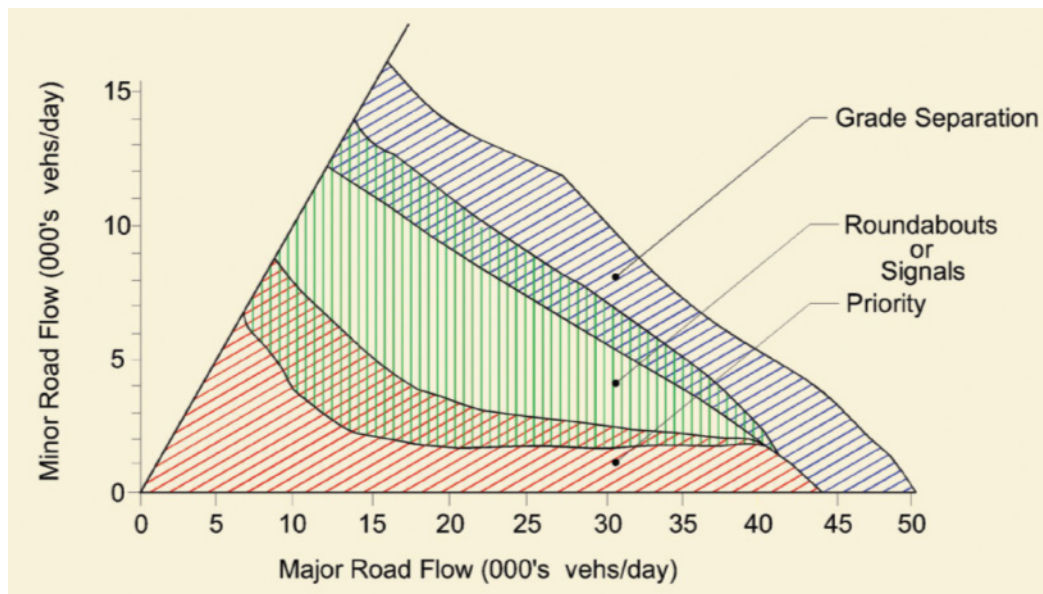


Figure 1.2.2 Junction types suitable for varying major and minor road flows

1.2.4 Network Connections

To ensure appropriate junction provision within the highway network it is essential that connections provided between varying functional classifications are appropriate. Recommended connections between the functional classifications are identified in Part 1 – Highway Strategy and Route Classifications.

Junction types between varying functional classifications should be considered in accordance with the key characteristics guidance provided in Part 1 – Highway Strategy and Route Classifications. However it is essential that the designer also considers such factors as capacity, safety and land availability in assessing the most suitable junction type at each location.

1.2.5 Junction Spacing

Junction spacing is primarily determined by a road's functional classification within the road hierarchy, the proportion of through traffic (non local) which it is intended to carry, and the nature and frequency of intersecting roads.

Should the number and importance of existing cross routes necessitate multiple, closely spaced junctions, consideration should be given to combining roads before they meet the main road in order to meet with the minimum requirements expressed in Part 1, providing benefits in relation to road safety and main road capacity.

Junctions should be spaced at regular intervals, where possible, so that driver expectation is reinforced and they are associated with a particular class of road.

Where weaving is required between junctions on multi-lane roads, adequate spacing must be provided to accommodate these manoeuvres. Requirements for weaving provision are detailed in Section 4.3

1.3 Design Principles

1.3.1 General Principles

The selection and design of junctions should be in line with key principles to address the following:

- Geometric and operational requirements of vehicular traffic;
- Safety;
- Provision for non-motorised users.

It is essential that junction layouts and control measures are considered along the length of routes, to ensure that a consistent strategy is adopted. On lengths of road under design, use of a mixture of junction types and control treatments is likely to create uncertainty for drivers and therefore increase the risk of collisions. Similarly for pedestrians, consistent treatment helps the user to understand and therefore use the system appropriately.

The provision of junctions must be consistent with the capacity and service provided by the associated route. This may result in a higher standard of junction being provided than is strictly necessary to accommodate predicted traffic flows.

Where a junction is to be part of an area wide traffic control system, or is likely to form part of a future system, due allowance must be made in the preliminary stages of the design process.

1.3.2 Geometric Requirements

Layouts for junctions should be designed to provide the heaviest traffic flows with the easiest and shortest paths. The introduction of sharp turns, or complex paths which include several changes of direction should be avoided wherever possible. Drivers should know what to expect in respect of traffic/traffic and non motorised user/traffic

conflicts when entering a junction having recognized its layout and taken adequate note of approach signing.

A significant aspect of the design of junctions is the type of vehicle that will be using the junction. Different sizes and classes of vehicle have varying swept paths and turning circles. All junctions need to be designed to allow the vehicle with the greatest swept path that will regularly use the junction to turn in a safe and easy manner. Typically the design vehicle shall be a 16.5m articulated vehicle, but designers should assess requirements at each junction location. Swept paths should be checked using a computer software package.

The vehicle classification to be used in Qatar is shown in Table 1.3.1. Failure to make adequate provision is likely to result in:

- A reduction in the junction capacity as the larger vehicles are forced to straddle two traffic lanes to facilitate the turning movement at the junction;
- Overrunning of kerbs;
- Reduced visibility for other traffic approaching or negotiating the junction.

These design principles should be extended to the positioning of street furniture such as signs, splitter islands, traffic signals and lighting columns.

Draft. For June 2013 Stakeholder
Workshop use only

Table 1.3.1 – Vehicle Classification (Sheet 1 of 2)

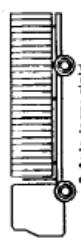
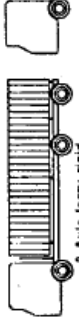
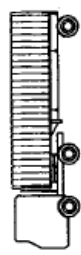
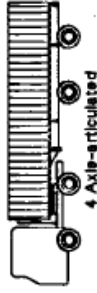
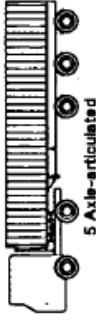
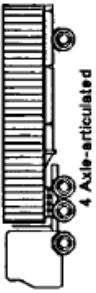
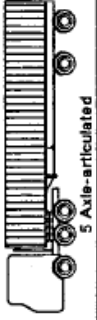
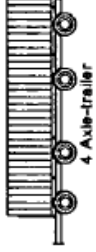
Vehicle Type	Class	Vehicle Dimensions				Turning Width between kerbs (180°) (m)	No. of Axles	Average No. of Standard Axles	Wheels (on each side of the vehicle)
		Weight (kg)	Length (m)	Width (m)	Height (m)				
Cars etc	 Saloon car	1800	4.5	1.7	1.5	5	2	-	1+1
	 4w-drive	2500	5	1.9	2				
	 Pick-up van	2600	5	1.9	2				
	 Taxi	1800	4.5	1.7	1.5	5	2	-	1+1
Buses/Coaches	 Mini-bus	5900	7	2	2.6	15	2	0.2-0.5	1+1 or 1+2
	 Bus/coach	16500	12	2.5	3	24	2	1.3-5.0	1+2
Medium goods vehicle	 Pick-up lorry	7500	8.5	2.5	3.2	15	2	0.5-7.0	1+1 or 1+2
Heavy goods vehicles	 2 Axle lorry-rigid	18000	12	2.6	4.1	24	2	0.5-7.0	1+2
	 3 Axle lorry-rigid	24000	12	2.6	4.1	24	3	1.5-4.0	1+2+2
	 3 Axle-articulated	30000	16.5	2.6	4.1	16	3	0.6-10.0	1+2+2

Table 1.3.1 – Vehicle Classification (Sheet 2 of 2)

Vehicle Type	Class	Vehicle Dimensions				Turning Width between kerbs (180°) (m)	No. of Axles	Average No. of Standard Axles	Wheels (on each side of the vehicle)
		Weight (kg)	Length (m)	Width (m)	Height (m)				
 4 Axle-articulated	9	36000	16.5	2.6	4.1	16	4	1.5-7.0	1+2+22
 5 Axle-articulated	10	43500	16.5	2.6	4.1	16	5	2.5-7.0	1+2+222
 4 Axle-articulated	11	36000	16.5	2.6	4.1	16	4	1.5-7.0	1+22+2
 5 Axle-articulated	12	42000	16.5	2.6	4.1	16	5	2.0-7.0	1+22+22
 6 Axle-articulated	13	49500	16.5	2.6	4.1	16	6	1.5-7.0	1+22+222
 3 Axle-trailer	14	30000	9	2.6	4.1	20	3	2.0-7.0	+2+22
 4 Axle-trailer	15	36000	9	2.6	4.1	20	4	2.0-10.0	+22+22
 Motor-bicycle	16	1000	2.3	0.6	1.8 (INCL rider)	-	-	-	-

It is critical that all road users have adequate visibility at junctions, including non-motorised users. This is to ensure that conflicting traffic movements can be seen in

sufficient time so that appropriate action can be taken to avoid collisions. This principle applies to all junctions irrespective of size or type.

Junction location should be restricted to locations where adequate visibility is provided. Sites that should be avoided include:

- Where the major road is on a sharp curve and visibility may be impaired by waiting vehicles;
- At the top or bottom of gradients greater than 4% on the main road;
- Where junction frequency is excessive.

Speed differentials between mainline traffic and turning (merging and diverging) traffic are undesirable. These may be reduced by providing merge or diverge lanes with tapered entrance/exits.

The design of road signing and road marking is an integral part of the design process for junctions and should receive serious attention to ensure that they fulfil their role effectively. Layouts should be checked to see that they can be adequately signed without ambiguity, that clear advance signing is provided and that signing does not affect junction visibility in anyway.

1.3.3 Safety

Safety considerations should remain as the core element for all junction design. Critical factors in the realization of a reduction in occurrence and severity of accidents at junctions are:

- Appropriate geometric standards for the anticipated speed of vehicles through the junction;
- Control of vehicle speeds through the junction;
- The presence of unobstructed visibility on all approaches to the junction;
- Appropriate geometric standards for the typical design vehicle, and
- Integration of the traffic information and control systems within the junction.

Whilst there remains flexibility in the planning process to design junctions appropriate to specific conditions, the following general recommendations hold:

- From a safety perspective, it is not recommended that traffic signals are used on high speed roads (where the posted speed on the approach roads exceeds 100kph);
- Similarly, it is not recommended that at-grade roundabouts are used on high speed roads (posted speeds greater than 100kph). An exception to this case would be the terminal points for high speed roads where roundabouts are a safe provision and particularly useful to introduce a change in road hierarchy or route classification.

1.3.4 Non-motorised users

Pedestrians and other non-motorised user's facilities at junctions should receive careful consideration from the earliest stage of design, especially for urban and semi-urban areas. This is covered further in Section 10.

Draft. For June 2013 stakeholder
workshop use only

2 Priority intersections

2.1 Introduction

2.1.1 Priority Intersections General

Priority intersections are the most frequent form of junction type and function by traffic on the minor roads giving way to traffic on the major road. Control is mandated by the provision of either a “Give Way” sign or a “Stop” sign with corresponding road markings as necessary.

All major/minor priority intersections have the advantage that major road traffic is not delayed; however care must be taken to ensure that very high speeds and overtaking manoeuvres are not encouraged in the area of the intersection, and that intersection design, particularly where traffic predictions are uncertain, should allow flexibility for efficient upgrading in the future.

The guidance contained in the Transportation Master Plan for Qatar must be considered in assessing the appropriate use of major/minor priority intersections within the Qatar roads hierarchy.

2.1.2 Siting of Priority Intersections

Priority intersections are areas of high conflict, and consequently have a relatively high level of vehicle and pedestrian accidents, particularly in the urban environment. These accidents are often associated with poorly judged left turn movements onto and from the major road and with incautious overtaking manoeuvres. Safety and location are therefore key considerations in the design of major/minor priority intersections.

On new single carriageways where overtaking opportunity is limited, major/minor priority intersections must not be sited on sections which provide overtaking opportunity

Incorporation of ghost islands and single lane dualling sections can reduce the level of conflict and improve safety and operational performance. However on existing single carriageway roads where overtaking opportunity is very limited, the isolated local improvement of an intersection to a ghost island could induce unsafe driver behaviour, since the short length of wider road thus created may be used by some frustrated drivers for overtaking.

Measures that have been found to reduce the number of such manoeuvres at existing ghost island or single lane dualling intersections include:

- The application of diagonal hatched road markings in the hardstrips at an existing single lane dualling intersection, which gives a more confined impression to approaching drivers;
- The use of double yellow lines along the hatching boundary at ghost island intersections.

Measures such as reduced speed limits, alignment constraints, additional signing and road markings can help to minimise the potential hazards to the driver.

A saving in accidents may be achieved, and an improvement made in operational performance, by reducing the number of lightly trafficked minor road connections to major roads. The feasibility of connecting such routes together with a link road before they join a new major road should always be investigated.

Horizontal Alignment

Ideally, major/minor priority intersections should not be sited where the major road is on a sharp curve. However, where the siting of a major/minor priority intersection on a curve is unavoidable, the preferred alignment is where T-junctions are sited with the minor road on the outside of the curve. This is especially important for intersections where multiple lanes are approaching on the major road, to ensure that minor road traffic has a clear view of vehicles on the major road that may be overtaking through the intersection. Intersections on the inside of sharp curves are not recommended.

Problems have been experienced with major/minor priority intersections containing a skewed minor road where the alignment is such that some drivers may perceive that the minor road retains priority. In such circumstances, the minor road approach should be aligned so as to join the major road as near to right angles as possible in order to eliminate any driver confusion as to which route has priority.

Vertical Alignment

The best locations for intersections are on level ground, or where the gradient of the approaches does not exceed 2% either uphill or downhill. Downhill approaches in excess of this figure, particularly on high speed roads, can induce traffic speeds above those desirable through the intersection, and lead to a misjudgement of the approach speed by drivers entering from the minor road. Uphill approaches are also undesirable as it is difficult for drivers to appreciate the layout of a intersection when they are approaching it on an up gradient.

Minor road approach gradients in the immediate vicinity of the intersection must be limited to ensure safe entry and exit to and from the major road.

2.2 Priority Intersection Types

2.2.1 Simple Intersection

A simple intersection is without any ghost or physical islands in the major road, and without channelizing islands in the minor road approach.

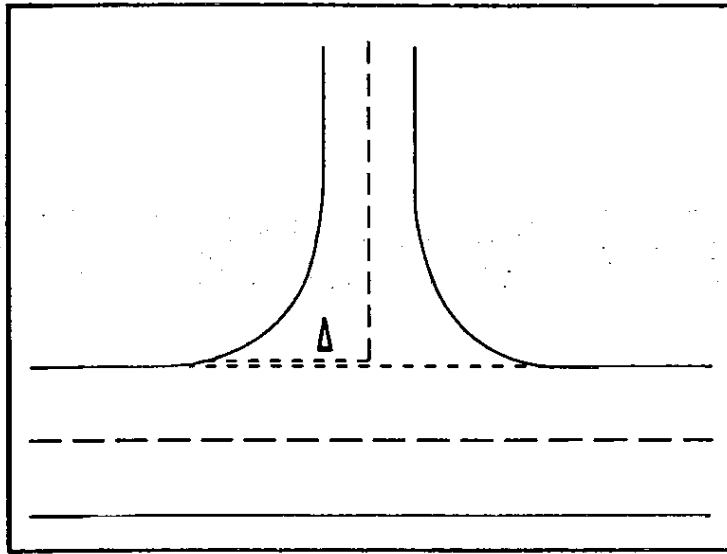


Figure 2.2.1 Simple Intersection

Simple intersections are appropriate for most minor intersections on single carriageway roads, but not dual carriageways. For new rural intersections, they should only be used when the design flow on the minor road does not exceed 300 vehicles AADT (two-way) and on the major road does not exceed 13000 vehicles AADT (two-way).

At existing rural and urban intersections upgrading to a right turning facility, ghost island or single lane dualling should be considered when safety considerations dictate or where the minor road flow exceeds 500 vehicles AADT (two-way).

2.2.2 Ghost Island Intersections

A ghost island intersection incorporates widening on the major road to accommodate a ghost island and an extra central lane for turning traffic. The minor road approach should also have a channelizing island to direct vehicles to the correct position for turning movements. Refer to Figure 2.2.2.

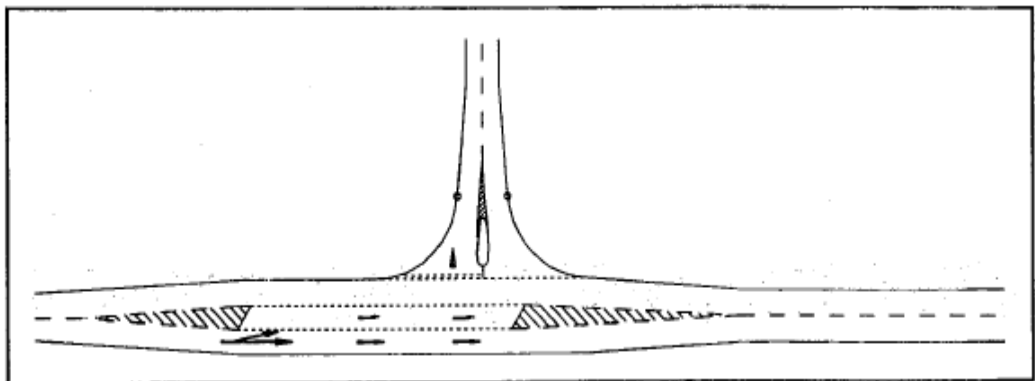


Figure 2.2.2 Ghost island intersection

Ghost islands will enhance safety of the intersection by giving shelter to left turning traffic from opposing vehicles and vehicles approaching from behind. Measures to discourage overtaking at ghost island widening may include the use of physical traffic islands, double yellow lines and ceramic studs.

Ghost islands should not be positioned where overtaking opportunity is restricted either side of the intersection because drivers may use the wide ghost island hatching and central lane as a place to overtake. In such situations alternative layouts such as single lane dualling should be considered.

Ghost island intersections should not be used where traffic turning left out of the minor road is required to make the manoeuvre in two stages. This can typically occur when the major road flow exceeds 18000 AADT (two-way).

2.2.3 Single Lane Dualling

Single lane dualling (physical islands) can be used on rural single carriageway roads to shelter left turning traffic on the major road and prevent overtaking. It can also be used where the traffic turning left out of the minor road needs to make the manoeuvre in two stages. Refer to Figure 2.2.3.

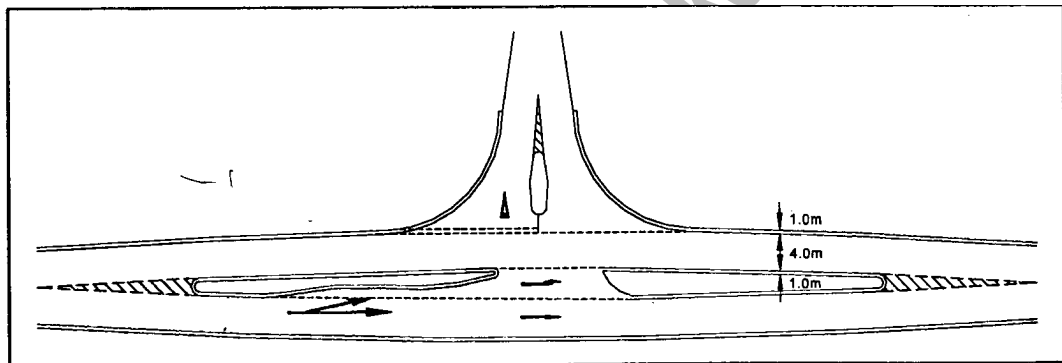


Figure 2.2.3 Single lane dualling

The improved highway layout through a single lane dualling section may introduce a tendency for drivers on the major route to speed up through the intersection where slow vehicles may be crossing. Care therefore needs to be taken when siting the intersection.

The single lane dualling carriageway width is 6m, where 4m is the running carriageway and there are 1m hardstrips on both sides. Where these values are not provided this shall be considered a Departure from Standards. Some drivers may try to overtake in this width and hatching of the hardstrips will discourage such manoeuvres.

There may be certain conditions when single lane dualling could be misinterpreted by drivers:

- Where a length of road contains alternating single and dual carriageway sections

- Where single lane dualling is proposed within 3 kilometres from the end of a long length of dual carriageway.

In these cases, other forms of junctions should be considered.

2.2.4 Dual Carriageway Intersections

On dual carriageways, major/minor priority intersections are only permitted where the left turn manoeuvre from the minor road is prevented by the median (refer to Figure 2.2.4), unless the minor road warrants signalization to be incorporated (refer to Section 8). A median opening on a dual carriageway intersection which is not signalized shall be considered a Departure from Standards.

Acceleration and deceleration lanes to and from the minor road should be designed in accordance with through traffic volumes and speeds.

Where priority intersections with carriageway separation are provided, turning facilities to accommodate other manoeuvres should be provided nearby at another junction. The nearby junction may be a grade separated, roundabout or signalized intersection.

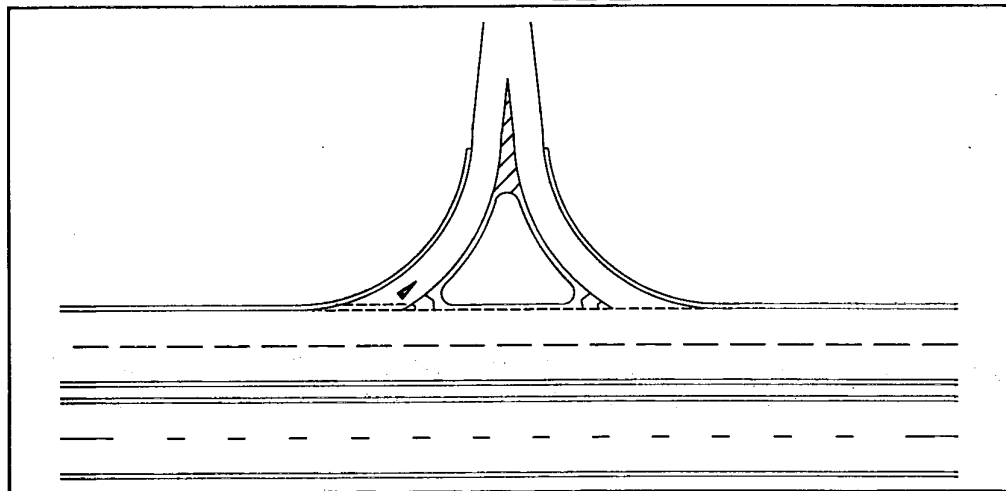


Figure 2.2.4 Dual Carriageway T-junction with Carriageway Separation

At-grade intersections incorporating left-turning facilities may be permitted on dual carriageways where traffic signals are incorporated (refer to Section 5). In such cases the median may be widened to provide space for a left turn lane.

2.3 Priority Intersection Configurations

2.3.1 T-junction

A T-junction is the simplest form of priority intersection, occurring where a single minor road gives way to the major road, intersecting at an approximate right angle.

2.3.2 Crossroads

Crossroads comprise two minor roads intersecting on either side of the major road. The minor roads are positioned facing each other. Refer to Figure 2.3.1.

Simple crossroads are not recommended due to the degree of conflict that they create at a single location. Staggered junctions are considered a safer alternative, especially if a significant proportion of the flow on the minor roads is cross movement. In residential areas, consideration should be given to closing off one of the arms of the crossroads to create a preferred simple T-Junction. Where a simple crossroads is provided at new priority intersection (not signalized) this shall be considered a Departure from Standards.

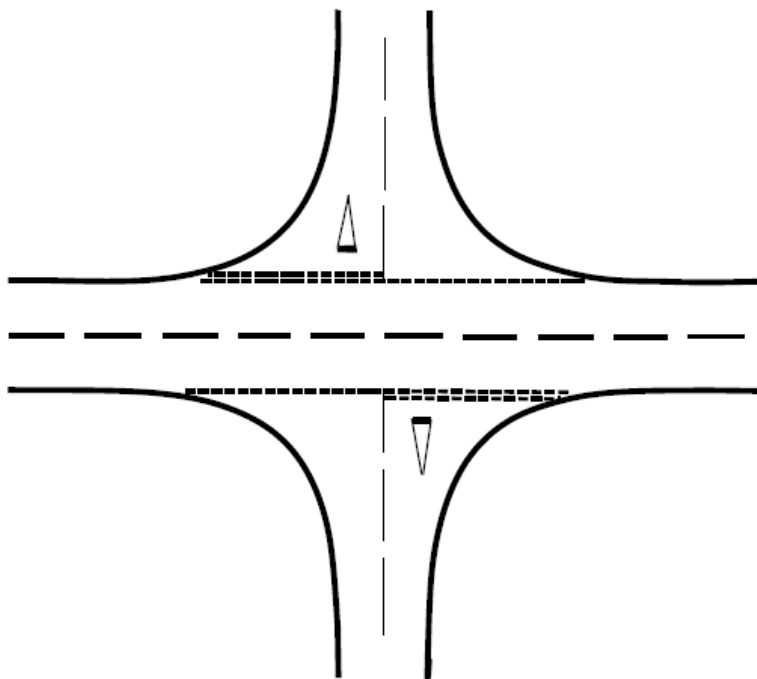


Figure 2.3.1 Crossroads

2.3.3 Staggered Junction

A staggered junction comprises a major road passing through the intersection with opposed T-Junctions on either side.

The left/right stagger is preferred because the two left turning traffic streams on the major road do not overlap, and the right turning traffic from the minor roads does not mix with the turning traffic on the major road. Refer to Figures 2.3.2 to 2.3.4.

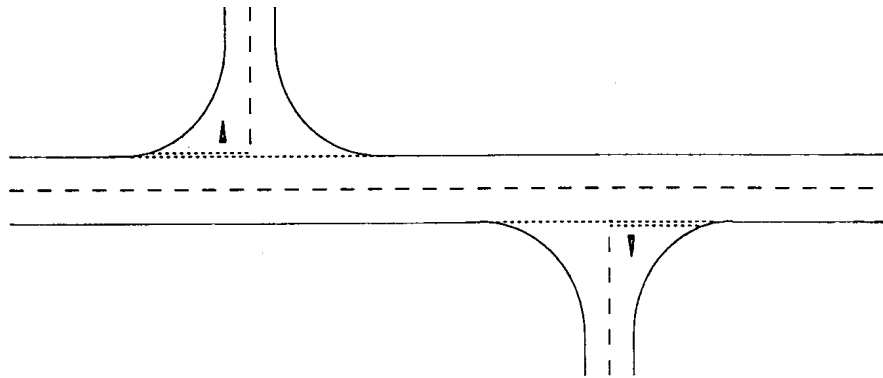


Figure 2.3.2 Simple Left/Right Staggered Junction

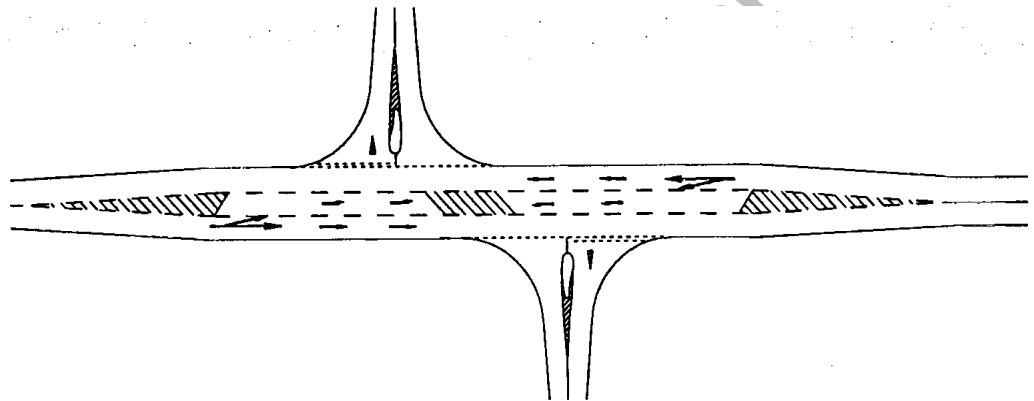


Figure 2.3.3 Left/Right Staggered Junction with Ghost Island

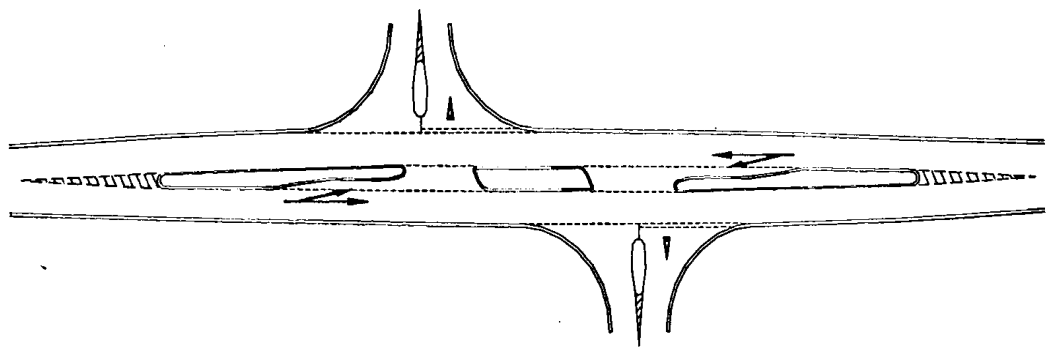


Figure 2.3.4 Left/Right Staggered Junction with Single Lane Dualling

A right/left staggered junction should not be considered at simple intersections, and shall be considered a Departure from Standards. However, the right/left staggered junction with ghost island or single lane dualling is a permitted alternative. Refer to Figure 2.3.5 and Figure 2.3.6.

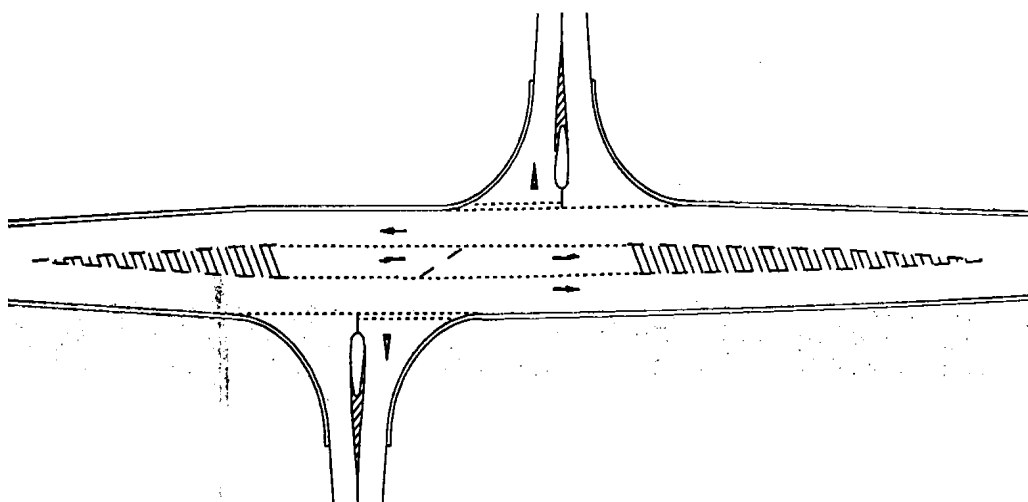


Figure 2.3.5 Right/Left Staggered Junction with Ghost Island

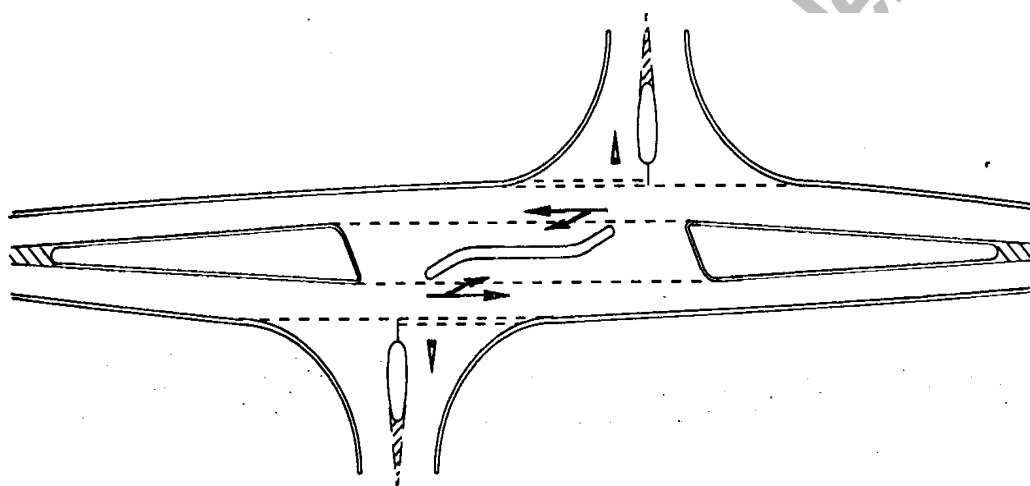


Figure 2.3.6 Right/Left Staggered Junction with Single Lane Dualling

2.3.4 Skew Junction

Figure 2.3.7 illustrates a left hand skew junction with a ghost island. The intersection could also be right handed.

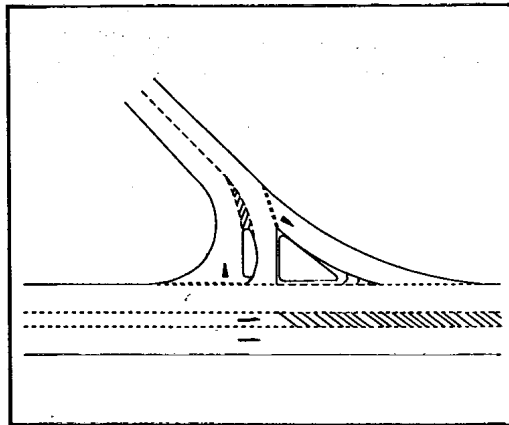


Figure 2.3.7 Simple Left-hand skew junction

This form of intersection can be a solution when an existing minor road joins the major road at a skew angle. It is sometimes called a Y-Junction.

The existing intersection is improved on safety grounds by channelizing the minor road with islands and road markings, and connecting it to the major road at right angles for optimum visibility.

Skew junction treatments may be incorporated within the other intersection configurations and layouts identified.

2.4 Design Procedure

2.4.1 Intersection design procedure

Intersection design is a key element of the overall design process for road schemes. The flow chart shown in Fig 2.4.1 outlines the design process for major/minor priority intersections in a series of interrelated design steps.

The most appropriate type of major/minor priority intersection to be used can be chosen from those described. This decision should be based on a wide range of factors, taking into account design year traffic flow, the nature and proportions of large goods and passenger carrying vehicles, geometric and traffic delays, an initial estimate of entry and turning stream capacities, and accident costs. It should also be based on a consideration of the particular site characteristics such as development and topography.

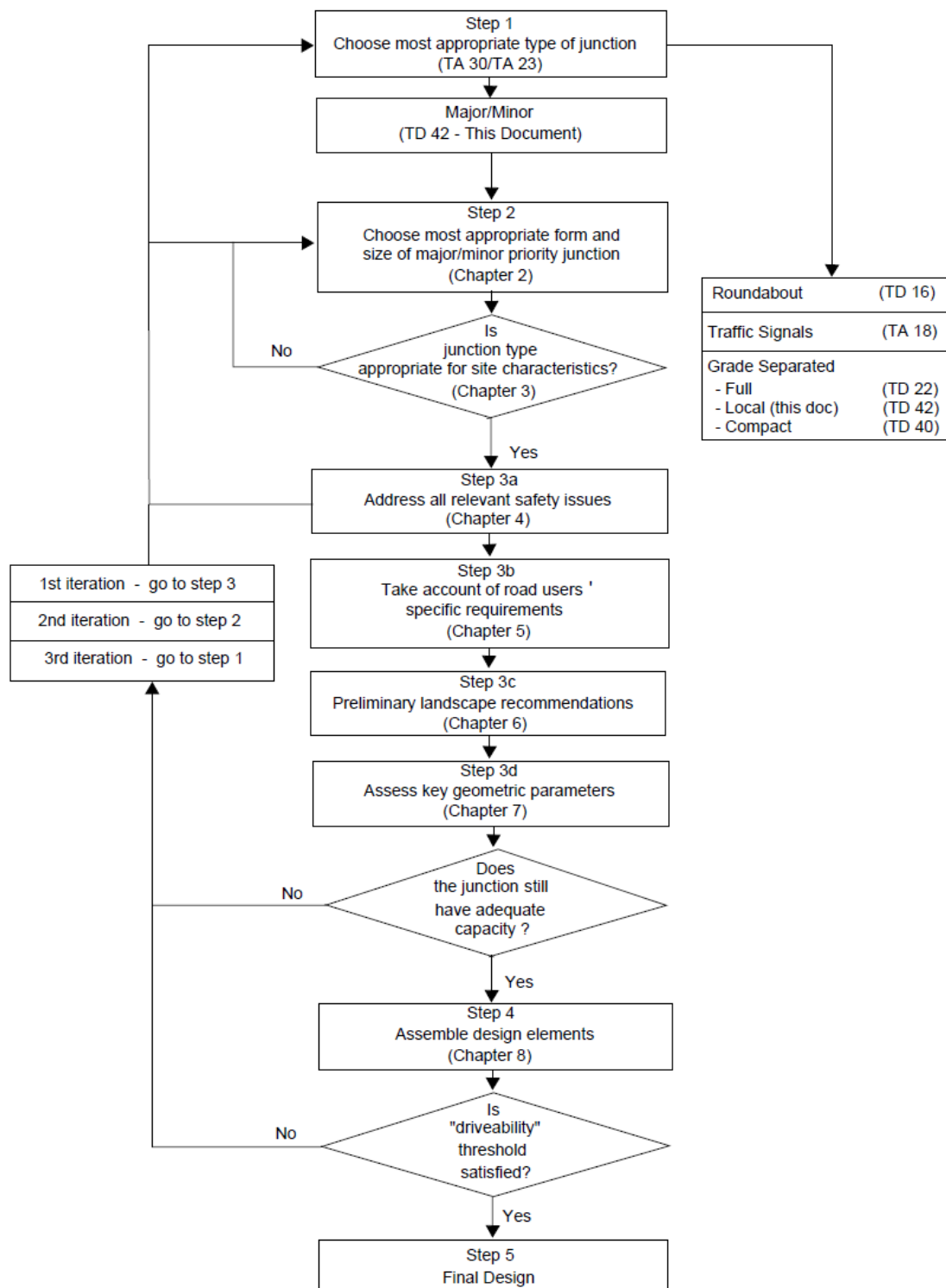


Figure 2.4.1 Flow chart outlining design procedure

The next step is to address all of the relevant safety issues to ensure as safe a design as possible, to take account of road users' specific requirements and to incorporate a preliminary landscape design within the intersection. At this point, the key geometric parameters of the intersection design should be assessed.

Having established the various components of the intersection design, the Designer should check that the capacity of the junction is still adequate. This includes a check if the intersection is located on a route which might experience a wide variation in flow and turning movements, particularly those having prolonged daily peak periods, over a day, week, or year. The check should be undertaken prior to assembling the component parts to form a complete intersection.

Before proceeding to final design, a "driveability" check should then be performed, to assess first the smooth assembly of the components of the intersection design. This should include a visual assessment of the intersection on all approaches from the driver's eye view. Secondly, the intersection should be considered within the context of its adjacent links and those adjacent junctions on the particular route. As a whole, the layout should be designed to suit the traffic pattern, with the principal movements following smooth vehicular paths. This improves the smoothness of operation and makes it more readily understood by drivers.

If, at any point in the design procedure, the intersection design is unsatisfactory, then the designer should return to the previous step in the procedure to refine the design. In certain extreme cases, this process could result in a change in junction type or form.

2.4.2 Choice of major/minor priority intersection

Figure 2.4.2 may be useful when considering further the options for a site. For single carriageway roads it shows approximately the various levels of T-junction which may be applicable for different combinations of flows. The information takes into account geometric and traffic delays, entry and turning traffic flows, and accident costs. However, it must be noted that Figure 5.4.2 gives the starting point for junction choice and other factors must be considered before a final decision is made.

In situations where the minor road is dual carriageway the designer shall consider alternative junction layouts, as priority intersections are unlikely to be the most appropriate solution.

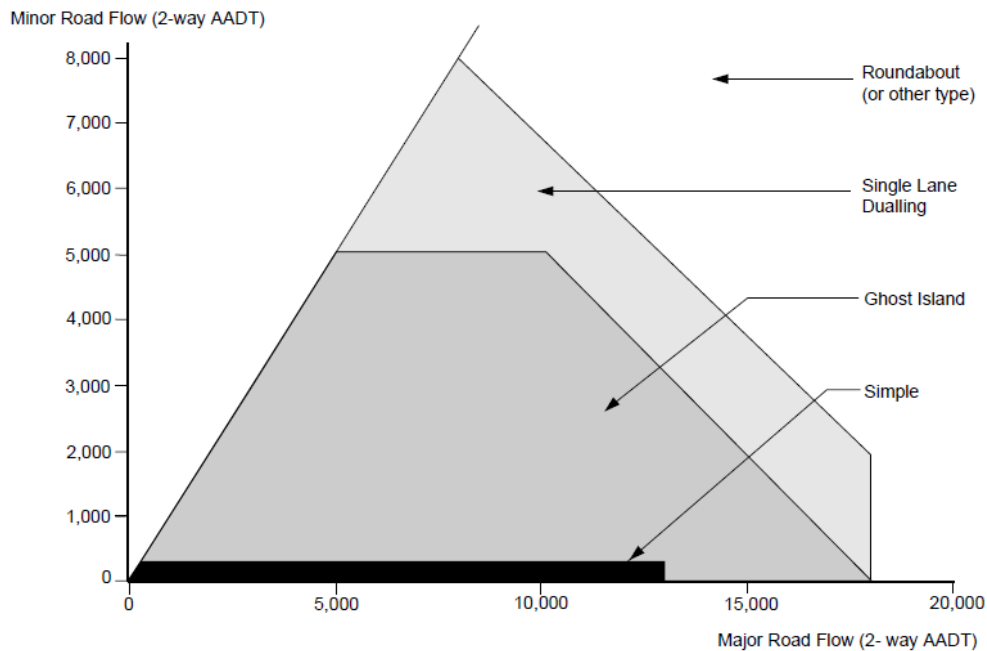


Figure 2.4.2 Approximate level of T-junction provision for varying traffic flows

2.5 Design Elements

2.5.1 General

This section outlines the geometric design elements to be considered in the design of priority intersections. Many of the elements are dealt with separately, and the designer should work systematically through the design procedure prior to assembling the component parts. This is an iterative process, and it may be necessary to alter part of the junction design covered previously in order to achieve a satisfactory solution.

Intersections are recognised as key areas of conflict and as a result a large proportion of collisions occur at intersections. To address this situation it is essential that adequate sight distance is provided on the immediate approaches to intersections.

For the purposes of this Standard the immediate approaches to a major/minor priority intersection shall be:

- For intersections without diverge and merge auxiliary lane, those lengths of carriageway on the minor roads between a point 1.5 times the minor road Minimum Stopping Sight Distance upstream of the “Give Way” or “Stop” line and the “Give Way” or “Stop” line itself, and those lengths of carriageway on the mainline between a point 1.5 times the major road Minimum Stopping Sight Distance from the centre line of the minor road and the centre line itself.

- Where diverging auxiliary lanes (or tapers) are included on the major road, as per priority intersections above, but to include that length of major road carriageway from a point 1.5 times the Minimum Stopping Sight Distance upstream of the start of the diverge taper.
- Where merging auxiliary lanes (or tapers) are included on the major road, as per priority intersections above, but to include that length of major road carriageway to the end of the merge taper.

2.5.2 Design Speed

Geometric standards for intersections are related to the traffic speed of the major road, and for new roads this is the design speed as defined in Section 2. Reference should be made to Section 2 in order to determine the appropriate design speed.

2.5.3 Gradient

Minor road gradients immediately in advance of the "Give Way" or "Stop" line, should be limited. This zone of limited gradient shall be within 15m of the "Give Way" or "Stop" line, but may be reduced to 10m in residential areas. Approach gradients within this zone shall be limited to a maximum of 3%. Gradients exceeding 3% within this zone shall be considered as Departures from Standards..

2.5.4 Visibility

Clear visibility on the approach to, at and travelling through an intersection is essential for the safe and efficient use of that intersection.

In determining the correct visibility requirements for an intersection, the designer must consider both the layout of the intersection and the vehicles that will use it. The visibility and inter-visibility requirements provided within this Section are related to the design speed of the major road and little benefit is to be gained by increasing them. However, each intersection must be considered on a site-specific basis with an assessment made of additional visibility to be provided due to factors such as:

- Width of major road to be crossed
- Traffic control on the minor approach road
- Turning movements to be made at the intersection
- Gradient of the approaches and departures

As well as having adverse safety implications, poor visibility reduces the capacity of turning movements.

These visibility standards apply to new intersections and to improvements to existing intersections.

Drivers approaching a priority intersection from both the major road and the minor road shall have unobstructed visibility in accordance with the following clauses. The envelope of visibility is measured from a driver's eye height of between 1.05 and 2.00m to an object height of between 0.26 and 2.00m, above the road surface, similar

to the envelope for stopping sight distance. Failure to provide compliant visibility on the approach to an intersection shall be considered a Departure from Standards.

Major Road

Drivers on the immediate approach to a intersections on the major road shall be able to see the minor road entry from a distance corresponding to the Junction Approach Sight Distance (JASD) for the design speed of the major road as described in Section 2. This visibility allows drivers on the major road to be aware of traffic entering from the minor road in time for them to be able to slow down and stop safely if necessary. Failure to provide JASD shall be considered a Departure from Standards.

The concept of adequate visibility to make safe turning movements also applies to vehicles turning left into the minor road from the major road.

Minor Road

Minor road traffic has to approach the intersection and join or cross the major road when there are gaps in the major road traffic streams. It is therefore essential that minor road drivers have adequate visibility in each direction to see the intersection layout and oncoming major road traffic in sufficient time to permit them to make their manoeuvres safely.

The principle of providing the required visibility for drivers approaching the intersection from the minor road has three distinct features (refer to Figure 2.5.1):

- W: Approaching drivers should have unobstructed visibility of the intersection from a distance corresponding to the Junction Approach Sight Distance (JASD) for the design speed of the minor road. Failure to provide JASD shall be considered a Departure from Standards. This allows drivers time to slow down safely at the intersection, or stop, if this is necessary. Where a “Give Way” or “Stop” sign is proposed, the visibility envelope shall be widened to include the sign;
- Z: A driver approaching the intersection shall be able to see clearly the intersection form and those peripheral elements of the intersection layout. This provides the driver with an idea of the intersection form, possible movements and conflicts, and possible required action before reaching the major road. This point is called the 'z' point which is 15m back along the centreline of the minor road measured from the continuation of the line of the nearside edge of the running carriageway of the major road (not from the continuation of the back of the major road hard shoulder or hardstrip, if this is present). Failure to comply with this requirement shall be considered a Departure from Standards.
- X: The distance back along the minor road from which the full visibility is measured is known as the 'x' distance. It is measured back along the centreline of the minor road from the continuation of the line of the nearside edge of the running carriageway of the major road.
- Y: The distance along the major road which must be visible to the left and right to minor road vehicles approaching the intersection within the 'x' distance. An approaching driver shall be able to see clearly points on the nearer edge of the

major road running carriageway at this distance, measured from its intersection with the centreline of the minor road.

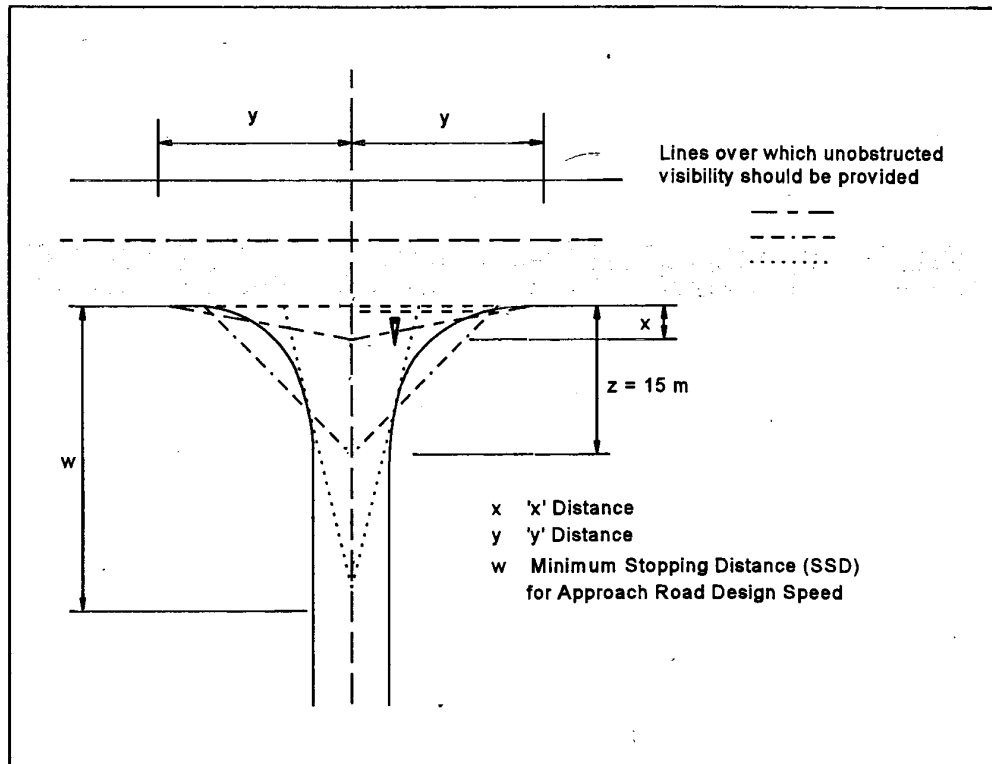


Figure 2.5.1 Visibility criteria at major/minor priority intersections

The minimum 'x' distance shall be 10m, except at simple intersections in urban locations, where it may be reduced to 5m. Failure to provide compliant 'x' distance shall be considered a Departure from Standards.

The 'x' distance, from which full 'y' distance visibility is provided, should be not significantly more than 10m as this induces high minor road approach speeds into the intersection, and leads to excessive landtake.

The 'y' distance shall be the Minimum Stopping Sight Distance (SSD) for the mainline design speed, as defined in **Part 3**. Failure to provide compliant 'y' distance shall be considered a Departure from Standards.

If the line of vision lies partially within the major road carriageway, it shall be made tangential to the nearer edge of the major road running carriageway, as shown in Figure 2.5.2.

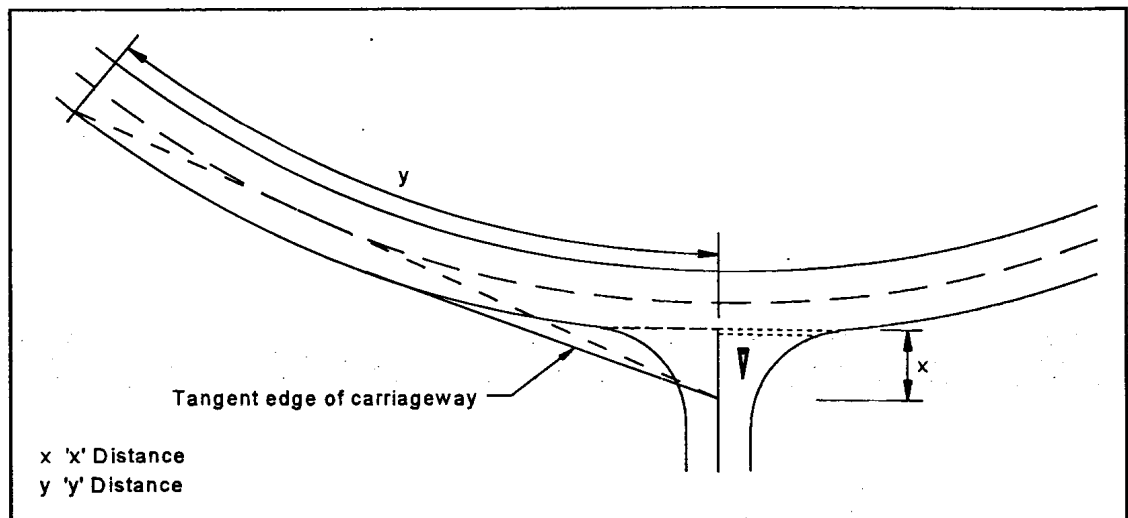


Figure 2.5.2 Measurement of X distance on curved major road

There is little advantage in increasing the 'y' distance, as this can induce high approach speeds and take the attention of the minor road driver away from the immediate intersection conditions. Increased visibility should not be provided to increase the capacities of various turning movements.

Where the major road is one way and on dual carriageways with median separation, a single visibility splay in the direction of approaching traffic will suffice. If the minor road serves as a one-way exit from the major road, no visibility splays will be required, provided that forward visibility for turning vehicles is adequate.

Parked vehicles within the splay lines will restrict visibility. Therefore parking facilities must not be provided within the visibility splay lines. Parking is considered in more detail in [Part 11](#).

Accesses should be designed to prevent encroachment on the visibility splay. Care should also be taken in the placing of signs, landscaping and street furniture within the visibility splay areas to ensure that their obstructive effect is minimised.

2.5.5 Geometric Requirements

Design Vehicle

Geometric parameters for use in the design of a priority intersection have been developed to cater for a 16.5m long articulated vehicle, whose turning width is greater than for most other vehicles that regularly use these intersections.

However, a 15.5m long articulated vehicle with a single rear axle has been shown to be more onerous than the 16.5m long vehicle. Hence, if the major/minor priority intersection being designed is in an area where there is likely to be regular use by such vehicles, the designer should take account of this either by amending the design to cater for such a vehicle, or by accepting that these vehicles may encroach into other

traffic lanes, or overrun other areas. In such instances, consideration may be given to providing differential coloured or raised surfacing indicating the area of allowable overrun.

Allowance shall be made for the swept turning paths of long vehicles where they can reasonably be expected to use an intersection. Consideration shall also be given to the manoeuvring characteristics of these vehicles in the design of staggered junctions.

Where buses or other long rigid vehicles form a significant portion of total or peak time traffic, and their turning movements within these dimensions would be awkward or present a hazard or significant delay, then corner radii and lane widths should be increased based on the use of appropriate swept path templates.

The composition and turning movements of traffic will influence the geometric layout adopted. A high proportion of heavy goods vehicles for example will dictate the minimum lane width and corner radii to be adopted at the intersection. A high proportion of turning traffic may require the provision of a segregated or dedicated turning lane at the intersection, to ensure that adequate through traffic capacity is maintained.

In cases where hardstrips are present, the design vehicle is assumed to use these.

In urban situations where the major road design speed is not greater than 70kph, and the proportion of heavy goods vehicles is not high, occasional encroachment on to opposing lanes may be permitted. In such cases it is essential that adequate visibility is provided.

Corner Radii

For simple intersections without merge or diverge tapers, where no provision is to be made for large goods vehicles or buses, the minimum circular corner radius for simple intersections should be 6m in urban areas and 10m in rural areas. Lower radii curves shall be considered Departures from Standards. Where provision is to be made for large goods vehicles, the recommended circular corner radius is:-

- 10m at urban simple intersections, followed by a taper of 1:5 over a distance of 30m, measured from the edge of the major road carriageway up the minor road in the case of the entry to the minor road, and followed by a similar taper measured from the centreline of the minor road along the major road for the entry to the major road, refer to Figure 2.5.3.
- 15m at rural simple intersections, with tapers of 1:10 over a distance of 25m.
- 15m at ghost island intersections, with tapers of 1:6 over a distance of 30m.
- 15m at simple staggered junctions, with tapers of 1:8 over a distance of 32m.
- 20m radius in all other circumstances.

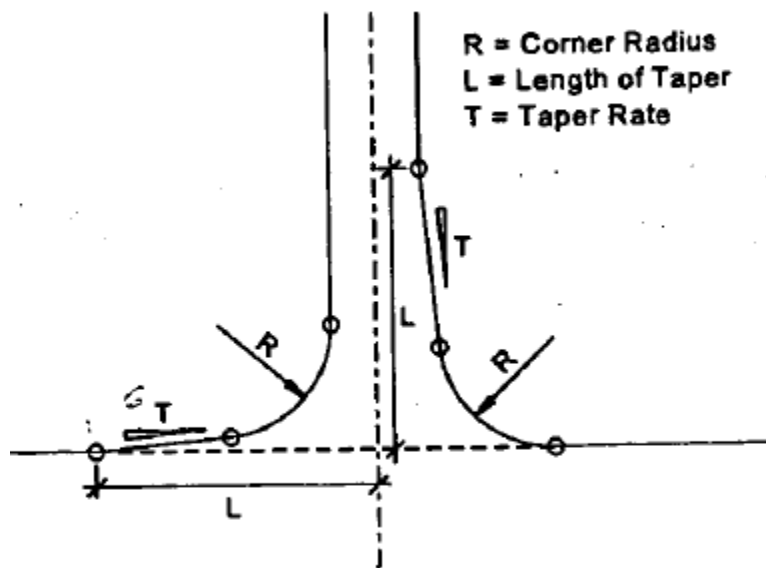


Figure 2.5.3 Circular Corner Radii incorporating tapers

These radii and associated tapers only apply where nearside acceleration and deceleration facilities are not provided. Alternatively, where large goods vehicles comprise a significant proportion of the turning movements, use of the compound curve illustrated in Figure 2.5.4 is recommended.

Where nearside acceleration facilities are not provided, the angle of incidence between the mainline carriageway edge line and the line of the vehicle entering, when positioned at the "Give Way" or "Stop" shall be not less than 70°. This will ensure that drivers entering the mainline carriageway will be able to look both ways without relying on mirrors for mainline visibility.

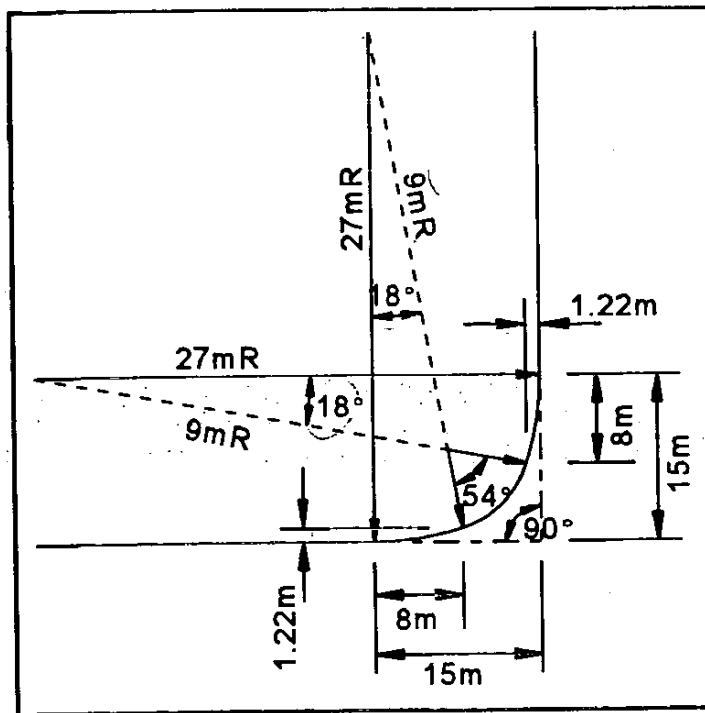


Figure 2.5.4 Design of a Compound Curve

Carriageway Widths – Through Lanes

The carriageway widths to be provided through priority intersections are dependent on the intersection type. The carriageway widths provided shall be in accordance with paragraphs below. Any reduction from these values shall be considered a Departure from Standards.

At simple intersections, the carriageway width remote from the intersection shall be continued through the intersection.

At ghost island intersections, the through lane widths remote from the intersection shall be continued through the intersection, with the overall carriageway width increased to accommodate the ghost island.

At single lane dualling intersections, the through lane in each direction shall be 4.0m wide exclusive of hardstrips. This width, with the hardstrips, will allow traffic to pass a stopped vehicle without leaving the paved width.

At dual carriageway intersections, the through lane widths remote from the intersection shall be continued through the intersection.

Carriageway Widths – Minor Road Approaches and Corners

On a minor road approach of nominal width 7.3m, where a channelizing island is provided, both lanes shall be 4.0m wide at the point where the hatched markings surrounding the channelizing island begin.

At the point where the channelizing island commences, the minimum widths on either side shall be as follows:

- On the approach to the major road, 4.0m wide for a ghost island or 4.5m wide for single lane dualling or a dual carriageway, exclusive of hardstrips. If the approach on the minor road consists of two lanes, this dimension shall be 5.5m.
- On the exit from the major road, 4.5m wide for a ghost island, or 5.0m wide for single lane dualling or a dual carriageway, exclusive of hardstrips.

Where these widths are not achieved it shall be considered a Departure from Standards.

If there are no channelizing islands in the minor road, the nominal approach width should continue up until the tangent point of the curve to join the edge of the major road running carriageway.

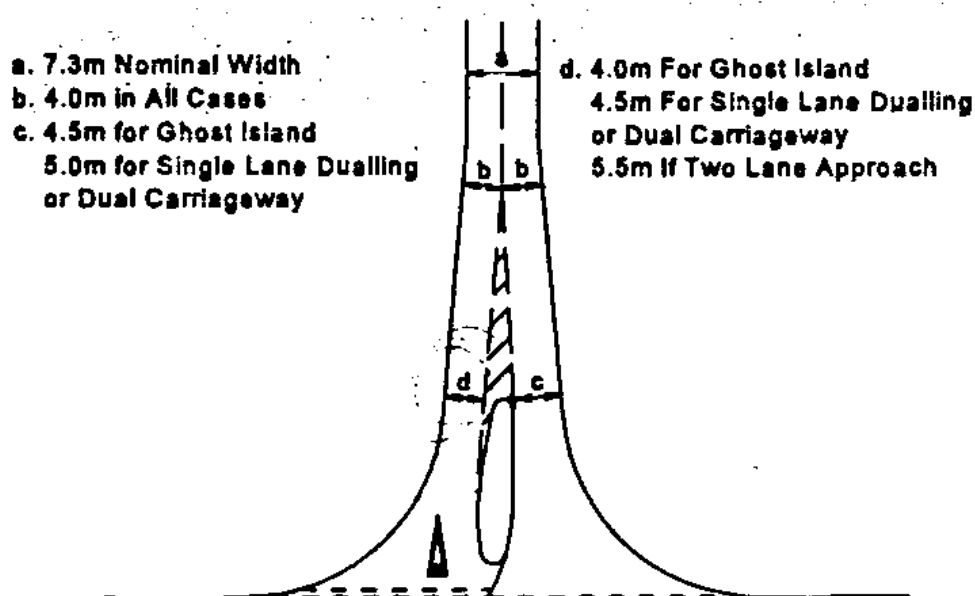


Figure 2.5.5 Minor Road Approaches

Where carriageways are taken around short radius corners, added width shall be provided to cater for the swept area of larger goods vehicles and the "cut in" of trailer units. On single lane sections greater than 50m in length an allowance must be made for broken down vehicles. Table 2.5.1 shows the recommended minimum widths for various nearside corner radii based on the 16.5m design vehicle.

Table 2.5.1 Minimum corner and curve radii and carriageway widths

Inside Corner/Curve radius (m)	Single lane width (excluding edge strip provision) (m)	Single lane width with width to pass stationary vehicles (excluding edge strip provision) (m)	Two lane width for one way or two way traffic (Excluding edge strip provision) (m)		
			Inside lane	Outside lane	Total
10	8.4	10.9	8.4	6.5	14.9
15	7.1	9.6	7.1	6.0	13.1
20	6.2	8.7	6.2	5.6	11.8
25	5.7	8.2	5.7	5.2	10.9
30	5.3	7.8	5.3	5.0	10.3
40	4.7	7.2	4.7	4.6	9.3
50	4.4	6.9	4.4	4.3	8.7
75	4.0	6.5	4.0	4.0	8.0
100	3.8	6.3	3.8	3.8	7.6

Where 16.5m long articulated vehicles (e.g. Class 8) are anticipated, but are likely to form only a very small percentage of the total number of vehicles and where conflicts will not occur on bends, the carriageway widths may be reduced to cater for the lower class vehicle that will regularly use the intersection with an additional 1m allowance for variation in vehicle position.

An articulated car transporter will turn in the widths shown, but where provision is to be made for this type of vehicle, street furniture above 2.5m high should be set back at least 1m from the edge of the minor road carriageway at the bell mouth (this does not apply for channelizing islands) to allow for the projection of the trailer over the tractor cab.

2.5.6 Central Islands

Merging and diverging movements can usefully be separated by physical or painted guide islands set out with road markings so that the number of traffic conflicts at any point is reduced.

Preventing or minimising conflicts by separation means that drivers are only faced with simple decisions on their choices of movement at any one time. This can lead to greater safety. For the separation to be effective, the intersection must be large enough for drivers to identify in adequate time those vehicles which will conflict with their intended path and those that will not. If this is not so, gaps in the flow cannot be used effectively by traffic entering the intersection

Tapers

Central islands, whether for ghost islands (Figure 2.5.6) or single lane dualling (Figure 2.5.7) should normally be developed symmetrically about the centreline of the major road to their maximum width at the tapers shown in Table 2.5.2. The maximum island width should continue through the intersection to the tangent point of the minor road radius and the edge of the major road carriageway. For single lane dualling, the central island should be introduced by means of hatched markings until there is sufficient width to accommodate the appropriate sign on the nose of the physical island with the required running clearances to it.

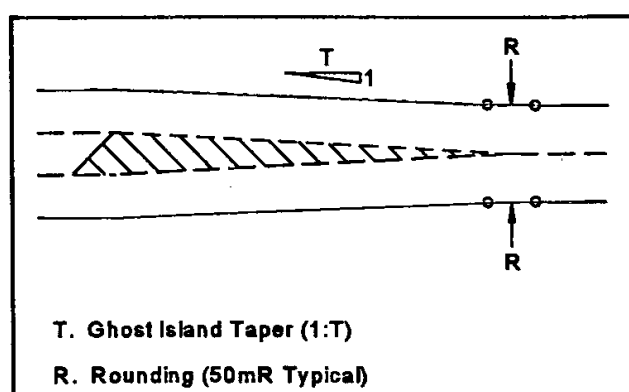


Figure 2.5.6 Ghost island development

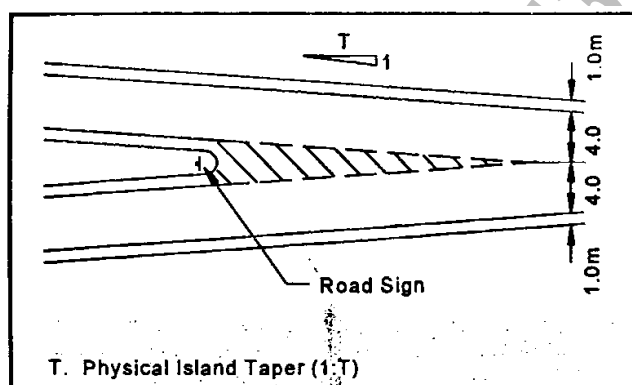


Figure 2.5.7 Physical island development

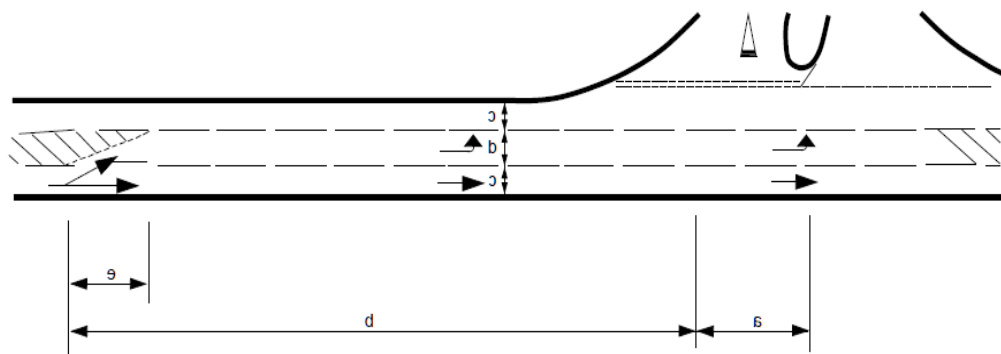
Where intersections are located on sharp curves, islands should be introduced asymmetrically to suit the circumstances. It is also acceptable to introduce islands asymmetrically in other circumstances. This can have the benefit of avoiding expense (for example Statutory Undertakers' works). In such cases tapers shall be installed at the same rates, as defined in Table 2.5.2, thus increasing the overall length of taper. Where the taper values are not as defined in Table 2.5.2 it shall be considered a Departure from Standards.

Table 2.5.2 Tapers for Central Islands

Design Speed (kph)	Taper for Ghost island and Single lane dualling
50	1:20
60	1:20
70	1:20
80	1:25
100	1:30

Left Turning Lanes

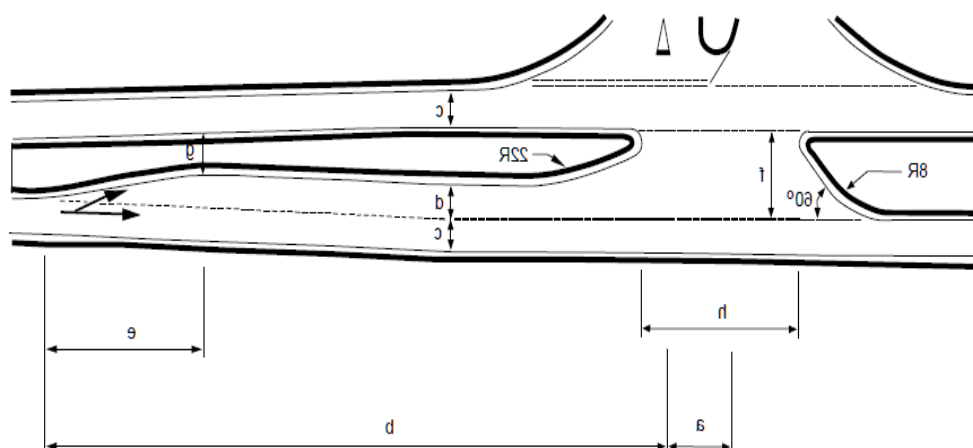
The turning length is provided to allow long vehicles to position themselves correctly for the left turn. The turning length shall be 10m long irrespective of the type of intersection, design speed or gradient, measured from the centreline of the minor road. It is shown on Figure 2.5.8 and Figure 2.5.9.



- a Turning length (+ queuing length if required)
- b Deceleration length
- c Through lane width
- d Turning lane width
- e direct taper length

All radii shown in metres

Figure 2.5.8 Major/minor priority intersection with a ghost island



- a Turning length (+ queuing length if required)
 - b Deceleration length
 - c Through lane width
 - d Turning lane width
 - e direct taper length
 - f Physical island width
 - g Minimum physical island width
 - h Central reserve opening
- All radii shown in metres

Figure 2.5.9 Major/minor priority intersection with single lane dualling

The width of a left turning lane shall be equal to the width of the adjacent through lane.

Where capacity calculations indicate that for significant periods of time there will be vehicles queuing to turn left from the major road, the turning length shall be increased to allow for a reservoir queuing length to accommodate such vehicles. Where reservoir provision appears desirable at an intersection with ghost islands, consideration shall be given to providing physical islands instead to afford greater protection to turning traffic. Where site conditions prevent this, the reservoir space may still be provided.

The overall length of a left turning lane provided at ghost island and single lane dualling intersections, will depend on the major road design speed and the gradient. It consists of a turning length and a deceleration length. This component shall be provided in accordance with Table 2.5.3, in which the gradient is the average for the 500m length before the minor road.

Table 2.5.3 Deceleration Length on Single Carriageway Roads

Design Speed (kph)	Up Gradient		Down Gradient	
	0-4%	Above 4%	0-4%	Above 4%
50	40	40	40	40
60	40	40	40	60
70	60	40	60	80

Design Speed (kph)	Up Gradient		Down Gradient	
	0-4%	Above 4%	0-4%	Above 4%
80	80	60	80	120
100	120	80	120	160
120	160	120	160	230

The deceleration lengths at design speeds 60 to 100kph are based on the assumption that vehicles will slow by one design speed step on the major road before entering the length. At lower design speeds no deceleration is assumed to occur in advance. The deceleration rate on the level is assumed to be 2.5m/s/s. There is no perception/reaction time as this is a planned manoeuvre.

The direct taper length is the length over which the width of a left turning lane is developed. For ghost islands and the physical islands in single lane dualling left turning lanes shall be introduced by means of a direct taper whose length is part of the deceleration length, and depends on the design speed. This taper length is given in Table 2.5.4.

Table 2.5.4 Direct Taper Length

Design Speed (kph)	Direct Taper Length – e (m)
60 (or less)	5
70 - 80	15
100	25

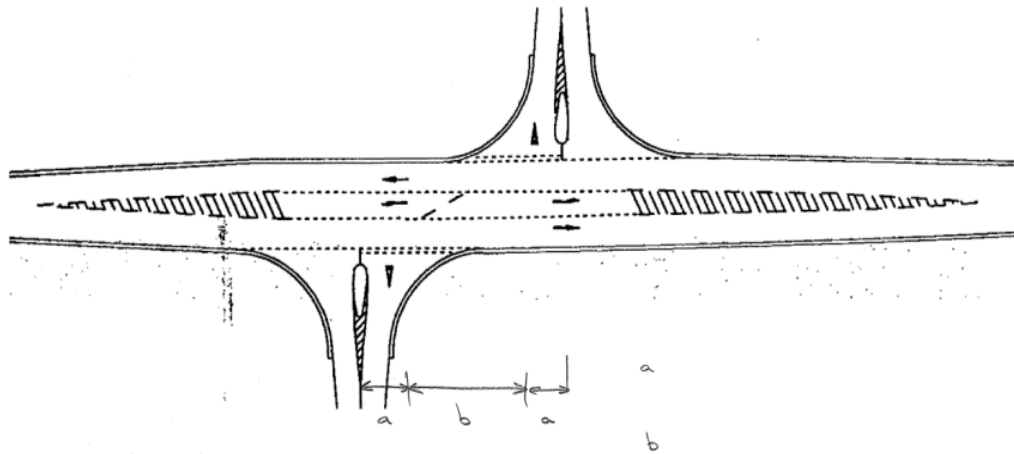
Any reduction in turning length, deceleration length as defined in Table 2.5.3 or direct taper length as defined in Table 2.5.5, shall be considered a Departure from Standards.

Ghost Islands

For new intersections, the minimum width of a ghost island turning lane shall be 3.5m and any reduction shall be considered a Departure from Standards. At urban and suburban intersections it can sometimes be advantageous to use a greater width not exceeding 5.0m to allow a degree of shelter in the centre of the road for large goods vehicles turning left from the minor road to execute the turn in two separate manoeuvres. On rural roads, with design speeds above 80kph or where hardstrips are present, widths greater than 3.65m are inadvisable because wide ghost islands in these situations create a sense of space that could encourage hazardous overtaking at intersections.

At right/left staggered junctions, the starting points of the left turning sections shall be joined by a straight line, with the result that the dedicated turning lane will only commence for vehicles approaching the left-turn after they have passed the left-turning lane for the opposing flow. However back-to-back full length deceleration lanes shall not be provided, as to do so would result in excessive stagger lengths. The result is that turning lane lengths will be reduced (as shown in Figure 2.5.10). The

minimum stagger length in this case must include the turning length (in both directions) and a single deceleration length (refer to Table 2.5.3). The width of the turning lane shall be the full width of the ghost island.



a Turning length (+ queuing length if required) b Deceleration Length

Figure 2.5.10 Right/Left Stagger Junction with Ghost Island (minimum stagger length)

Physical islands for Left-turns

At single lane dualling the width of the central island at the crossing point shall be 10.0m, including central reserve hardstrips. This width will shelter most large goods vehicles turning left from the minor road, except for very long vehicles. In exceptional circumstances where use by very long vehicles is expected and a roundabout is not feasible, a width of 14.0m including hardstrips, will be needed to shelter the largest articulated vehicles (16.5m) and a width of 16.5m, including hardstrips, will be required to shelter drawbar trailer combinations (20.0m).

The minimum width of a physical island, usually located at the end of the direct taper shall be 3.5m. Any reduction shall be considered a Departure from Standards

The opening in the central reserve for single lane dualling intersections at the crossing point shall be 15.0m wide, as shown on Figure 2.5.9.

Problems have been experienced with driver confusion over priority within the central reserve, particularly where the width of the physical island has been increased to cater for large goods vehicles. Measures to regularise the priority arrangement within the central reserve opening include channelizing the central area to arrive at a priority arrangement.

Consideration may also be given in these circumstances to introducing differential coloured surfacing to enhance the road markings or indicate the area of allowable overrun for large goods vehicles. However, such coloured surfacing should also be visible at night and in poor weather conditions.

2.5.7 Stagger Distances

The stagger distance of an intersection is the distance along the major road between the centrelines of the two minor roads.

At left/right staggers the minimum stagger length shall be 40m.

At right/left stagger junctions the minimum stagger length shall be defined by the turning lengths and the appropriate deceleration length for the major road design speed. The minimum stagger lengths for various design speeds at right/left staggered junctions are detailed in Table 2.5.5.

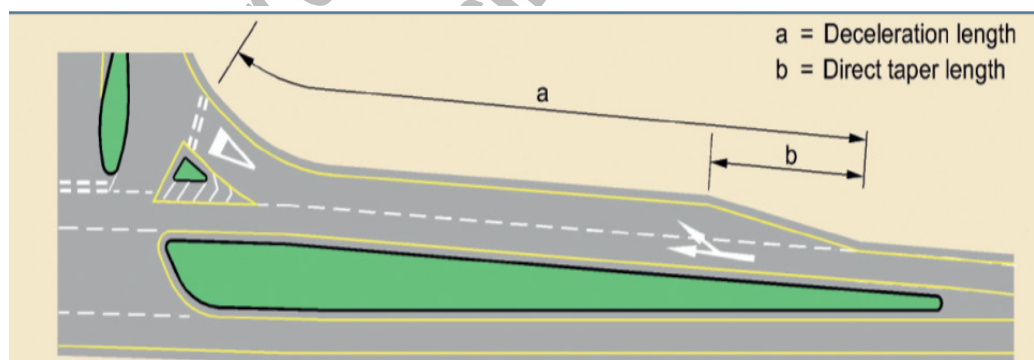
Table 2.5.5 Minimum Stagger Distance for Right/Left Staggered Junctions

Design Speed (kph)	Stagger Distance (m)
50	60 (10 + 40 + 10)
60	60 (10 + 40 + 10)
70	80 (10 + 60 + 10)
80	100 (10 + 80 + 10)
100	140 (10 + 120 + 10)

Stagger distances may be increased where reservoir space for queuing traffic is required. Reduced stagger distances shall be considered a Departure from Standards.

2.5.8 Diverging Auxiliary Lanes

Major road traffic, when slowing down on the approach to an intersection in order to turn into a minor road, may impede following vehicles that are not turning. It is helpful, therefore, to permit the divergence of the two streams in advance of the intersection by the provision of a nearside auxiliary lane for deceleration. Refer to Figure 2.5.11.



a Auxiliary lane length

b Direct taper length

Figure 2.5.11 Auxiliary lane on Diverge

Nearside auxiliary lanes are of less benefit in terms of operation and safety than left turning lanes because the right turn from the major road does not cross an opposing

traffic stream and is rarely impeded. However, nearside diverging auxiliary lanes should always be considered for higher speed roads or on gradients.

Nearside auxiliary lanes shall not be provided at simple intersections. Nor shall they be provided when the minor road is on the inside of a curve where traffic in the diverging lane could adversely affect visibility for drivers emerging from the minor road. Minor road intersections on the inside of curves should be avoided.

Unless these conditions occur, auxiliary lanes shall be provided at all priority intersections between major and minor roads where the design speed for the major road is 80 kph or above. They shall also be provided in the following circumstances for traffic in the design year:

- Where the volume of right turning traffic is greater than 600 vehicles AADT (one-way).
- Where the percentage of large goods vehicles is greater than 20%, and the volume of right turning traffic is greater than 450 vehicles AADT (one-way).
- Where the intersection is on an up or down gradient of greater than 4% at any design speed and the volume of right turning traffic is greater than 450 vehicles AADT (one-way).

Where the major road traffic flow is greater than 7000-8000 AADT (one-way), then the figures given above for turning traffic should be halved.

The auxiliary lane length is defined as being from the beginning of the taper up to the start of the radius around the corner, as shown in Figure 2.5.11.

The nearside auxiliary lane should be of sufficient length to allow vehicles to slow to a stop at the end of the auxiliary lane. The minimum auxiliary lane lengths are defined in Table 2.5.6. Any reduction shall be a Departure from Standards. The minimum lengths are based on deceleration requirements, and at design speeds 60 to 100kph are based on the assumption that vehicles will slow by one design speed step on the major road before entering the length. At lower design speeds no deceleration is assumed to occur in advance. The deceleration rate on the level is assumed to be 2.5m/s/s. Notwithstanding this, minimum auxiliary lane lengths shall be not less than 80m.

Table 2.5.6 Minimum Auxiliary Lane Lengths on Diverge

Design speed (kph)	Up Gradient		Down Gradient	
	0-4%	Above 4%	0-4%	Above 4%
50	80	80	80	80
60	80	80	80	80
70	80	80	80	80
80	80	80	80	120
100	120	80	120	160
120	160	120	160	230

Auxiliary lane lengths may be increased from the minimum lengths defined to incorporate reservoir space for turning vehicles.

The width of the auxiliary lane shall be equal to the width of the adjacent through lane.

Where the intersection accommodates vehicles making left turns into the minor road (generally on single carriageways), "Give Way" markings must be provided at the end of the auxiliary lane, as illustrated in Figure 2.5.11. These markings are not required where left turns from the major are not incorporated.

At the end of the auxiliary lane a curve radius into the minor road of minimum 20m should be used where the main road design speed is 80kph or less. At higher speeds the minimum radius shall be 40m. The minimum carriageway width around this corner will be dependent on the curve radius selected and is defined in Table 5.1.1.

Where diverging auxiliary lanes are provided they should include an adjacent hard shoulder or hardstrip equal to that of the associated major road.

2.5.9 Merging Auxiliary Lanes and Tapers

Merging auxiliary lanes permit minor road traffic to accelerate before joining the faster traffic streams on the mainline where the joining traffic may otherwise impede flow or be a hazard (Figure 2.5.12).

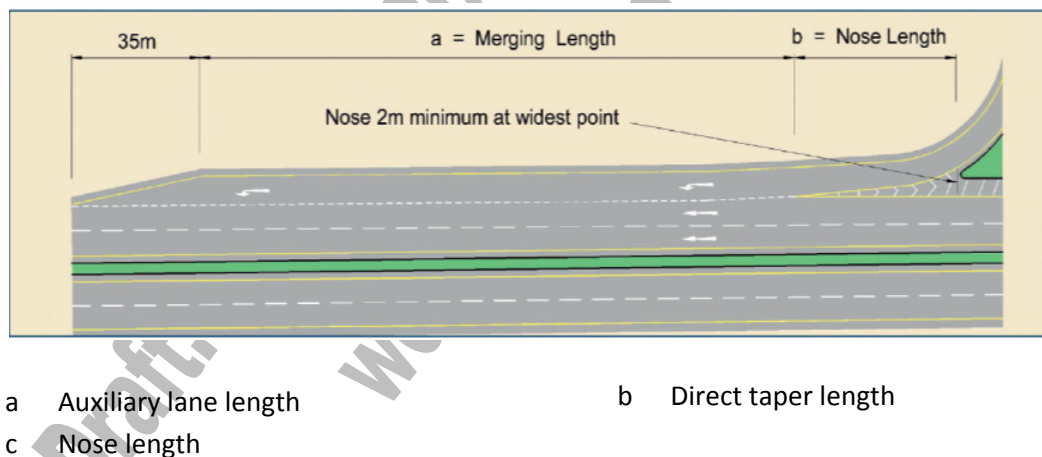


Figure 2.5.12 Auxiliary Lane on Merge

Such merging facilities shall only be used at dual carriageway intersections. They must not be used at single lane dualling intersections.

They must be provided where the volume of right turning traffic in the design year exceeds 600 vehicles AADT (one-way). Failure to provide a merging facility in this situation shall be considered a Departure from Standards. Where the merging taper is

for an up gradient of greater than 4% or where the percentage of large goods vehicles exceeds 20%, this threshold value may be reduced to 450 vehicles AADT (one-way).

At some intersections on dual carriageways, there may be safety benefits in providing merging facilities at lower flows.

A separate turning lane, with a radius of minimum 25m where the major road design speed is 80 kph, and of minimum 30m where the major road design speed is 100kph and above, shall be used to introduce the merging facility from the minor road.

The standard merging facility shall be a parallel auxiliary lane. Auxiliary lane lengths shall be in accordance with Table 2.5.7, sufficient for a car to accelerate from 30kph through the corner radius to one-step below the major road design speed..

Table 2.5.7 Minimum Auxiliary Lane Lengths on Merge

Design Speed (kph)	Up Gradient		Down Gradient		Alternative taper length (m)
	0-4%	Above 4%	0-4%	Above 4%	
80	175	245	175	125	(90)
100	245	445	245	175	(110)
120	445	795	445	245	(130)

* Note - Taper lengths shown in brackets, refer to Figure 5.5.13. These shall not be introduced without approval of the roads authority.

The auxiliary lane lengths specified in Table 2.5.7 shall be inclusive of direct taper of 35m length at the end of the parallel section.

The width of the auxiliary lane shall be equal to the width of the adjacent through lane.

It is essential that vehicles travelling within an auxiliary lane have sufficient opportunity to accelerate to at least one step below the major road design speed, to ensure that merging manoeuvres can be undertaken safely. Therefore auxiliary lanes of lengths less than those specified in Table 2.5.7 shall be considered a Departure from Standard.

At the commencement of the merging facility, the merging auxiliary lane must be preceded by a short nose of 40m length formed between it and the end of the 30m approach curve. The back of the nose should have a minimum width of 2m.

Where merging auxiliary lanes are provided they should include an adjacent hard shoulder or hardstrip equal to that of the associated major road.

Where compliant auxiliary lane lengths cannot be achieved due to constraints, a taper layout is a preferable alternative to a sub-standard auxiliary lane. Refer to Figure

5.5.13. However this shall be a Departure from Standards. Suitable taper lengths are included in brackets in Table 2.5.7. The minimum initial width of a merging taper shall be 4.0m

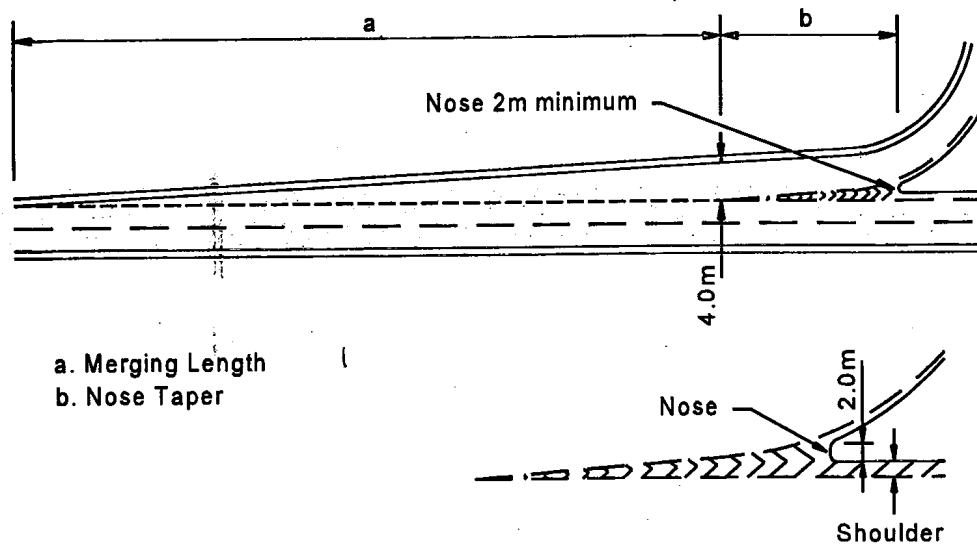


Figure 2.5.13 Merging Taper (non-standard arrangement)

2.5.10 Skew Junctions

Typical layouts for skew junctions are illustrated in Figure 2.5.14. the geometric design parameters for skew junctions are similar to those for more standard priority intersections. The designer must ensure that adequate minor road entry and exit widths are provided adjacent to channelizing islands to accommodate vehicle movements. Refer to clauses 5.5.16 to 5.5.21.

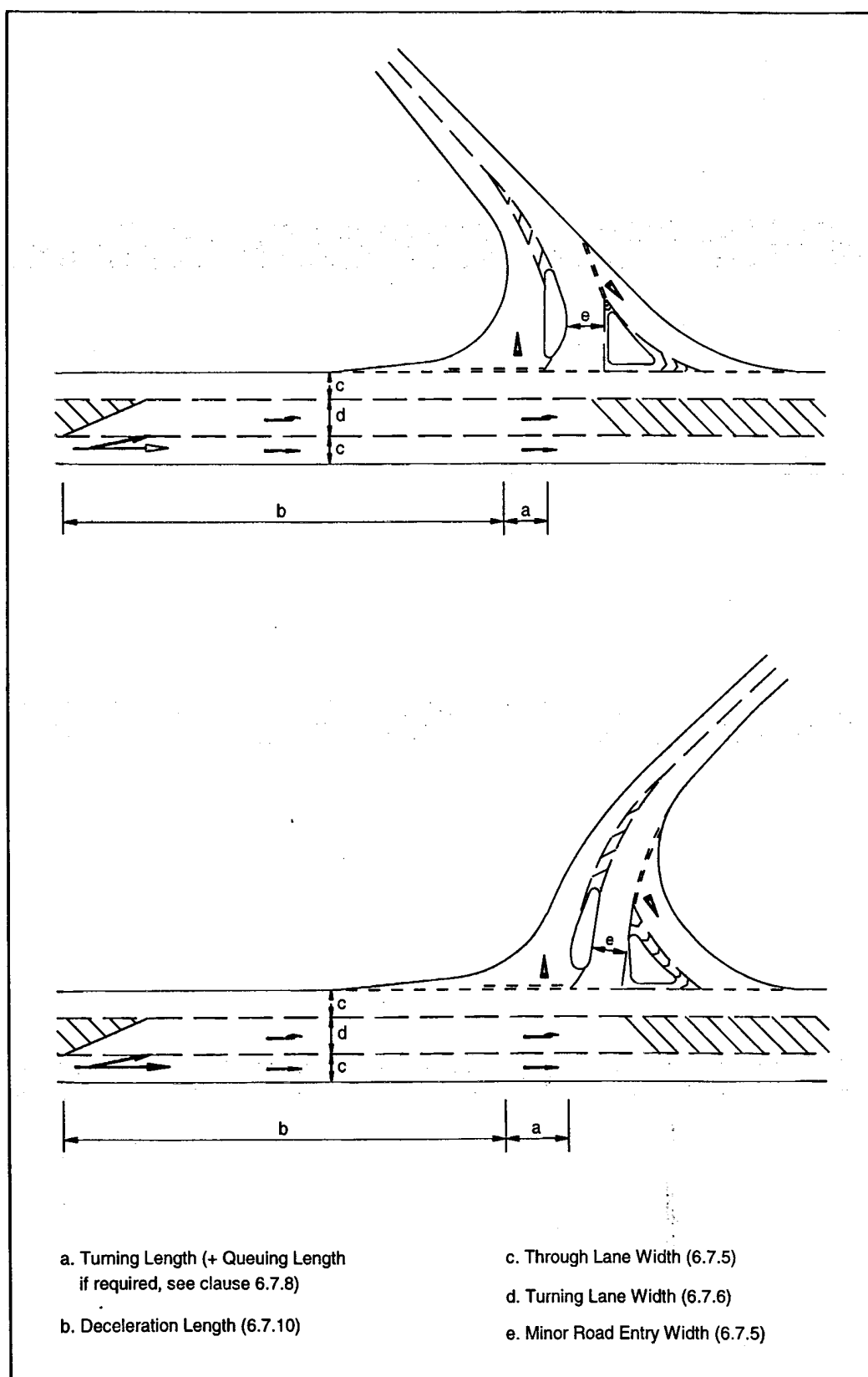


Figure 2.5.14 Major/minor priority intersection with Skew minor road

2.5.11 T-Junction with Carriageway Separation

On dual carriageways, left turn crossing manoeuvres at the intersection are prevented and facilities shall be provided nearby for turning traffic. The resulting T-junction with carriageway separation incorporating a right-in/right-out layout is illustrated in Figure 2.2.4.

Preventing left turns removes the need to signalize the carriageways on the major road to cater for these movements. The major road carriageway can pass through the intersection at a constant width.

For the right turn diverge from the major road, the channelizing shall be designed so as to provide a constant width around the turn to the minor road. The width shall be determined from Table 2.5.1

Traffic may be introduced to the right turn lane by a nearside auxiliary lane in accordance with clause 5.8. Where a nearside auxiliary lane is present the hatched markings should be extended along their current path until the intersection with the centreline of the minor road, and the channelizing island shall be provided within them. This is shown in Figure 2.5.15 and Figure 2.5.16.

For the right turn merge to the main road, the minor road channelizing island shall be designed so as to provide a constant width of turn into the major road. The width shall be determined from Table 2.5.1

Traffic leaving the right turn lane should "Give Way" or merge with the major road traffic. This merge may incorporate an auxiliary lane, in accordance with clause 5.9. The hatched markings shall be extended from the minor road centreline to link with those for the merge taper, the channelizing island being provided within them, as in Figure 2.5.15 and Figure 2.5.16.

Channelizing island dimensions shall be as set out in clause 5.12.

In order to cater for all required traffic movements, T-Junctions with carriageway separation are required to be incorporated with other nearby facilities for turning traffic. One method of achieving this is to provide local grade separations, the principle of which is shown in Figure 2.5.17. Two right-in/right-out connections are used with an overbridge or underpass. Link roads shall be designed in accordance with Section 2.

Where successive T-junctions are introduced on dual carriageway roads, weaving lengths must be considered in accordance with Section 7. Failure to provide adequate weaving lengths shall be considered a Departure from Standards.

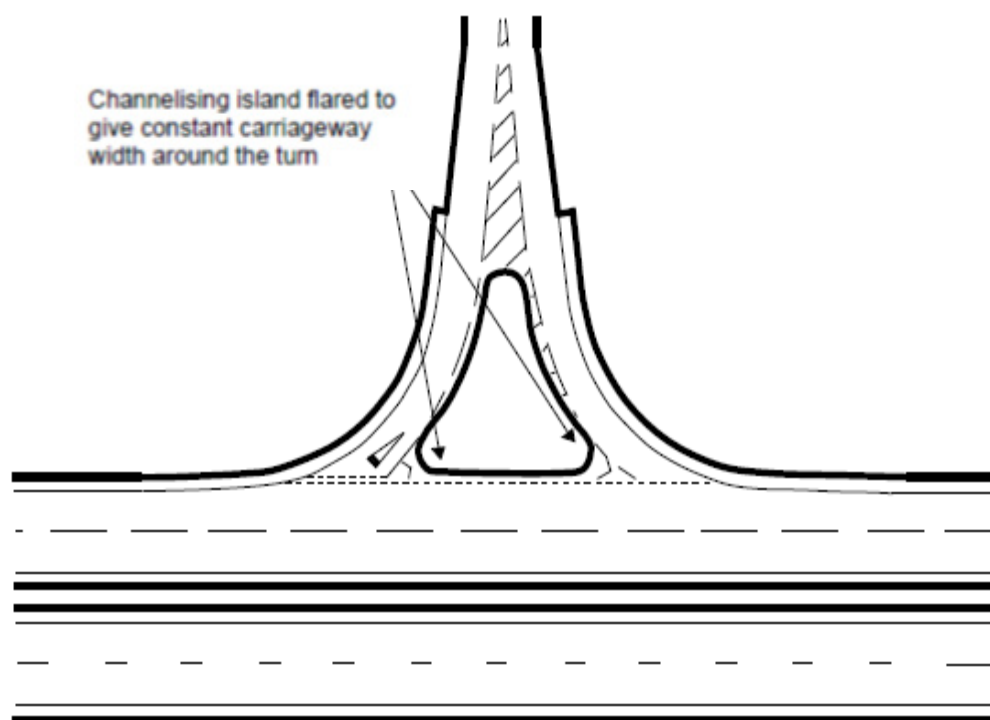


Figure 2.5.15 Local grade separation T-junction

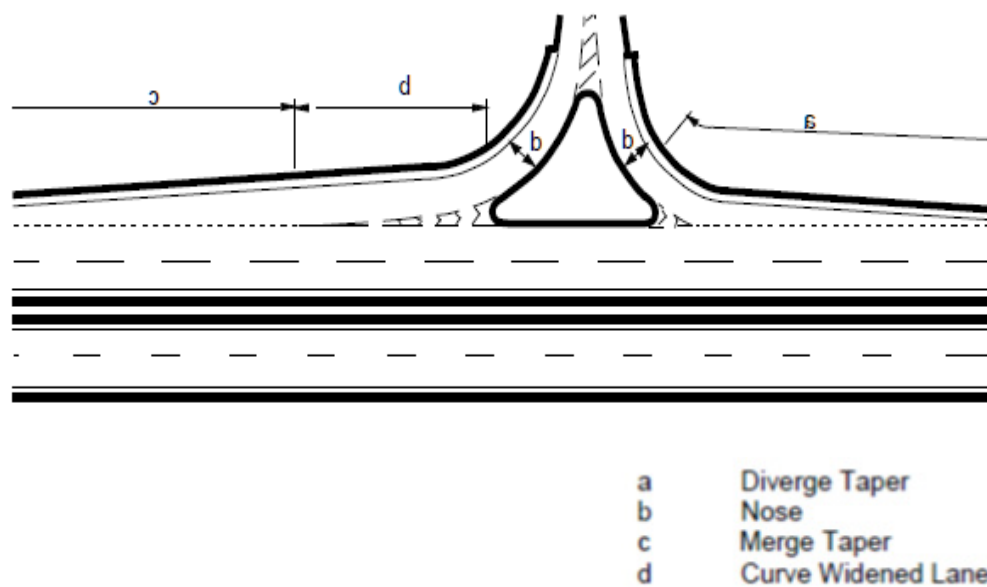


Figure 2.5.16 Local grade separation T-junction incorporating merge and diverge facilities

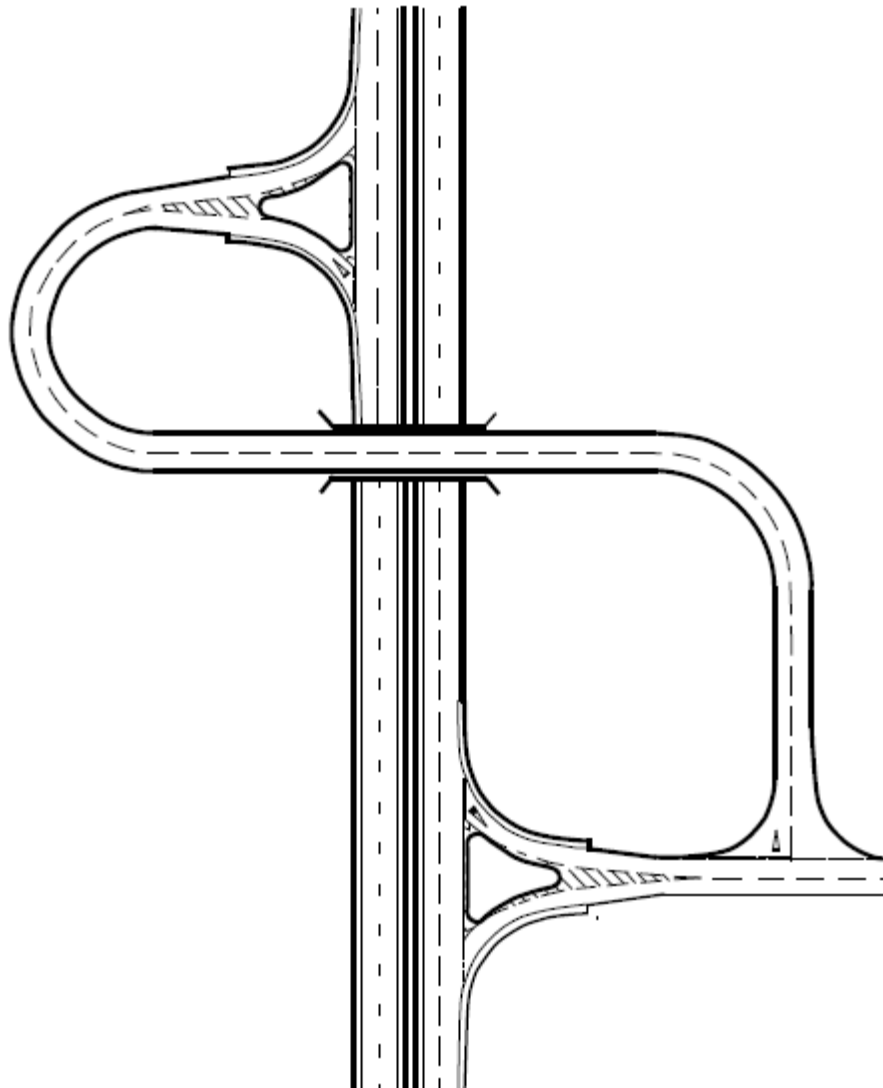


Figure 2.5.17 Local grade separation

2.5.12 Channelizing Traffic Islands

Traffic islands should be provided in the mouth of the minor road at major/minor priority intersections, except simple intersections, to:-

- Give guidance to long vehicles carrying out turning movements;
- Channelize intersecting or merging traffic streams;
- Warn drivers on the minor road that a intersection is ahead;
- Provide shelter for vehicles waiting to carry out turning manoeuvres;
- Assist pedestrians, where necessary.

Physical islands shall have an area of at least 4.5 square metres, and shall be treated to be conspicuous in poor lighting conditions. Smaller areas should be defined by road markings. The risk of overriding the islands can be reduced by offsetting the approach nose from the edge of the vehicle paths.

T-Junction

The recommended channelizing island layout for T-Junctions or staggered junctions, where the minor road centreline is inclined to the major road at an angle of between 70° or 110° , as shown in Figure 2.5.18: This should be read in conjunction with Table 2.5.8 and Table 2.5.9.

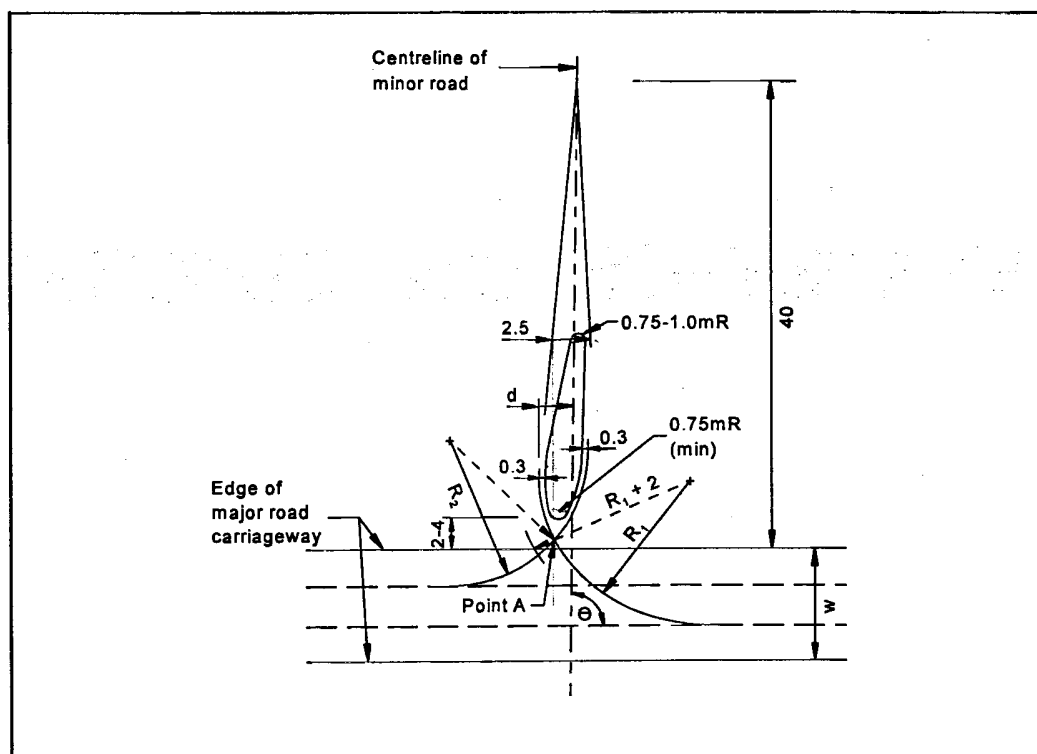


Figure 2.5.18 Design of Channelizing Island

Table 2.5.8 Channelizing Island Offset

Minor road inclination θ°	Offset – d (m)
70	1.5
80	2.0
90	2.5
100	2.0
110	1.5

Table 2.5.9 Design of Radius R_1

Major Road layout at intersection	Radius – R_1 (m)
Two lane single carriageway	12
Ghost Island	14
Single lane dualling	22

The following points should also be noted:

- "Edge of major road carriageway" means edge of major road travelled way.
- The circular arc R, is tangential to the offset, d, from the minor road centreline and the offside edge of the through traffic lane on the major road into which left turning traffic from the minor road will turn.
- By striking a circular arc of radius $(R1 + 2)$ metres from the same centre point as arc R1 to intersect the edge of the major road carriageway, point A is established where a straight-line drawn from the centre point of arc R, to this intersection crosses R.
- The circular arc R2 is tangential to the offside edge of the major road offside diverging lane and also passes through point A.
- Radius R2 is normally the same value as R1 but should be designed to ensure that the island nose is positioned between 2 to 4 metres from the edge of the main carriageway and that the width of the island lies between 2 to 5 metres.
- The design ensures that left turning traffic from the major road will not clash with traffic waiting to turn left from the minor road.

Skew Junctions

The design of a channelizing island for skew junctions is similar to that outlined above, but the following points should be noted:

- The centreline of the minor road is turned with a radius of at least 50 metres to meet the edge of the major road at right angles.
- For right hand skew junctions, the island should be about 15 metres long. The left hand side of its tail (viewed from the minor road approach) should touch the curved minor road centreline and be rounded off at a radius of 0.75m to 1.00m.
- The offset, d, for right hand skew junctions is 4.5 metres.
- For left hand skew junctions, the circular arc R, touches the curved minor road centreline and is tangential to the offset edge of the through traffic lane on the major road into which left turning traffic from the minor road will turn.
- The island should be about 15 metres long. The tail is offset about 1m to the left of the curved minor road centreline (viewed from the minor road approach) and rounded off with a radius of 0.75m to 1.00m.

Traffic Islands featuring Pedestrian Refuge

In urban areas where pedestrian use is required, traffic islands should be used as refuges to assist crossing. Where a traffic island serves as a refuge for pedestrians it shall be at least 1.5m wide, though 2.0m is a more desirable minimum. This may be increased depending on anticipated pedestrian flows and associated requirements. Where the facility is required to accommodate dismounted cyclists the minimum width shall be 2.0m. The island shall have openings in the centre at carriageway level to make the crossing easier for pedestrians (see Figure 2.5.19). Opposite the refuge openings, dropped kerbs shall be installed for the same reason. A refuge beacon about 4-5m high may be placed between the bollards. Care shall be taken that street furniture does not obstruct the drivers' view of pedestrians.

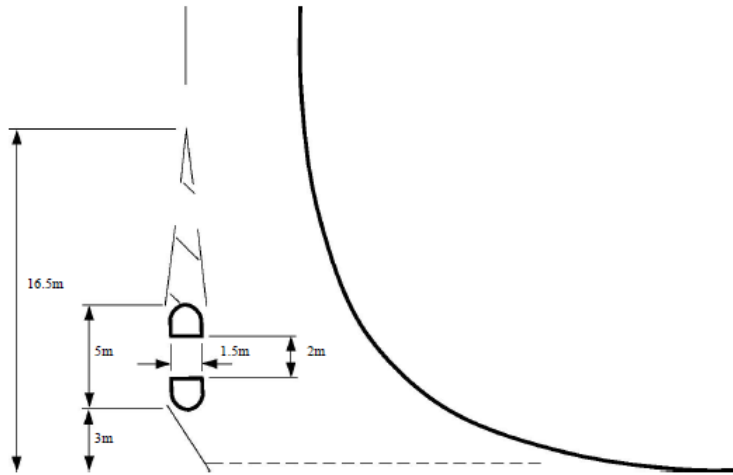


Figure 2.5.19 Typical urban traffic island with pedestrian refuge

2.5.13 Splitter/Right Turn Islands

Splitter/right turn islands may be used to channelize traffic flows and separate conflict points within an intersection.

They have additional benefits of reserving space for signing and aiding pedestrian movement by providing a refuge at busy intersections. Refer to Figure 5.5.21.

Corner radii and carriageway widths given in Table 2.5.1 Minimum corner and curve radii and carriageway widths shall be used to construct the right turn lane. The raised island shall be set back from the carriageway as illustrated in Figure 5.5.21.

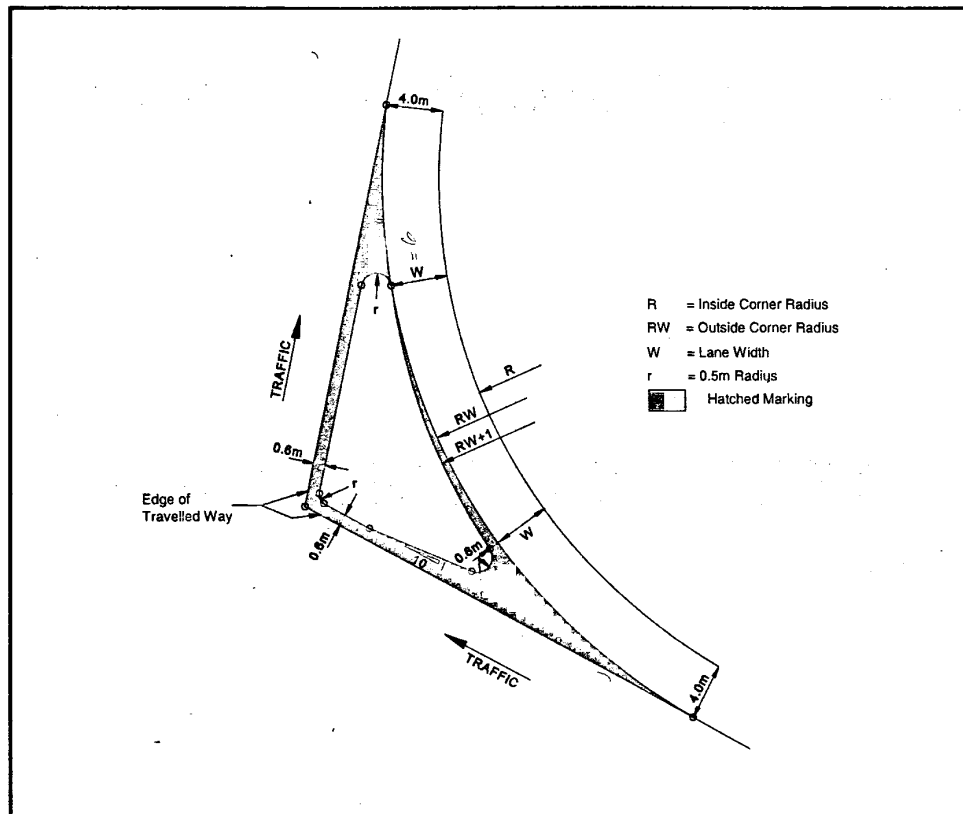


Figure 2.5.20 Typical layout of splitter island

2.6 Service Road Diverges and Merges

2.6.1 Service Road Provision

Service roads should be provided in the urban situation where through traffic on a dual carriageway road will be significantly affected by traffic manoeuvres from developments lying adjacent to the through road. The function of the service road is therefore twofold:

- Collects connecting minor roads and concentrates the entrances and exits to a limited number of locations along the major road, thereby allowing major road traffic to flow more freely
- Provides road users with a safer environment adjacent to developments by separation from higher speed through traffic.

Service roads typically run parallel to the major road. However, their vertical alignment is often governed by a lower design speed and can therefore be used to match threshold levels in existing development situations.

Cross sectional elements of urban service roads are further detailed in Section 2.

2.6.2 Service Road Junctions

Service roads should preferably be connected to major roads using the major/minor intersections criteria listed earlier in this Section. However, limited reservation space usually requires the intersection to connect at a skew to the major road. This creates the following undesirable situations which the designer should recognise in preparing service road designs:

Angled diverge off the main carriageway encourages high speed entry into the service road and consequent danger to other service road users

Angled merge onto the main carriageway requires the driver to make use of his mirrors to effect a safe merge with major road through traffic.

The above points can be mitigated to some extent by:

- Eliminating parking and providing uncluttered visibility in the area of merges and diverges
- Introducing a chicane type manoeuvre at the entrance to a service road therefore slowing traffic entering the service road
- Increasing the conflict angle where vehicles entering and vehicles using the service road meet
- Avoiding long straight service roads
- Siting diverges and merges away from other intersections or traffic generation points (both on the major and service roads).
- Providing satisfactory diverge/merge lengths (see below).

Angled intersections from and to service roads shall only be permitted where the major road is dual carriageway.

Where an angled diverge arrangement is necessary it is essential (regardless of traffic flows) that an appropriate deceleration facility is provided. Where the traffic turning and layout conditions in clause 2.5.8 are met, this facility should constitute an auxiliary lane in accordance with the requirements of clause 2.5.8.

Where the turning and layout conditions in clause 2.5.8 are not met a direct taper may be incorporated in place of the auxiliary lane. Taper lengths shall be in accordance with Table 2.6.1.

Table 2.6.1 Taper lengths for diverges at urban service road junctions

Design Speed (kph)	Up Gradient		Down Gradient	
	0-4%	Above 4%	0-4%	Above 4%
50	25	25	25	25
60	25	25	25	25
70	40	25	40	40
80	55	40	55	55
100	80	55	80	80
120	110	80	110	110

Where an angled merge arrangement is necessary it is essential (regardless of traffic flows) that an appropriate acceleration facility is provided. Where the traffic turning and layout conditions in clause 2.5.9 are met, this facility should constitute an auxiliary lane in accordance with the requirements of clause 2.5.9.

Where the turning and layout conditions in clause 2.5.9 are not met a direct taper may be incorporated in place of the auxiliary lane. Taper lengths shall be as identified in Table 2.5.6.

Failure to provide an adequate facility for acceleration and deceleration at angled merges and diverges shall be considered a Departure from Standards.

Figure 2.6.1 shows a diverge and merge for a service road off an urban road of design speed 100 kph or greater. The spacing of diverge nose to merge nose is fixed by the design constraints of the facility. Major road hard shoulders shall be provided adjacent to the diverge/merge facility (auxiliary lane or taper), terminating at the chicane entry/exit linking the diverge/merge facility with the service road.

In the case of an angled service road merge for design speed greater than or equal to 100kph, the major road hard shoulder shall be terminated by hatching from a location equivalent to major road stopping sight distance upstream of the merge facility (refer to Figure 2.6.1). This is to avoid any potential conflict between merging vehicles and vehicles running on the hard shoulder.

Figure 2.6.2 shows a similar diverge and merge for a service road off an urban road of design speed less than 100 kph. The spacing of diverge nose to merge nose for this design speed is fixed by the design constraints of the facility. Under these conditions major road hard shoulders may be terminated in advance of the facility and replaced by a 0.5m hardstrip.

Visibility requirements on service roads shall be in accordance with Section 2 for the appropriate design speed. The service road junction visibility requirements shall be in accordance with those for other junctions, as outlined in this Section. Any reduction in these requirements shall be a Departure from Standards.

Where roadside parking is provided on the major road, it is essential that this does not infringe on visibility requirements. A minimum length of 20m shall be provided between the service road chicane and associated acceleration/deceleration facility, and any roadside parking facility. However this length may be increased as required to ensure that visibility requirements are met.

Where successive merges and diverges are introduced on the major road, weaving lengths must be considered in accordance with Section 7. Failure to provide adequate weaving lengths shall be considered a Departure from Standards.

The minimum length between successive Merge/Merge or Diverge/Diverge measured between the tips of the noses shall be $3.75V$ where V is the design speed of the major road (kph). This length may be increased where necessary for signing requirements.

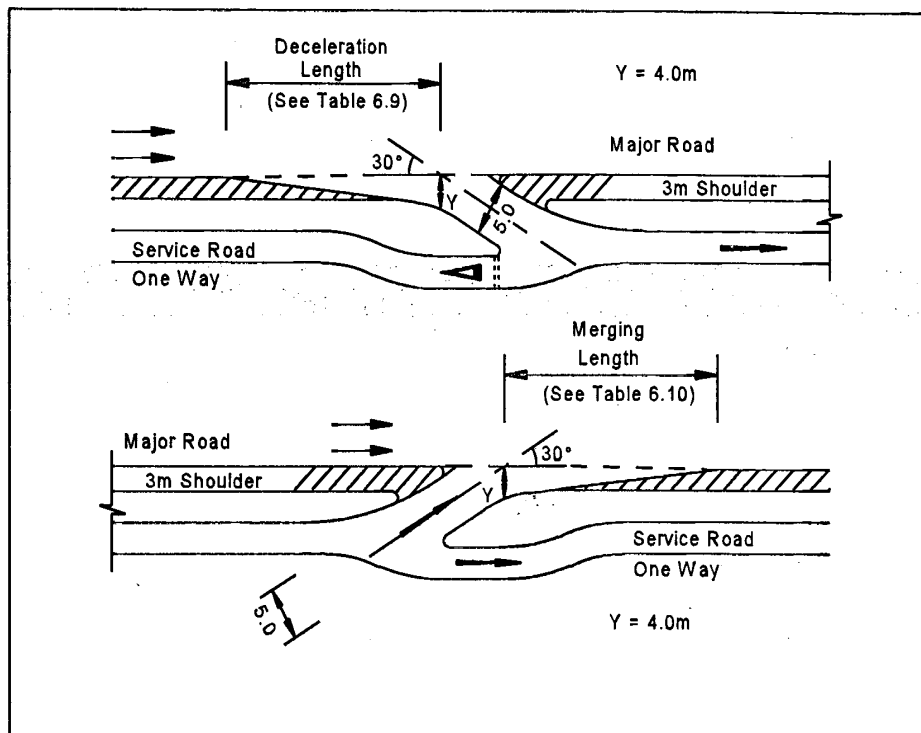


Figure 2.6.1 Service Road Diverge/Merge for Speeds $\geq 100\text{kph}$

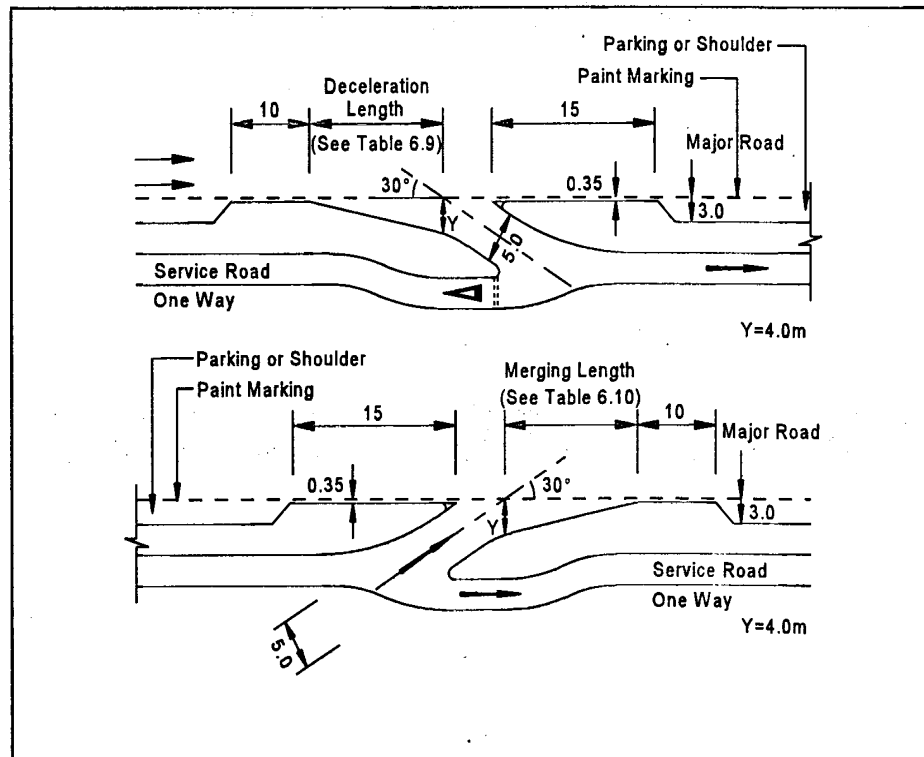


Figure 2.6.2 Service Road Diverge/Merge for Speeds < 100kph

2.7 U-Turn Facilities

2.7.1 General Principles

U-turn facilities are appropriate on urban dual carriageways with relatively low traffic demands, where major road speeds are moderate and main line traffic levels are not high. U-Turns require a generous median which may be difficult to provide in constrained locations.

U-turn facilities should only be used where the posted speed on the road is 60kph or less. They should not be used on routes incorporating grade separated interchanges. Guidance on appropriate route classifications for the use of U-turn facilities is provided in Part 1.

Although it is considered preferable not to use U-Turns facilities as a deliberate road design policy, this provision can become necessary in specific circumstances, examples of which are;

- For removing U-turn manoeuvres from a downstream intersection where it might reduce overall junction capacity,

- For reducing left turns from major roads at cross road junctions by providing a U-Turn downstream of the junction to enable drivers to access developments on the opposite carriageway.

Where U-turn facilities are provided these should be treated as intersections and adequate spacing to adjacent intersections shall be provided in accordance with Part.

Issues which relate to the design of U-Turns are:

- The median width, which will need to accommodate the expected design vehicle without it encroaching into the carriageway that is being entered, or that which is being left.
- Traffic conditions -which will require consideration of the level of traffic flows on the main carriageways and the type and intensity of traffic likely to use the U-Turn for various design conditions.
- Visibility and sight distances - to ensure drivers can anticipate traffic paths and movements and make the necessary adjustments to avoid conflict.
- Requirements of left turning lanes -without which, major road traffic will be interrupted and queues may form which project into the high speed lane of the through carriageway which is being left. This increases potential for rear end collisions.
- The combined median width and carriageway width in order to allow the design U-Turning vehicle to perform the necessary maneuvers to the slow lane of the joining carriageway.

2.7.2 Geometric Design

The basic design procedures for U-Turn facilities follow the same principles as that for left turns from major roads. A U-turn facility shall incorporate the following key features, as identified in Figure 2.5.1:

- A turning lane (with direct taper) on approach to the median opening.;
- A median opening of 15m length, adequate to allow the design vehicle to make the necessary manoeuvre;
- Where necessary, a widened median to accommodate the turning circle of the design vehicle.

The turning lane length shall be provided in accordance with Table 2.5.3, in which the gradient is the average for the 500m length before the minor road.

U-turn figure to be added

Figure 2.7.1 U-turn Facility

The width of a left turning lane shall be equal to the width of the adjacent through lane. The direct taper length shall be 5m. This shall be included in the deceleration length.

The minimum median width will be influenced by the width of the opposing carriageway into which vehicles are turning. An overall minimum width of 16.0m is required between the offside edge of the outer through carriageway from which the vehicle is turning, to the nearside edge of the opposing running carriageway. The design shall be checked for the design vehicle. U-turning vehicles shall not be required to use the hard shoulder.

Where capacity calculations indicate that for significant periods of time there will be vehicles queuing to make the U-turn manoeuvre, the turning length shall be increased to allow for a reservoir queuing length to accommodate such vehicles.

Table 2.7.1 Deceleration Length on Single Carriageway Roads

Design Speed (kph)	Up Gradient		Down Gradient	
	0-4%	Above 4%	0-4%	Above 4%
50	40	40	40	40
60	40	40	40	60

The movement of the design vehicle performing the U-Turn will be checked on the final design layout using appropriate computer software to confirm the safety of the stationary position in the middle of the median opening and the swept paths on the carriageway being entered.

Adjustments to median width will be made as necessary to ensure adequate turning width and clear views of oncoming traffic for the driver.

U-Turns without the provision of left turn lanes of diverging tapers are not recommended for general traffic use.

U-Turns are not permitted on three lane dual carriageways.

2.8 Priority Intersections in Residential Areas

2.8.1 Typical Configurations

In urban areas and, in particular, within residential areas, where there is the likelihood of pedestrians crossing the road and where parking may be on-street, careful consideration is required at road junctions.

The most commonly used junction to access developments and the most appropriate is the T-Junction.

In the layout shown in Figure 2.8.1 the major traffic flow is on the through route, typically a local access road, with individual residential access roads joining. However in order to reduce the degree of access on to the through route, it is desirable where possible to consolidate junctions, by linking them on to a secondary access road, prior to entering on to the through route, as shown in Figure 2.8.2. This can reduce the number of junctions on the through route, therefore improving capacity and safety. It can also have the benefit reducing speed on residential roads by introducing additional low speed corners between the through route and residential areas.

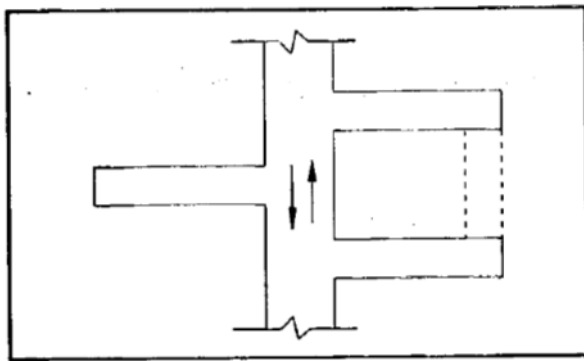


Figure 2.8.1 Multiple accesses joining a major road

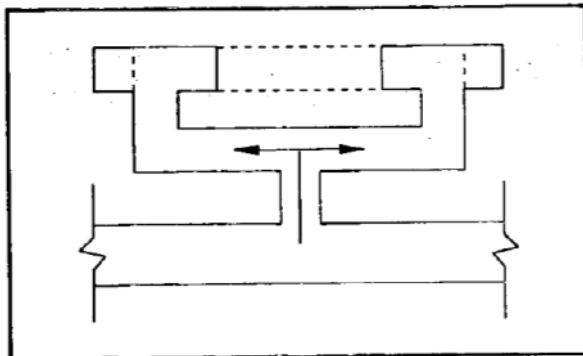


Figure 2.8.2 Access Roads Consolidated Prior to Access to Through Route

The use of 'simple' crossroads is not encouraged as there is a tendency, particularly in areas of low traffic flow, for drivers on the minor road to fail to obey the priority

signing and drive through the junction, thereby creating a hazard to traffic on the major road. The preferred form of vehicular crossing movement is a stagger junction. Wherever possible this should be in a left/right configuration so that vehicles making the cross-movement first turn left then right.

Roundabouts may be used at the intersections in residential areas. However, roundabouts are generally only required where the volume of traffic on the minor road approaches is of the same order as that on the major road, and where the overall level of traffic is such that vehicles on the minor road experience severe delay.

Compact Roundabouts may be appropriate in residential areas, refer to Section 6.

2.8.2 Older Residential Areas

Many existing older residential areas in Qatar have particular requirements. Common issues relating to older residential areas include:

- Narrow road reservations giving rise to poor visibility, especially at intersections
- High parking requirements
- Street system of ill defined through-ways, crossroads and rat-runs

Consideration may be given to enhancements through treatment of existing priority intersections, to control traffic movement and improve safety and environmental conditions. Improvements shall be carefully planned to meet the requirements of the area. Traffic should be restricted from areas where it is undesirable, rat-runs should be closed, parking regulated and surface water effectively collected. The following are typical actions:

- Closure or partial closure of one or more legs of a crossroads;
- Introduction of parking at appropriate locations;
- Closure of some minor access roads leading into residential developments from local or district distributors;
- Identification of areas such as schools, shops, mosques, etc that may require specific consideration for parking.

2.8.3 Corner lots at Priority Intersections

When developing roads in urban situations, it is essential that adjacent developments, and their impact on the road standards, are given due consideration. This is particularly the case at urban intersections, where visibility requirements must be achieved.

Notwithstanding the details contained in this clause, the road designer is required to ensure that visibility requirements are met in accordance with clause 5.3.

In order to enable adjacent developments to be planned to allow for road visibility requirements, planners must determine appropriate Right of Way “clippings” at corner lots.

At the planning stage it is noted that little or no information may be available regarding the road design parameters. The guidance within this clause enables planners to determine appropriate “clippings” and associated right of way chamfer distances for corner lots, in advance of the road design criteria being determined.

Chamfer distances are determined on the basis of the Right of Way widths provided on the approaching roads. The development of chamfers is illustrated in Figure 2.8.3.

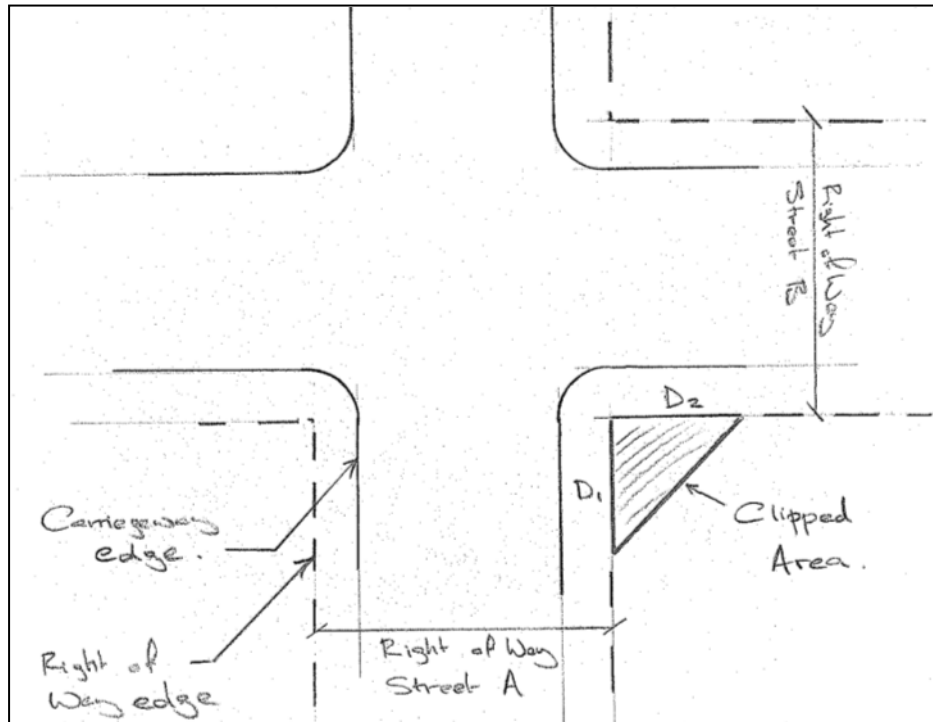


Figure 2.8.3 Development of Chamfer at Corner Lot

The minimum chamfer distances at corners are as indicated in Table 7.1.1. The chamfer length is determined by the Right of Way width of the adjacent road. Therefore with reference to Figure 2.8.3 the dimension D_1 is determined by the Right of Way width of Street A, and D_2 is determined by the Right of Way width of Street B.

Table 2.8.1 Chamfer length at Corner Lot

Right of Way Width (m)	Adjacent chamfer length D (m)
Less than 24	8
24 to 32	12
Greater than 32	16

The dimensions included in Table 2.8.1 are appropriate where the angle of intersecting roads lies between 75 and 105 degree. Where intersection angles are outside of this range further guidance should be sought from the relevant Planning authority.

The dimensions included in Table Table 2.8.1 apply to residential roads only. In commercial and industrial areas range further guidance should be sought from the relevant Planning authority.

**Draft. For June 2013 stakeholder
workshop use only**

3 Roundabouts

3.1 Introduction

3.1.1 General

Roundabouts are intersections with a one-way circulatory carriageway around a central island. Vehicles on the circulatory carriageway have priority over those approaching the roundabout. This document describes the geometric design of the various types of roundabout for application to new and improved intersections.

The use of roundabouts on various road classifications in Qatar shall be subject to the permitted junction types defined in Section 4.

The capacity of roundabouts will vary depending on their size and geometrical design, but will generally have a higher capacity than uncontrolled priority intersections and a lower capacity than grade separated interchanges.

This section relates to all permitted roundabout types on the Qatar road network. Recommendations are given on the selection of roundabout type, geometric layout, visibility requirements and crossfall, with respect to the speed limit on the approach roads, the traffic flow and the level of non-motorised user demand.

3.1.2 Design Principles

The principal objective of roundabout design is to secure the safe passage of vehicles between crossing traffic streams with minimum delay. This is achieved by a combination of geometric layout features that, ideally, are matched to the traffic stream volumes, their speed, and to any location constraints that apply. In urban situations land constraints have a significant influence on the design process for improvements to junctions.

Roundabouts should be designed to match forecast demand. They work most efficiently when vehicular flows are reasonably balanced between the arms, but they may also be the optimum choice in other cases.

Consideration of the geometric layout of the approach arms to roundabouts is essential to ensure a satisfactory design. Reductions in Junction Approach Sight Distance (JASD) for the approach arm design speed, as defined in Section 2, on the immediate approach to a roundabout shall not be permitted. Within this Section the immediate approach to a roundabout is defined in clause 8.1.

Entry width and sharpness of flare are the most important determinants of capacity, whereas entry deflection is the most important factor for safety as it governs the speed of vehicles through the roundabout. This is particularly important whenever approach speeds are high. Entry deflection is related to the entry path radius and limiting this radius of curvature in the vicinity of the entry ensures that sufficient deflection will be undergone by entering vehicles to limit through speeds.

Consideration of the need for and layout of traffic signs, road markings and lighting should be an integral part of the design process. Reference should be made to the Qatar Traffic Control Manual.

3.1.3 Definitions

Roundabouts are made up of a number of distinct but inter-related elements. In consideration of the design of roundabouts it is essential that these elements are correctly defined and measured for compliance. For clarity, definitions of key elements are outlined below. Graphical representations of these elements can be found in sub-Section 7 of this Section 4.

Approach Half Width is measured at a point in the approach carriageway upstream from any entry flare, from the median line (or offside edge of carriageway on dual carriageways) to the nearside kerb, along a normal.

Central Island is the raised island at the centre of the roundabout. On compact and smaller roundabouts the central island may include an overrun area to ensure that larger vehicles can negotiate the roundabout while a sufficiently low entry path radius is maintained.

Circulatory carriageway is the carriageway circulating around the central island.

Entry Angle is the angle at which vehicles entering the roundabout coincide with vehicles on the circulating carriageway. At smaller roundabouts where there is insufficient spacing between the entry and exit arms for a vehicle to join the circulating carriageway, the angle may be measured relative to the adjacent exit.

Entry Flare is localised widening at the point of entry. Normal Roundabouts usually have flared entries with the addition of a further lane at the give way line to increase capacity.

Entry Kerb Radius is the minimum radius of curvature of the nearside kerb line over the distance from 25m ahead of the give way line to 10m downstream of it. This should not be confused with Entry Path Radius.

Entry Path Radius (or its inverse, the entry path curvature) is a measure of the deflection to the right imposed on vehicles entering a roundabout. Entry path curvature can be used to control vehicle entry speeds and is therefore a critical factor in ensuring the safety of the roundabout design.

Entry Width is the width available on immediate entry to the roundabout, measured normal to the approach carriageway, between the nearside kerb and the entry deflection island or median.

Inscribed Circle Diameter is the diameter of the largest circle that can be inscribed within the junction outline. In cases where the outline is asymmetric, the local value in the region of the entry is taken.

Traffic Deflection Island is a kerbed raised area on the carriageway, which is located and shaped so as to direct and also separate traffic movements onto and from a roundabout. This may be enhanced by use of markings to further guide vehicles on to the roundabout.

3.2 Types of Roundabouts

3.2.1 Normal Roundabouts

A Normal Roundabout has a kerbed central island at least 4 metres in diameter (Figure 3.2.1). Its approaches may be dual or single carriageway roads. Usually, a Normal Roundabout has flared entries and exits to allow two vehicles to enter or leave the roundabout on any given arm at the same time. If so, its circulatory carriageway needs to be wide enough for two vehicles to travel alongside each other on the roundabout itself.

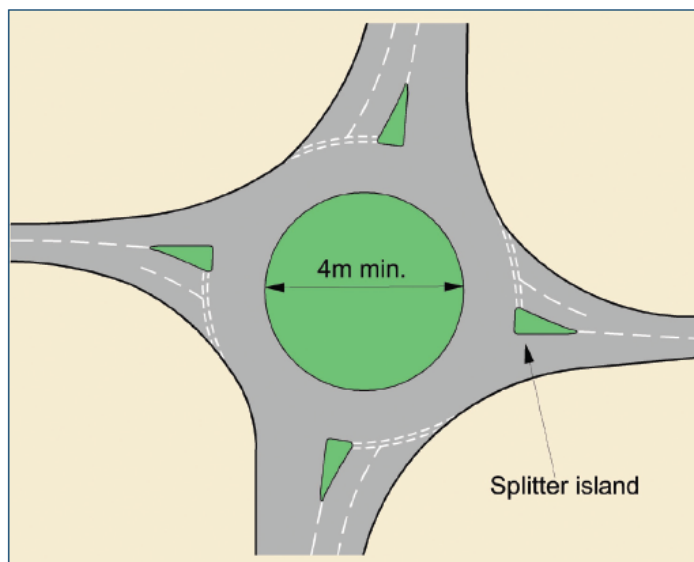


Figure 3.2.1 – Normal Roundabout

If a Normal Roundabout has more than four arms, it becomes large with the probability that higher circulatory speeds will result. Either a Double Roundabout or a Signalized Roundabout is a potential solution in these circumstances.

3.2.2 Compact Roundabouts

Compact roundabouts are appropriate on lower classification, urban routes (e.g. minor collectors and local access roads), providing a safer alternative to a crossroad intersection. In addition, the non-flared entries/exits give the designer more flexibility in siting pedestrian crossings. A Compact Roundabout (Figure 3.2.2) has single lane entries and exits on each arm. The width of the circulatory carriageway is such that it is not possible for two cars to pass one another.

On roads with a posted speed of 60kph or less within 100m of the give way line on all approaches, Compact Roundabouts may have low values of entry and exit radii in conjunction with high values of entry deflection. This design has less capacity than that of Normal Roundabouts, but is particularly suitable where there is a need to accommodate the movement of pedestrians and cyclists.

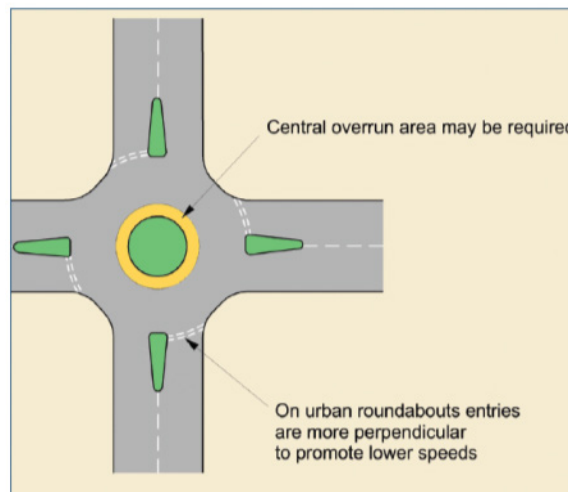


Figure 3.2.2 – Compact Roundabout

On roads with posted speeds exceeding 60kph, the design of Compact Roundabouts reverts to that for Normal Roundabouts, but the single-lane entries and exits are retained.

3.2.3 Grade Separated Roundabouts

A Grade Separated Roundabout is a roundabout that has at least one approach arm coming from a road at a different level. This type of roundabout may be employed at interchanges.

Roundabouts can be designed to be at a higher level than the major roads, or vice-versa, at ground level with the major road passing above. A typical example is shown in Figure 3.2.3.

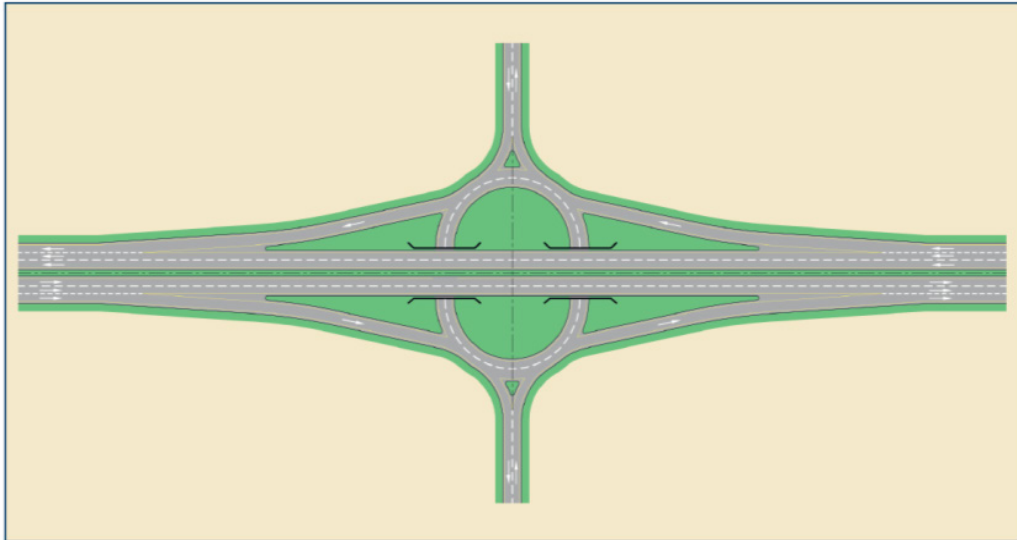


Figure 3.2.3 – Grade Separated Roundabout

3.2.4 Signalized Roundabouts

A Signalized Roundabout has traffic signals on one or more of the approach arms and at the corresponding point on the circulatory carriageway itself.

Installing traffic signals, with either continuous or part-time operation, at some or all of the entry points can be appropriate where a roundabout does not naturally self-regulate. This may be for a combination of reasons such as:

- a growth in traffic flow;
- an overloading or an unbalanced flow at one or more entries;
- high circulatory speeds;
- significantly different flows during peak hour operation.

In some cases, it may be possible to achieve the desired result without traffic signal installation, by making suitable changes to the layout, and this should be checked using suitable software before installing traffic signals.

At busy traffic signal controlled roundabouts there may be insufficient storage space on the circulatory carriageway for all traffic waiting, and therefore queuing traffic may have to extend along the approach arm. In such instances appropriate controls should be in place, through road markings and signal phasing, to ensure that queuing traffic does not block the circulatory carriageway.

3.2.5 Double Roundabouts

A Double Roundabout is a intersection comprising two roundabouts separated by a short link (see Figure 3.2.4). The roundabouts may be Compact or Normal Roundabouts.

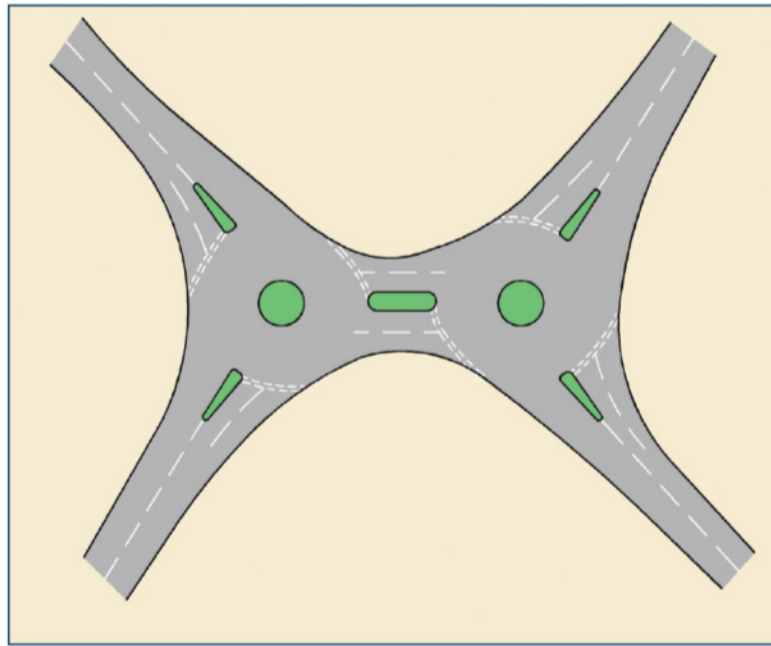


Figure 3.2.4 – Double Roundabout with Short Central Link

Double Roundabouts can be particularly useful:

- for improving an existing staggered junction where the stagger distance is insufficient to accommodate desirable deceleration lengths and turning lengths. This avoids the need to realign one of the approach roads and can achieve a considerable construction cost saving compared with a larger, single island roundabout;
- for joining two parallel routes separated by a feature such as a river, a railway line or a Freeway;
- at overloaded single roundabouts where, by reducing the circulating flow past critical entries, they increase capacity;
- at intersections with more than four entries, where they may achieve better capacity and make more efficient use of space with better safety characteristics compared with a large roundabout which may generate high circulatory speeds which result in a loss of capacity and safety.

A Double Roundabout should be designed as a single system rather than as two individual roundabouts. The link joining the pair of roundabouts is usually short and there is often insufficient distance to change lane. The lane use on the link should be established from the turning volumes feeding it and should be checked so that lane balance is produced on the common link. Reducing the capacity of the entries that feed the common link can prevent traffic blocking back onto the roundabouts, thus increasing the overall capacity.

3.3 Safety at Roundabouts

3.3.1 General

The characteristics of roundabout accidents and their frequencies in relation to geometric layout design and traffic flows have been studied in the UK by Transportation Research Laboratory (TRL). The relationships derived from these studies have provided insights into how various aspects of design interact to influence the types and frequencies of accidents at roundabouts. These relationships therefore, constitute the fundamentals of design for safety. As relationships between aspects of design are not always mutually compatible, minimising the likely incidence of a particular type of accident may increase the potential for another. Design, therefore is a trade-off between operational efficiency, minimising delays at the intersection, and various safety aspects within whichever location constraints apply. The latter are often the dominating factor when designing improvements to an existing intersection, particularly in urban areas.

Numerous studies have shown significant safety improvements at intersections converted from conventional forms to roundabouts. It is generally known from studies that fewer accidents occur at roundabouts than at signalized intersections of similar traffic flows. The severity of accidents is also much less than at other junctions.

Care must be taken in layout design to secure the essential safety aspects. The most common problem affecting safety is excessive speed, both at entry or within the roundabout. The most significant factors contributing to high entry and circulating speeds are:

- Inadequate entry deflection (excessive entry path radius);
- A very acute entry angle which encourages fast merging manoeuvres with circulating traffic;
- Poor visibility to the "Give Way" line;
- Poorly designed or positioned warning and advance direction signing;
- Very large roundabouts encouraging high circulatory speeds.

Additional safety aspects to be considered in designing a layout include:

- Gradient: Approach gradients should provide appropriate conditions for vehicles entering the roundabout. Steep uphill gradients can make roundabout entry difficult, particularly for large vehicles, while steep downhill gradients may encourage excessive speeds at entry, therefore increasing collision potential;
- Visibility to the left at entry: This has comparatively little influence upon collision risk. There is nothing to be gained by increasing visibility above the recommended level;
- Crest Curves: Roundabouts should not be sited on crest curves where the visibility on approach to the roundabout is impaired;
- Design to encourage slow entry to the roundabout and quick exit to leave the roundabout clear for the next users.

Measures to reduce collisions at existing roundabouts with poor safety records include:

- Repositioning or reinforcement of warning signs;
- Provision of map type advance direction signs;
- Making the "Give Way" line more conspicuous;
- Ensuring that chevron signing placed on the central island is conspicuous to approaching drivers to emphasise the angle of turn. Extending the central island chevron sign further to the right, and placing chevron signs in the median in line with the offside lane approach on dual carriageways may be beneficial. Chevron boards can impinge on circulatory visibility but the effects can be minimised by positioning the boards (and associated turn right sign) 2m back from the central island curb line;
- When approach speeds are low (usually in urban areas), a ring of contrasting paving can be laid in a chevron pattern inside the central island perimeter at a gentle slope. Where used, regular maintenance inspections of this type of treatment are required to ensure that the block work remains visible. Normal chevron signs should also be included at these locations. In rural areas it is not recommended to install raised kerbed chevrons on roundabouts. Experience has shown that physical obstructions such as chevron kerbing will be hit inadvertently at night time by vehicles whose drivers are not aware of the junction ahead. Chevron signs should be placed in these locations only;
- Landscaping where approach speeds are high in urban areas can provide a useful enhancement to the visibility of the roundabout;
- Provision of Transverse "Yellow Bar Markings" on fast dual carriageway approaches has shown that a 57% reduction in accidents can be achieved. This is from studies carried out in the UK by the TRL;
- Provision of appropriate levels of skidding resistance on the approaches to roundabouts and on the circulatory carriageways;
- Avoidance of abrupt and excessive super elevation in the entry region;
- Physical adjustment of central and/or entry deflection islands to achieve compliant roundabout geometry;
- Provision of "Reduce Speed Now" signs and/or "Count-down" markers;

Skidding resistance on the circulatory carriageway is derived from the surface texture of the aggregates which form the surface of the road (the micro-texture). Particular consideration should be given to ensure that the aggregates used have skid resisting properties appropriate to the circumstances.

Care should be taken with the choice of kerb type for roundabout design. A safety problem can arise where certain specialist, high profile kerbs are used around a central island as they can be a danger to vehicles over-running the entry. Observations have shown that these kerbs can result in loss of control or overturning of vehicles unless the approach angle is small and actual vehicle speeds are low. Where high profile kerbs are to be used on approaches, the kerbs can be hazardous for vehicles and pedestrians, and consideration should be given to the provision of pedestrian guardrails. Care should be taken to ensure that visibility sightlines are maintained.

High circulatory speeds cause associated entry problems and normally occur at large roundabouts with excessively long circulatory carriageways. The solution to high circulatory speeds may involve the signalisation of problem entry arms at peak hours.

If entry problems are caused by poor visibility to the left, good results can be achieved by moving the "Give Way" line forward in conjunction with curtailing the adjacent circulatory carriageway by hatching or extension of the traffic deflection island.

3.3.2 Two Wheeled Vehicles

Roundabouts have an impressive overall safety record for most vehicle types. However two-wheeled vehicles are particularly vulnerable in areas of conflict and it is therefore essential that these vehicle types are considered in the design process.

3.3.3 Large Goods Vehicles

Poorly designed roundabouts may introduce problems for large goods vehicles relating to overturning or load shedding. Damage-only accidents a year in this category often involve great congestion and delay, and are expensive to clear, especially if occurring at major junctions. Experience suggests that roundabouts where these problems persist usually exhibit one or more of the following features:

- Long, straight high speed approaches with inadequate entry deflection leading to high entry speeds;
- Low circulating flow combined with excessive visibility to the left;
- Long straight sections of circulatory carriageway leading into deceptively tight bends;
- Sharp turns into exits;
- Excessive crossfall changes on the circulatory carriageway;
- Excessive adverse crossfall on a nearside lane of the circulatory carriageway.

Shedding loads is an inherent problem for some vehicles at low speeds. Research has shown that an articulated, large goods vehicle with a centre of gravity height of 2.5m above the ground can overturn on a 20m radius bend at speeds as low as 24 kph. Particular attention should be paid to ensure that pavement surface tolerances are complied with and that abrupt changes in crossfall are avoided. It is good practice to make the exit radii greater than the entry radii.

3.4 Siting of Roundabouts

3.4.1 General

In addition to its natural function as an intersection, a roundabout may usefully:

- facilitate a significant change in road standard, for example, from dual to single carriageway roads or from grade separated interchange roads to at-grade intersection roads, although complete reliance should not be placed on the roundabout alone to act as an indicator to drivers;
- emphasise the transition from a rural to an urban or suburban environment (although using one when there are no joining roads is not recommended);

- allow U-turns to be executed safely;
- facilitate heavy left turn flows.

The majority of collisions at major/minor priority intersections are associated with left turns. The inconvenience of banned left turns can be mitigated by providing a roundabout nearby.

Roundabouts are not permitted as an option for at-grade intersections on rural three-lane dual carriageway roads.

On single carriageway roads where overtaking opportunity is limited, roundabouts may be sited in order to optimise the length of straight overtaking sections along the route (see Section 2). They can also be used to provide an overtaking opportunity by having a short length of two lanes on the exit arms. The length of these sections will depend on site conditions and traffic demand.

Roundabouts should preferably be sited on level ground or in sags rather than at or near crests because it is difficult for drivers to appreciate the layout when approaching on an up gradient. However, there is no evidence that roundabouts on crests are intrinsically unsafe if correctly signed and where the visibility standards have been provided on the approach to the give way line. Roundabouts should not be sited at the bottom of or on long descents.

Roundabouts in urban areas are often not compatible with Urban Traffic Control (UTC) systems. These systems move vehicles through their controlled areas in platoons by adjusting traffic signal times to suit the required progress. Roundabouts can interfere with platoon movement to the extent that subsequent inflows to downstream traffic signals cannot be reliably predicted, and thus the sequence breaks down. However, in some cases, for example, where there is a heavy left turn flow, the roundabout may be a better option.

Where several roundabouts are to be installed on the same route, they should be of similar design in the interests of route consistency and hence safety, to the extent that this is possible with the traffic volumes concerned.

Where a proposed roundabout may affect the operation of an adjacent junction, or vice versa, the interactive effects should be examined. Where appropriate, traffic management measures such as prohibited turns or one-way traffic orders may be considered. The effects of queuing should be examined to check that additional risk is not generated.

3.5 Design Hierarchy

3.5.1 Selection of Roundabout Type and Provision for Non-motorised Users

The selection of appropriate roundabout type is governed by a combination of factors including:

- whether the intersecting roads are single or dual carriageway, or grade separated;
- the speed limit on the approach roads;
- the level of traffic flow;
- the level of non-motorised user (NMU) flow;
- other constraints such as land-take.

Table 3.5.1 gives the attributes of the different roundabout types, and indicates the normal type of provision for cyclists and pedestrians where there is sufficient demand to justify them. Further advice on non-motorised users is provided in Section 12. Grade separation for non-motorised users is the best option at high speed roundabouts, but this may not be cost-effective.

Draft. For June 2013 stakeholder
workshop use only

Table 3.5.1 – Selection of roundabout types and provision for Non-motorised Users

Roundabout category	Highest class of road on any approach	Highest posted speed within 100m on any approach	Highest two-way AADT on any approach	Recommended cyclist provision	Recommended pedestrian provision	Combined cycle and pedestrian provision	Roundabout type
1	Grade separated entry/exit	Any	Any	Signal controlled / grade separated ¹	Signal controlled / grade separated ¹	Signal controlled / grade separated ¹	Grade Separated
2	Dual carriageway	>60kph	Any	Signal controlled / grade separated ¹	Signal controlled / grade separated ¹	Signal controlled / grade separated ¹	Normal
3	Single carriageway	>60kph	>8,000	Signal controlled ¹	Signal controlled ¹	Signal controlled ¹	Normal
4	Single carriageway	>60kph	<8,000	Informal	Informal	N/A	Compact
5	Dual carriageway	≤60kph	>25,000	Signal controlled	Signal controlled	Signal controlled	Normal
6	Dual carriageway	≤60kph	16,000-25,000	Signal controlled	Uncontrolled or signal controlled	Signal controlled	Normal
7	Dual carriageway	≤60kph	<16,000	Informal	Informal or uncontrolled crossing	Informal	Normal
8	Single carriageway	≤60kph	>12,000	Signal controlled	Signal controlled	Signal controlled	Normal
9	Single carriageway	≤60kph	8,000-12,000	Informal	Informal or uncontrolled crossing	Informal or signal-controlled	Normal or Compact
10	Single carriageway	≤60kph	<8,000	Informal	Informal	Informal	Compact

1) Signal controlled crossing to be provided only if warranted by site-specific conditions; an alternative is grade separated provision.

3.6 Geometric Design – Circulatory Carriageway

3.6.1 Inscribed Circle Diameter (ICD)

The following advice is based on the swept turning paths generated by a 15.5m long articulated vehicle with a single axle at the rear of the trailer. This is referred to below as the "Design Vehicle".

The turning width required by this type of vehicle is greater than that for all other vehicles within the normal maximum dimensions permitted in the classifications given in Section 4, or likely to be permitted in the near future. The requirements for other vehicles (including an 11m long rigid vehicle, 12m long coach, 20m drawbar trailer combination, and a 16.5m articulated vehicle) are less onerous.

The smallest ICD for a Compact or Normal Roundabout that will accommodate the "Design Vehicle" is 28m. It should be noted that it may be difficult, if not impossible, to meet the entry deflection requirement with normal roundabouts which have ICD's up to 40m. In this case consideration could be given to the installation of a low profile central island which would provide adequate deflection for standard vehicles but allow overrun by the rear wheels of articulated vehicles and trailers. Such islands should have the same profile as the circulatory carriageway with a maximum upstand of 50mm. Roundabouts of less than 28m ICD are not permitted and shall be considered a Departure from Standards.

The turning space requirements for the "Design Vehicle" at compact and smaller normal roundabouts from 28m to 36m ICD are shown in Figure 3.6.1.

3.6.2 Circulatory Carriageway

The circulatory carriageway should, if possible, be circular in plan, avoiding deceptively tight bends. In cases of complex roundabouts where non-circular geometry is required, the use of tight curves should be avoided as they increase the risk of commercial vehicles shedding loads, and increase the risk of loss of control by drivers.

The width of the circulatory carriageway on Normal and Grade Separated Roundabouts (exclusive of any block paving overrun areas, see clause 6.2.3 below) shall not exceed 10m and shall consist of two lanes. At Compact Roundabouts a circulatory width of 6m shall not be exceeded. Where the circulatory carriageway width does not correspond to these widths it shall be considered a Departure from Standards.

Block paving "collars" around the central island can be used to provide additional width if long vehicle turning movements need to be catered for on smaller Normal Roundabouts and Compact Roundabouts. This additional width shall not be included in the definition of the circulatory carriageway width.

The width of the circulatory carriageway shall be constant and lie between 1.0 and 1.2 times the maximum entry width (see clause 7.1 for entry width details). Where the

circulatory carriageway width does not correspond to this width it shall be considered a Departure from Standards.

It is normal practice to avoid short lengths of reverse curve between entry and adjacent exits by linking these curves or joining them with straights between the entry kerb radius and the exit radius.

There may be situations where the turning proportions are such that one section of circulatory carriageway will have a relatively low flow. In this case, there may be an over provision in circulating carriageway width and an area of carriageway, usually adjacent to an entry deflection island, becomes unused. It is not acceptable to reduce the circulatory carriageway width by extending the deflection island into the circulatory carriageway.

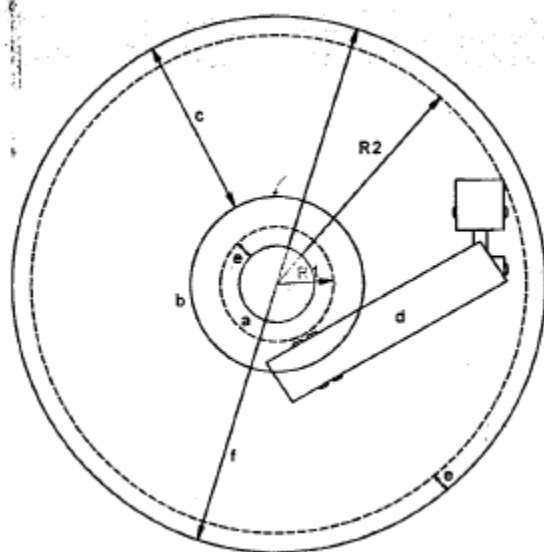
For smaller roundabouts it may be appropriate to consider interim circulatory carriageway reduction by increasing the size of the central island. If this is to be introduced from the outset, a preferable measure would be the use of contrasting hard surfacing.

3.6.3 Central Island

The central island should be circular and at least 4 metres in diameter. The inscribed circle diameter, the width of the circulatory carriageway and the central island diameter are all interdependent: once any two of these are established, the remaining measurement is determined automatically.

It should be noted that the swept path for the Design Vehicle (as detailed in clause 6.1, ICD) may impinge slightly (by up to 0.3m) into either the inner or outer 1m clearance allowance. Given the anticipated frequency of this type of vehicle, this is not considered to be particularly significant and the dimensions in Figure 3.6.1 and associated Table 3.6.1 should not be increased accordingly.

In order to ensure that light vehicles encounter sufficient entry deflection at Compact or small Normal Roundabouts, an overrun area (i.e. a raised low profile area around the central island) may be necessary (Figure 3.6.1). It should be capable of being mounted by the trailers of large goods vehicle, but be unattractive to cars e.g. by having a slope and/or a textured surface.



- a. Main central island
- b. Central overrun area, where provided
- c. Circulatory carriageway width = $1.0-1.2 \times$ maximum entry width
- d. Vehicle
- e. 1m clearance minimum
- f. Inscribed Circle Diameter

Figure 3.6.1 – Turning widths for compact and smaller normal roundabouts

Table 3.6.1 – Turning widths for compact and smaller normal roundabouts

Central Island Diameter (m)	R1(m)	R2(m)	Minimum ICD (m)
4.0	3.0	13.0	28.0
6.0	4.0	13.4	28.8
8.0	5.0	13.9	29.8
10.0	6.0	14.4	30.8
12.0	7.0	15.0	32.0
14.0	8.0	15.6	33.2
16.0	9.0	16.3	34.6
18.0	10.0	17.0	36.0

Note: Entry deflection islands shall not encroach within the inscribed circle diameter

3.6.4 Entry Deflection Islands

Entry deflection islands are used on each roundabout arm, located and shaped to separate and direct traffic entering and leaving the roundabout. Entry deflection island geometry is defined by the alignment geometry of entrances and exits and is generally unique to each site. It is the residual area at the approach arms to roundabouts between entrances and exits which is left after the optimum roundabout geometry has been established.

They are usually kerbed, which is the recommended treatment, but if there is insufficient space to accommodate a kerbed island, they may consist entirely of markings. Markings may also be used to extend an entry deflection island on the approach, the exit or the circulatory carriageway.

Kerbed entry deflection islands can act as pedestrian refuges provided that they are large enough to give adequate safe standing space for accompanied wheelchair users and pedestrians with pushchairs or pedal cycles. A minimum width of 2.0m shall be provided though this may be increased depending on anticipated pedestrian flows and associated requirements. Signs and other street furniture can also be sited on kerbed islands provided that there is sufficient room to maintain the required clearances and adequate visibility is maintained.

3.7 Geometric Design – Entries and exits

3.7.1 Roundabout entries

The design of roundabout entries is a complex procedure, with several variables that need to be addressed to ensure a design which is safe and has adequate capacity.

The designer has flexibility in the application of the parameters to best meet the particular site requirements and constraints. The variables include:

- Entry Width (e);
- Approach Half Width (v);

- Flare Length (l');
- Entry Angle (ϕ);
- Entry Kerb Radius (r);
- Entry Path Radius (a).

Entry Width

Entry Width is measured from the point A along the normal to the nearside kerb. Refer to Figure 3.7.1.

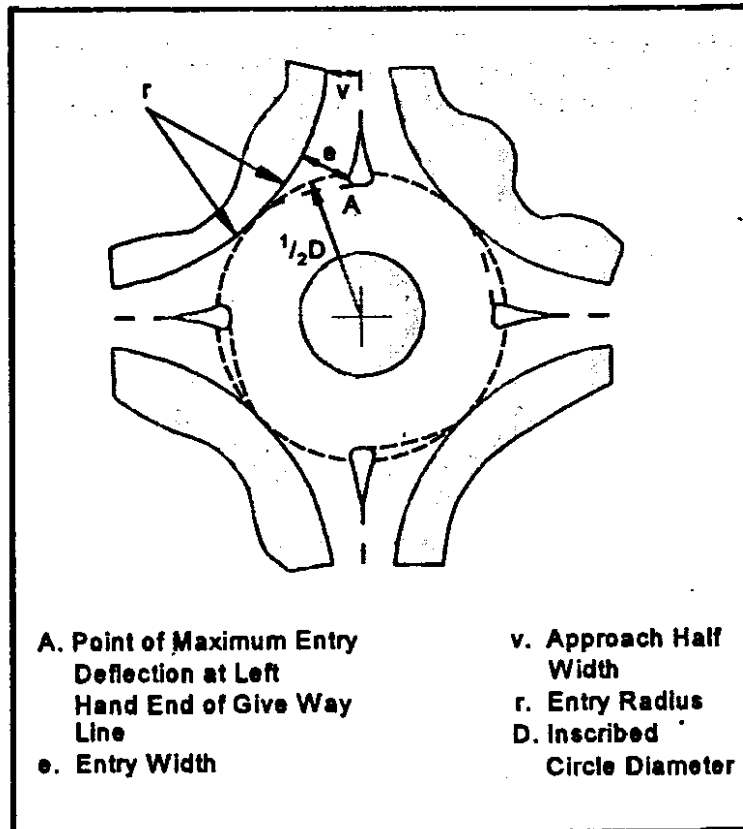


Figure 3.7.1 – Geometric Design Features at Entry

It is good practice to have two lanes on the entry to the roundabout (except at compact roundabouts). Therefore where the approach road is limited to one lane upstream, an additional lane should be provided in advance of the roundabout entry. The relationship between entry width and capacity is quite significant. Entry width is the largest single factor, apart from approach carriageway half width, affecting capacity.

There may be some cases, usually associated with low predicted flows, where increased entry width is not operationally necessary, but in these circumstances it is still recommended that two entry lanes be provided. This will give added flexibility at abnormal flow periods in the future, a passing facility in the event of breakdown, and will ease the problem of space provision for long vehicles turning.

Lane widths at the “Give Way” line must be not less than 3m. Lane widths should be tapered back in the entry flare to a minimum width of 2.5m. Any reduction in these widths shall be considered a Departure from Standards. It is generally better to use wide lane widths because they are more suitable for large goods vehicles.

The development of entry lanes must take account of the anticipated turning proportions and possible lane bias since drivers often have a tendency to use the nearside lane. The use of lane bifurcation where a lane widens into two should maximise use of the entry width. The use of short offside lanes is not recommended.

The alignment of entry lanes is also critical. On rural roundabouts, where design speeds are relatively high, the kerb line of the entry deflection island (or median in the case of a dual carriageway) should be on an arc which, when projected forward, meets the central island tangentially in order to reduce the likelihood of vehicle paths overlapping. In urban areas, where design speeds are lower, this is less important, but nevertheless should be achieved where possible. Care should be taken to ensure that the resultant entry angle is not too low.

For capacity assessment, the entry width should be taken as the width which drivers are likely to use. Where the offside kerb line forms a vehicle path which is tangential to the central islands, the entry width and effective entry width are the same.

It is usual to consider design flows 15 years after opening for highway schemes. This can result in excessive roundabout entry widths for earlier year flows and lead to operational problems. A design year layout will determine overall geometry and land requirements for the roundabout, but for the early years, it may be necessary for the designer to consider an interim stage. This approach can result in reduced entry widths and entry lanes.

Flare Design at Entry

Entry flaring is localised widening at the point of entry. Normal Roundabouts usually have flared entries with the addition of a lane at the give way line to increase capacity. Single lane entries e.g. those at Compact Roundabouts, should be slightly flared to accommodate large goods vehicles. Even a small increase in entry width may increase capacity.

The Average Effective Flare Length l' , is determined as shown in Figure 3.7.2 and outlined below:

- construct curve GD parallel to the median HA (centre line or edge of central reserve or entry deflection island) and distance v from it;
- construct curve CF' parallel to curve BG (the nearside kerb) and at a constant distance of $\frac{1}{2} BD$ from it, with F' the point where CF' intersects line DG;
- the length of curve CF' is the average effective flare length l' .

In cases where the line AB is not perpendicular to the median, the length AD will differ slightly from v .

The sharpness of the entry flare S is defined by the relationship:

$$S = 1.6[e-v]/l'$$

and is a measure of the rate at which extra width is developed in the entry flare. Large values of S correspond to short severe flares and small values ($0 \leq S \leq 1$) to long gradual flares.

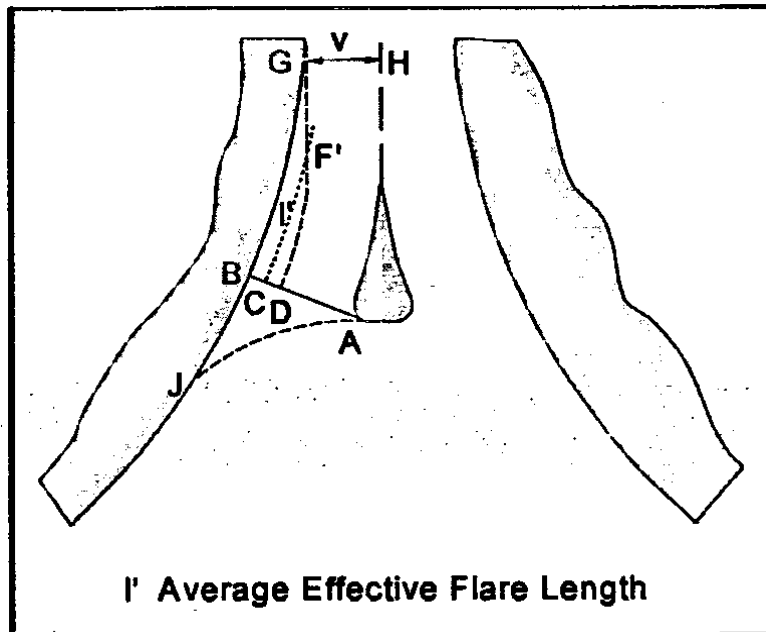


Figure 3.7.2 – Average Effective Flare Length

Flares on the approach to roundabouts shall be such that:

- The maximum entry width shall not exceed 8.33m on approach roads. Any increase shall be considered a Departure from Standards;
- The average effective flare length shall not exceed 100m, but it should be noted that beyond 30 or 40m any expected extra capacity is derived from extrapolation beyond the bounds of experimental data and should therefore be treated with caution.

The capacity of an entry can be improved by increasing the average effective flare length, though this is of limited effect. A minimum length of about 5m is desirable in urban areas, whilst a length of 25m is considered adequate in rural areas. Flare lengths greater than 25m may improve the geometric layout but have little effect in increasing capacity. Flare lengths should not be greater than 100m as beyond this the design becomes one of link widening. Where the design speed is high, entry widening should be developed gradually, avoiding any sharp angles. In urban areas the use of long flare lengths is often not possible due to land constraints and capacity may have to be achieved using wider entries and shorter flares.

The total length of the entry widening (BG) should be about twice the average effective flare length l' (Figure 3.7.2).

Entry Angle

The Entry Angle ϕ , serves as a geometric proxy for the conflict angle between entering and circulating traffic streams. Depending on the size of the roundabout, the following methods should be used to determine the entry angle.

For large roundabouts where links are widely spaced the entry angle is measured as shown in Figure 3.7.3.

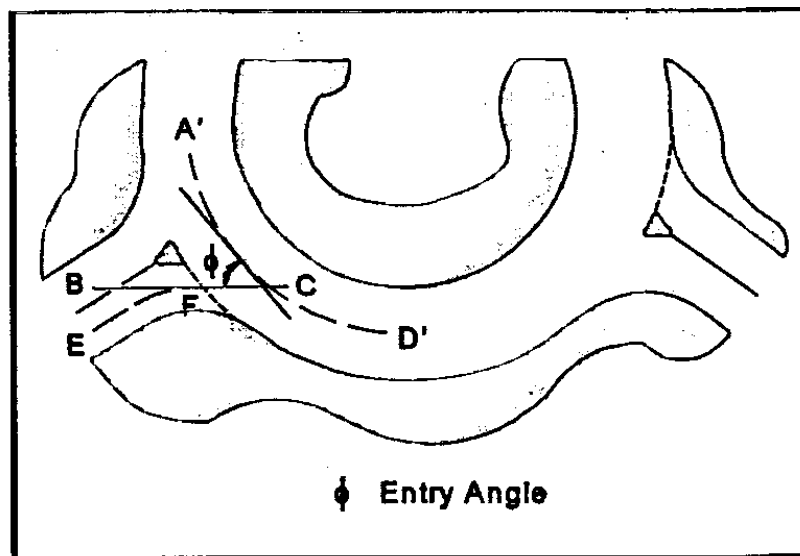


Figure 3.7.3 - Entry Angle measurement on large roundabouts

The line BC is a tangent to the line EF, which is midway between the nearside kerb line and the median line or the edge of any median island on the offside, where this line intersects the "Give Way" line. ϕ is measured as the acute angle between BC and the tangent to AD at the point of intersection between BC and AD shown in Figure 3.7.3.

For smaller roundabouts, the construction is shown in Figure 3.7.4. This construction is used when there is insufficient separation between entry and adjacent exit to be able to define the path of the circulating vehicle clearly. The angle between the projected entry and exit paths is measured and then halved to find ϕ :

The line BC is the same as in Figure 3.7.3;

The line GH is the tangent to the line JK, which is in the following exit, midway between the nearside kerb and the median line or the edge of any median island on the offside, where this line intersects the outer edge of the circulatory carriageway.

BC and GH intersect at L. ϕ is then defined by:

$$\phi = BLH/2$$

When this value is zero or negative the angle ϕ is taken to be zero.

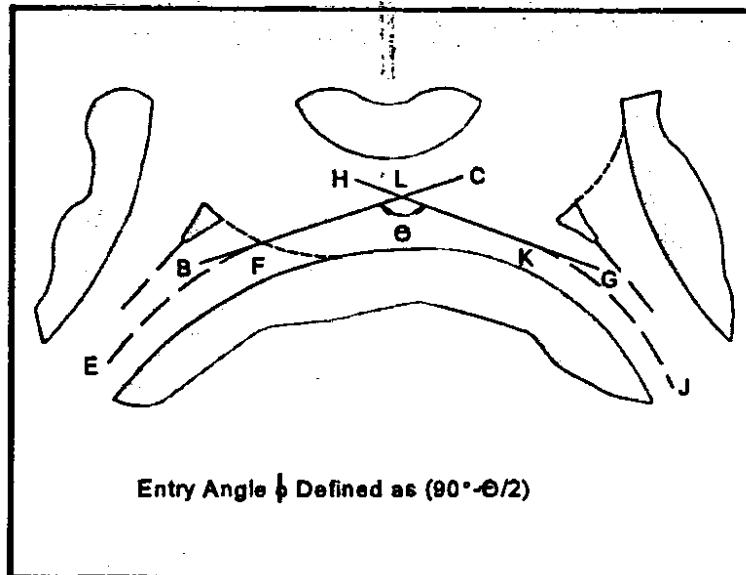


Figure 3.7.4 - Entry Angle measurement at smaller roundabouts

The effect of entry angle on entry capacity is negative; as the angle increases, capacity decreases slightly. However, care should be taken in the choice of entry angle since high and low angles may result in increased collision potential.

The angle should, if possible, lie between 20 and 60 degrees, with the best entry angle value being approximately 30 degrees. Low entry angles force drivers into merging positions where they must either look over their shoulders to their left or attempt a true merge using their mirrors (leading to the problem of disregarding the "Give Way" line and the generation of high entry speeds).

High entry angles tend to have lower capacity and produce excessive entry deflection which can lead to sharp braking at entries accompanied by "nose to tail" collisions, especially in rural areas.

Entry Kerb Radius

The entry kerb radius, r , is the minimum radius of curvature of the nearside kerb line over the distance from 25m ahead of the give way line to 10m downstream of it, see r in Figure 3.7.1.

For small roundabouts entry capacity increases with entry kerb radius up to about 20m, higher radii result in very little increase in capacity. For larger roundabouts (40-60m diameter), large entry radii will almost certainly result in inadequate entry deflection. For example, it will not be possible to achieve the required deflection standard if the entry kerb radius is 100m or more.

The minimum entry radius must not be less than 10m. Where a roundabout is designed to cater for large goods vehicles in particular, the entry kerb radius must not be less than 20m. Any reduction in these values shall be considered a Departure from Standards.

Entry Path Radius

Entry Path Radius (and its inverse, entry path curvature) is one of the most important determinants of safety at roundabouts. It is a measure of the amount of entry deflection to the right imposed on vehicles at entry to the roundabout. This governs the speed of vehicles through the roundabout and whether drivers are likely to give way to circulating vehicles.

The entry path radius must be checked for all turning movements. It must not exceed 70m at Compact Roundabouts in urban areas (where the speed limit and the design speed within 100m of the give way line on any approach does not exceed 70kph). At all other roundabout types, the entry path radius must not exceed 100m. Where these values are exceeded, it shall be considered a Departure from Standard.

The method of determining the entry path radius is described below, and shown in Figure 3.7.5 to Figure 3.7.8.

Assume:

- That the entering vehicle is 2m wide so that it maintains a distance of at least 1m between its centreline and any kerb or edge marking, and that it will be taking the 'straight ahead' movement at a 4 arm roundabout and across the head of the Tee at a 3 arm roundabout;
- That there is no other traffic on the approach and on the circulatory carriageway;
- That the driver will negotiate the site constraints with minimum deflections and that lane markings by the "Give Way" line will be ignored;
- The initial approach position for entry path curvature measured from a point not less than 50m from the "Give Way" line is within the range (a) 1m from the nearside kerb and (b) 1m from the centreline of a single carriageway or 1m from the offside kerb of a dual carriageway;
- That the vehicle proceeds towards the "Give Way" line, then;
- That the vehicles proceeds towards the central island of the roundabout passing through a point not less than 1m from the nearside channel or kerb, the position of which relative to the starting point depends on the amount of approach flare to the right, then;
- That the vehicle continues on a smooth path with its centreline never passing closer than 1m from the central island (it may be more in some configurations).

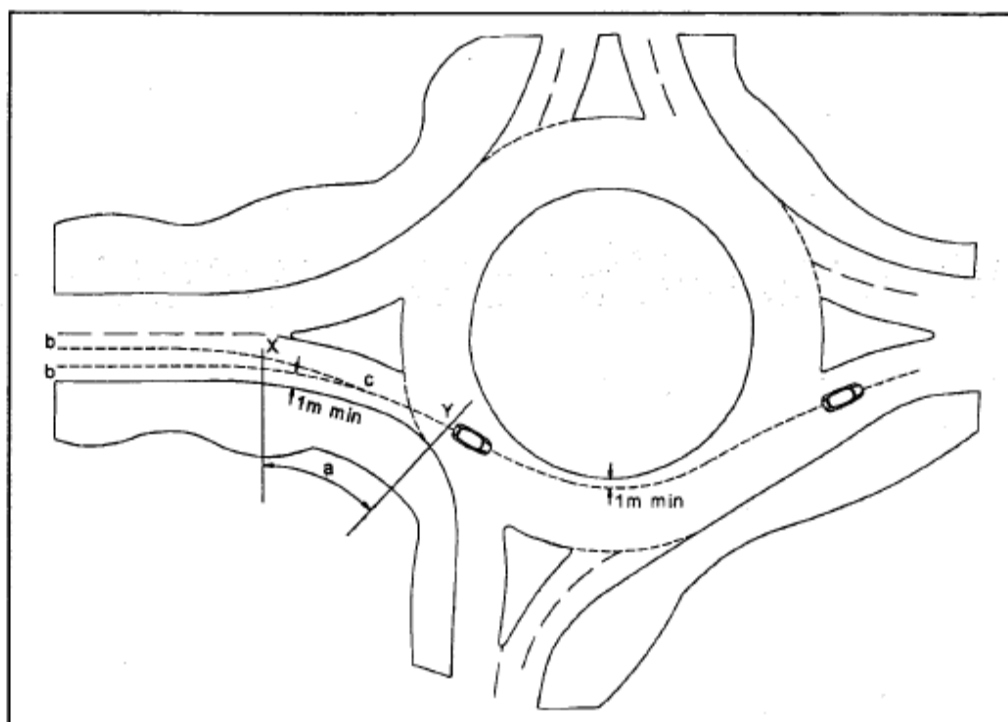


Figure 3.7.5 – Determination of Entry Path Radius

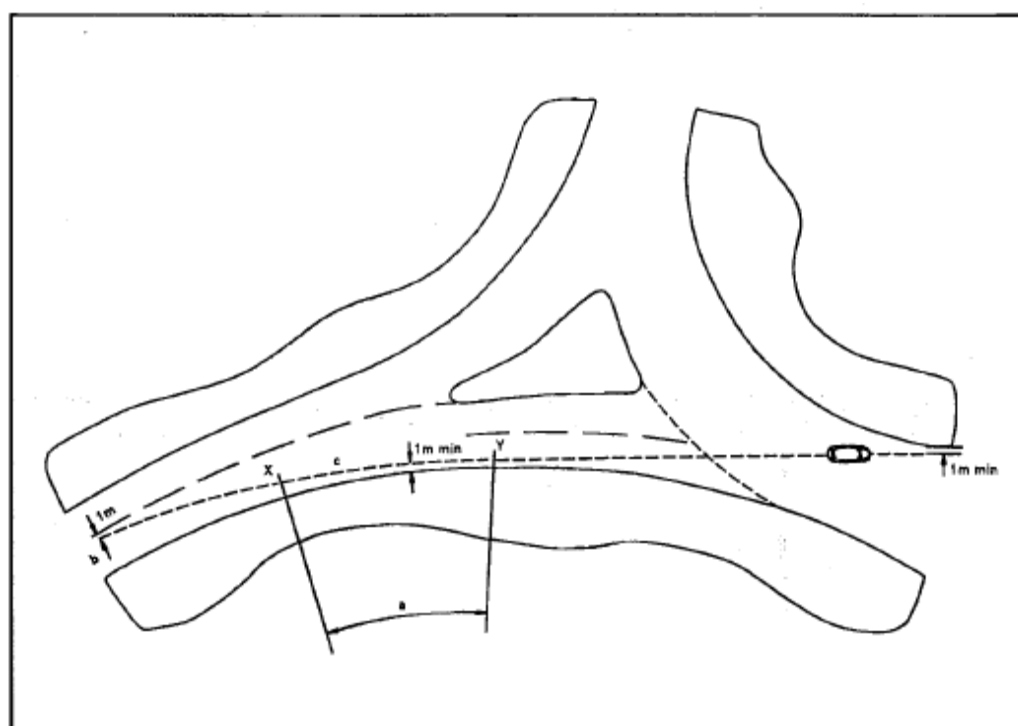


Figure 3.7.6 – Determination of Entry Path Radius (on a curved approach arm with negative approach curvature)

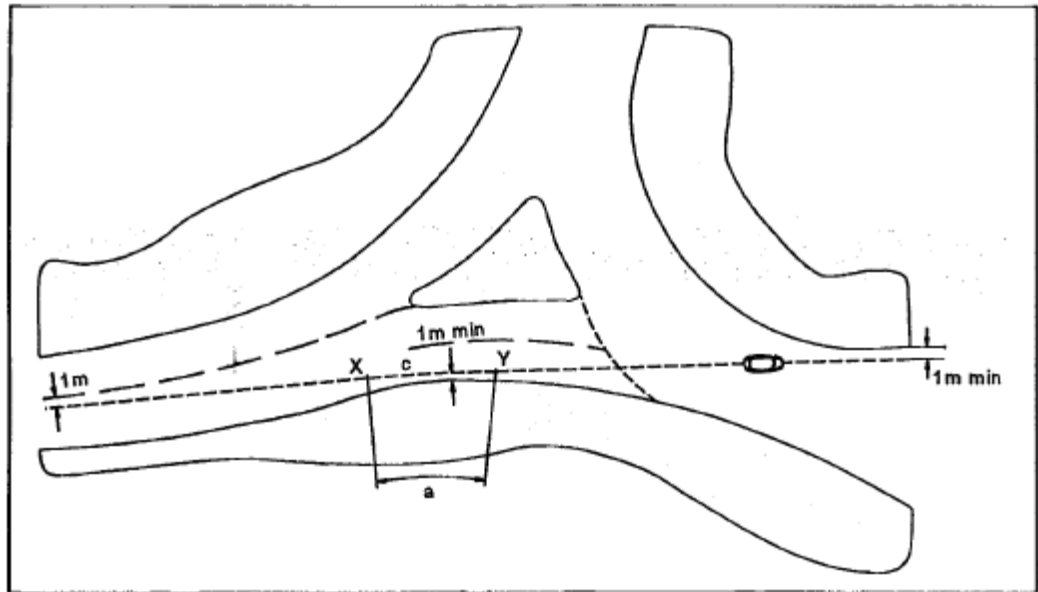


Figure 3.7.7 – Determination of Entry Path Radius (on a curved approach arm with positive approach curvature)

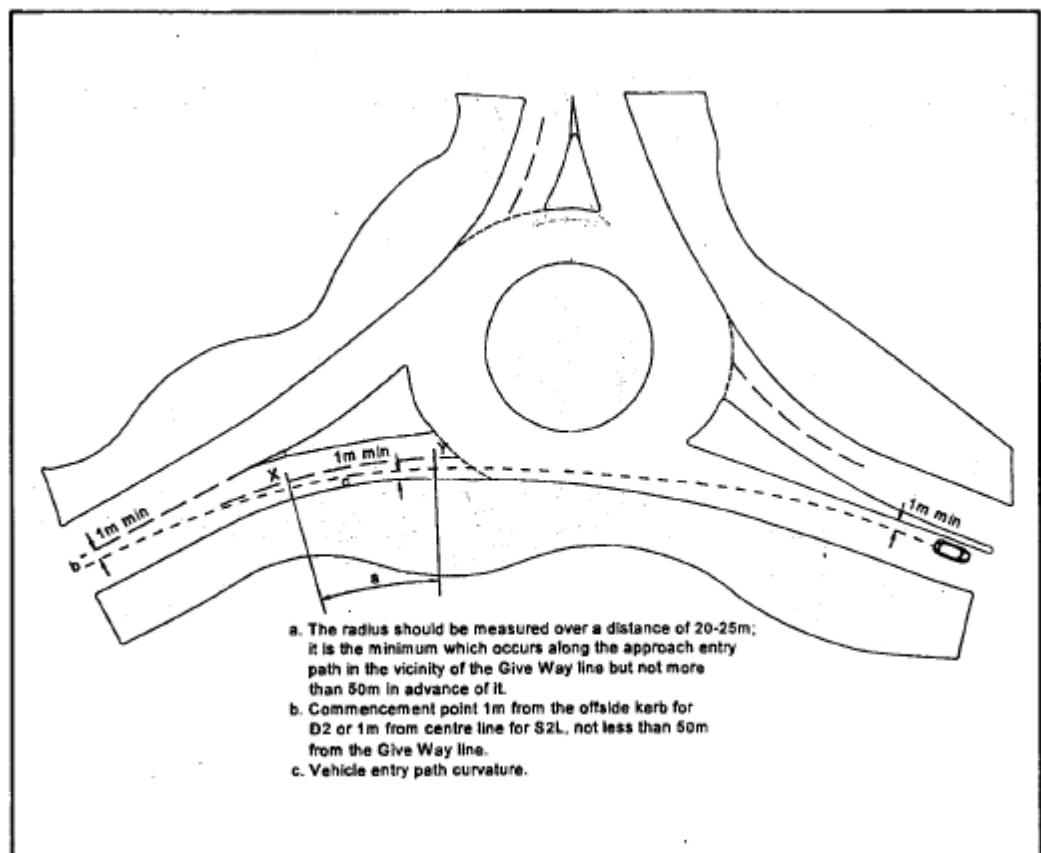


Figure 3.7.8 – Determination of Entry Path Radius for a roundabout at a Y-junction

Draw, to a scale not less than 1:500 using a flexible curve or equivalent, the centre line of the most realistic path that a vehicle would take in its complete passage through the roundabout on a smooth alignment without sharp transitions. More than one independent assessment of the vehicle paths must be carried out.

The exact path drawn will be a matter of personal judgement and the results should be examined for compliance and consistency with the appropriate clauses in this section. Any reverse of curvature in the vehicle path around the central island must be drawn so that there is no sharp deviation between that curve and the entry curve. Particular care in checking entry path radius is required when considering small central island designs.

This tightest radius shall be measured by means of suitable templates. The Entry Path Radius is measured on the curved length of path in the vicinity of the "Give Way" line (but not more than 50m in advance of it) between points X and Y (see Figures 6.7.5 to 6.7.8.) about 20m to 25m but not less than 20m in length, over which the smallest best fit radius occurs.

In certain cases, such as in urban areas where space is insufficient and there is a need to accommodate large commercial vehicles, it may require the selection of a small Normal Roundabout or a Compact Roundabout which is unable to provide sufficient entry deflection by means of the central island alone. For such cases, the deflection should be provided by enlarging the entry deflection islands or providing a central over-run area for good vehicles as detailed in sub-sections 6.2 and 6.3.

Where an over-run area is provided that deters light vehicles from over-running the central island, the entry path radius should be measured relative to the perimeter of this area rather than that of the central island.

3.7.2 Roundabout Exits

The exit width is the width of carriageway on exit from the circulatory carriageway and is measured in a similar manner to the entry width. It is the distance between the nearside kerb and the exit median (or the edge of any entry deflection island) or dual carriageway median, where it intersects with the outer edge of the circulatory carriageway. As with the entry width, it is measured normal to the nearside kerb. Values are typically similar to or slightly less than entry widths (exits have less flaring).

At a Compact Roundabout, the value of the exit kerb radius should lie between 15m and 20m.

At other roundabouts, the exit kerb radius should not be less than 20m or greater than 100m. Values outside of this range shall be considered a Departure from Standards. A value of 40m is desirable, but for larger roundabouts on high speed roads, a higher value may suit the overall junction geometry. A compound curve starting with a 40m radius and developing to a larger radius, of up to 100m, will usually offer the best solution. Larger values of exit radii may lead to high exit speed, which will not be

appropriate if there are significant numbers of cyclists using the roundabout or where pedestrian crossing facilities are located immediately downstream.

The spacing of an exit and the preceding entry shall not be less than that which results from the combination of the minimum entry kerb radius (10m) and the minimum exit radius (15m at a Compact Roundabout, otherwise 20m), though desirable radii of 20m and 40m respectively should be used where possible. If an existing roundabout is to be modified to include an additional entry, care must be taken to ensure that this does not affect safety at the proceeding entry and the following exit. It may be necessary to redesign the whole roundabout if adequate spacing between adjacent entry/exit arms cannot be achieved.

At the beginning of an exit, its width, measured normally to the exit radius, should, where possible, allow for two lanes, except at Compact Roundabouts. A maximum of 2 lanes on exit should not be exceeded.

The width of the exit must not exceed the width of the circulatory carriageway but will exceed the width of the downstream carriageway. This extra width should be reduced on the nearside in such a way as to avoid exiting vehicles encroaching onto the entering carriageway at the end of the traffic deflection island. Normally, this would be at a taper of 1:15 to 1:20, though where the exit is on an up gradient, the local widening may be extended to reduce intermittent congestion from slow moving larger vehicles and to provide an overtaking opportunity for faster vehicles. Similarly, if the exit road is on a right hand curve, it may be necessary to extend the taper length and the length of the traffic deflection island.

Within single carriageway exits, a minimum width of 6m, measured normally to the nearside kerb, must be provided adjacent to traffic deflection islands to allow traffic to pass a broken down vehicle. A lesser width shall be considered a Departure from Standards. Figure 3.7.9 shows a typical single carriageway exit embodying some of the above principles.

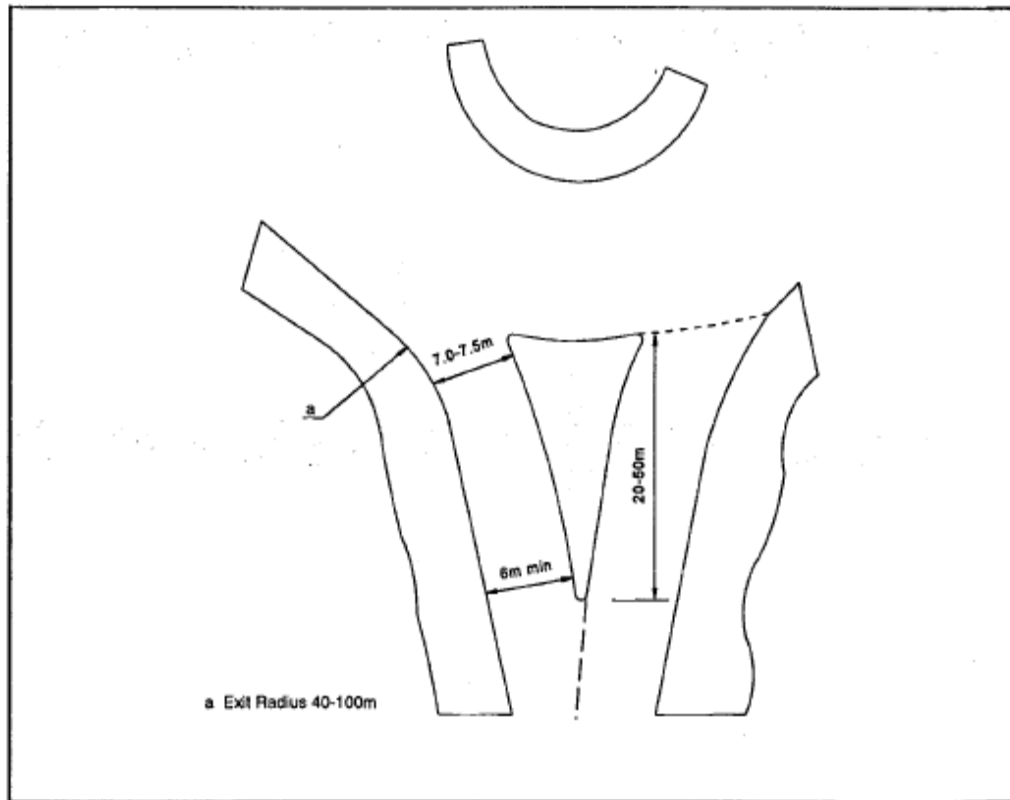


Figure 3.7.9 Typical Single Carriageway Exit

3.8 Design – Visibility

3.8.1 General

All visibility requirements within this clause 8 shall be deemed as mandatory and any reductions shall be considered as Departures from Standards.

3.8.2 Approach Visibility

The forward visibility at the approach to a roundabout shall be as indicated in Section 2 for the appropriate design speed of the approach link. This Junction Approach Sight Distance (JASD) is measured to the “Give Way” line. As shown in Figure 3.8.1.

Eye and target height requirements on the approach shall be as defined in Section 2.

Reductions in Junction Approach Sight Distance and vertical crest K value shall not be permitted on the immediate approach to roundabouts. The immediate approach to the roundabout shall be defined as those lengths of carriageway on the roundabout approach road between a point 1.5 times the approach road Desirable Minimum Stopping Sight Distance upstream of the roundabout “Give Way” line and the roundabout “Give Way” line itself.

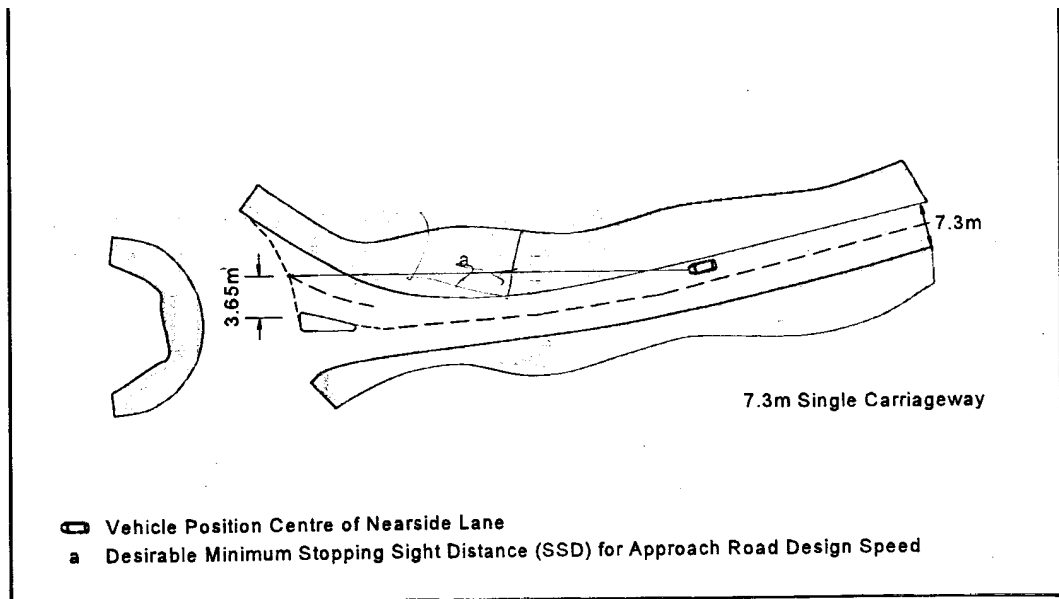


Figure 3.8.1 Measurement of Junction Approach Sight Distance on Curved Approach

3.8.3 Visibility of the Circulatory Carriageway

Table 3.8.1 defines the visibility requirements at the circulatory carriageway based on the Inscribed Circle Diameter of the roundabout. This must be considered when assessing the forward visibility at entry, visibility to the left at entry and circulatory visibility (refer to Figures 6.8.2 to 6.8.5).

Table 3.8.1 – Visibility Distance at Circulatory Carriageway

Inscribed Circle Diameter (m)	Visibility Distance (m) (as in Figure 3.8.2 to Figure 3.8.5)
< 40	Whole Junction
40 – 60	40
60 – 100	50
> 100	70

3.8.4 Forward Visibility at Entry

Drivers of all vehicles approaching the “Give Way” line must be able to see objects of height between 0.26m and 2m for the full width of the circulatory carriageway ahead of them for a distance (measured along the centre line of the circulatory carriageway) appropriate to the size of the roundabout, as indicated in Table 3.8.1.

The visibility must be checked from the centre of the nearside lane at a distance of 15m back from the “Give Way” line, as shown in Figure 3.8.2.

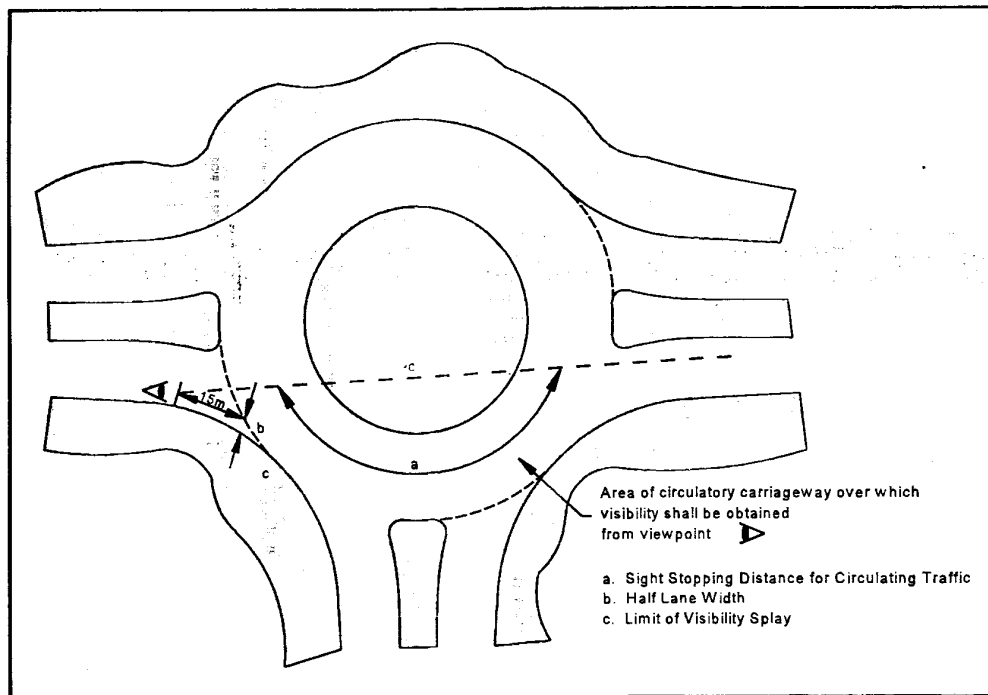


Figure 3.8.2 Forward Visibility Required at Entry

3.8.5 Visibility to the Left at Entry

Drivers of all vehicles approaching the "Give Way" line shall be able to see the full width of the circulatory carriageway to their left from the centre of the offside lane at the "Give Way" line for a distance appropriate to the Visibility Distance (measured along the centreline of the circulatory carriageway) as indicated in Table 3.8.1, and shown in Figure 3.8.3.

This visibility must also be checked from the centre of the offside lane at a distance of 15m back from the "Give Way" line as shown in Figure 3.8.4.

The envelope of visibility must be obtainable from a driver's eye height of between 1.05m and 2m to an object height of between 1.05m and 2m.

Checks shall be made that crossfall design, sign location, street furniture and other potential obstructions, including parapet walls and road restraint systems do not restrict visibility.

It should be noted that excessive visibility at entry or visibility between adjacent entries can result in approach and entry speeds greater than those desirable for the junction geometry, potentially leading to collisions. Consideration shall be given to limiting in particular the visibility of adjacent entries to the left from 15m back on the approach, and the visibility along the approach to no more than the Desirable Minimum Stopping Sight Distances for the design speed of the approach, by the selective use of landscaping.

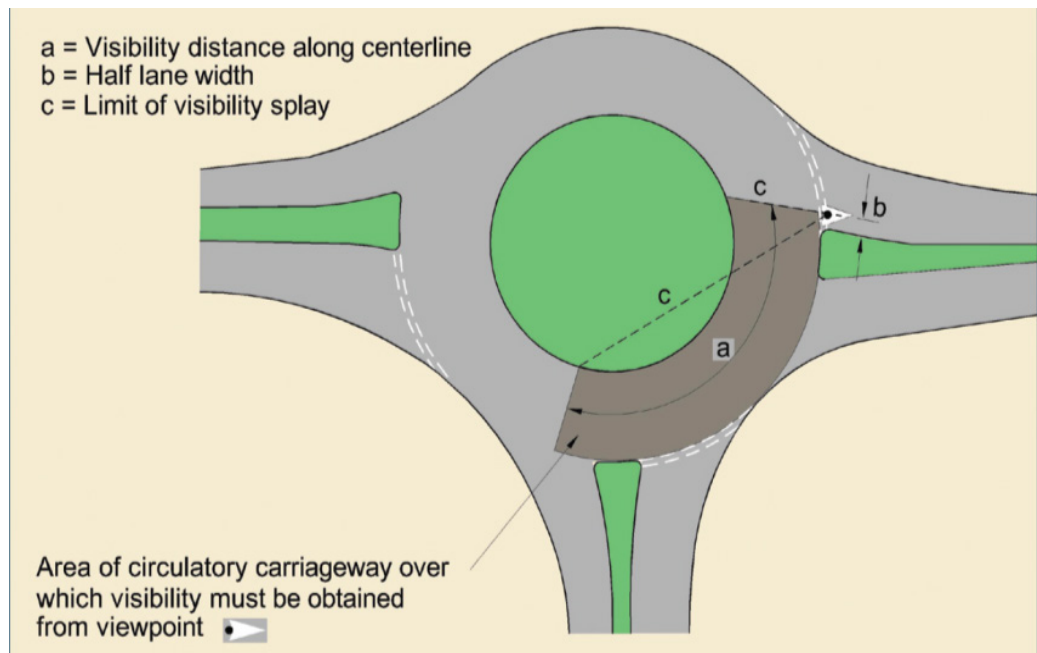


Figure 3.8.3 Visibility to the Left Required at Entry (from “Give Way” Line)

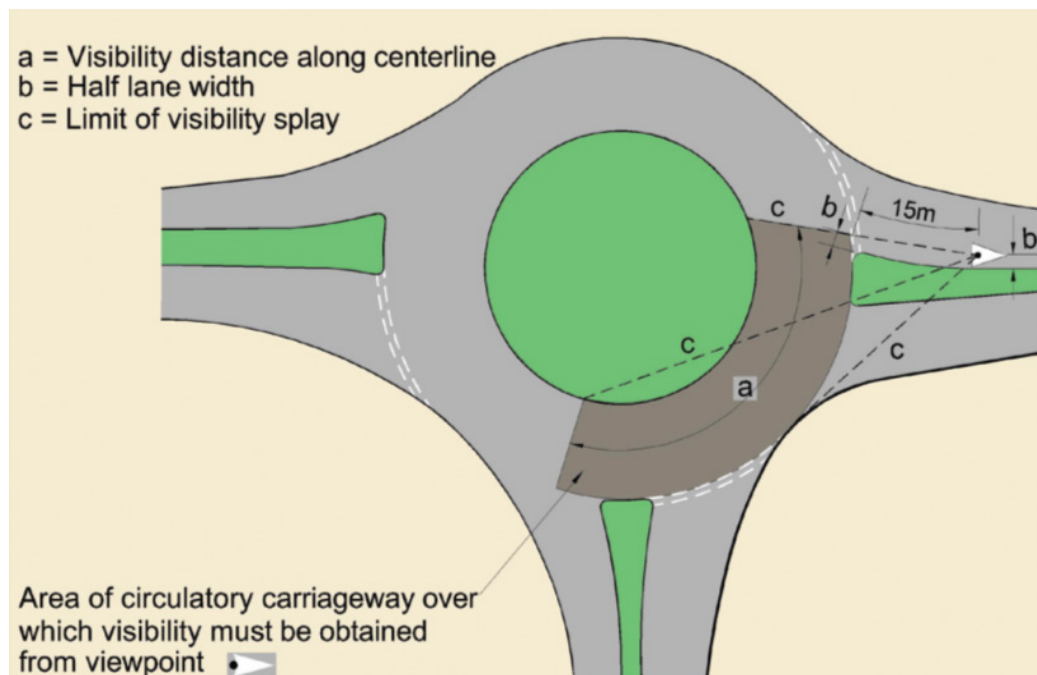


Figure 3.8.4 Visibility to the Left Required at Entry 15m back (from “Give Way” Line)

3.8.6 Circulatory Visibility

Drivers of all vehicles circulating on a roundabout must be able to see the full width of the circulatory carriageway ahead of them for the Visibility Distance (as indicated in Table 3.8.1). This visibility shall be checked from a point 2m in from the central island as shown in Figure 3.8.5.

The envelope of circulatory visibility must be obtainable from a driver's eye height of between 1.05m and 2m to an object height of between 1.05m and 2m.

It is often useful to improve the conspicuousness of central islands by the use of landscaping, but the circulatory visibility must be checked to ensure it is not obstructed. The circulatory visibility envelope will encroach onto the height of vegetation or surface treatment. In these situations, limited penetration into the visibility envelope by vegetative growth of a dispersed nature would not be unacceptable. Normally, at least the outer 2m of the central island should be hard standing or planted with grass or similar low level vegetation.

Once a vehicle has crossed the inscribed circle at the exit from the roundabout, the Desirable Minimum Stopping Sight Distance should conform to Section 2.

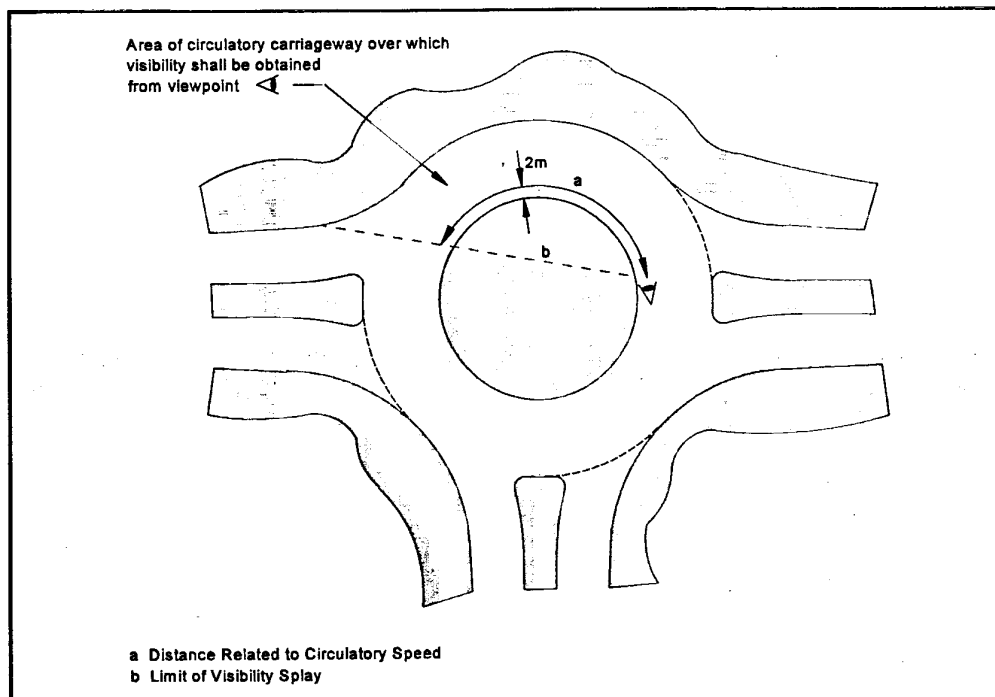


Figure 3.8.5 Circulatory Visibility

3.8.7 Pedestrian Crossing Visibility

Drivers of all vehicles approaching a roundabout with a pedestrian crossing across an entry shall have a minimum distance of visibility to it of the Junction Approach Sight Distance for the design speed of the link (see Section 2) across the whole width of the crossing. At the "Give Way" line, drivers of all vehicles must be able to see the full width of a pedestrian crossing across the next exit if the crossing is within 20m of the roundabout (see Figure 3.8.6). Pedestrian crossings should not be positioned between 20m and 60m from the "Give Way" line. Refer to Section 12 for further advice relating to pedestrians and other non-motorised users.

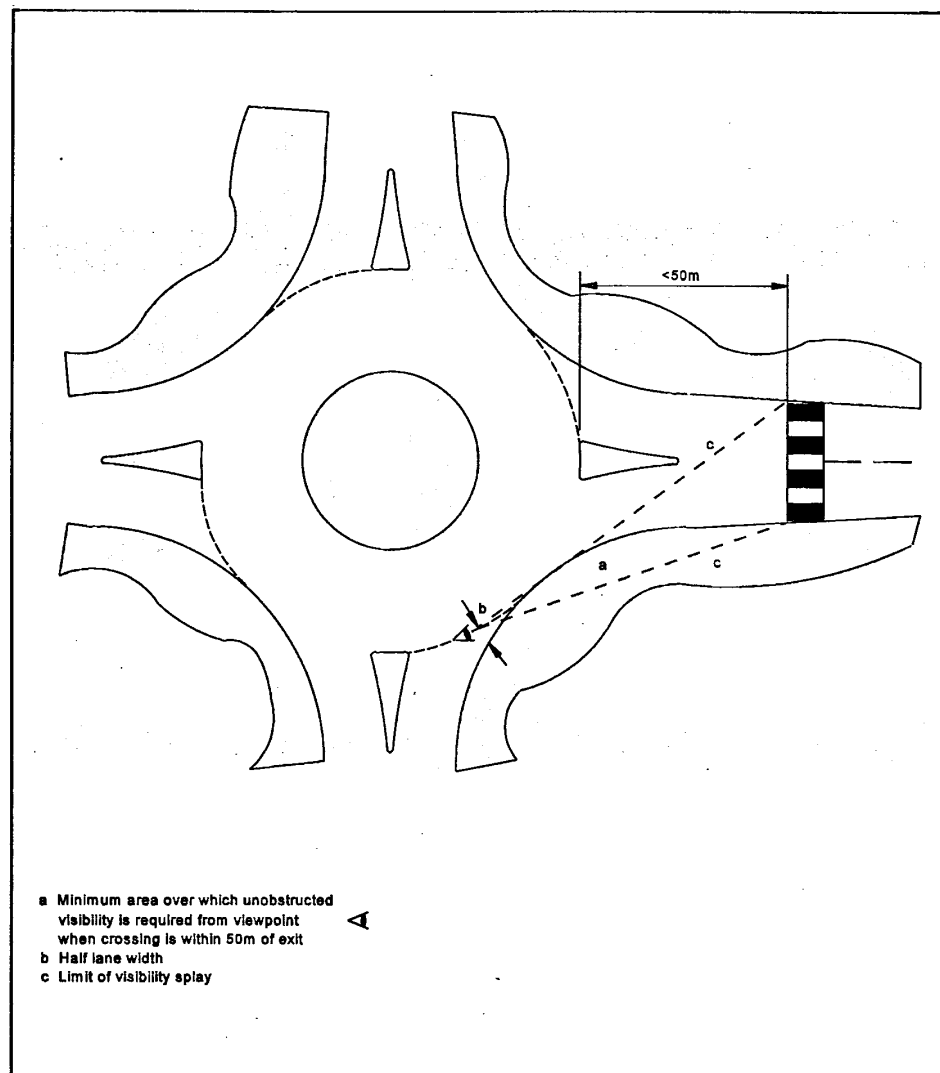


Figure 3.8.6 Visibility Required at Entry, to a pedestrian crossing at next exit

3.8.8 Visual Intrusions

Where traffic and direction signs are to be erected on a central reservation, verge, or deflection island within the envelope of visibility, including to the left, the mounting height shall not be less than 2.0m above the carriageway surface and the envelope checked on sites with changes of gradient.

Signs, street furniture and planting shall not be placed within the visibility envelopes so as to obstruct visibility, but infringements by isolated slim projections such as lamp columns, sign supports or bridge columns can be ignored provided they are less than 550mm wide. The only exception to this will be positioning of bollards on deflection islands and staggered chevron boards on central islands. Where possible, care shall be taken to minimise the effects of pedestrians on visibility requirements.

3.9 Design – Other aspects

3.9.1 Crossfall and Longitudinal Gradient

Immediately in advance of the roundabout “Give Way” line, steep gradients should be avoided or flattened. This zone of limited gradient shall be within 15m of the “Give Way” or “Stop” line, but may be reduced to 10m in residential areas. Approach gradients within this zone shall be limited to a maximum of 3%, and any increase in this value shall be deemed a Departure from Standards.

On the approaches and exits, superelevation can assist drivers in negotiating the associated curves. Its value, when used, should be appropriate to the speed of vehicles, and equal to or greater than those necessary for surface drainage, but should not exceed 5% (1 in 20). Superelevation should be reduced to 2% at 20m from the give way line, since with adequate advance signing and entry deflection, speeds on approaches should be reducing.

Crossfall and longitudinal gradient combine to provide the necessary slope that will drain surface water from the carriageway. Thus, although the following clauses are for simplicity written in terms of crossfall, the value and direction of the greatest slope must always be taken into account when considering drainage flow paths.

Except on large Grade Separated Roundabouts (where long sections of circulatory carriageway should have appropriate superelevation), crossfall is required to drain surface water on circulatory carriageways. A crossfall exceeding 2.5% shall be considered a Departure from Standards. To avoid ponding, longitudinal edge profiles should be graded at not less than 0.67% (1 in 150), with 0.5% (1 in 200) considered the minimum. The design gradients do not in themselves ensure satisfactory drainage, and, therefore, the correct siting and spacing of gullies is critical.

At Normal Roundabouts on high speed roads, it is good practice to arrange for crossfall to assist vehicles manoeuvring around the circulatory carriageway and to reduce drainage flow paths. To do this, a crown line is formed. This line can divide the circulatory carriageway in the proportion 2:1 internal to external as shown in Figure 3.9.1, or alternatively can either join the ends of the entry deflection islands.

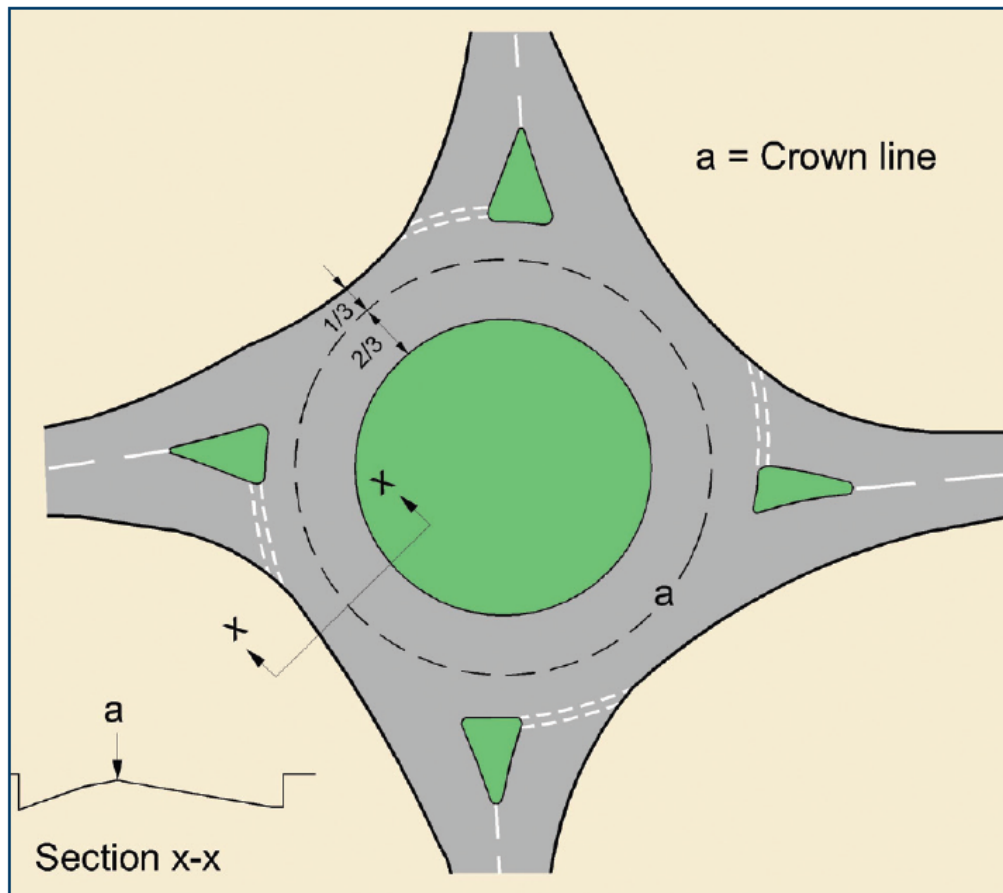


Figure 3.9.1 Crossfall Design using 2:1 Ratio Circular Crown Line.

The conflicting crossfalls at the crown lines have a direct effect on driver comfort and may also be a contributory factor in load shedding and large goods vehicle roll-over accidents. Over a given section, the maximum recommended arithmetic difference in crossfall is 5%. Lower values are desirable, particularly for roundabouts with a small inscribed circle diameter. There should be no sharp changes in crossfall and a smooth crown is essential.

At Compact Roundabouts and small Normal Roundabouts, it is more appropriate to apply constant crossfall in one direction across the full width of the circulatory carriageway. At roundabouts where the speed limit within 100m from the give way line does not exceed 60kph on any approach, this crossfall can slope outwards to ease drainage and help keep speeds down. It also makes the central island more conspicuous.

At exits, superelevation should be provided where necessary to allow vehicles to accelerate safely away from the roundabout. However, as with entries, crossfall adjacent to the roundabout should not exceed 2%. If the exit leads into a left hand curve, superelevation should be introduced gradually.

3.9.2 Kerbing

Roundabout entries and exits should be kerbed, and hardstrips or hard shoulders on each approach should terminate where entry widening begins. The simplest procedure is to start the kerbs on the approach at the back of the hardstrip and then terminate the hardstrip edge line in a short smooth curve or taper (see Figures 6.9.2 and 6.9.3).

On the exit, the kerbing can terminate where the hardstrip starts.

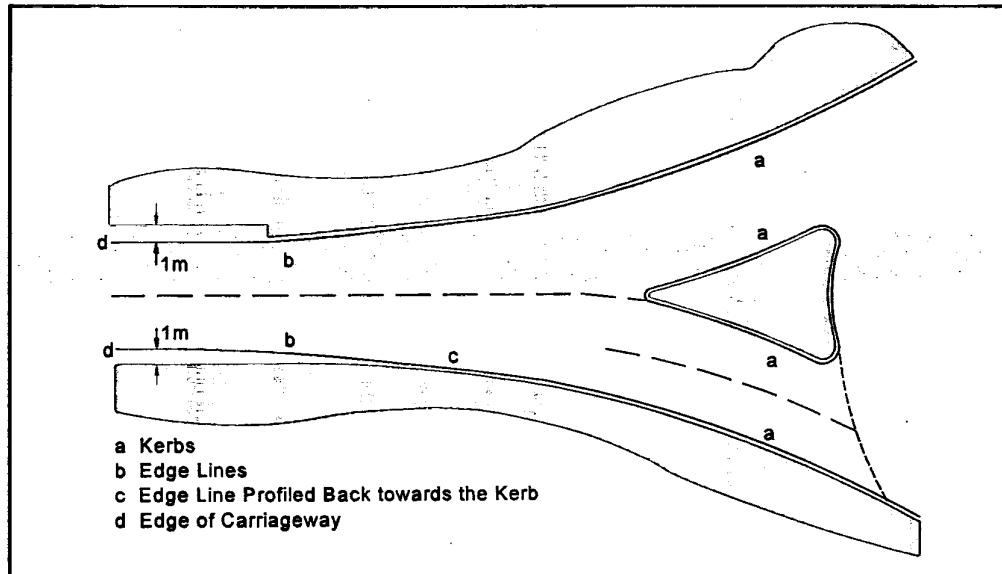


Figure 3.9.2 Method of Terminating Edge Strips on Single Carriageway Approach to a Roundabout

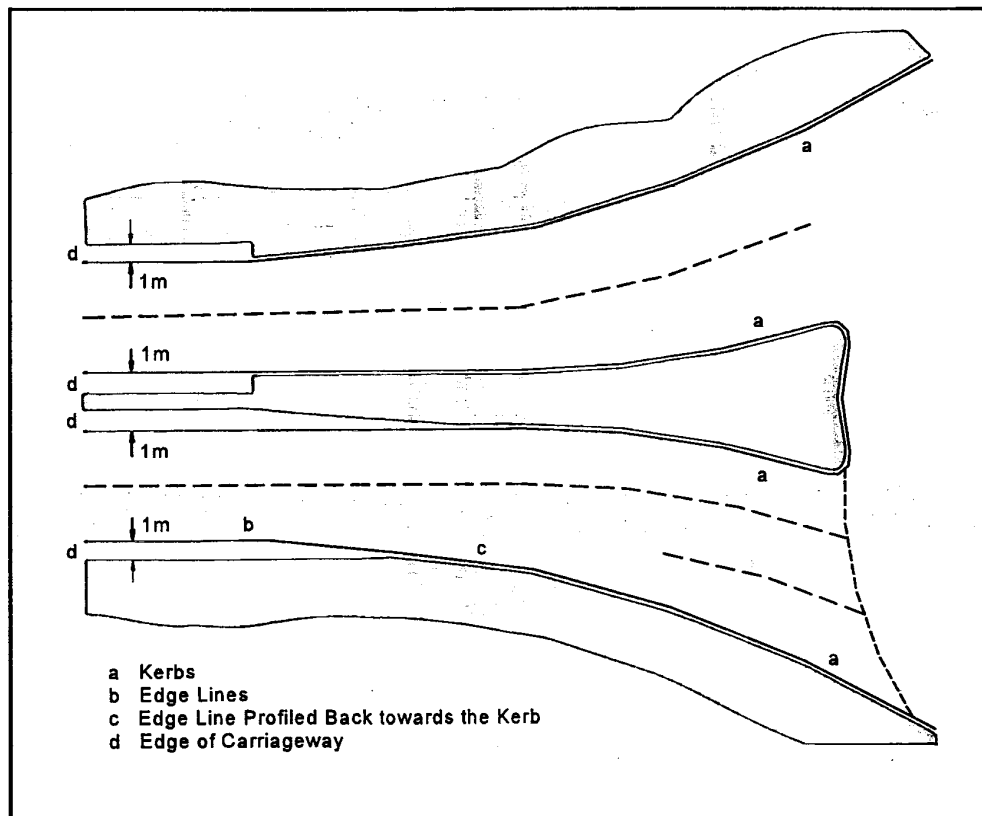


Figure 3.9.3 Method of Terminating Edge Strips on Dual Carriageway Approach to a Roundabout

3.9.3 Dedicated Right Turning Lanes

Dedicated right turn lanes are a useful method for giving an improved service to vehicles intending to leave a roundabout at the first exit after entry. This removal of flow from the circulatory carriageway can improve the overall capacity of the roundabout. However, when considering the use of these lanes, vehicle composition should be examined. If the right turn vehicles are predominantly light and there are a high proportion of cyclists and/or large goods vehicles leaving the roundabout, there could be problems with differential speeds at the merge, particularly if this is on an uphill gradient. If dedicated lanes are to be used in these situations they should finish with a "Give Way" line at the exit from the lane.

There is a simple procedure to provide guidance to determine if any exclusive right turning lane would be beneficial to a roundabout design and merit further investigation. It is based on total traffic in-flows at entry, vehicle composition, right turning traffic and number of entry lanes. The inclusion of a right turning lane should be considered if:

$$L \geq F/E, \text{ where } L = \text{flow of right turning vehicles}$$

$$F = \text{total entry arm flow in vehicles per hour}$$

$$E = \text{total number of entry lanes on the arm including the segregated right turn}$$

In cases where L and F/E are very close, consideration of other factors such as safety would need to be included in the appraisal.

The use of these lanes in urban areas where pedestrians are expected to cross should be carefully considered. In no circumstances should pedestrians be expected to cross right turn lanes segregated by road markings.

If pedestrians are anticipated they should be channelled with the use of guard rail to a safer crossing point. If this is not possible the segregation should be by a physical island of sufficient width to accommodate the anticipated peak number of pedestrians.

There are two basic types of dedicated right turn lanes, namely segregation by road markings and physical segregation through the use of a raised, kerbed island. In both types, vehicles are channelled into the right hand lane by lane arrows and road markings supplemented by advance direction signs, and vehicles proceed to the first exit without having to "Give Way" to vehicles on the circulatory carriageway. Segregation by road markings is more common, but is less effective because it is subject to abuse. It is essential that the operation of the segregated lane is not impaired by traffic queuing to use the roundabout itself. The designer should ensure that the approach arrangements are sufficiently clear so that they are relatively self-enforcing.

Dedicated right turn lanes are comprised of three elements, namely:

1. Entry taper or lane;
2. Segregated right turn lane, and
3. Exit taper or lane.

The three elements are shown on Figure 3.9.4, Figure 3.9.5 and Figure 3.9.6.

Dedicated right turn lanes should not be designed to encourage high speeds. The curve radius used for the segregated right turn lane will be dependent on both the design speed of the approach road and site constraints. The driver's perception of the approach and segregated right turn lane radii will be a determining factor in their approach speed. The designer should therefore consider the need for speed reduction measures on the approach depending on the minimum curve radii used. Inside curve radii of less than 10m are not recommended. The exit radius used should be greater than, or equal to, the entry radius.

Superelevation along the segregated right turn lane shall be applied in accordance with Section 2 to a maximum value of 5%.

Desirable minimum stopping sight distance for the design speed of the main alignment shall be provided to the start of the nearside curve radius at the start of the segregated right turn lane. Throughout the segregated right turn lane the desirable minimum stopping sight distance given in Table 3.9.1 shall be provided appropriate to the maximum nearside curve radius. The desirable minimum stopping sight distance

shall be applied to the segregated right turning lane between the end of the entry taper and the start of exit taper. Any reduction in desirable minimum stopping sight distance shall be deemed as a Departure from Standards.

Table 3.9.1 Desirable minimum stopping sight distance on segregated right turn lane

Maximum Curve Radius (m)	Desirable Minimum Stopping Sight Distance (m)
less than or equal to 20	35
21 to 40	70
41 to 80	90
81 to 100	120
Greater than 100	215

The maximum curve radius used to determine the desirable minimum stopping sight distance from Table 3.9.1, shall be the greater of either the entry or exit radius of the segregated right turn lane, these being defined as the radius that occurs immediately after the entry taper and immediately before the exit taper in the direction of travel.

The carriageway widths shall be sufficient to accommodate the swept path of a Large Goods Vehicle (refer to Section 5). However hatch markings shall be provided on the inside of the curve to reduce the marked lane width to a minimum of 3.65m.

Where road markings are used to create the lane segregation, the overall width of the marking should be a minimum of 1.0m.

It is not always necessary to make allowance for broken down vehicles. With segregation by road markings, such vehicles can be overtaken with caution. Where physical segregation is introduced, this should not prevent a right turn at the roundabout in the normal way from the non-segregated part of the approach. However where a physical island in excess of 50m in length is proposed, the lane widths should be increased as specified in the third column of Table 3.9.2 to allow passing of broken down vehicles.

Table 3.9.2 Minimum Corner and Curve Radii and Carriageway Widths

Minimum Inside Corner Radius or Curve Radius (m)	Segregated Right Turn Lane Carriageway Width (for physical island lengths < 50m) (m)	Segregated Right Turn Lane Carriageway Width (for physical island lengths ≥ 50m) (m)
10	8.4	10.9
15	7.1	9.6
20	6.2	8.7
25	5.7	8.2
30	5.3	7.8
40	4.7	7.2

Minimum Inside Corner Radius or Curve Radius (m)	Segregated Right Turn Lane Carriageway Width (for physical island lengths < 50m) (m)	Segregated Right Turn Lane Carriageway Width (for physical island lengths ≥ 50m) (m)
50	4.4	6.9
75	4.0	6.5
100	3.8	6.3
> 100	3.5	6.0

These lanes have been observed to comfortably handle 1300 vehicles per hour and for design purposes a maximum capacity of 1800 light vehicles per hour may be assumed where the exit is free running. Dedicated right turn lanes need not be considered as part of the entry when calculating capacities for other traffic movements.

The merging between vehicles from a dedicated right turn and other vehicles exiting the roundabout should take place within 50m of the roundabout, where speeds are still comparatively low.

Under no circumstances should two dedicated right turn lanes be used together. If right turn traffic is very high and cannot be accommodated by a single dedicated right turn lane, then alternative forms of junction should be investigated.

Approach Layout

The layout of the approach can consist of either a dedicated lane or diverge taper arrangement.

Dedicated lanes on approach (see Figure 3.9.4) provide the highest capacity entry to a segregated right turn lane. They require careful design of signing and road markings on the approach, to avoid driver confusion that may result in lane changing manoeuvres occurring adjacent to the segregated right turn lane entry.

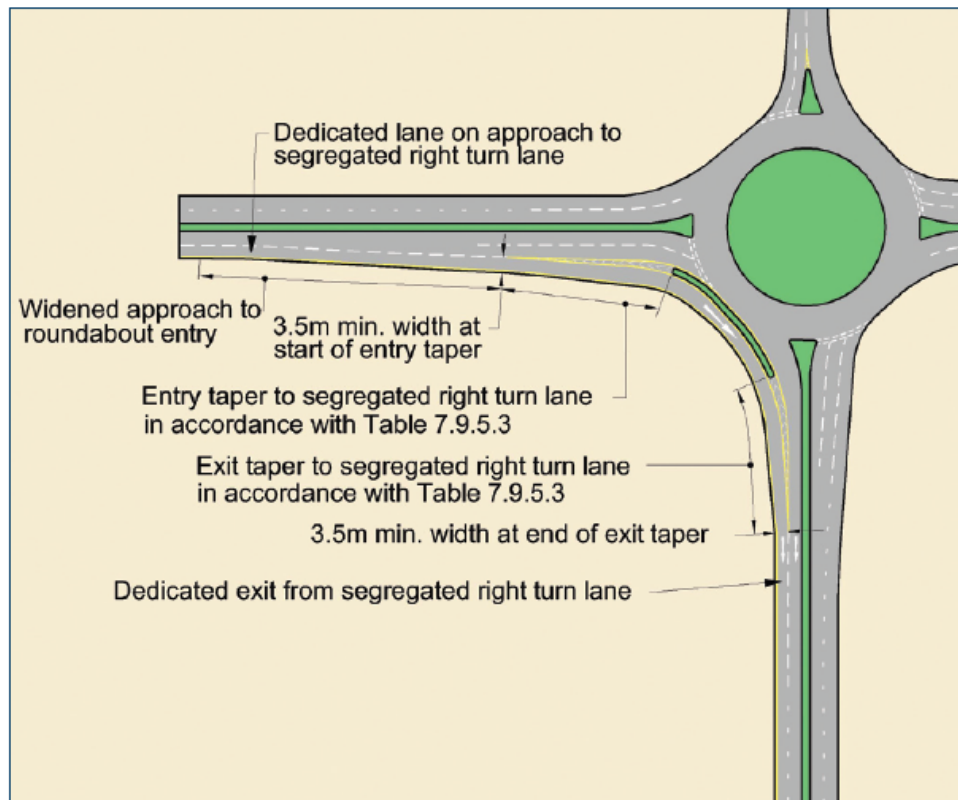


Figure 3.9.4 Dedicated Approach and Exit for Segregated Right Turn Lane Approach and Exit (Design Speed $\leq 60\text{kph}$)

Diverge layouts, as shown on Figure 3.9.5, are a way of starting a segregated right turn lane as an enhancement to an existing layout. Diverging layouts are also necessary where the approach road is a single carriageway. Where exiting on to a single carriageway a "Give-way" line arrangement shall be provided and merging tapers must not be used, refer to Figure 3.9.6.

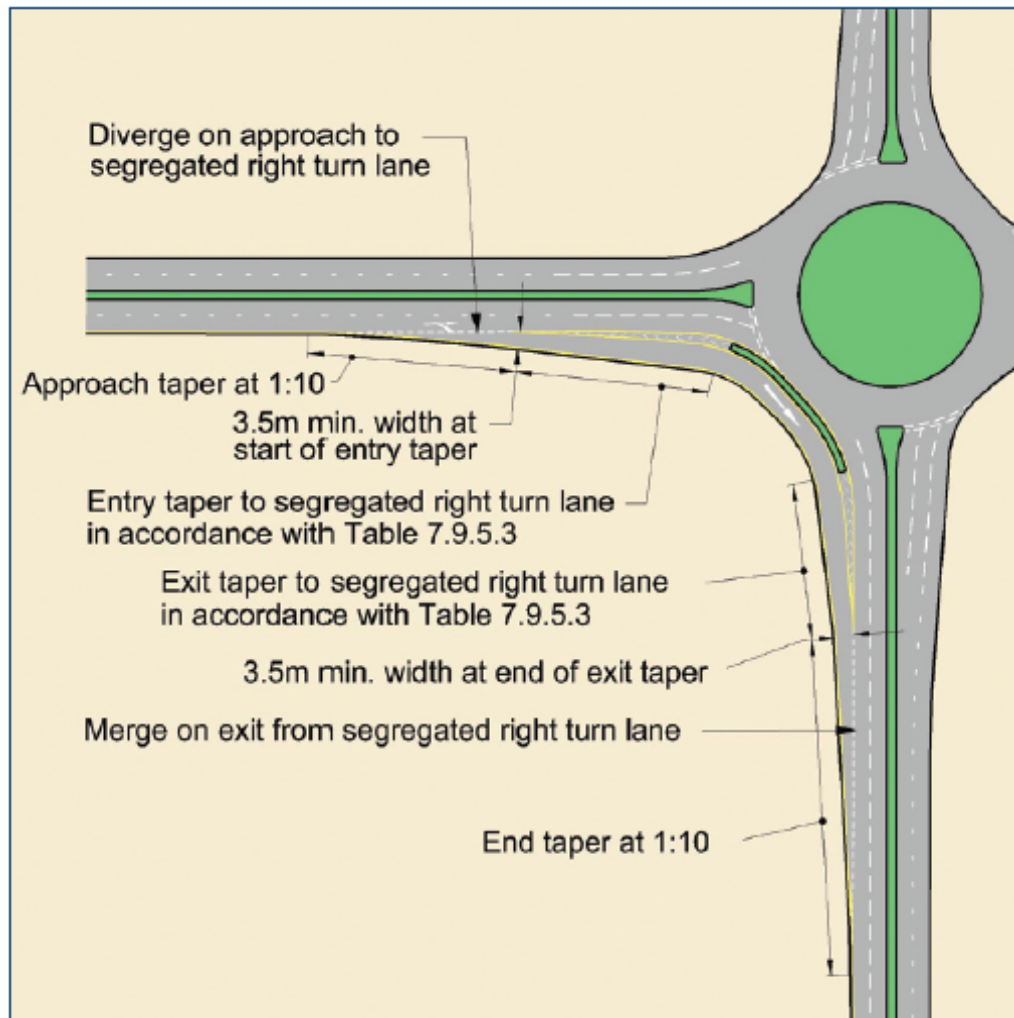


Figure 3.9.5 Diverge / Merge Layout for Segregated Right Turn Lane with Island < 50m long

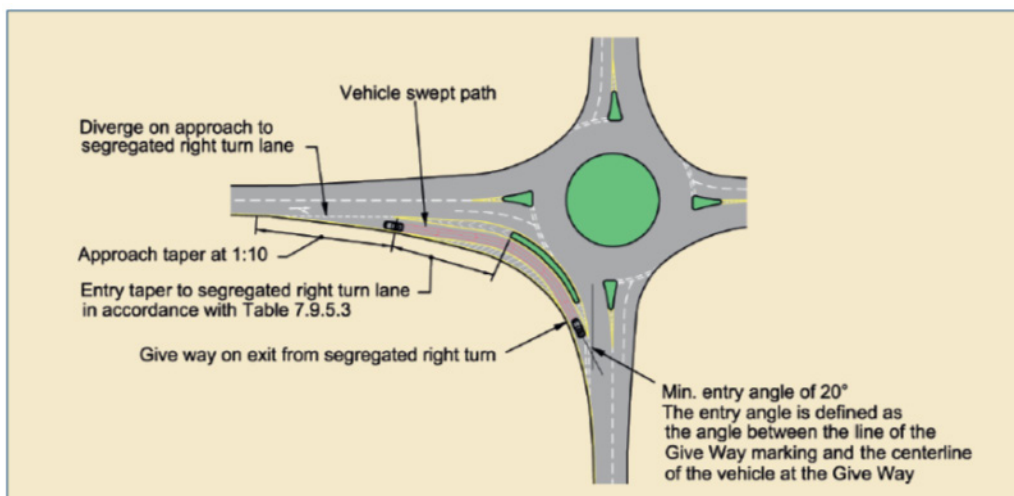


Figure 3.9.6 Physically Segregated Right Turn Lane with "Give Way" on Exit

Dedicated lanes on approach can create difficulties for cyclists and should only be used if there is negligible cycle use or when cycle movements can be provided with off carriageway facilities. Diverge layouts are more cycle friendly than dedicated lanes.

The entry arrangements consist of an approach taper, if required, and an entry in accordance with Table 3.9.3 and as shown on Figure 3.9.4 to Figure 3.9.6

The approach taper will be dependent on site constraints and the use of the minimum taper values contained in Table 3.9.4 is recommended.

Table 3.9.3 Segregated Right Turn Lane Approach Treatments

Approach Type	Approach Taper	Entry Taper
Dedicated Approach Lane	No	Yes
Diverge	Yes	Yes

Table 3.9.4 Minimum Approach and End Tapers

Design Speed	Minimum Taper
≤ 60 kph	1:10
> 60 kph	1:15

Table 3.9.5 Desirable Minimum Entry/Exit Taper Length Factor

Design Speed (kph)	Entry/Exit Taper Length Factor
50	20
60	20
70	20
85	25
≥100	30

The entry taper length for the segregated right turn lane shall be provided in accordance with Table 3.9.5. The segregated right turn lane width shall be a minimum of 3.65m at the start of the entry taper, as shown on Figure 3.9.4. Any reduction from this value shall be considered a Departure from Standards.

The length of the entry taper shall be calculated using the following method:

The length of the entry taper shall be dependent on the widening required to accommodate the segregation island, subject to a minimum width of 1.0m for non-physical islands and 2.1m for physical islands (consisting of a 1.5m wide island plus a 0.3m marking offset on each side, Figure 3.9.7 refers), or the widening required to accommodate the swept path of a Large Goods Vehicle (Table 3.9.2). The larger of the

two values shall be used to determine the entry taper length using the factors contained in Table 3.9.5.

Figure 3.9.7 shows an example of how to calculate the entry taper length for a 1.5m wide physical island less than 50m in length, for a 70 kph single carriageway approach.

The taper for the hatching shall be developed asymmetrically on the segregated right turn lane side of the entry taper as shown on Figure 3.9.7 and shall terminate in a position offset 0.3m from the edge of a physical island as shown on Figure 3.9.8. The 0.3m offset may be reduced to 0.15m where the speed limit is 40mph or less.

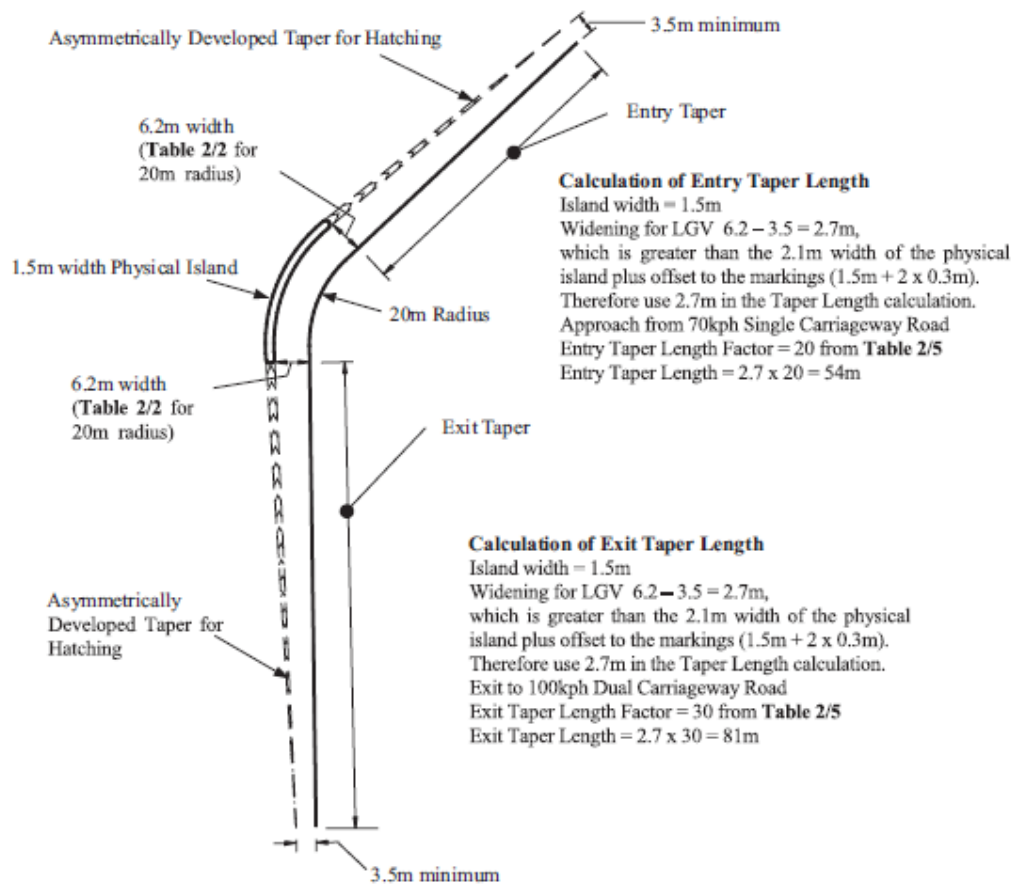


Figure 3.9.7 Example of Calculation of Entry/Exit Taper Lengths (1.5m wide island less than 50m long, 70kph approach design speed)

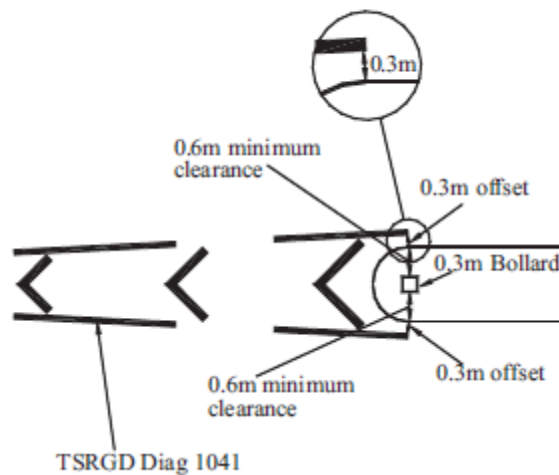


Figure 3.9.8 Termination of Taper Hatching at Physical Island

Exit Layout

The three basic types of exit layout from a segregated right turn lane are:

- Dedicated lane consisting of an exit taper as shown on Figure 3.9.4;
- Merge consisting of an exit and end taper as shown on Figure 3.9.5;
- "Give-way" as shown on Figure 3.9.6.

The dedicated exit lane (see Figure 3.9.4), provides a free running exit for traffic from the segregated right turn lane. This exit type does not reduce the link capacity of the segregated right turn lane and is considered a safer layout compared with a merge exit.

Merge exits consist of a merge manoeuvre between the traffic leaving the roundabout circulatory carriageway and the segregated right turn lane. Merge exit layouts inherently include risks associated with vehicles exiting the roundabout being in the wing mirror "blind spot" for traffic using the segregated right turn lane. This can be associated with collisions between merging vehicles and nose-to-tail collisions. This is a particular problem for those motorists with a limited ability to look over their shoulders and for drivers of some large vehicles and left-hand drive vehicles.

Merge exits shall only be provided where two or more lanes can be provided on the exit (see Figure 3.9.5). For the case where only one lane can be provided at the segregated right turn lane exit point, a give way from the segregated right turn shall be provided (see Figure 3.9.6).

The exit taper for the segregated right turn lane shall be provided in accordance with Table 3.9.5. The segregated right turn lane width shall be a minimum of 3.65m at the end of the exit taper, as shown on Figure 3.9.4. Any reduction in this width shall be considered a Departure from Standards. Any widening required to accommodate the swept paths of Large Goods Vehicles through the segregated right turn lane shall be

removed along the length of the exit taper. As with the entry taper, the length of the exit taper shall be calculated by using the larger value when comparing the width of the segregated right turn lane island with the width reduction required between the start and end of the exit taper, as shown on Figure 3.9.7.

The taper for the hatching shall be developed asymmetrically on the segregated right turn lane side of the exit taper as shown on Figure 3.9.7 and shall terminate in a position offset from the edge of a physical island in accordance with clause 9.3.26 of this Section.

It is recommended that at the beginning of a roundabout exit, its width should allow for an extra traffic lane over and above that of the link downstream, provided that a maximum of 2 lanes on exit is not exceeded. This extra width should be reduced on the nearside, normally at a taper of 1:15 to 1:20. Where a segregated right turn lane is present, the exit width reduction must be completed upstream of the end of the segregated right turn lane exit taper. This may require extending the segregated right turn lane exit taper to accommodate the roundabout exit width reduction.

The end taper will be dependent on site constraints and the use of the minimum taper values contained in Table 3.9.4 is recommended.

A give way exit from a segregated right turn lane should be located as close as practicable to the roundabout, at a minimum entry angle of 20° between the “Give Way” line and vehicle. The entry angle is defined as the angle between the line of the “Give Way” marking and the centreline of the vehicle at the “Give Way” line as shown on Figure 3.9.6. The position of the vehicle at the “Give Way” line should be determined by carrying out a swept path analysis.

Where signs and street furniture are placed on the physical island in the vicinity of the exit, they should be located so as not to obstruct inter-visibility between the segregated right turn lane exit and adjacent roundabout exit lane.

Non-Physical Segregated Right Turn Lanes

Non-physical segregated right turn lanes are subject to abuse by drivers resulting in conflicts on the approach to or exit from a roundabout and on the circulatory carriageway section, especially on older existing roundabout junctions. The use of a physical island is therefore recommended where possible.

The use of raised or domed surfaces, flush kerbs or infilling with marking material to reinforce road markings is not permitted.

Physical segregated right turn lanes shall be used where vehicles using the segregated right turn lane have to give way at the exit.

Buses

Segregated right turn lanes give priority to all vehicles turning right at a junction including buses. These facilities can therefore improve journey time reliability on bus routes, either in isolation or as part of a larger traffic management proposal.

The use of bus only segregated right turn lanes to provide priority for right turning buses at roundabouts requires careful consideration. Factors including the number of buses using the dedicated lane and any detrimental impact on the overall capacity of the roundabout entry and affected exit will need to be taken into account.

Bus stops shall not be located within segregated right turn lanes.

3.9.4 Road Markings

Road markings are used to channel traffic and, where required, to indicate a dedicated lane. Lane indication arrows to reinforce the advance map type direction signs at entries can be beneficial where heavy flows occur in a particular direction.

Lane dedication by arrows and markings on the circulatory carriageway is not normally recommended. Where a roundabout is particularly extensive and partially signalled and it is tending to a gyratory system, then some degree of channelization by road markings may prove beneficial in the operation of the roundabout.

3.9.5 Lighting

The provision of road lighting at roundabouts is an essential safety requirement. In some locations lighting requirements may conflict with environmental considerations and alternative lighting methods may be considered. However, these must not compromise the requirement to provide adequate lighting at the roundabout.

When an existing roundabout is being modified, the lighting layout should be checked for suitability with the new road arrangement. It is important that approaching drivers see and perceive that they are approaching a roundabout and are not misled by the projection of the lighting layout, particularly at times of poor visibility.

4 Interchanges

4.1 Introduction

4.1.1 General

Grade separation removes conflicts between the vehicle flows of intersecting roads by means of a structure such as a bridge or tunnel, thereby improving safety and capacity of an intersection. A grade separated interchange is formed where connector roads are provided to link the grade separated flows, thus enabling movement between the intersecting roads.

For new roads with high predicted traffic flows, consideration can be given to grade separation. Grade separated interchanges may be complex and include extensive connecting roads, land-take and associated infrastructure.

Grade separated interchanges shall be used for all intersections on urban and rural freeways. They shall also normally be used where the mainline is an urban or rural expressway (refer to Section 4 for recommended junction types within road hierarchy classifications).

On other road classifications the use of grade separated interchanges shall not be standard practice but may be considered by the designer on a site specific basis where conditions are appropriate.

Local grade separation may be considered on lower classification dual carriageway roads where left turn manoeuvres are eliminated. Such treatments shall be subject to geometric standards defined in Section 5 and shall not be defined as grade separated interchanges, as outlined in this section.

For existing at-grade intersections, grade separation can also be considered to improve conditions, particularly where problems have been identified. Reasons for upgrading to a grade-separated layout may include:

- To remove a hazardous at-grade intersection in order to improve safety;
- To eliminate traffic delays at a bottleneck caused by the volume of crossing and turning traffic;
- To improve the alignment of a road;
- To standardise junction types when upgrading a corridor to a higher classification.

Grade separated interchanges take a variety of forms, depending on the nature of the intersecting roads. The connector roads within a grade separated interchange may take one of two basic forms:

- **Slip Road** – A connector road which includes a free-flow merge or diverge taper at one end, and an at-grade intersection or roundabout at the other end.
- **Interchange Link** – A connector road which includes free-flow merge or diverge tapers at both ends. Where a grade separated interchange incorporates interchange links throughout, it may be said to provide full free-flow conditions.

Additionally, link roads may be provided adjacent to the mainline to reduce weaving requirements, refer to sub-section 5.

This section sets out the requirements for the design, layout and size of grade separated interchanges. It is essential that the designer produces safe designs that provide adequate capacity.

4.1.2 Definitions

Grade separated interchanges are made up of distinct elements. In consideration of the design of grade separated interchanges it is essential that elements are correctly defined. For clarity, definitions are outlined below.

Auxiliary Lane: An additional lane at the side of the mainline carriageway to provide increased merge or diverge opportunity or additional space for weaving traffic.

Connector Road: A collective term for interchange links, link roads, slip roads and loops.

Downstream: That part of the carriageway(s) where the traffic is flowing away from the section in question.

Free-flow Interchange: A grade separated interchange that provides free-flow from one mainline to another.

Fork: An at-grade junction of two roads, usually within an interchange, which diverge from the approach road at similar angles. Usually both diverging roads have equal status.

Interchange Link: A connector road, one or two way, carrying free flowing traffic within a free-flow interchange between one level and/or direction and another.

Lane Gain: A layout where a merging connector road becomes a lane or lanes of the downstream main carriageway.

Lane Drop: A layout where a lane or lanes of the upstream carriageway becomes the diverging connector road.

Link Road: In the context of junctions, a one way connector road adjacent to but separate from the mainline carriageway carrying traffic in the same direction, which is used to connect the mainline carriageway to the local highway network where successive direct connections cannot be provided to an adequate standard because the junction spacing is too close.

Loop: A connector road, one or two way, which is made up of the elements of the loops shown in Figure 4.4.13 and which passes through an angle in the range of approximately 180 to 270 degrees. The loop is considered to extend to the end of the near straight length of road contiguous with the back of the diverge or merge nose.

Mainline: The carriageway carrying the major road flow of traffic; generally traffic passing straight through the interchange. At a free-flow interchange both intersecting roads shall be considered as mainline.

Near Straight: A length of road with a radius no less than the Desirable Minimum Radius for the mainline design speed.

Nose: A paved area, approximately triangular in shape, between a connector road and the mainline at a merge or diverge, suitably marked to discourage drivers from crossing it.

Parallel Merge/Diverge: A layout where an auxiliary lane is provided alongside the mainline carriageway.

Slip Road: A connector road within an interchange between the mainline and a lower classification road, or vice versa, which meets lower classification road at-grade. Traffic using a slip road usually has to give way to traffic already on the lower classification road.

Taper Merge/Diverge: A layout where merging or diverging traffic joins or leaves the mainline carriageway through an area forming a funnel to or flare from the mainline carriageway. This would be alternative to an auxiliary lane arrangement and is not standard practice in Qatar.

Upstream: That part of the carriageway(s) where traffic is flowing towards the section in question.

Weaving Section: The length of the carriageway between a successive merge or lane gain and diverge or lane drop, where vehicles leaving the mainline at the diverge or lane drop have to cross the paths of vehicles that have joined the mainline at the merge or lane gain.

4.2 Interchange Layouts

4.2.1 General

The decision to provide a grade separated interchange and its type and detailed design will be specific to a particular site. The selection of the most suitable facility for a particular site and the associated design parameters depend upon a number of controlling factors which include:

- Safety;
- Road classification for intersecting roads;
- Design speed of intersecting roads;
- Traffic volume and mix;
- Required junction capacity;
- Number of junction legs;
- Topography;
- Land available, the type of land and its present use;
- Economics;
- Environmental impact;
- Access to local communities;
- Non-motorised users.

The two basic forms of grade separated interchange can be identified as the following generic types:

- Free-flow Interchanges – incorporating interchange links and therefore providing free-flow conditions, with merge and diverge tapers included on both intersecting roads. Free-flow interchanges shall generally be used where intersecting roads are of similar status e.g. at intersecting Freeways, at intersecting Expressways and where Freeways intersect with Expressways.
- Standard Grade Separated Interchanges – incorporating slip roads and therefore featuring at-grade priority intersections, signal controlled intersections or roundabouts on the lower classification intersecting road. Standard Grade Separated Interchanges shall generally be used where one of the intersecting roads has clear priority e.g. where Expressways intersect with lower classification roads, most commonly Arterial routes.

A wide variety of layouts are available within these basic forms. Layouts will vary for different locations. It is unlikely that the layout for one site could be directly applicable for another. The traffic and topography are unlikely to be the same. However, it is desirable to standardise layouts along a particular route to attempt to reduce confusion to drivers and thereby improve safety.

Some commonly used layouts are described in the following sections. It should be noted however that these are sample layouts only, and the most suitable layout will be dependent on the key controlling factors listed above.

4.2.2 Free-flow Interchanges

Free-flow interchanges combine grade separation of major conflicts with interchange links or loop roads that begin and end with diverges and merges. They are suitable for use where both intersecting routes are of high classification and high traffic flows, and therefore free-flow mainline conditions are required throughout the junction.

A 2-level or 'cyclic' interchange is shown in Figure 4.2.1. This utilises reverse curves and a low number of conflict points, the land take is extensive and there is a high structural content. However, since this form of interchange fits easily into the topography it is a suitable solution for schemes where land is not at a premium. A disadvantage is that it requires separate diverge points for left and right movements from both mainlines, which can be difficult to sign.

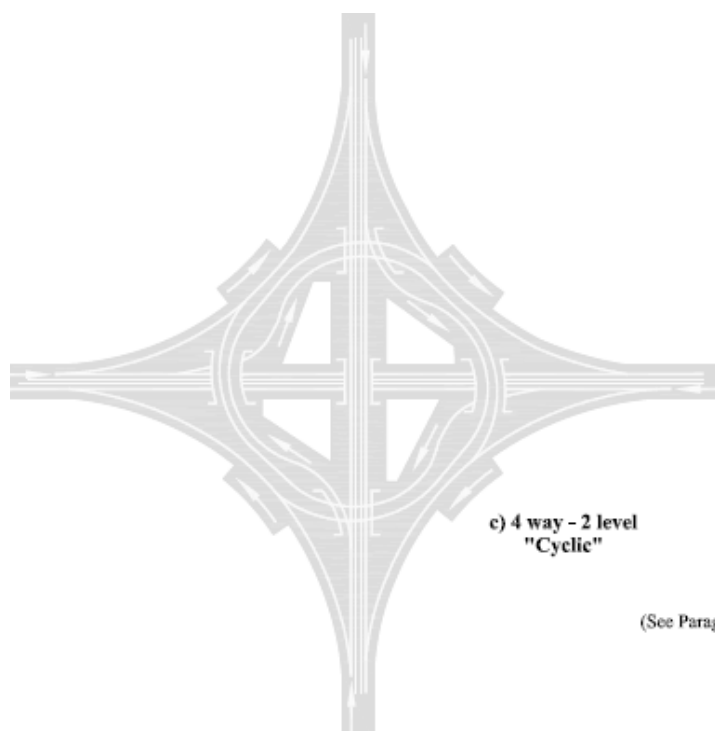


Figure 4.2.1 – 2-level Cyclic Interchange

A layout which provides full free-flow conditions with a single bridge structure is the "Full Cloverleaf" (see Figure 4.2.2). In order to achieve sufficient radius on the ramp loops, this layout requires sufficient land area which spreads for a considerable distance from the mainline centreline. The key disadvantage with the full cloverleaf arrangement is that merging traffic enters the mainline upstream of diverging traffic leaving, therefore creating a sub-standard "weaving section" for the two flows to cross. For this reason the provision of a "Full Cloverleaf" layout is non-standard and considered a Departure from Standards. The arrangement may only be considered when merging and diverging movements are light. Link roads may be considered to remove the weaving sections from the mainline through traffic.

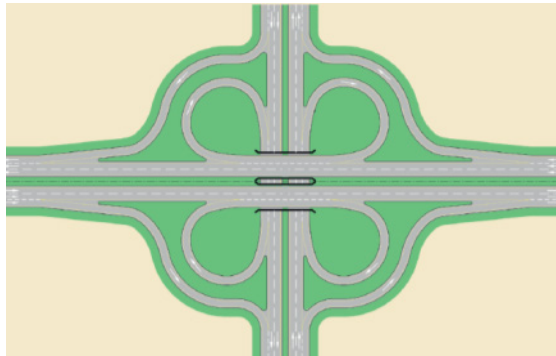


Figure 4.2.2 – Full Cloverleaf Interchange

The “Half Cloverleaf Interchange” may be suitable where land is not available in all four quadrants. Here the ramps are located in two quadrants only and a single bridge structure is required. The layout incorporates loops (refer to clause 4.7). In Figure 4.2.3, ramps are shown in quadrants 2 and 4. However, the interchange would work equally well if they were in quadrants 2 and 3, 1 and 3, or 1 and 4. This layout may provide free-flow movements, via interchange links, but equally may be applied to a Standard Grade Separated Interchange scenario, where slip roads are incorporated with at-grade intersections located at the interface with the lower classification route. It should be noted that this layout requires land at a further distance from the mainline centreline than many other layouts.

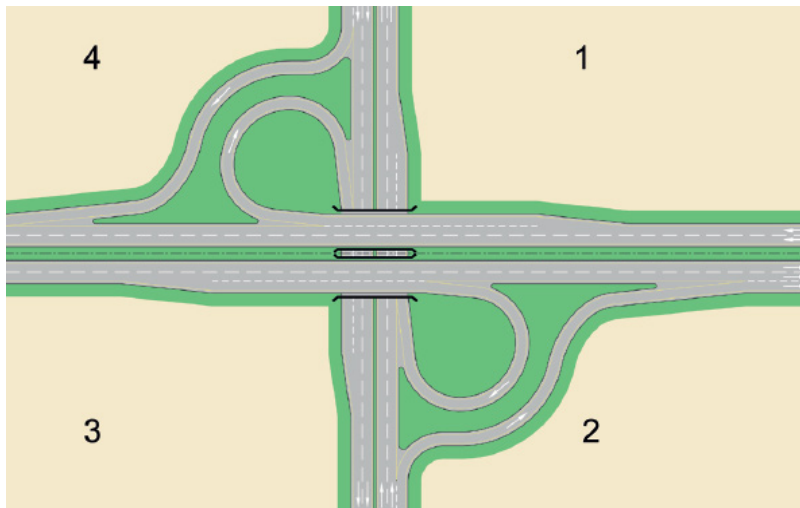


Figure 4.2.3 – Half Cloverleaf Interchange

A common junction pattern for free flow connection to one side only of the mainline is the “Trumpet Junction” (see Figure 4.2.4). This three legged interchange may access either side of the mainline. Full connectivity is provided using only a single bridge structure. A limitation of this interchange type is that it is difficult to convert to a 4 leg pattern interchange if this were to become necessary.

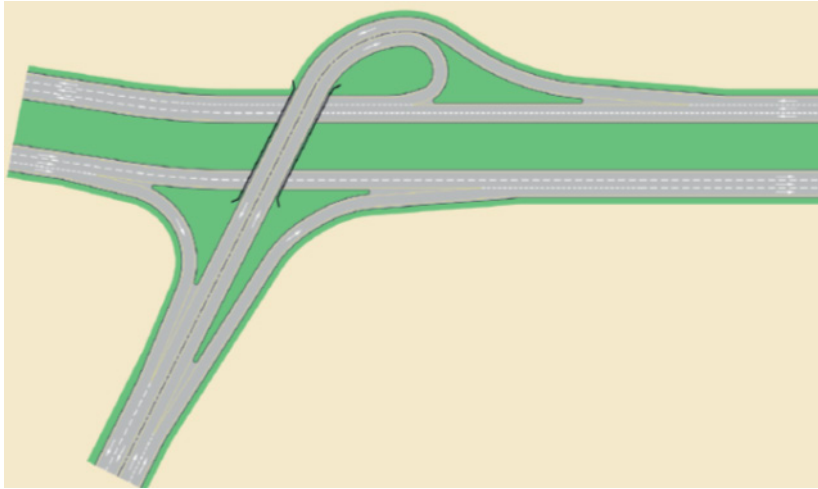


Figure 4.2.4 – Trumpet Junction

4.2.3 Standard Grade Separated Interchanges

Standard Grade Separated Interchanges combine grade separation of major conflicts with connector roads that either begin or end with a form of junction other than a diverge or merge. They are suitable where one intersecting road has the dominant classification and flow (usually a Freeway or Expressway), and the lower classification intersecting road is suitable to incorporate at-grade intersections.

The simplest form of interchange giving access from the mainline to the intersecting road system is known as a “Diamond Junction” (refer to Figure 4.2.5). Requiring a single bridge structure, this provides a clear through route for mainline traffic and ramp connection in all directions with a single cross route by means of at-grade priority or signal controlled intersections. A similar form of interchange with roundabouts in place of the at-grade priority or signal intersections is known as a “Dumb Bell Junction”. Un-signalised crossroads at the intersection with the minor road are not recommended (refer to Section 5).

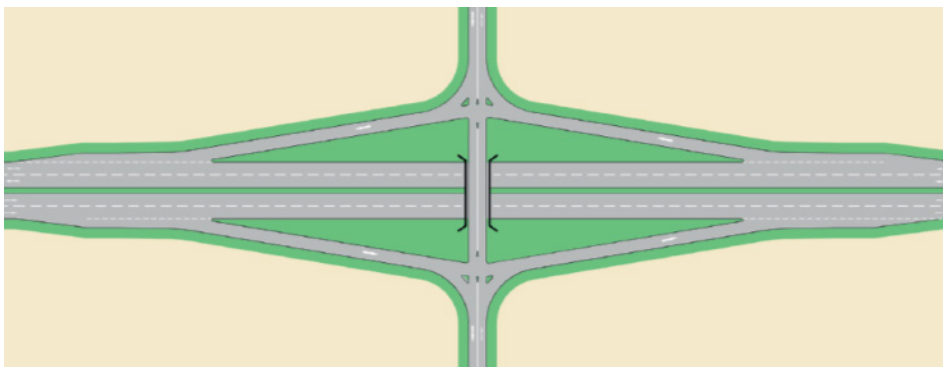


Figure 4.2.5 – Diamond Junction

Another common layout for Standard Grade Separated Interchange is the “Grade Separated Roundabout” (refer to Figure 4.2.6). This requires two bridge structures but is compact and allows full connectivity. The layout is suitable for a situation in which

the mainline crosses a traffic stream which can be routed through the roundabout. One difficulty can be providing a roundabout design that provides adequate geometry for traffic joining and leaving the roundabout at adjacent ramp and cross route entry and exits. In general, the roundabout and cross route are at existing grade while the mainline is either elevated or depressed. The design approach to be followed for the roundabout is covered in Section 6.

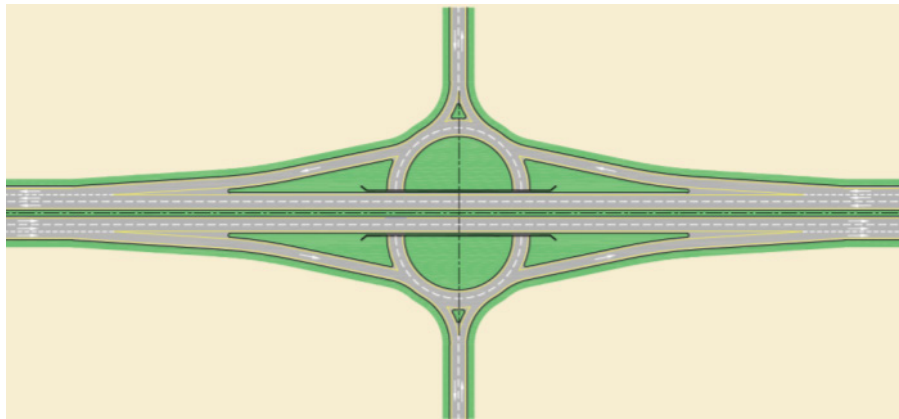


Figure 4.2.6 – Grade Separated Roundabout

Grade separated interchanges may incorporate signal control over the at-grade junction elements. An example of this is illustrated in Figure 4.2.7, a “Single Point Junction”. This allows control of traffic conflicts with traffic signals at a single point instead of using two physically separate junctions (Diamond configuration) or a single large roundabout (Two Bridge Roundabout configuration). Its main advantage is that it may have higher traffic capacity and less delay in comparison to conventionally designed signal controlled diamond interchanges. Care must be exercised to reduce the size of the interchange as it can result in quite large open areas if poorly designed.

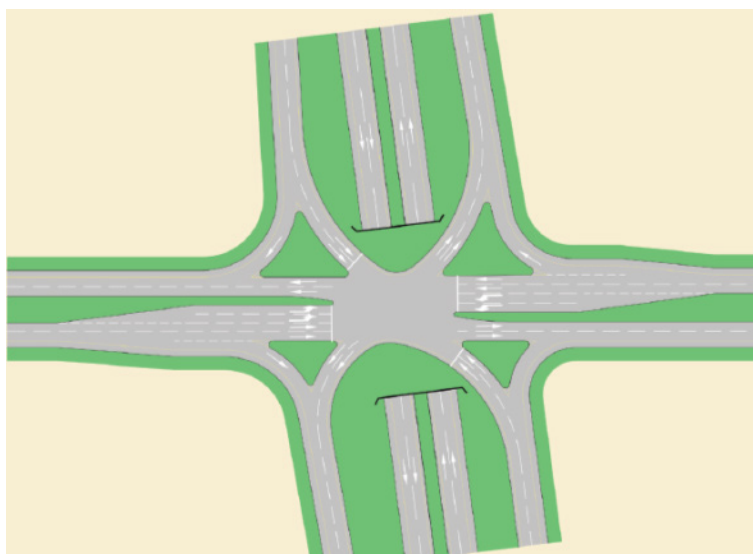


Figure 4.2.7 – Single Point Junction (Signal Controlled At-grade element)

4.3 Design Strategy

4.3.1 General

This section outlines the design procedures for selecting a form of interchange most suitable for a particular location. A series of preliminary designs shall be prepared for comparison before final selection and production of a detailed design.

An interchange layout should give drivers and other road users a clear understanding of what is required of them. Poor layouts lead to driver confusion, indecisiveness and rash decisions that could contribute to accidents. The design should provide:

- advance notification of the layout on the approach to a junction;
- conspicuous junction locations and layouts;
- understanding of permitted changes to the direction of travel;
- understanding of other traffic movements;
- avoidance of potential hazards.

4.3.2 Safety

The main objective of grade separated interchange design is to provide a junction which is safe for the forecast traffic flows. Certain layouts are not recommended for safety reasons and must be avoided. These include:

- grade separated interchanges on single carriageways;
- grade separation on dual carriageways within 0.5 km of a changeover to single carriageway standard, measured from the end of the merge taper to the beginning of the right hand lane hatching that removes the offside lane or lanes;

Other layouts not recommended for safety reasons and which should be avoided include:

- offside merges and diverges;
- major/minor intersections, particularly those with left turning movements, on an otherwise grade separated route, particularly on Freeways and Expressways.

Incorporation of these layouts shall be considered a Departure from Standards.

4.3.3 Traffic Flows and Design Year

For the road network to operate efficiently, new junctions must have sufficient capacity. It is not possible to ensure at the time of design that a new interchange has sufficient capacity indefinitely. Instead, new and improved junctions shall be designed on traffic levels predicted to occur in the Design Year, typically 15 years after the opening of the schemes, to ensure that they are free of congestion for a reasonable period.

Predicted traffic flows shall be based on the existing, observed traffic flows factored up to model the Design Year flows. All Junctions and Interchanges shall be designed using the peak hour flows. The use of peak hour flows will model the worst case for traffic congestion. Of particular importance to junction design is the volume of traffic undertaking each turning manoeuvre. All predicted traffic volumes and turning volumes for the Design Year shall be agreed with the Roads Authority.

4.3.4 Urban/Rural

The design of grade separated interchanges is based on the peak hour flows which usually vary according to road type and classification and to whether the road is rural or urban. Urban standards for most elements of road design are, however, lower than those applicable to rural design, since lower driver expectation accompanied by higher perception offset the increased risks caused by reductions in standards. For example, the presence of kerbs, frequent lack of hardstrips, narrow median, lighting and speed limits would all indicate the urban nature of a road. The lower urban standards are shown within the hierarchy of geometric standards, as detailed in Section 2.

4.3.5 Junction Spacing Within the Network

In deciding on the form of the interchange the designer must consider the location within the overall road network, as this can have a significant effect on both its operational performance and environmental impact. The aim must be to produce a consistent junction strategy across the network that maximises safety. Guidance on the junction strategy for a particular location shall be sought from the Roads Authority.

The minimum spacing of consecutive junctions on a multi-lane road is based on safety requirements for weaving movements, refer to sub-Section 5 of this Section.

4.3.6 Initial Information Requirements and Decisions

The following information must be collated to form the basis for the selection of the most appropriate type of interchange for a particular location:

- Define the classification of the roads approaching the intersection;
- Define the carriageway cross-section of the roads on each side;
- Define the design speed of the roads;
- Define the proposed opening year for the new facility;
- Existing traffic volumes must be obtained for the peak hour and growth factors applied;
- Define the location of any constraints to the scheme. These include land ownership, existing and proposed utilities, planning constraints, topography, dry water courses, flood plains and ground conditions;
- Define the environmental constraints. These include proximity to dwellings, severance of communities, plants of particular importance, animal habitats and regularly used animal tracks and migration routes.

Having collated the above information, the following decisions must be made before finalizing the form to be used.

- Agree the overall strategy with the Roads Authority;
- Agree predicted traffic volumes and turning volumes with the Roads Authority;
- Decide which turning movements will be accommodated;
- Decide which movements will be given mainline priority, and which movements will be accommodated by at-grade intersections;
- Confirm horizontal and vertical clearances for structures.

4.3.7 Design Development

The design development should be appropriate for the classification of roads at the intersection, refer to Section 4. For a given location various layouts and facility types may be developed for evaluation.

No fixed rules can be given for the selection due to the multitude of criteria that must be considered. Each location will have different governing criteria and it is for the designer to use his experience to select the most appropriate type for evaluation.

Figure 4.3.1 provides guidance on the factors to be considered at each step in the preliminary interchange design process.

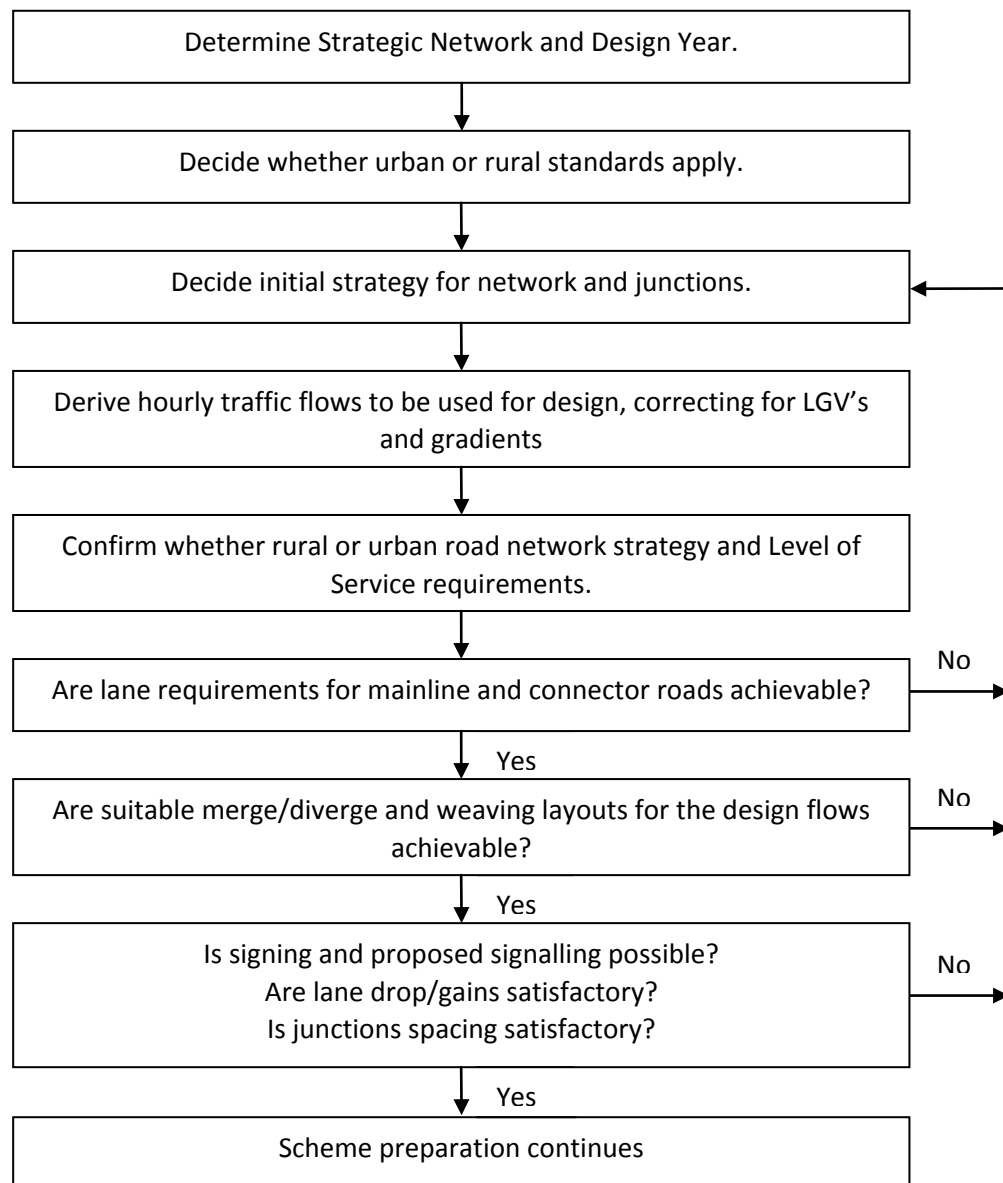


Figure 4.3.1 – Flow Chart Showing the Intersection / Interchange Design Process

Preliminary designs should be prepared for alternative arrangements to assess suitability and relative costs. The main elements of the facility must be defined in sufficient detail and at a suitable scale to determine the land take required.

The items to be defined in the preliminary design include:

- Safety implications for road users and non-road users;
- Number of lanes required for each movement;
- Radii of links and loops;
- Merging and diverging arrangements;

- Vertical and horizontal clearances for structures;
- Maximum carriageway gradients;
- Lengths of loop roads and slip roads;
- Lengths of weaving sections;
- At-grade intersection layouts (where necessary);
- Provision for non-motorway traffic and non-motor vehicle road users;
- Estimate of construction costs.

The designer must also consider:

- Method of construction;
- Method of maintenance;
- Environmental effects including landscaping;
- Lighting and signing principles;
- Provision of safety fences and barriers.

Junction strategies and preliminary designs should be discussed and further development proposals agreed with the Roads Authority prior to detailed design.

4.4 Design Elements

4.4.1 Design Speed

Design speeds for slip roads and link roads are related to the design speeds for the associated mainline as shown in Table 4.4.1.

Table 4.4.1 Design Speed of Connector Roads

Mainline Design Speed kph	Slip Road kph	Interchange link kph	Link Road kph
Rural			
140kph	80	100	80
120kph	70	80	70
100kph	60	70	60
Urban			
120kph	70	80	70
100kph	60	70	60
80kph	50	60	50

Where transition curves are used between design elements within the Interchange, the transition curve relating to the higher design speed must be used. Failure to comply with this requirement shall be considered a Departure from Standards.

Reductions below the desirable minimum standards for visibility and vertical curvature are not permitted at any point on connector roads. Any reduction in these requirements shall be considered a Departure from Standards.

Reductions below the Junction Approach Sight Distance (JASD) as defined in Section 2, and desirable minimum standards for vertical curvature, are not permitted on the mainline or connector roads on the immediate approach to a junction, because the majority of collisions occur in the vicinity of junctions.

For the purposes of this Standard the immediate approaches to a junction shall be:

- for diverges, that portion of the mainline from a point 1.5 x desirable minimum stopping sight distance for the mainline design speed upstream of the commencement of the diverge taper, to the back of the diverge nose.
- for merges, that portion of the mainline from a point 1.5 x desirable minimum stopping sight distance for the mainline design speed upstream of the back of the merge nose, to the tip of the merge taper.
- for slip road approaches to at-grade intersections, those lengths of carriageway on the slip road between a point 1.5 times the slip road Desirable Minimum Stopping Sight Distance upstream of the “Give Way” or “Stop” line, and the “Give Way” or “Stop” line itself;
- for link road approaches to at-grade minor road connections those lengths of carriageway on the link road between a point 1.5 times the link road Desirable Minimum Stopping Sight Distance upstream of the centre line of connecting minor road, and the centre line of connecting minor road itself.

4.4.2 Lane Provision and Capacity

Lane provision for the main road, slip roads, link roads and loops shall be based on the agreed traffic flows derived from a level of service requirement. As a guide for interchanges, the minimum number of lanes provided on any particular element of the junction shall be based on 1400 vehicles per lane per hour. The number of lanes shall be rounded up to the nearest whole number. .

The designer may wish to increase the lane provision above the minimum defined above for operational reasons.

Where the minimum lane provision is one lane, the designer may wish to add an extra lane to reduce the potential for problems with broken down vehicles blocking the carriageway or restricted space for maintenance.

For the majority of interchanges, the maximum number of lanes provided for connector roads is likely to be two. If the lane provision for any particular connector road is more than two, the designer may have incorrectly identified the main road.

Where more than two lanes are required to merge and diverge, the designer should refer to the Roads Authority.

4.4.3 Hard Shoulders and Hardstrips

Where hard shoulders or hardstrips are provided on the main road either side of the interchange, they shall be continued through the interchange. For connector roads, the provision of hard shoulders or hardstrips shall be in accordance with Section 2.

On the mainline, the hard shoulder or hardstrip shall continue immediately after the chevrons for the nose.

4.4.4 Merges and Diverges at Interchanges

Within interchange areas, merges and diverges are the locations where collisions are most likely to occur. It is essential for the designer to pay particular attention to their layout. Traffic should be able to leave or join the main road as smoothly as possible. In order to achieve this, the speeds of traffic joining or leaving the main road must be similar to that on the main road. Acceleration or deceleration to the appropriate speed should take place on the slip road or link road before the merge or after the diverge. The geometry of the carriageway or other conditions in the vicinity of the merge or diverge must not impede this smooth flow. Queuing in the area of the merge or diverge must also be avoided.

There are a range of configurations for merges and diverges which shall be used depending on the volumes of traffic on the mainline and connector road. Each layout incorporates an auxiliary lane, which provides an additional lane or lanes parallel to the main road to facilitate the required traffic movements.

Junction Approach Sight Distance in accordance with the mainline design speed shall be provided over the whole length of the merge or diverge facility and along the full length of the merge or diverge nose.

The designer should ensure that the crossfalls in the vicinity of the merge and diverge areas are suitable for the safety of high speed vehicles crossing at angles. Ideally the mainline crossfall should be continued across the merge or diverge up to the painted nose. If this cannot be achieved the maximum permitted difference in crossfall between the mainline and the merge or diverge auxiliary lane is 4% for design speeds less than 120kph and 2.5% for design speeds of 120kph or greater. Any further variation shall be considered a Departure from Standards.

The crossfall on the painted nose should ideally follow the mainline crossfall. Where this cannot be achieved the maximum permitted difference in crossfall between the mainline and the nose and between the nose and the adjacent connector road is 4%. The crossfall across the nose shall not exceed 10%. Non compliance with these requirements shall be considered a Departure from Standards.

The radius of the edge of carriageway or kerb line on merges and diverges may be reduced to that applicable to the next lowest design speed in the immediate vicinity of the join to the slip road or link road. Transitions in this vicinity may be used at the designer's discretion.

Merge Layouts

To select a merge layout, hourly Design Year flows for the merge and the upstream mainline are inserted into Figure 4.4.1. The intersection point of the merge and upstream mainline flows will fall within a segment from which the number of lanes required on the connector road, and the most appropriate merging layout are determined. The mainline and interchange lane capacities shall be based on the required level of service. The mainline lane capacity used in Figure 4.4.1 is based on a flow of 1800 vehicles per hour.

An auxiliary lane layout must be used on all merges. The auxiliary lane width shall be the same as the nearside lane of the main road. Any reduction in this width shall be considered a Departure from Standards.

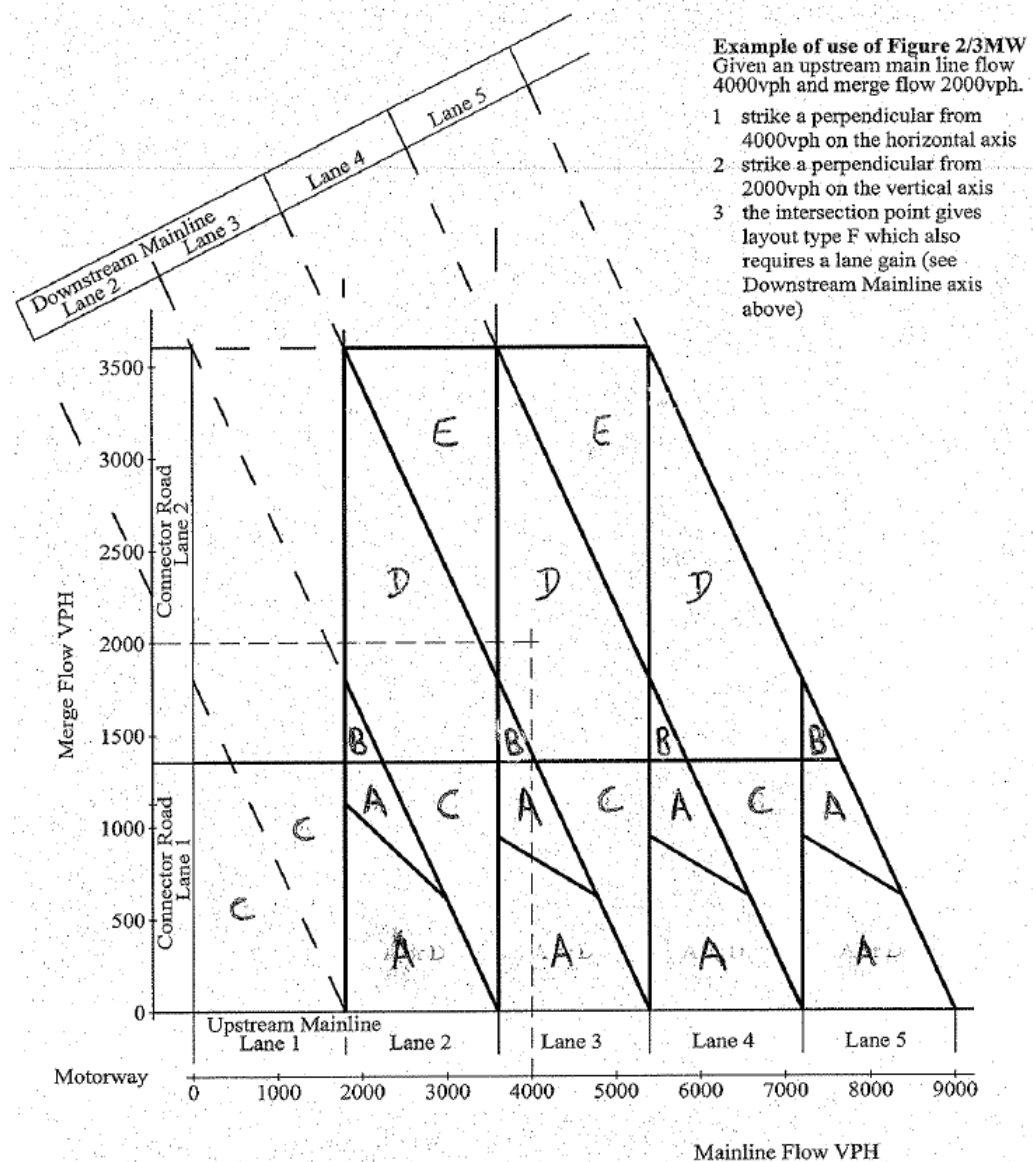
Geometric parameters for merging layouts are defined in Table 4.4.2. Extended auxiliary lanes of length greater than those defined may be necessary where additional merging opportunity is required.

Where the merge flows are high, provision of lane gains may be required. Requirements for lane gains can be derived from Figure 4.4.1.

Two lane merges are not desirable and it is recommended that where the connector road has two lanes a lane gain should be incorporated on the mainline. However, where the mainline has three upstream lanes or more, a two lane merge without lane gain, in accordance with Figure 4.4.3 is acceptable. Where the mainline has less than three lanes upstream, a two lane merge without lane gain shall be considered a Departure from Standards.

In rural locations where a lane gain is provided this shall be incorporated over a minimum length of 2km, measured from the tip of the merge nose, and in accordance with traffic requirements. Lane reductions within the mainline shall be in accordance with Section 3.

For all connector roads, a near straight at least equal in length to the nose length given in Table 4.4.2 for the appropriate design speed must be provided upstream of the back of the merge nose. This requirement will enable merging traffic to achieve a matching speed. Any reduction in this length shall be considered a Departure from Standards.



Note: Use of Layout B is not recommended and a lane gain shall be considered. Use of layout B where upstream mainline has less than three lanes is considered a Departure from Standard.

Figure 4.4.1 Merging Diagram – Design Traffic Flows

Table 4.4.2 Geometric Parameters for Merging Lanes

Mainline Design Speed	Nose Ratio (2)	Nose Length m (3)	Minimum Auxiliary Lane Length m (4)	Length of Auxiliary lane Taper m (5)
140kph	1:40	115	200	75
120kph	1:30	85	170	55
100kph	1:25	75	140	55
80kph	1:15	50	115	40

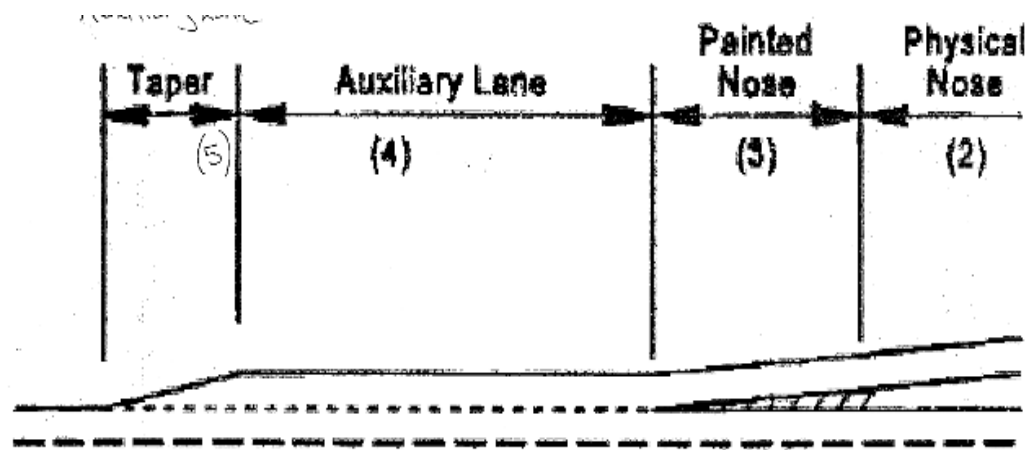


Figure 4.4.2 Merging Layout A – Parallel Merge

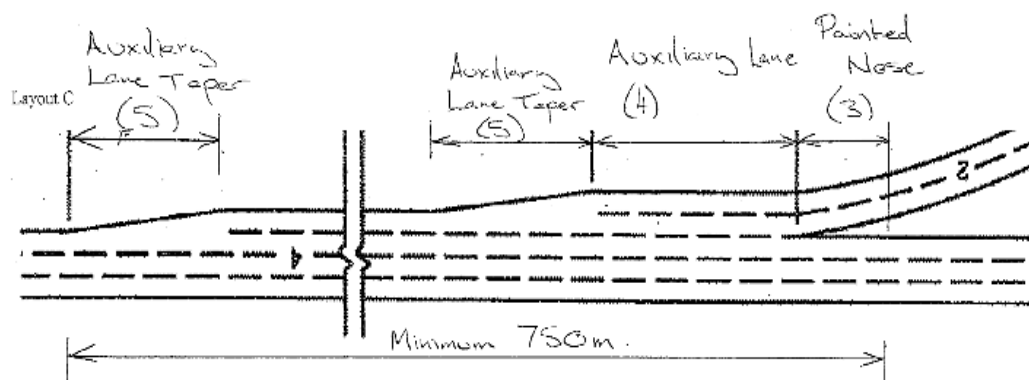


Figure 4.4.3 Merging Layout B – 2 Lane Parallel Merge (refer to clause 4.4.10)

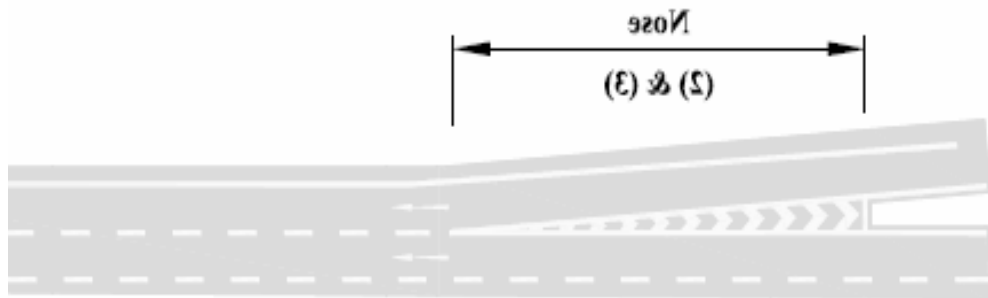


Figure 4.4.4 Merging Layout C – Lane Gain

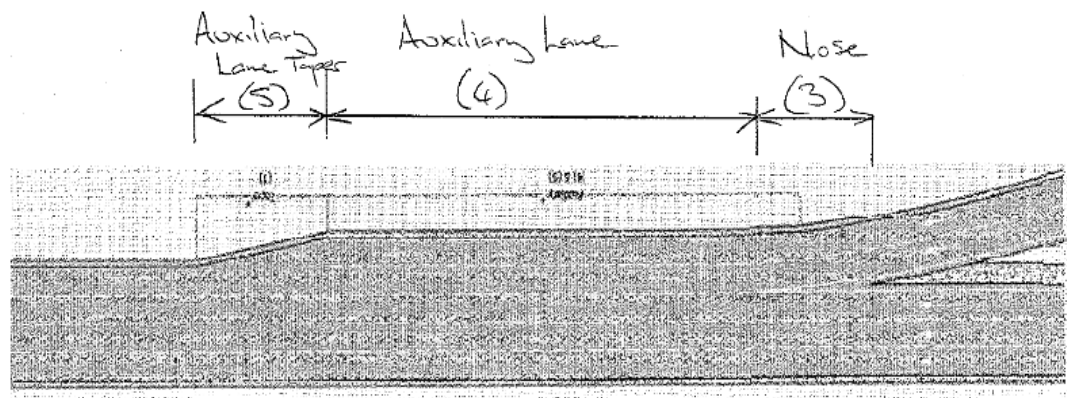


Figure 4.4.5 Merging Layout D – Lane Gain with Parallel Merge

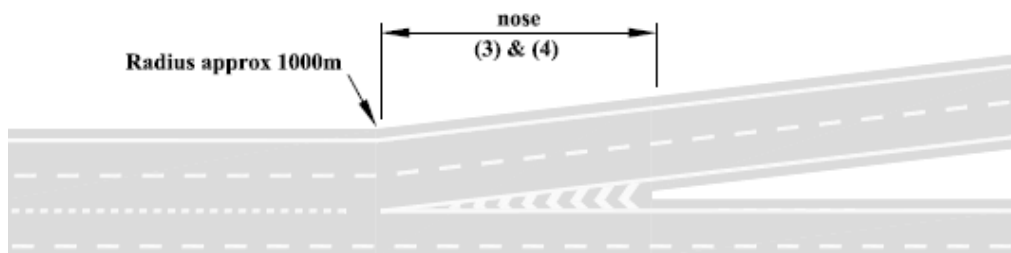


Figure 4.4.6 Merging Layout E – 2 Lane Gain

Diverge Layouts

To select a diverge layout, a similar procedure is required to that for merges, with reference to Figure 4.4.7. The mainline and interchange lane capacities shall be based on the required level of service. The mainline lane capacity used in Figure 4.4.7 is based on a flow of 1800 vehicles per hour.

Auxiliary lanes must be provided on all diverges. For 2 lane diverge slip roads, a staggered auxiliary lane layout as illustrated in Figure 4.4.9 must be provided. Lengths of auxiliary lane and staggered auxiliary lanes are based on mainline speeds. Where

auxiliary lane layouts are not provided this shall be considered a Departure from Standards.

Geometric parameters for diverging layouts are defined in Table 4.4.3. Extended auxiliary lanes of length greater than those defined may be necessary where queuing is likely to occur within the diverging facility.

Where the diverge flows are high, provision of lane drops may be required, which can be derived from Figure 4.4.7.

For all connector roads, a near straight length appropriate to the mainline design speed and at least equal in length to the nose length given in Table 4.4.3 for the appropriate design speed must be provided downstream of the back of the diverge nose. This requirement will enable drivers to comprehend the layout ahead and adjust their speed accordingly. Any reduction in this length shall be considered a Departure from Standards.

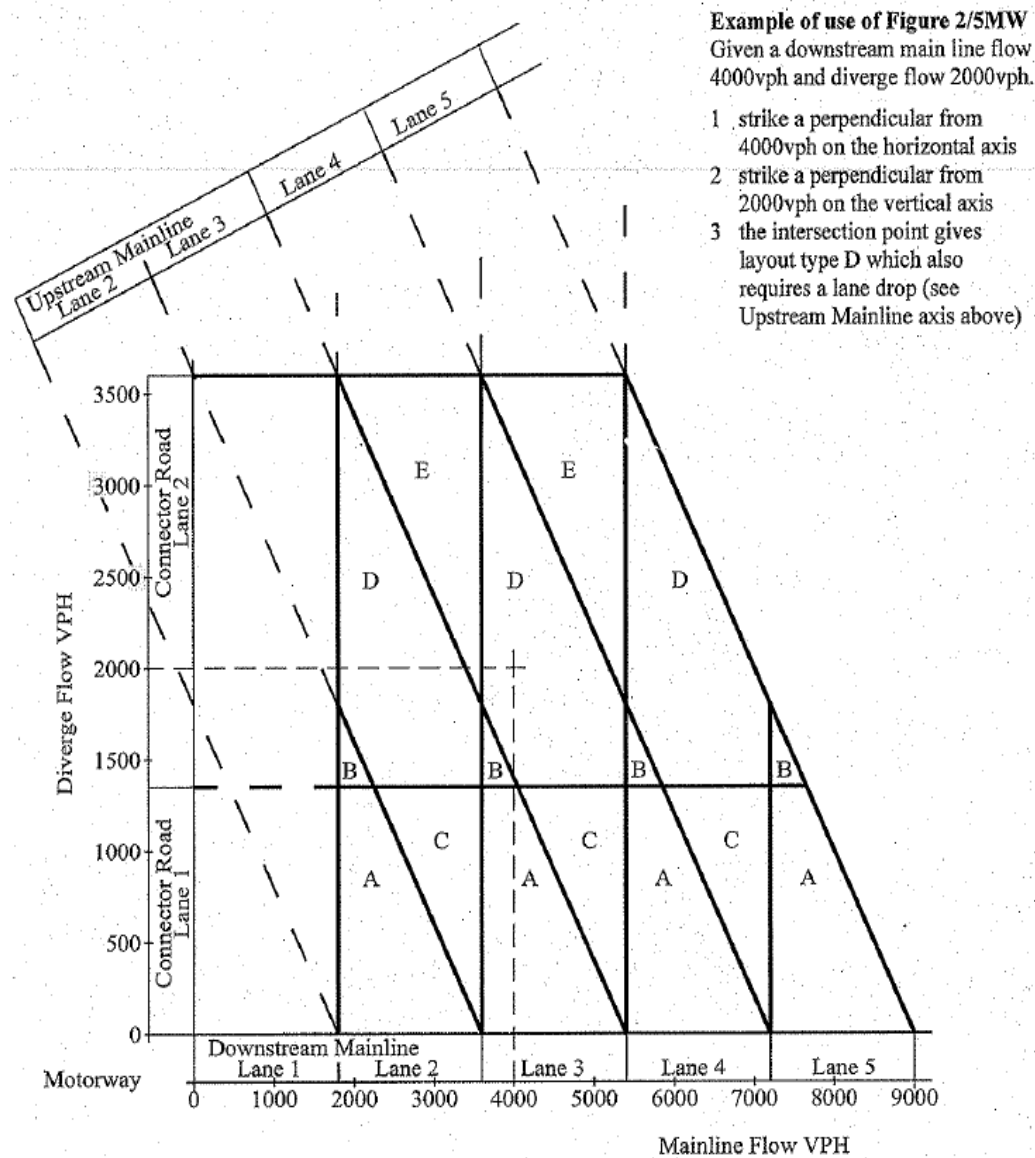


Figure 4.4.7 Diverging Diagram – Design Traffic Flows

Table 4.4.3 Geometric Parameters for Diverging Lanes

	Nose Ratio (2)	Nose Length m (3)	Minimum Auxiliary Lane Length m (4)	Length of Auxiliary Lane Taper m (5)
140kph	1:15	80	200	75
120kph	1:15	70	170	55
100kph	1:15	70	150	55
80kph	1:12	50	125	40

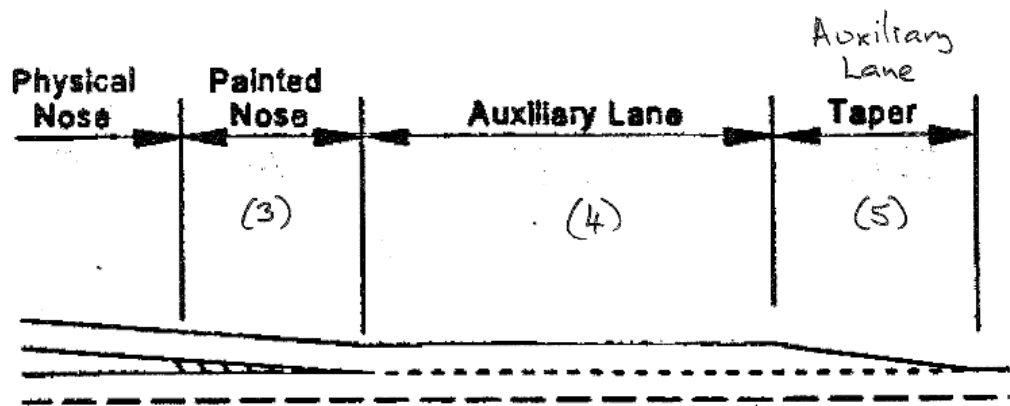


Figure 4.4.8 Diverging Layout A – Auxiliary Lane Diverge

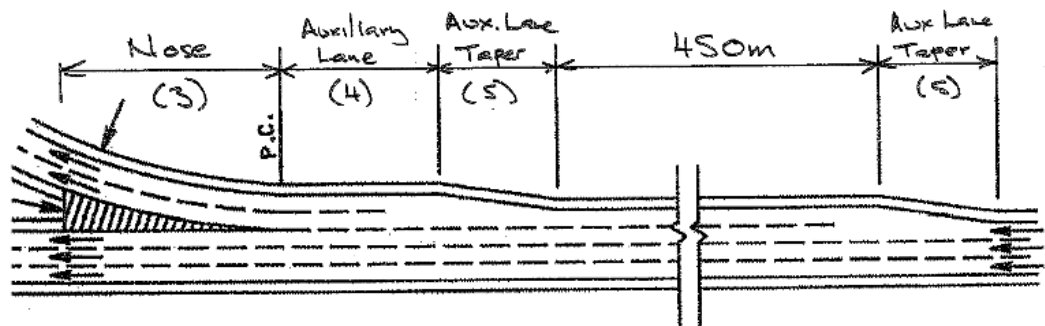


Figure 4.4.9 Diverging Layout B – 2 Lane Parallel Diverge

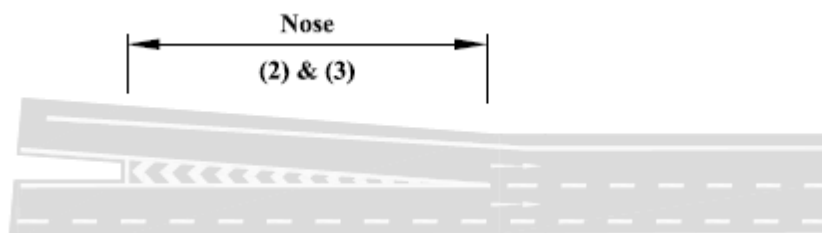


Figure 4.4.10 Diverging Layout C – Lane Drop

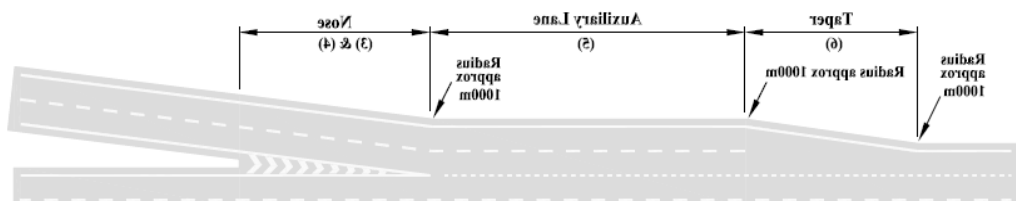


Figure 4.4.11 Diverging Layout D – Lane drop at Parallel Diverge

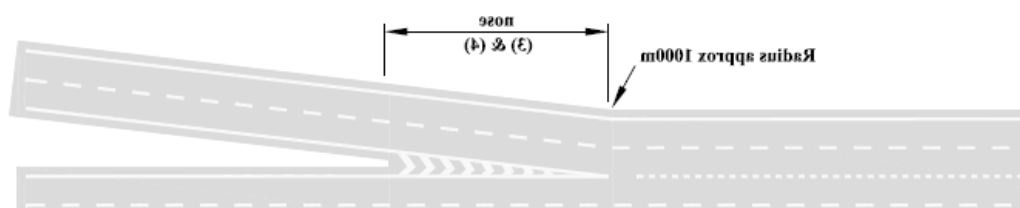


Figure 4.4.12 Diverging Layout E – 2 Lane Drop

4.4.5 Slip Roads

Slip roads shall be designed in accordance with the design speeds from Table 4.4.1. If a slip road is longer than 750m it shall be designed as an Interchange Link.

Horizontal and vertical design of slip roads shall be in accordance with Section 2. Notwithstanding this the maximum vertical gradient shall be 6%.

Slip road cross sections shall be in accordance with Section 3.

The slip road shall be of sufficient length in order to develop the level difference required for grade separation from the mainline. The minimum length of a diverge slip road measured from the back of the diverge nose shall be the desirable minimum stopping sight distance for the mainline design speed. Any reduction shall be a Departure from Standard.

The designer shall ensure that the slope gradient between verges of the connector road and mainline beyond the back of the paved nose shall not exceed the maximum safe angle of the slope. This will be dependent on the nature of the soil, refer to Part 5.

4.4.6 Interchange Links

Interchange links must ensure the smooth flow of traffic between the main roads. They shall be designed in accordance with the appropriate design speeds from Table 4.4.1.

4.4.7 Loops

In the case of the horizontal curvature and superelevation there is evidence to suggest that the radii of loops can safely be much less than for curves turning through lesser angles, provided that adequate warning is given to drivers and clear sight lines are maintained. The provisions for loops must apply only to the layouts shown in Figure 4.4.13 which may be used in combination as shown in Figure 4.4.14.

The types of loops shown in Figure 4.4.13 are as follows:

- **Basic diverge:** A loop that passes through approximately 270° where traffic diverges from the mainline flow. This Basic Diverge, when combined with the Hook Merge, forms the layout in Figure 4.4.14(a).

- **Basic merge:** A loop that passes through approximately 270° where traffic merges with the mainline flow. This Basic Merge, when combined with the Hook Diverge, forms the layout in Figure 4.4.14(b).
- **D merge:** The loop commences at a T-junction or roundabout and merges with the mainline flow. The angle turned is typically approximately 180° .
- **D diverge:** The loop commences at a diverge from the mainline flow and ends at a T-junction or roundabout. The angle turned is typically approximately 180° .
- **Hook merge:** This layout is classified as a loop and the notional total angle is between 180° and 270° . This Hook merge, when combined with the Basic diverge, forms the layout in Figure 4.4.14(a).
- **Hook diverge:** This layout is classified as a loop and the notional total angle is between 180° and 270° . This Hook diverge, when combined with the Basic merge, forms the layout in Figure 4.4.14(b).

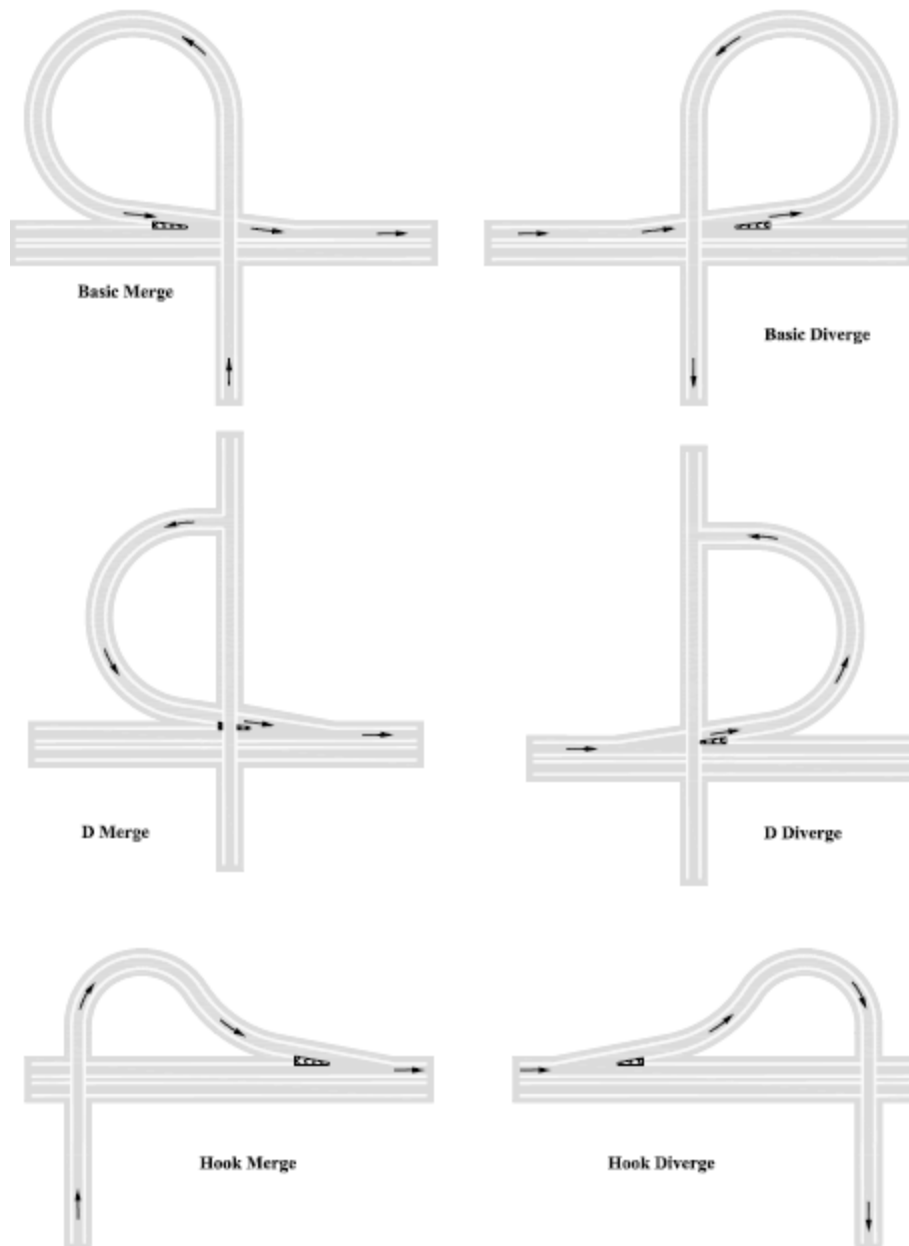
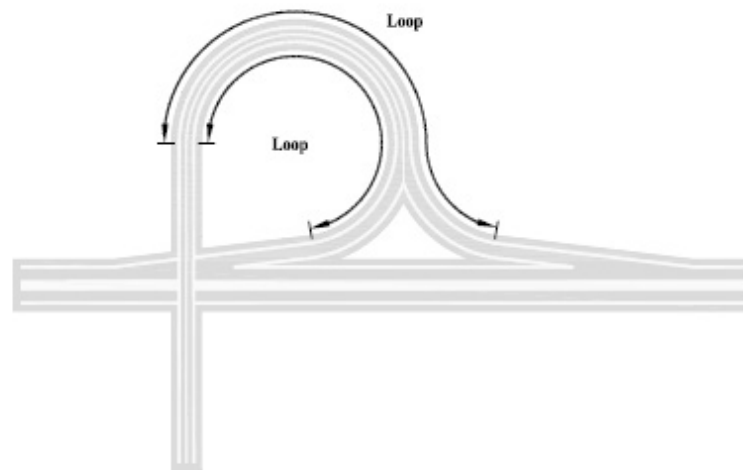
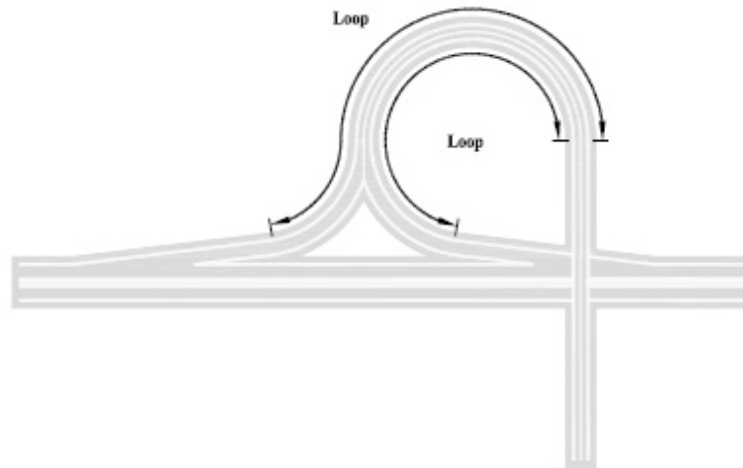


Figure 4.4.13 Types of Loop



a) Basic diverge plus hook merge



b) Basic merge plus hook diverge

Figure 4.4.14 Examples of Loop Combinations

For loops the minimum radii may be those given in Table 4.4.4. Within the loop, successive radii of the same hand must not reduce in radius. Loops shall have standard superelevation of 7%. Any reduction in radii or superelevation on loops shall be considered a Departure from Standards. Where loops leave or join the mainline, the adequate near straight length must be provided, refer to clauses 4.4.13 and 4.4.18. Widening on loops must be as set out in Section 3 for the appropriate radius.

Table 4.4.4 Minimum Loop Radii

Mainline Design Speed	Minimum Loop Radius (m) On to Mainline	Minimum Loop Radius (m) Off Mainline
120kph or greater	75	75
Less than 100kph	30	50

For loops, in addition to the general stopping sight distance requirements, there must also be no obstruction to sightlines across the full extent of loops of low radius. This includes where the loops connect to the main carriageway as shown in Figure 4.4.14. This is to ensure that drivers are able to perceive the whole of the loop layout on their approach from upstream and adjust their speed and conduct accordingly. The only permitted variance to these requirements is when the necessary vehicle restraint systems obstruct the view to the 0.26m object height, in which case a clear sightline must be available above the vehicle restraint system to the 1.05m object height.

The maximum gradient applicable to loops shall be 6%. Any increase in this value shall be considered a Departure from Standards.

4.5 Weaving and Junction Spacing

4.5.1 Weaving length

The weaving length is the length of the carriageway between a successive merge or lane gain and diverge or lane drop, where vehicles leaving the mainline at the diverge or lane drop have to cross the paths of vehicles that have joined the mainline upstream at the merge or lane gain. Adequate length must be provided to ensure that vehicles have the opportunity to get into the correct lane in advance of the approaching interchange. Consideration must be given to the location of advanced direction signs, prior to the interchange location, to ensure drivers have enough warning to make the necessary decisions and manoeuvres to negotiate the interchange safely.

In assessing the weaving length it is essential that the correct points are defined, Points X and Y, from which the weaving length measurement is taken. Point X is defined as the start of the weaving length, and Point Y is defined as the end of the weaving length.

For the various merging conditions identified in sub-Section 4.4, Point X is located as follows:

- For standard one lane auxiliary lane merge (as per Figure 4.4.2 and Figure 4.4.5), Point X is located a distance A downstream of the tip of the merge nose. The length A is dependent on mainline design speed and is defined in Table 4.5.1.
- For one and two lane gain layouts (as per Figure 4.4.4 and Figure 4.4.6) Point X is located at the tip of the merge nose.
- For two lane merges without lane gain (as per Figure 4.4.3) the Point X is located a distance B upstream of the end of the merge taper. The length B is derived from Figure 4.5.5.

For the various diverging conditions identified in sub-Section 4.4, Point Y is located as follows:

- For standard one lane auxiliary lane diverge (as per Figure 4.4.8 and Figure 4.4.11), Point Y is located a distance C upstream of the tip of the diverge nose. The length C is dependent on mainline design speed and is defined in Table 7.4.5.
- For one and two lane drop layouts (as per Figures 7.4.2C and E) Point Y is located a distance D upstream of the tip of the diverge nose. The length D is dependent on mainline design speed and is defined in Table 7.4.5.
- For two lane diverges without lane drop (as per Figure 4.4.9) the Point Y is located a distance E upstream of the end of the merge taper. The length E is derived from Figure 4.5.6.

Table 4.5.1 – Diverge and merge distances for weaving length calculations

Mainline Design Speed (kph)	Distance A	Distance B	Distance C	Distance D	Distance E
140	205	Fig 7.5.5	170	100	Fig 7.5.6
120	150	Fig 7.5.5	150	100	Fig 7.5.6
100	130	Fig 7.5.5	130	100	Fig 7.5.6
80	95	Fig 7.5.5	95	50	Fig 7.5.6

Weaving lengths L act must be measured as shown in Figures 7.5.1 to 7.5.6.

Figure placeholder

Figure 4.5.1 Weaving Length Measurement – Auxiliary Lane Layouts

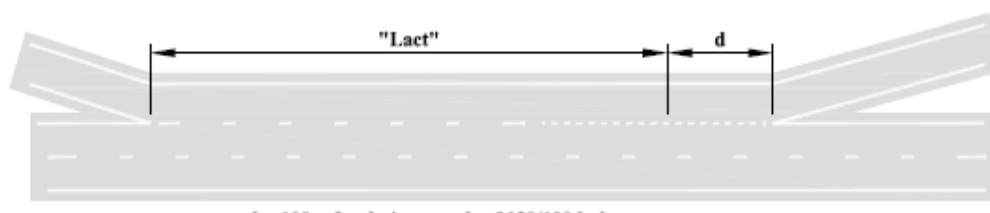


Figure 4.5.2 Weaving Length Measurement – Lane Gain/Lane Drop

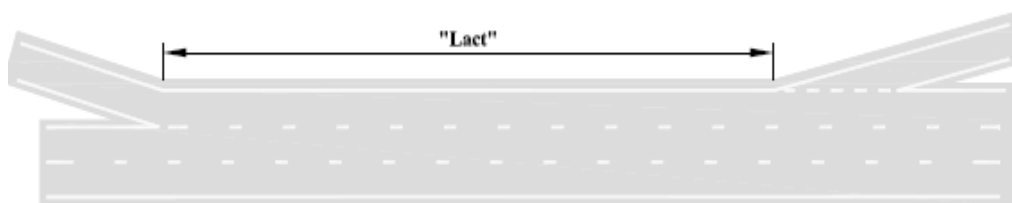


Figure 4.5.3 Weaving Length Measurement – Lane Gain Only

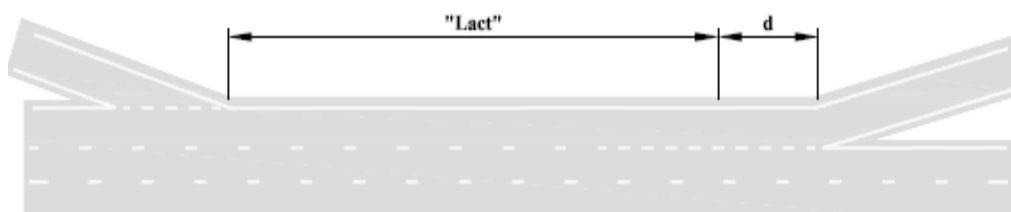
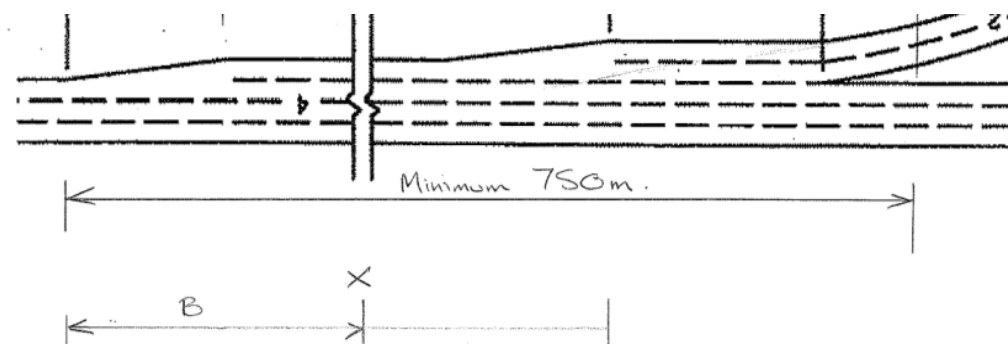
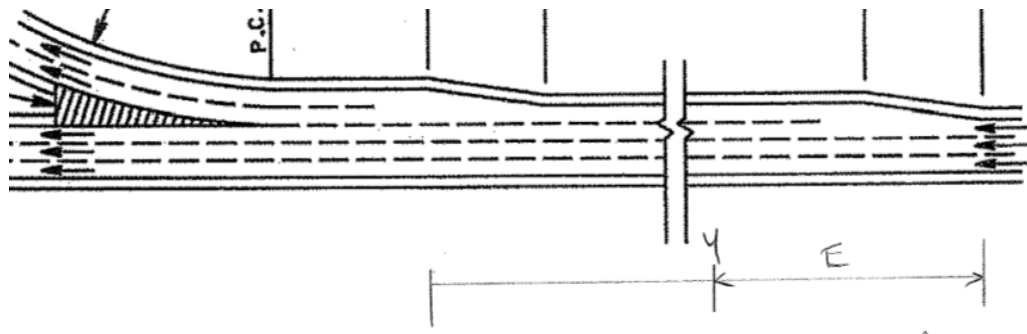


Figure 4.5.4 Weaving Length Measurement – Lane Drop Only



Note: Dimension B is half the length between the end of the first auxiliary lane and the end of the second taper.

Figure 4.5.5 Definition of Distance B at two lane merge



Note: Dimension E is half the length between the start of the first taper and the start of the second auxiliary lane

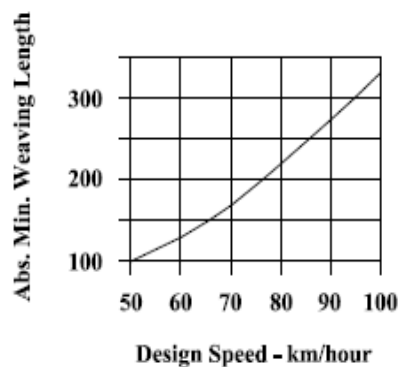
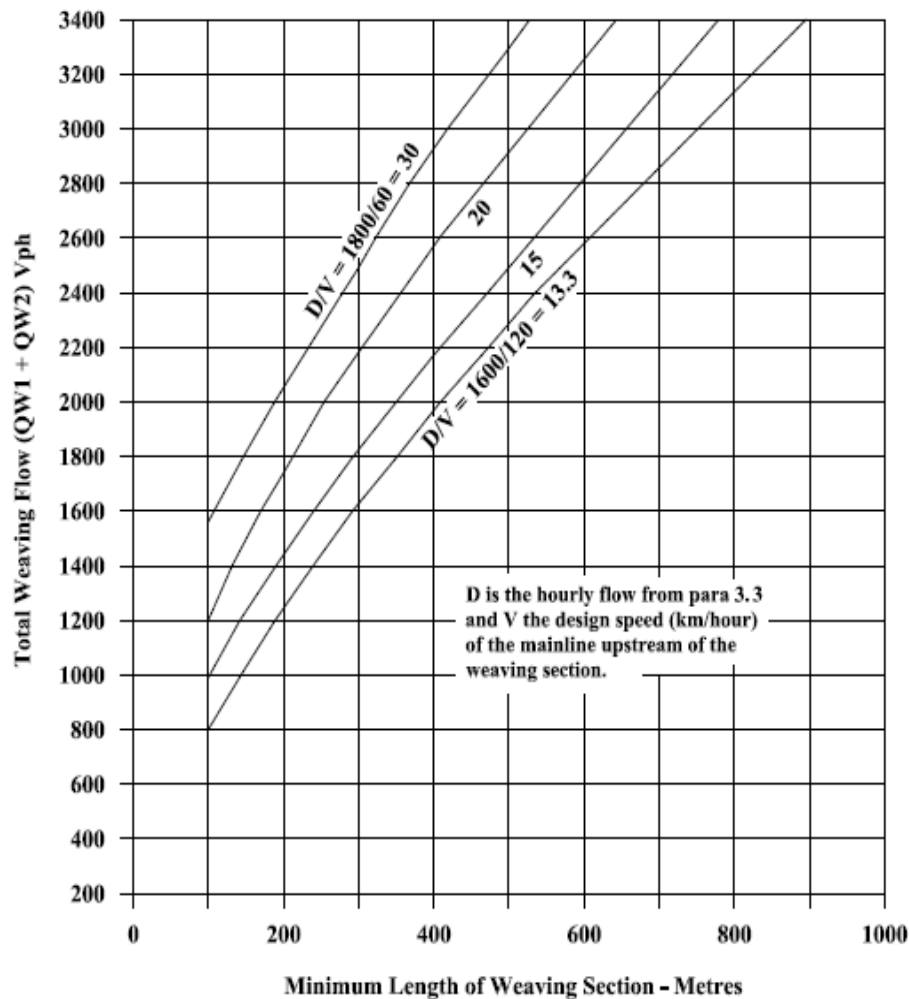
Figure 4.5.6 Definition of Distance E at two lane diverge

For rural Freeways, the minimum weaving length shall be 2 kilometres. Merges and diverges more than 3 kilometres apart tend not to interact and can be considered as separate entities since weaving ceases to occur. The maximum possible weaving length can thus be taken as 3 kilometres. This would appear to be the case up to and including weaving sections 5 lanes wide. The weaving formula (see clause 5.2) is not to be used for weaving lengths above 3 kilometres.

For all other rural classifications the minimum weaving length shall be 1 kilometre. On carriageways up to 3 lanes wide, the maximum distance over which successive merges and diverges are likely to interact and cause weaving is around 2 kilometres and this should be taken as the maximum weaving length. The weaving formula is not to be used for weaving lengths above 2km.

For Urban Roads, the design flows must be inserted in Figure 4.5.7 to obtain a minimum weaving length (L_{min}). This must then be compared to the Design Speed related to Absolute Minimum weaving length in Figure 4.5.7 and the greater of the two lengths taken as the minimum length of weaving section, provided that signing requirements can be met.

Any reduction in weaving length requirements detailed in clause 5.1.6 to 5.1.8 above shall be considered a Departure from Standards.



To determine the minimum length of weaving section (L_{min}) for insertion within the formula of Paragraph 2.71.

1. For known total weaving flow and chosen D/V value, read off the minimum length of weaving section from the graph above.
2. Check the absolute minimum weaving length allowable for chosen design speed from the graph on the left.
3. Select the greater of the two lengths.

Figure 4.5.7 Weaving Length Diagram for Urban Roads

Where at-grade intersections (including roundabouts) occur on the mainline, the minimum length between a grade separated interchange designed to this standard and an at-grade intersection or direct access must be the desirable minimum weaving length as defined in above.

4.5.2 Lane provision

When considering weaving requirements between junctions, the relationship between the weaving flows, weaving lengths and the lane provision on the mainline between successive junctions must be considered.

Where junctions are closely spaced, it is often desirable to provide continuous auxiliary lanes between the successive merge and diverge layouts. This provides continuity and assists in weaving manoeuvres.

The designer should ensure that there is sufficient lane provision between successive junctions to accommodate the weaving flows, by reference to the weaving equation below (refer to Figure 4.5.8):

$$N = 1/D (Q_{nw} + Q_{w1} + Q_{w2} (2 L_{min}/L_{act} + 1))$$

where:

- N = Number of traffic lanes
- Q_{nw} = Total non-weaving flow in vph
- Q_{w1} = Major weaving flow in vph
- Q_{w2} = Minor weaving flow in vph
- D = Maximum mainline flow per lane based on Operating Speed and required Level of Service
- L_{min} = Desirable Minimum weaving length for the road class
- L_{act} = Actual weaving length available

(L_{act} must always be greater than or equal to L_{min})

Figure placeholder

Figure 4.5.8 Terms used in Weaving

When two grade separated interchanges with high flows are closely spaced, potential weaving problems caused by the short length of carriageway available can be removed by the inclusion of link roads. No link should be provided between carriageways other than at the start and finish of the segregated lengths of carriageway. An example of

such a interchange is shown at Figure 4.5.9 where weaving is separated from the mainline flow.

In measuring the weaving length, it will be necessary to consider whether distance is available to adequately sign the second interchange and allow adequate visibility to the sign from all lanes.

Figure placeholder

Figure 4.5.9 Example of link road interchange

4.6 Major Interchange Design

4.6.1 General

At major free-flow interchanges, intersecting grade separated mainlines are connected by interchange links. Major interchanges may incorporate diverges and merges on the interchange links. Where diverges are incorporated within the interchange these shall be designed as forks.

Where there are closely spaced successive merges or diverges within a interchange or interchange, the minimum spacing between the tips of noses must be $3.75V$ m, where V is the design speed in kph, subject to the minimum requirements for effective signing and signalling. If the merges or diverges are on a connector road, the design speed must be that for the connector road. This clause applies to successive merges (merge followed by a merge) or successive diverges (diverge followed by a diverge). It also applies to a diverge followed by a merge but not to a merge followed by a diverge (the latter is a weaving section). Weaving within interchanges should be avoided if possible.

At a fork within an interchange link, the taper must be developed as shown in Table 4.6.1 and Figure 4.6.1. Problems may be encountered if a broken down vehicle were

to be situated alongside the nose where a single lane fork passes to the right. The only additional width of carriageway available is the hardstrip. Under such circumstances the offside verge should be hardened.

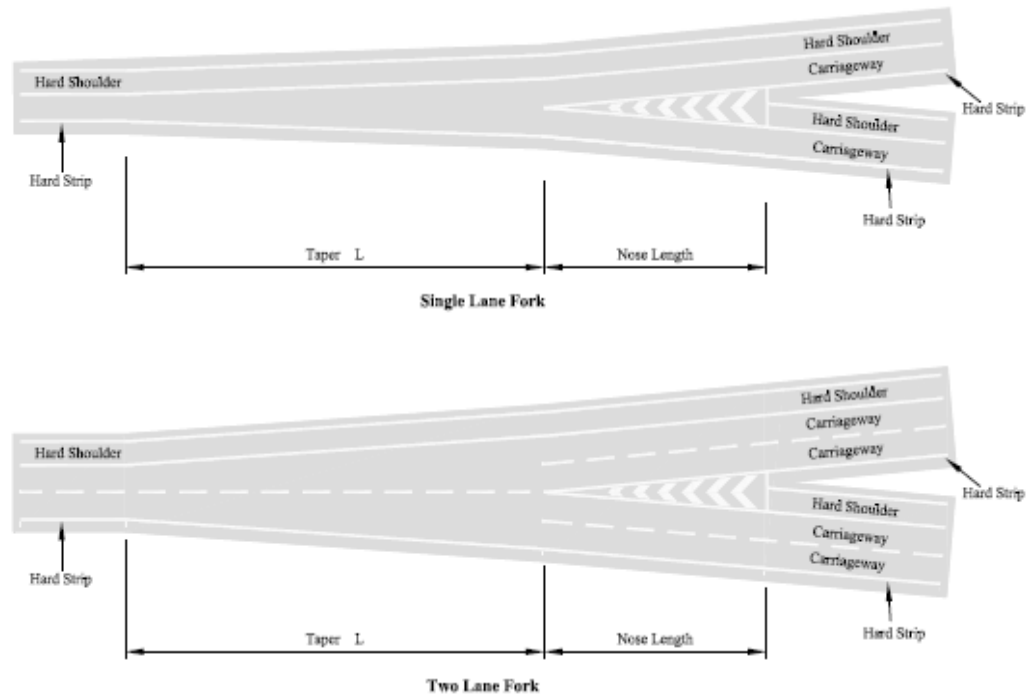


Figure 4.6.1 Development of Taper at Fork (to be reversed for RHD)

Table 4.6.1 Geometric Parameters for a Fork within an Interchange Link

Length of Taper m		Nose Ratio	Nose Length m
1 lane	2 lanes		
75	90	1:12	40

4.7 Other Design Considerations

4.7.1 Clearance and Headroom

Clearances and headroom shall be designed in accordance with Section 3. The designer shall seek guidance from the Roads Authority to define if any additional clearance or headroom is required for specific structures to accommodate abnormal load routes.

4.7.2 Superelevation

Superelevation and camber shall be designed in accordance with Section 2. Special consideration shall be given to the superelevation on adjacent design elements. The

designer must ensure that the entire carriageway will drain efficiently and that there is minimal risk of long vehicles grounding at changes of superelevation.

4.7.3 Safety Fencing

Safety fencing shall be provided at in accordance with Part 12 (Road Safety). Special consideration must be given to measures at the physical nose of diverges. High speed vehicles crossing the painted nose are at particular risk. The ends of safety barriers at these locations must be given special treatment to reduce the dangers of head-on impact. Consideration shall be given to the provision of energy absorbing terminations for these locations.

Direction and warning signs for interchanges may be large and possibly gantry mounted. Consideration must be given to the protection of isolated signs and gantry legs.

In addition to safety fencing designed to mitigate accidents, consideration should be given to provision of safety fencing to prevent illegal movements within the interchange. Illegal movements across the verges between slip or link roads are highly dangerous to all traffic and must be strongly discouraged.

4.7.4 Signing

Effective and clear signing is essential for the safe operation of any junction. This is particularly relevant to interchanges where vehicle speed and traffic volumes are high. Signs at such junctions will be large and possibly gantry mounted. Adequate clearance must be provided for the large foundations required.

Detailed guidance on signing is provided in the Qatar Traffic Control Manual. As a general point, the designer must consider signing requirements at the preliminary design stage. At this stage the designer can build in suitable locations and visibility splays for the signs.

4.7.5 Lighting

Suitable roadway lighting greatly reduces the potential for accidents throughout the road network. Lighting design is detailed in Part 8. As with signing, the designer must consider lighting requirements at the preliminary design stage. Lighting columns can have very large bases which may need special consideration.

4.7.6 Utilities

Information must be obtained from the Utility Authorities at an early stage of the design. Diversion or modification to existing or proposed equipment can have a major impact on the design and the cost of an interchange. Utility Authorities may require service reservations to be provided through the interchange to accommodate future equipment not yet detailed. Refer to Part 9.

4.7.7 Emergency Vehicles

At the preliminary design stage the designer must consider how emergency vehicles could reach the scene of an incident, particularly if the carriageway is blocked by other

vehicles held up by that incident. Provision of additional lateral clearances at structures could be considered along with emergency median crossovers with demountable safety fences.

4.7.8 Maintenance Provisions

Maintenance of the carriageway is an important long term objective for the network. The designer must consider the implications of maintenance strategies and traffic management on the layout of the proposed interchange. The designer must ensure that the facility will be safe to maintain and that turning movements can be reasonably accommodated whilst maintenance is taking place.

4.7.9 Environmental Issues

Environmental issues shall be considered at the preliminary stage. All reasonable efforts shall be made to design out unacceptable environmental impacts. The remaining impacts shall be mitigated as far as reasonably practical.

One main impact of interchanges is visual intrusion due to their size. Careful landscaping can reduce the impact of large structures above ground level. A combination of hard and soft landscaping can usually achieve the best results. Materials in keeping with the surroundings should be used, with careful consideration of colours, textures and styles. In proposing soft landscaping, the designer must consider how it could be safely maintained throughout the year, including regular watering.

The design of hard and soft landscaping must not interfere with the operational requirements of the facility. No landscaping features shall obstruct stopping sight distances, visibility of signs or the effectiveness of roadway lighting.

5 Signal Control of Intersections

5.1 Introduction

5.1.1 General

Traffic-control signals are devices that control vehicular and pedestrian traffic by assigning the right-of-way to various movements for certain pre-timed or traffic-actuated intervals of time. They are one of the key elements in the function of many urban streets and of some rural junctions.

Traffic signals may be implemented on a number of junction types to control the movement of traffic. These junctions may be specifically designed for signal control or signal control may be added to existing junction layouts.

Careful consideration should be given to horizontal and vertical curvature with respect to signal visibility, pedestrian needs, and geometric schematics to ensure effective signal operation. This standard identifies those aspects of signal control which have an effect on geometric layout design, and which should be considered throughout the design process. The design of the physical features for this type of intersection, excluding the signal design, are covered within this Section. The design of signals is covered within Section 4 of the Qatar Traffic Control Manual (QTCM).

This section also sets out standards, methodology and good practice for the design of geometric layouts for signal-controlled intersections where the 85th percentile approach speed does not exceed 105kph. Traffic signals are not recommended where this approach speed is exceeded.

The geometric layout of signalized roundabouts should be designed in accordance with this section, however additional geometric design guidance on the application of traffic signals to roundabouts is provided in sub-Section 4 (Roundabouts) and in Section 4 of the QTCM.

The information contained within this standard shall apply to all new intersections which are signal-controlled and to all existing uncontrolled priority intersections which are modified or improved to operate with signal control.

Advice on the method of installation, control and signal display sequences is contained within the QTCM. It is important to note that close co-operation is necessary where a different engineering team or discipline is responsible for separate aspects of design, e.g. geometry, signal control and street lighting. This is particularly relevant in the early stages of design.

Reference shall be made to the Qatar Traffic Control Manual and a concept layout should be agreed with the relevant Roads Authority prior to proceeding with the preliminary and detail design stages.

5.1.2 Design Principles

Introducing signal control at a intersection, including measures to provide the maximum degree of safety and convenience for all road users, can enhance efficiency by reducing congestion and conflict between different vehicle movements, within the available road space. The use of signal control should therefore be considered as an option at the scheme assessment stage for new intersections and the improvement of existing intersections. Signal control intersections are also generally low cost, with capital costs usually less than for roundabouts and substantially less than for grade separated interchanges.

Justification for the installation of traffic signals is based on a number of factors, including:

- The feasibility and desirability of alternative solutions (i.e. priority, roundabout, grade separated);
- The expected traffic speeds;
- Accident records, if it is an existing intersection;
- Whether there is a desire to introduce controls on the intersection;
- Whether the intersection is within an Urban Traffic Control (UTC) area, and how close it is to other junctions.

Signal control may also be used in association with (or to implement) other strategies such as:

- augmenting or altering a natural or designated route priority;
- providing a safe, convenient environment for pedestrians and cyclists;
- giving priority to buses and coaches;
- area traffic control;
- light rapid transit systems.

It is important to identify the full requirements of the scheme at the preliminary design stage, before acquiring land (e.g. if pedestrian crossing routes are not identified it could be difficult to include them later without either obtaining additional land or compromising the layout).

Design of a signal-controlled intersection is an iterative process involving the assessment of traffic performance of draft layouts followed by appropriate modifications to the geometric layout to finally obtain the optimum solution. There is a limit to what may be achieved in terms of increased capacity by, for example, widening intersections to provide additional lanes, introducing traffic islands or improving turning radii. A balance normally needs to be sought.

Design features which relate specifically to pedestrians, cyclists and buses are contained in sub-Section 4 of this document.

When designing traffic signal installations, care should be taken to ensure the following:

- Drivers have sufficient advance warning to know exactly which direction to take at the intersection;
- Drivers are guided into the intended lane or lanes by road markings;
- Drivers have a clear view of the signals at the intersection itself;
- The intersection layout allows easy visual recognition of correct exit lanes and required vehicle trajectory;
- Movement from the "Stop" line to the exit lane is a natural flowing movement and does not interfere with other movements allowed at the same time.

The geometric features and layout should be designed to accommodate the positioning of signalling equipment (including mast-arms where appropriate), pedestrian facilities and equipment, signs, illuminated bollards, guardrails, and "Stop" lines. It is also necessary to consider maintenance requirements and use of the intersection under police control when carrying out the geometric design.

In the various figures within this Section, the intersection arms are referenced clockwise (commencing at the major road), so that the order is major-minor-major. Basic primary and secondary signals, pedestrian signals and push buttons are generally indicated in the figures, however advice on the type, aspect and symbol for particular circumstances is contained in the QTCM. Other design features and turning restrictions are included to illustrate their application. The inclusion or exclusion of design features is not intended to suggest applicability to particular intersection arrangements.

Particular care needs to be taken when siting traffic signals on high speed roads. "High speed" for signal-controlled intersections is taken to mean a road where the posted approach speed at the intersection is 80kph or greater. Traffic signals are not recommended where 85th percentile vehicle speeds in excess of 105kph are expected. The minimum visibility distance to the primary signal for various approach speeds are related to the Junction Approach Sight Distance (as defined in Section 2) and outlined in Table 5.1.1.

Table 5.1.1 Minimum Visibility Distance to Primary Signals

Design Speed (kph) (new roads) Posted Speed (kph) (existing roads)	Visibility Distance (m)
50	105
60	135
70	180

Design Speed (kph) (new roads) Posted Speed (kph) (existing roads)	Visibility Distance (m)
80	240
100	325

Duplicate primary signals are recommended on all high speed approaches. At some sites, signal visibility may be improved by installing additional heads on tall posts, above the signal head, or on mast arm brackets above the carriageway. If intending to use mast arm signals, the designer should check Route Classification and associated vertical clearance. When drawing up the signal head arrangement, two issues should be addressed:

- Possible maintenance problems;
- Signal visibility as drivers travel towards the “Stop” line.

Notwithstanding the above, it is essential that standard height signals are visible to all drivers on the approach.

5.1.3 Arrangements and Operation

Complex layouts for signal-controlled intersections should be avoided and it is desirable to adopt the simplest solution appropriate to the intersection. The size and complexity of an intersection is dependent on the combination of geometric design features described in sub-Section 3, and the number of phases, stages and separately signalled movements.

An example of a small signal-controlled T-Junction is provided in Figure 5.1.1 below, and similar principles may be adopted on other layouts. The various features of traffic signal controlled layouts identified may be considered for most situations.

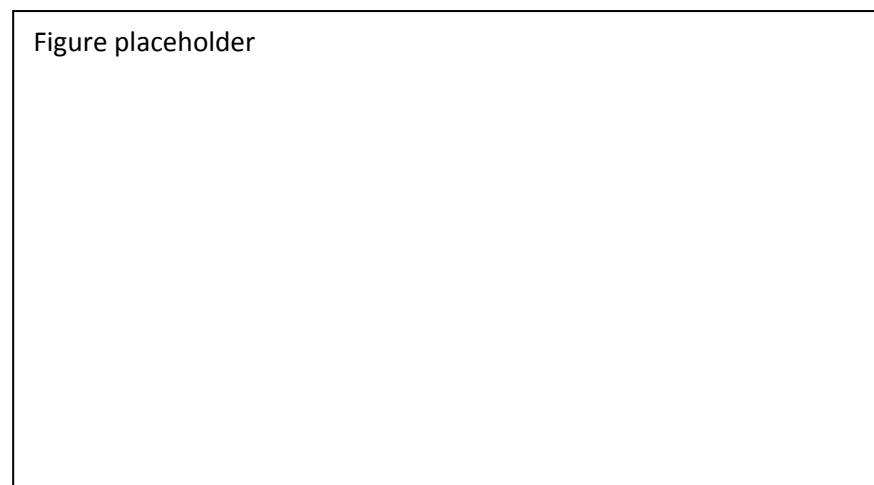


Figure 5.1.1 Example of a Small Signal-Controlled T-Junction

When designing signal-controlled intersections the designer should ensure that drivers:

- have sufficient advance warning to know exactly which route to take at the intersection;
- are then guided into the intended lane (or lanes) by road markings and signs;
- have a clear view of the signals at the intersection;
- have a clear view of pedestrian crossing facilities on their approach and departure;
- have adequate inter-visibility within the junction inter-visibility zone.

Existing priority intersections such as simple T-junctions, crossroads and roundabouts can often be modified to accommodate the requirements of signal control more readily than staggered junctions, skew junctions or those with more than four arms.

5.1.4 Classified Traffic Counts

Classified traffic counts (including pedestrians and cyclists) for all proposed operating conditions, including off-peak, should be undertaken in order to assess the intersection operation for both opening and design years. It is important that confidence can be placed in both the peak and off-peak period flows used for signal control design purposes, particularly where part-time signals are to be used. The intersection layout and arrangement should be designed to achieve a safe efficient layout and signalling system to cater for all road users.

5.2 Types of Signalized Intersection

5.2.1 Layouts

There is a wide variation in layouts which can be provided for signal-controlled intersections in accordance with Sections 5 and 6 and as detailed within this document. As such, it is not possible to illustrate all variations in intersection arrangements and designers will be required to develop particular solutions to suit site conditions at the locations in question. For all configurations, the design methodology detailed in sub-Sections 1 to 4 should be followed to ensure an adequate layout taking account of all design variables is provided.

Traffic signals may be implemented on a number of junction types. The layouts of priority intersections detailed in Section 5 and roundabouts detailed in Section 6 may be designed to incorporate signal control. However, some layouts are more applicable for signal-control than priority use, such as simple crossroads. Further information on these layouts is provided within this sub-Section. Signal control may also be added to existing intersection layouts designed in accordance with Section 5 and Section 6 at a later stage subject to some geometric modifications.

The lane arrangement is key to successful operation of signalized intersections. The crossing distances for both vehicles and pedestrians should be kept as short as practical to reduce exposure to conflicting movements. This also reduces intergreen lengths, hence the amount of lost time during signal group changes.

The size of traffic islands and pedestrian refuge areas is also important. Adequate clearance between the kerb and any street furniture is needed to prevent damage by vehicles having a lateral overhang.

The lane width on the approach to the intersection shall be in accordance with sub-Section 3.7.

The number of lanes at the “Stop” line shall be maintained across the intersection to the exit lanes.

The possibility of introducing slip roads at the corners of a junction should always be considered. These allow right turning traffic to “Give Way” or “Stop” rather than wait for the signals. They also provide larger turning radii than would otherwise be the case and can be beneficial to pedestrians when provided with clearly defined crossing points.

If U-Turns are to be provided at the junction, lane widths and turning movements of different vehicles should be considered and the position of pedestrian refuge points checked against possible conflict.

It is preferable that left-turn lanes and through lanes are segregated by physical islands for the entire queuing length. It is also preferable that entry and exit traffic on opposing carriageways is segregated by a median or physical island.

Minimum visibility requirements to the primary signals are detailed in sub-Section 3.

Refer to the QTCM for information in relation to the equipment required at all new traffic signs installations and the operation of this equipment.

5.2.2 Simple Crossroads

The crossroad is an at-grade intersection of two roads that cross approximately at right angles, as shown in Figure 5.2.1.

As detailed in Section 5, simple crossroads are not recommended as priority intersections due to the high number of traffic movement conflicts that can occur at the same location. For this reason, the use of crossroads is not recommended unless signal control is provided.

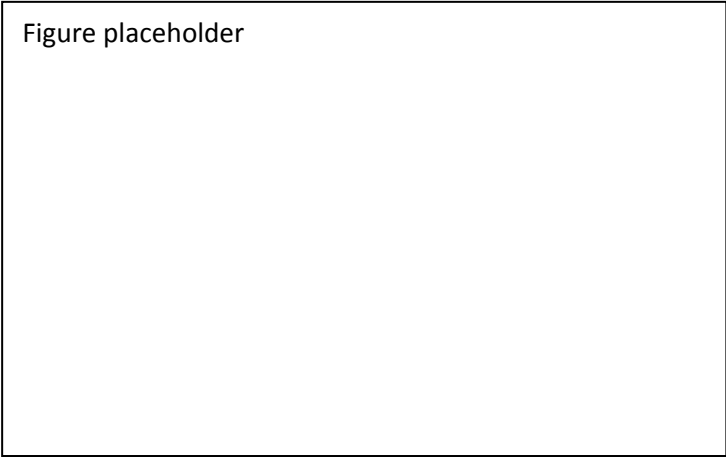


Figure placeholder

Figure 5.2.1 Crossroads

5.2.3 Signal-Controlled T-junctions

Figure 5.2.2 illustrates a simple, small urban signal-controlled T-junction, typical of a situation where available road space may be restricted and the presence of large goods vehicles in significant proportions is not expected. For details of geometric design features including junction inter-visibility, pedestrian crossing provision and storage length as shown in Figure 5.2.2, refer to sub-Section 3 of this document. For the purpose of this example it is assumed that the low pedestrian movements combined with the requirement to provide a left turn from Arm C to Arm B have led to a decision not to provide a pedestrian crossing on Arm C. The following specific design features are incorporated into the example:

- circular corner radii without tapers (no provision for swept paths of large goods vehicles);
- a 'displaced' pedestrian crossing on Arm B linked to the intersection signals;
- an in-line pedestrian crossing on Arm A.

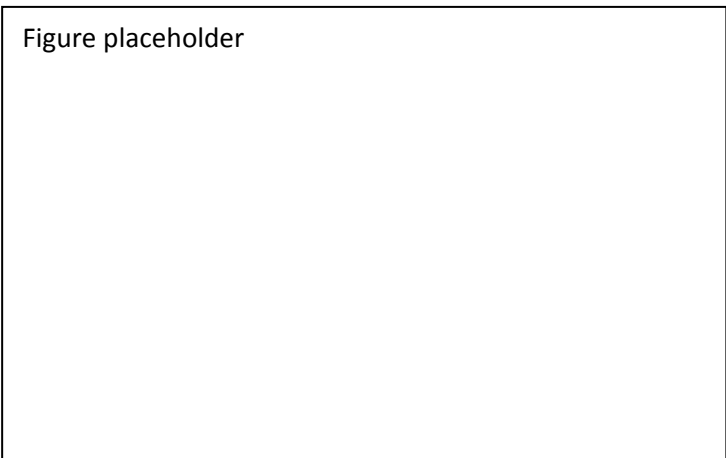


Figure placeholder

Figure 5.2.2 Example of a Small Signal-Controlled T-Junction

5.2.4 T-Junction on a Dual Carriageway with Median Opening (Signalized)

These T-Junctions may be used on two or three lane dual carriageways. This layout shall only be implemented with traffic signals. Refer to Figure 5.2.3.

On continuous dual carriageways the median width is usually between 2 and 8m. If required, this width can be widened to provide space for a left turn lane and waiting space for vehicles turning left into the minor road.

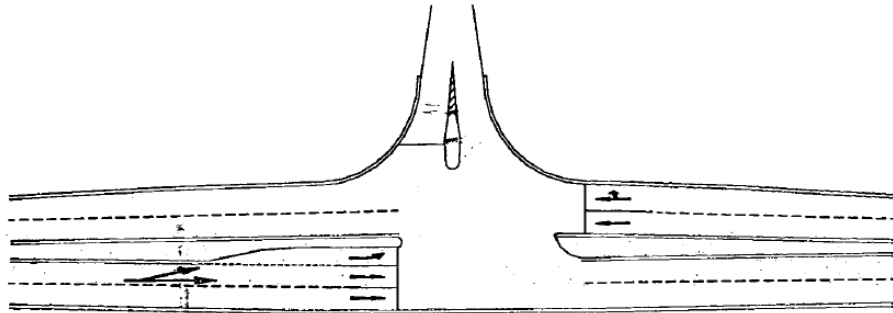


Figure 5.2.3 T-Junction with Dual Carriageway with Median Opening (Signalized Only)

5.2.5 Signal-Controlled Staggered Junctions

Signal-controlled staggered junctions may be of left/right or right/left configuration. Both arrangements for signal-controlled staggered junctions present their own problems with respect to signal control and as a prerequisite to design, traffic management techniques should be considered to eliminate or reduce these problems. No two junctions are alike in these respects and general guidance only is provided.

The combination of turning movements from each individual traffic lane and the geometric constraints imposed by the intersection may cause junction blocking where insufficient reservoir length (see sub-Section 3) is provided. This can result in traffic congestion and conflict and thereby reduce intersection safety for all road users.

5.2.6 Signalized Roundabouts

As with priority intersections, traffic signals can be installed at roundabouts to improve safety or traffic capacity. Operational benefits over a conventional roundabout can also include:

- queue management;
- pedestrian facilities;
- Urban Traffic Control Linkage.

Further information on the signalization of roundabouts is included within sub-Section 5.

5.3 Geometric Design Features

5.3.1 General

This sub-Section outlines the geometric design features to be considered in the design of signal-controlled intersections. Many of the features are considered separately, and designers should adopt a systematic approach to achieve a satisfactory design incorporating all appropriate geometric design features.

5.3.2 Design Speed

Some design standards are dependent on the approach speed of vehicles and reference should be made to Section 2 to determine appropriate design speeds for each entry arm. Where these design speed related standards cannot be achieved, traffic management measures should be introduced to reduce the approach speed to an appropriate value, for the available Junction Approach Site Distance (JASD).

Section 2 provides guidance for determining speed limits, and design speeds.

Drivers travelling at even moderately high speeds on roads where signal control is installed can find themselves with a difficult decision to make when green changes to amber. When this occurs, drivers are often faced with a choice between attempting to brake to a halt at the "Stop" line, or continuing at the same speed through the intersection and clearing it safely. Due to the increased braking distances required at high speeds, drivers need adequate warning that they are approaching a signal-controlled intersection. The use of High Friction Surfacing should also be considered.

High approach speeds can also result in those drivers making left turn manoeuvres misjudging the lengths of gaps in opposing traffic flows, which in turn increases the risk of collisions. The resulting indecision in these circumstances may put drivers and others at risk and designers should consider measures to mitigate these effects.

5.3.3 Visibility on the Approach to Intersections

The Desirable Minimum Stopping Sight Distance on the immediate approach to a signalized intersection shall be the Junction Approach Sight Distance (JASD) for the approach arm design speed as described in Section 2. Any reduction in JASD on the immediate approaches to the intersection shall be considered a Departure from Standards.

Each traffic lane shall have clear vision of at least one primary signal associated with its particular movement, from a distance equivalent to the JASD. The visibility envelope shall be increased to include the height of the signal head as indicated in Figure 5.3.1.

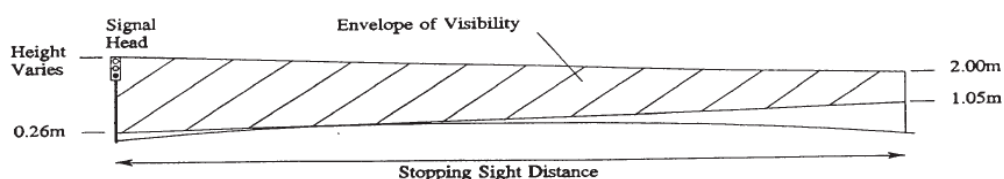


Figure 5.3.1 Visibility Requirements on Approach to Intersection

Once the control strategy for the junction has been established and queue lengths determined, further checks should be undertaken to ensure that the Junction Approach Sight Distance is provided to the back of the queue. Where the JASD cannot be achieved, measures should be taken to reduce queue lengths and provide signs warning drivers of potential stationary traffic ahead.

The visibility requirements for pedestrians using crossings are contained in sub-Section 4 of this document.

5.3.4 Junction Inter-visibility Zone

The junction inter-visibility zone is the area identified for the purpose of assessing visibility within the intersection between drivers at each “Stop” line, or between drivers and pedestrians, and facilitates identification of measures to mitigate the effect of obstructions. The junction inter-visibility zone is defined as the area bounded by measurements from a distance of 2.5m behind the “Stop” line extending across the full carriageway width for each arm as indicated in Figure 5.3.2.

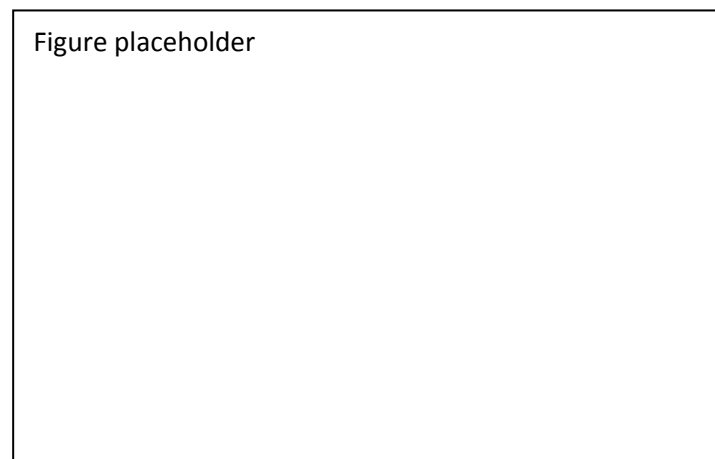


Figure 5.3.2 Junction Inter-visibility Zone (without crossings)

To ensure that the drivers of all vehicles on each entry lane are able to see the full extent of the pedestrian crossing (and its approach) the junction inter-visibility zone should be extended, where necessary, to include the full width of the strip of tactile paving laid parallel to the edge of carriageway, as indicated on Arm A of Figure 5.3.3.

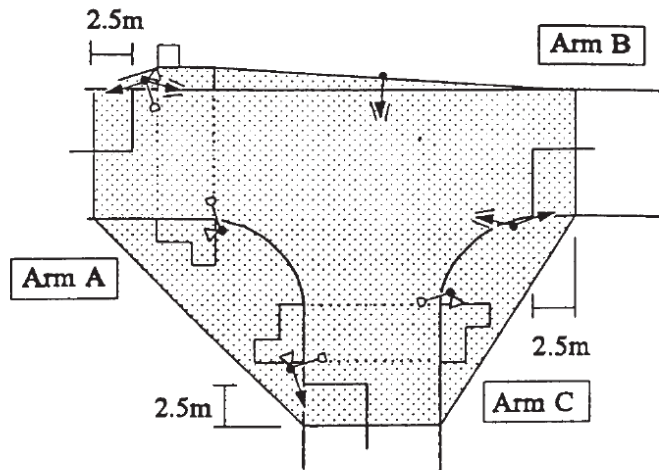


Figure 5.3.3 Junction Inter-visibility Zone (with crossings) (to be reversed for RHD)

At a staggered junction the layout will result in two independent junction inter-visibility zones. However as the stagger length reduces the junction inter-visibility zones will overlap, forming a single junction inter-visibility zone.

Where a staggered pedestrian crossing is provided, the section of the crossing immediately adjacent to the intersection should be included in the junction inter-visibility zone. The junction inter-visibility zone does not have to be extended to include a displaced pedestrian crossing which is remote from the main intersection.

5.3.5 Junction Inter-visibility

Due to the control imposed on drivers, the visibility requirements measured from the “Stop” line for signal-controlled intersections are not as onerous as those for priority intersections (see Section 5). However, it is essential to provide adequate inter-visibility for drivers at each “Stop” line, and between drivers at a “Stop” line and each of its associated exit lanes (and pedestrian crossings), to permit manoeuvres to be completed safely once the driver has entered the junction inter-visibility zone.

Adequate inter-visibility ensures a level of safety for all road users of the intersection. Designers should aim to achieve the greatest level of inter-visibility for both drivers and pedestrians within the junction inter-visibility zone. It is also important to consider the combined effect of building lines and pedestrian crossing locations when checking inter-visibility and identifying pedestrian crossings locations.

At new signalized intersections, major obstructions to inter-visibility within the junction inter-visibility zone, such as that caused by buildings should be avoided. Under these conditions each obstruction to visibility shall be considered as a Departure from Standard and measures shall be taken to mitigate the effects on inter-visibility.

Figure 5.3.4 illustrates the reduction in inter-visibility for a vehicle at the “Stop” line on the right turn entry lane (Arm C) and the exit lane and pedestrian crossing (Arm D), caused by a major obstruction. Figure 5.3.5 illustrates how the inter-visibility between

Arm C and Arm D can be mitigated, by moving the “Stop” line forward and providing an in-line pedestrian crossing on Arm C. When adjusting the position of the “Stop” line and the pedestrian crossing, the effect of the position of the pedestrian refuge area on vehicle swept paths should be checked, and its effect on pedestrians, particularly visually impaired people, should be considered.

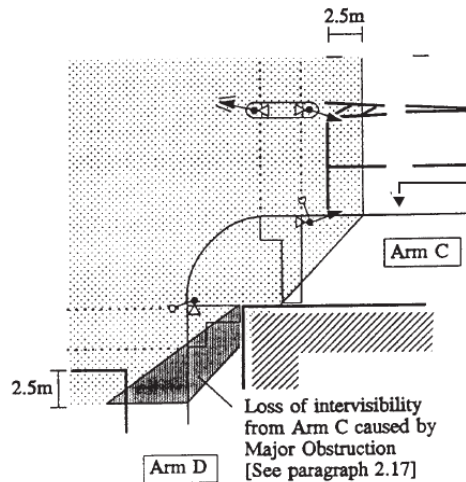


Figure 5.3.4 Major Obstruction to Inter-visibility (to be reversed for RHD)

Minor obstructions to visibility caused by slim objects such as lighting columns, sign supports, signal posts, controller cabinet and guardrails placed within the junction inter-visibility zone may be unavoidable in the optimum design. When placing signs, street furniture and planting, consideration should be given to ensure that their obstructive effect is minimised. Minor obstructions are not considered as a Departure from Standard.

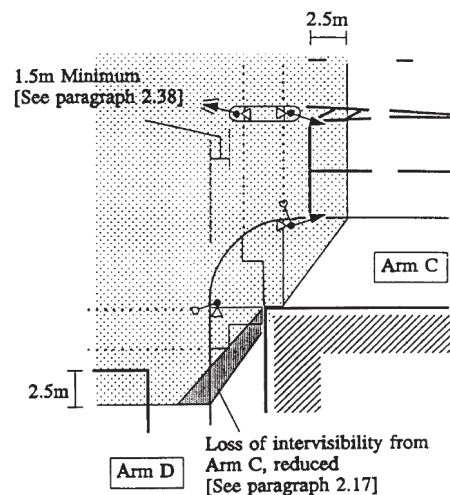


Figure 5.3.5 Mitigation of Major Obstruction to Inter-visibility (to be reversed for RHD)

5.3.6 Corner Radii

Corner radii and associated provision for large goods vehicles shall be in accordance with the standards contained in Section 5.

5.3.7 Carriageway Widths

Where new junctions are being designed as signal-controlled intersections, entry lane widths shall be between 3m and 3.65m. Any reduction in these widths at new intersections shall be considered a Departure from Standard.

Where an existing signal-controlled intersection or an uncontrolled intersection is being improved or modified and available road space is restricted, then the permitted lane widths for straight ahead entry lanes may be reduced to 2.5m providing that the posted speed does not exceed 60kph, and the reduced width enables a necessary extra lane to be provided on multilane entries. Any reduction below these widths at an existing intersection shall be considered a Departure from Standard.

Road markings should be provided to channelize traffic and hatch out areas of carriageway which would otherwise result in excessively wide lanes, or which could cause driver confusion.

5.3.8 Entry Lanes

Where land is available, intersection capacity can be increased by widening the road in the vicinity of the intersection to provide dedicated right or left turn entry lanes. Vehicles in the dedicated turning lanes will often move independently to those in other lanes and sufficient lane width and length should be provided to allow this. A minimum width of 3m is required for the dedicated turning lanes developed with tapers of 1 in 5, as indicated in Figure 5.3.6 and Figure 5.3.7. Any reduction in this width shall be considered a Departure from Standard

On single carriageway roads, left turn entry lanes may be accommodated by the provision of a ghost island. The ghost island should be designed to provide adequate storage length for left turn vehicles and should normally be developed symmetrically about the centreline of the road with a taper of 1 in 10, as indicated in Figure 5.3.8.

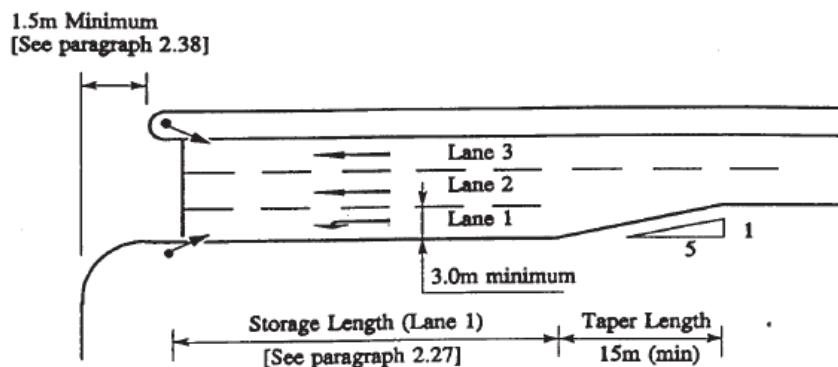


Figure 5.3.6 Right Turn Approach Lane (to be reversed for RHD)

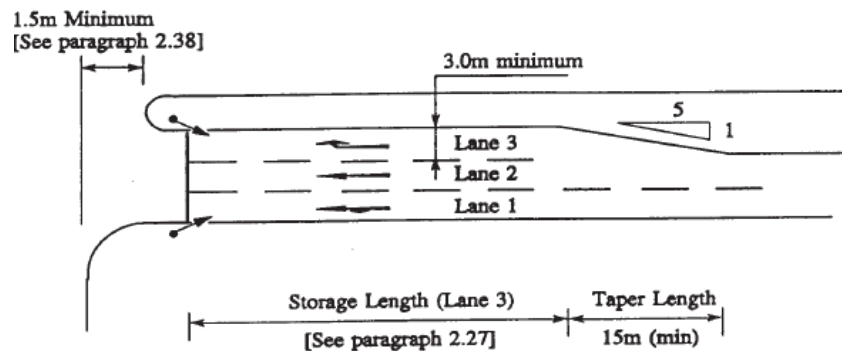


Figure 5.3.7 Left Turn Approach Lane (to be reversed for RHD)

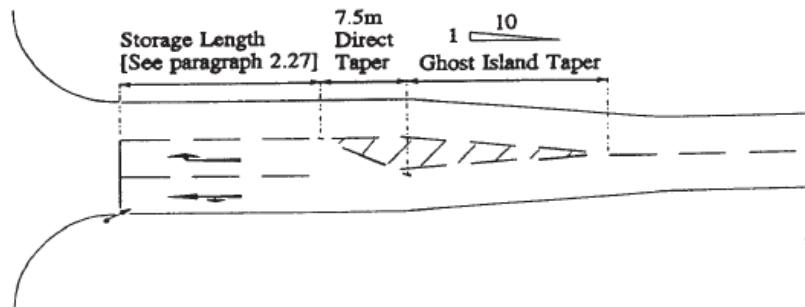


Figure 5.3.8 Ghost Island Layout (to be reversed for RHD)

5.3.9 Storage Length

The storage length is the length of the full width entry lane, measured from the “Stop” line, over which vehicles can queue without causing obstruction to, or being obstructed by, vehicles in the adjacent lane.

The storage length of the right and left turn entry lanes should be designed to meet the capacity requirements of the intersection. To avoid turning traffic blocking the adjacent lane it should be of sufficient length to accommodate the longest queue of stopped traffic. Similarly traffic may be prevented from entering the right or left turn lane where there is a high proportion of straight ahead traffic queuing in the adjacent lane. The storage length may be extended to enable traffic to enter the turning lane unobstructed.

Where displaced (see Figure 5.2.2) or remote pedestrian crossings are installed, designers should ensure that adequate storage length is provided to avoid traffic queuing back into the crossing.

5.3.10 Staggered Junctions

Stagger Distances

The stagger distance at an intersection is the distance along the major road between the centre-lines of the two minor roads as indicated in Figure 5.3.9 and has a major influence on safety and capacity. A large stagger may result in the arrangement needing to be treated as two separately signal-controlled intersections, whereas a small stagger, possibly with a banned turn, may allow the intersection to be treated as a simple signal-controlled crossroad. The stagger distances will usually determine the phasing, stages and timing of the traffic signals.

Where the stagger distance is greater than 250m the intersections should normally be considered as two separate independent signal-controlled T-junctions.

With a stagger distance between 75m and 250m the intersections should normally be treated as two separate, signal-controlled T-junctions with local linking of the signals to favour the major flows of traffic through the intersection:

- “straight ahead” on the major road (Arms A to C and C to A);
- the flow to and from the two staggered arms (Arms B to D and D to B);

or

- a combination of the above.

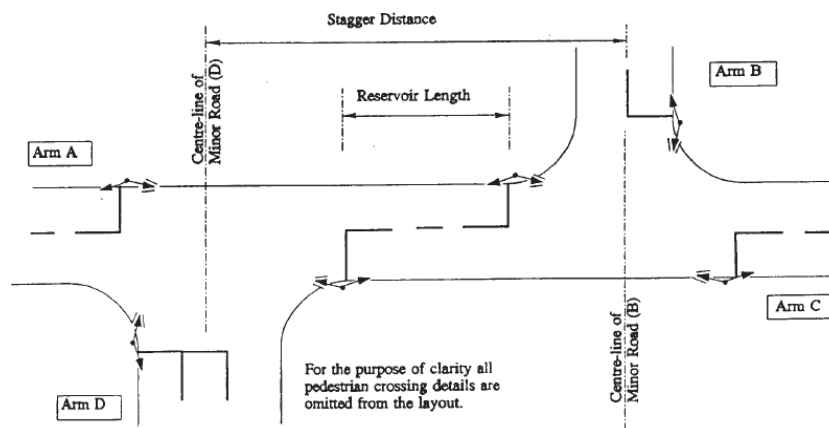


Figure 5.3.9 Stagger Distance and Reservoir Length (to be reversed for RHD)

Where the stagger distance is below 75m the intersection should normally be considered as a single signal-controlled staggered junction, provided there is sufficient reservoir length.

Reservoir Length

The reservoir length is the distance between the inner “Stop” lines, as indicated in Figure 5.3.9. The available length for the reservoir is dependent upon the stagger distance and whether or not pedestrian crossing facilities are provided within the stagger distance.

As the stagger distance reduces below 75m it becomes more difficult to provide for the inner “Stop” lines, pedestrian crossing facilities and the associated signals, where required. The shortest effective reservoir length is 15m. With a reservoir length below 15m it is recommended that the intersection be treated as a signal-controlled crossroad with special account being taken of the longer clearance distances.

Staggered junctions may suffer from intersection blocking due to a limited reservoir length between the two staggered arms.

Left/Right Stagers

Depending on the volumes and distribution of traffic, and the stagger distance, the inner “Stop” lines are of varying importance. With a stagger distance of 75m or greater, the inner “Stop” lines should be included to eliminate the very long clearance distances and extended intergreen periods which would otherwise be necessary.

Where a significant volume of pedestrian movement is anticipated the staggered junction may require pedestrian facilities at each “Stop” line. Where no pedestrian desire lines exist, and the stagger distance is not too great, a reduced number of pedestrian crossing facilities may be justified.

Right/Left Stagers

A right/left stagger will usually have difficult traffic conflicts which could have an adverse effect upon safety.

If such a intersection with less than a 75m stagger is signalled using a 2-stage control (i.e. both the staggered arms run together), the major problem is conflict of traffic as the traffic emerging from one of the arms turns right across the path of vehicles turning right into the same arm. This can be particularly dangerous when drivers do not have inter-visibility approaching the conflict point. Unless these movements are very low in volume and the length of stagger is small, it is recommended that 3-stage signalling be used with separate stages for each of the staggered approaches.

5.3.11 Lane Continuity

The number of straight ahead entry and exit lanes for a traffic stream should be balanced in order to reduce conflict caused by traffic merging or diverging within the junction inter-visibility zone. Where it is necessary to reduce the number of lanes on the exit arm this should be carried out beyond the junction inter-visibility zone, over a distance of 100 metres for a single lane reduction, measured from the limit of the junction inter-visibility zone, as indicated in Figure 5.3.10. The lane reduction may be carried out on either the nearside or offside dependent upon traffic conditions.

The use of lane markings within the junction inter-visibility zone, as illustrated in Figure 5.3.10, may also be beneficial to direct traffic streams and reduce conflict where entry and exit lane widths vary or the alignment through the intersection is not a direct path.

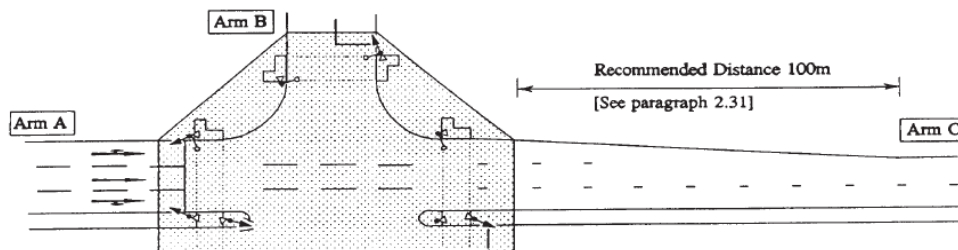


Figure 5.3.10 Lane Continuity Through Junction Inter-visibility Zone (to be reversed for RHD)

5.3.12 Carriageway Widths Around Curves

Where provision is to be made for large goods vehicles, buses and coaches, carriageways or lanes may require widening around curves in accordance with the standards contained in Section 5.

5.3.13 Swept Path Requirements

The swept path requirements of the Design Vehicle are defined in Section 5.

The nature of the signal-controlled intersection and its associated splitter islands and pedestrian refuges may restrict the movement of vehicles, particularly large goods vehicles. Where provision is to be made for large goods vehicles, an allowance must be made for the swept turning paths of the design vehicle.

It is essential to ensure that adequate turning radii are provided for the swept paths of all types of vehicles using the intersection and the swept paths should be checked for all permitted turning movements. Figure 5.3.11 and Figure 5.3.12 indicate examples of swept paths to illustrate the general requirements.

The assessment of swept paths using simple templates or overlays is not recommended as they do not adequately predict the swept paths of the vehicles for non-standard situations. The use of computer simulated models of the vehicles and their movements which can be interactively superimposed upon a computer generated design model of the intersection is preferred. The use of computer simulated models to predict swept paths may assist the designer to minimise the required widening within the intersection. This may identify areas of surplus carriageway (see Figure 5.3.11) which can be effectively removed to provide greater footway width for pedestrians, or to minimise the required widening and hence construction costs.

The nosing of central reserves and pedestrian refuges should be set back a minimum distance of 1.5m, measured from a line extended from the edge of the intersecting road as indicated in Figure 5.3.5, Figure 5.3.6 and Figure 5.3.7.

Adequate clearance between the edge of carriageway and any street furniture (including signal heads, backing boards and subsidiary signal heads) is needed to prevent damage by vehicles having a lateral overhang. A minimum clearance of 450mm should be provided. Additional clearance may be required where the crossfall of the carriageway is greater than 2.0%.

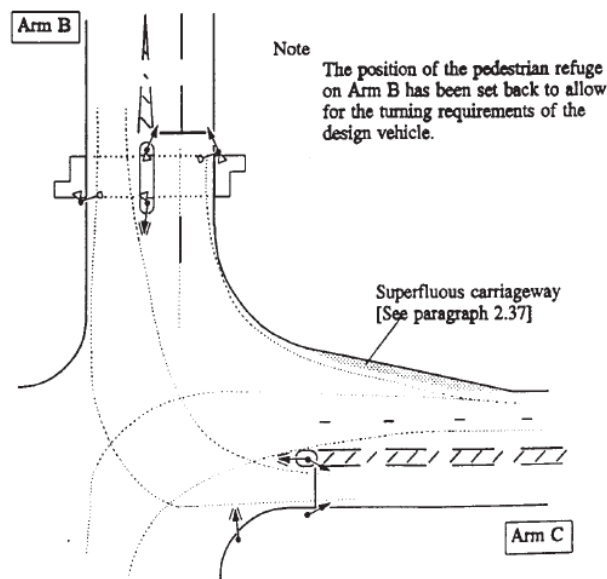


Figure 5.3.11 Examples of Swept Paths (to be reversed for RHD)

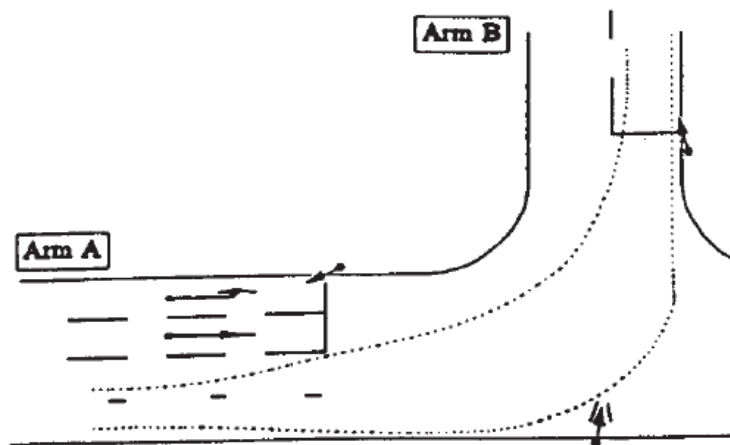


Figure 5.3.12 Setting Back "Stop" Lines (to be reversed for RHD)

Where no provision is specifically made for large goods vehicles, these may have difficulty in completing a manoeuvre without encroaching into opposing lanes. When this is likely it may be necessary to set back the "Stop" line (and crossings if present)

where the conflict would occur, as indicated in Figure 5.3.12. “Stop” lines on adjacent entry lanes should not be staggered as large goods vehicles in the nearside entry lane may prevent vehicles in the offside entry lane seeing the nearside primary signal or pedestrians.

In difficult confined situations, the channel and footway opposite the minor road may be set back to provide additional carriageway for the swept path of the large goods vehicle as indicated in Figure 5.3.13.

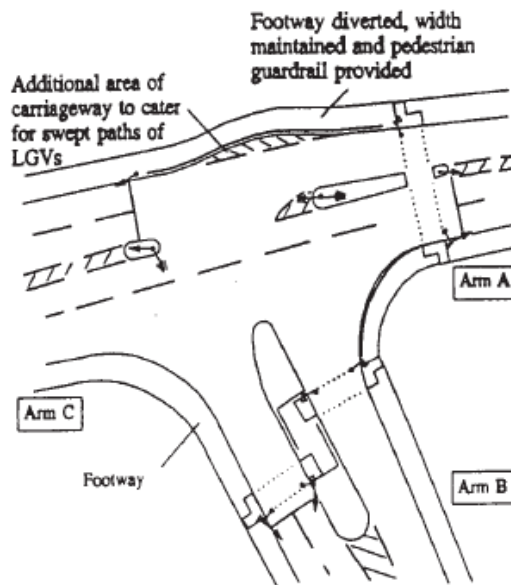


Figure 5.3.13 Localised Widening at T Junction (to be reversed for RHD)

5.3.14 Right Turn Slip Lanes

Figure 5.3.14 illustrates an example of a right turn slip lane and separation island typical of a situation where the proportion of large goods vehicles within the right turning traffic is low. Large goods vehicles which experience difficulty turning may encroach into the entry lane (Arm C), causing conflict. Where the proportion of large goods vehicles is significant, adjusting the corner radius, providing a taper and setting the “Stop” line back, as indicated in Figure 5.3.15, should be considered to reduce the conflict.

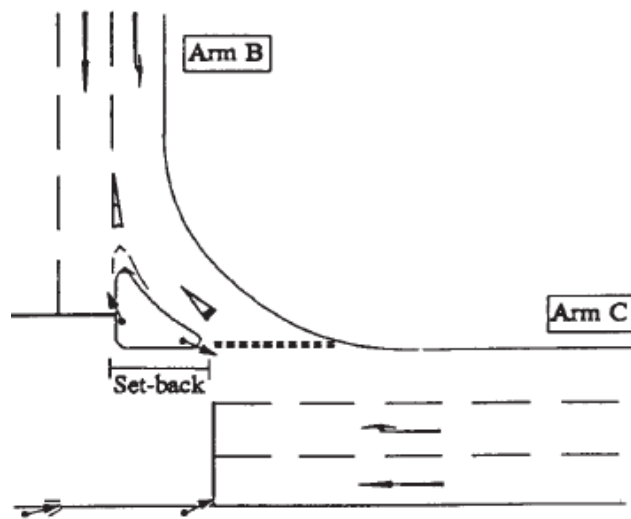


Figure 5.3.14 Right Turn Slip Lane (without Taper) (to be reversed for RHD)

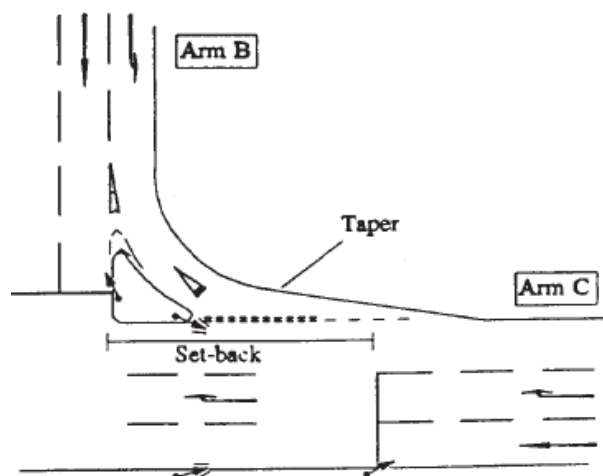


Figure 5.3.15 Right Turn Slip Lane (with Taper) (to be reversed for RHD)

Right turn slip lanes may be signal-controlled or uncontrolled. A consistent approach to the layout of the slip lanes and their associated pedestrian crossing facilities should be adopted. Individual intersection layouts should not mix uncontrolled and controlled crossings where they combine to form a single pedestrian crossing route.

Uncontrolled right turn slip lanes may make crossing for pedestrians more difficult as a result of increased vehicle speeds, and it is important to consider the whole effect of the geometric layout upon pedestrian crossing facilities. The effect of the taper, crossing lengths and pedestrian desire lines should be considered when identifying the locations for pedestrian crossings.

Right turn slip lanes with a separation island should be considered where:

- the right turn traffic movement is high;
- right turn manoeuvres for large goods vehicles need to be facilitated;
- delay for right turn vehicles would otherwise be significant;
- right turn traffic capacity requirements would extend the green time required for the straight ahead traffic movement phase.

5.3.15 Separation Islands

Separation islands shall be provided to separate uncontrolled traffic from controlled traffic where right turn slip lanes are provided, as indicated in Figure 5.3.14. Failure to provide a separation island in these circumstances will be considered a Departure from Standards.

Separation islands which also act as refuges for pedestrians should be designed to accommodate pedestrian refuge crossing facilities and associated equipment and should be uniformly lit to current standards. Separation islands can assist in providing safe crossings for pedestrians whilst improving traffic capacity by the incorporation of pedestrian call stages, as illustrated in Figure 5.4.2.

Guidance on the geometric requirements for pedestrian refuges is contained in sub-Section 4 of this document.

5.3.16 Left Turning Traffic Movements

Collisions at signal-controlled intersections can occur as a result of conflict arising from left turning traffic movements. If local circumstances permit, left turn movements may be banned. Alternatively a number of signalling techniques may be employed to control the left turn movements and these techniques should be considered at an early stage of the design to determine the appropriate measures.

Where the posted approach speed is greater than 70kph there is an increased risk of collisions between left-turning vehicles seeking gaps and on-coming vehicles travelling at speed. It is recommended in such situations that left-turns should be separately signalled.

5.3.17 High Friction Surfacing (HFS)

High friction surfacing may be incorporated on the approach to signal controlled intersections to assist drivers in braking to a stop where they are required to do so. Where high friction surfacing is to be applied to an approach road it shall extend over the full width of the traffic lanes and be applied from the "Stop" line back for a distance related to the design speed or posted speed. The recommended minimum length over which the high friction surfacing should be applied is defined in Table 8.3.1. Further advice on High Friction Surfacing is contained in Part 6.

Table 8.3.1 Recommended Length of Application of High Friction Surfacing

Design Speed (kph) (new roads) Posted Speed (kph) (existing roads)	Length of High Friction Surfacing (m)
50	35
60	45
70	60
80	80
100	115

5.3.18 Location of Signals

There should be at least two signals visible from each approach, and “Stop” line, usually comprising a primary signal and a secondary signal. Where separate signalling of turning movements is employed, this advice applies to the approach lane(s) associated with each turning movement, and a signal post can then display information applicable to more than one turning movement.

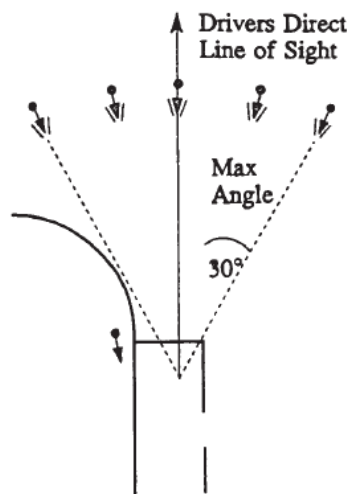


Figure 5.3.16 Locating Secondary Signals (to be reversed for RHD)

Primary signal heads should be located a minimum of 1m beyond the “Stop” line and in advance of crossing studs or marks if pedestrian facilities are provided. For general advice on signal-controlled pedestrian crossings designers should make reference to the QTCM.

In some circumstances it may not be possible to locate the secondary signal in the direct line of sight of the driver. For example at intersections with angled approaches the maximum angle that the secondary signal should be displaced is 30° from the driver’s line of forward sight, as indicated in Figure 5.3.16.

The distance between the “Stop” line and an associated secondary signal should not exceed 50m.

Where mast arms are being considered, any technical approval and the requirements for the mast arm foundation and maintenance requirements should all be determined at an early stage of the layout design.

Care must be exercised when providing multi phased signal layouts, as indicated in Figure 5.2.2 where a displaced pedestrian crossing is illustrated, to avoid “see through” where traffic (at point X) may be confused by the signal at the next “Stop” line (point Y). An additional secondary signal should be considered in such circumstances.

5.4 Road Users’ Specific Requirements

5.4.1 General

When signal control is being considered the extent of pedestrian crossing movements, cyclist usage and bus movements should be determined and the provision of specific measures included unless site specific considerations warrant their exclusion. Further advice on consideration of such users is provided in Part 10.

Provisions for pedestrians, cyclists, and buses may require additional signing in accordance with the Qatar Traffic Control Manual.

5.4.2 Specific Measures for Pedestrians

Where a pedestrian need is established then appropriate signal-controlled facilities should be provided.

Pedestrian crossings should normally be located beyond the limits of the intersection radius (inset crossings) to minimise the road crossing distance. However, in some circumstances it may not be possible to provide inset crossings and the crossing may need to be positioned within the limits of the intersection radii (in-line crossing). In these cases, the pedestrian refuge should be located at a minimum offset of 1.5m measured from a line extended from the edge of the intersecting carriageway as indicated in Figure 5.3.5. In-line pedestrian crossings will result in longer pedestrian crossing distances and particular consideration should be given to the problems associated with vulnerable road users (i.e. disabled pedestrians).

The use of dropped kerbs and tactile surfacing may be considered in accordance with Section 12.

Where pedestrians are expected to cross arms of a intersection, tactile surfaces and dropped kerbs shall be provided. The provision of tactile paving and tactile devices, audible signals, dropped kerbs and guardrail are all mobility aids designed to assist disabled pedestrians at the crossing.

Pedestrians should be encouraged to use defined points to cross the road. Preferably, crossings should be located to minimise crossing distances and to avoid excessive detours. It may be desirable to restrict the pedestrian crossings to certain approaches at a signal-controlled intersection (e.g. limitations on inter-visibility or conflicts with private accesses). Guardrails should be used to discourage pedestrians from crossing at dangerous locations and to channelize them to the appropriate crossing points. The following measures can contribute to improved safety and convenience:

- fitting crossing routes to the pedestrian desire lines;
- the provision of pedestrian guard rails;
- the provision of tactile surfaces to assist pedestrians with impaired vision;
- the provision of dropped kerbs to assist wheelchair users;
- the provision of pedestrian signal phases;
- providing good inter-visibility between pedestrians and drivers.

Where existing junctions are being modified, buildings may obstruct inter-visibility (see sub-Section 3.5.1 and 3.5.2) and in these circumstances measures to move the "Stop" line forward should be considered. This may require pedestrian crossing routes to be diverted away from the immediate junction inter-visibility zone (or the provision of inset crossings), and the effect on pedestrian desire lines should be considered.

5.4.3 Pedestrian Refuges and Separation Islands

Where a pedestrian crossing stage is timed to permit pedestrians to cross a whole carriageway in one movement, then the width of the pedestrian refuge 'w', as indicated in Figure 5.4.1, shall be 1.5m minimum. Where anticipated pedestrian flows are high, this dimension may be increased to accommodate higher level of pedestrian use. Any reduction in this width shall be considered a Departure from Standards.

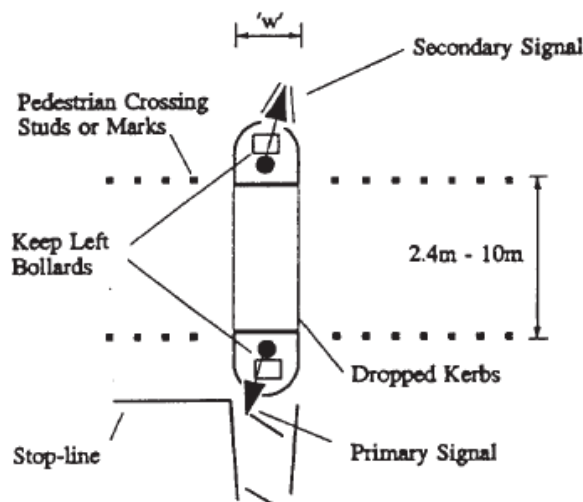


Figure 5.4.1 Pedestrian Refuge (to be reversed for RHD)

Complex patterns or large areas of tactile paving should be avoided as these may confuse visually impaired pedestrians. A consistent approach should be adopted for all separation islands within an individual intersection layout.

Tactile surfacing at the extremities of pedestrian crossing places shall be laid in the “L” shape pattern. Tactile surfacing is not recommended within pedestrian refuges or separation islands where the signal staging is intended to allow pedestrians to cross the whole width of the carriageway in one movement.

5.4.4 Crossing Places

The crossing place should be indicated by two rows of studs or marks each of the dimensions given in the Qatar Traffic Control Manual, and a minimum crossing place width between the studs of 2.7m should be provided. The width of the crossing place is dependent on the site conditions but is normally in the range 2.7 to 5 metres. Usage by large numbers of pedestrians may require the width to be increased up to 10.0m. Toucan crossings should be a minimum of 3.0m wide and preferably 4.0m wide.

Pedestrian crossings should be perpendicular to the edge of the carriageway to assist inter-visibility and benefit visually impaired people (see Figure 5.4.2). However in some circumstances it may be necessary to provide them at a skew angle. In all circumstances, the tactile paving should be correctly aligned to direct visually impaired people safely across the crossing. To achieve this, the upright of the “L” shape shall always be aligned in the direction of the crossing.

The preferred orientation of staggered pedestrian crossing facilities is such that pedestrians within the central reserve are facing oncoming traffic as they approach the crossing. However, in some circumstances, due to geometric or capacity constraints and the pedestrian desire lines, this may not be achievable.

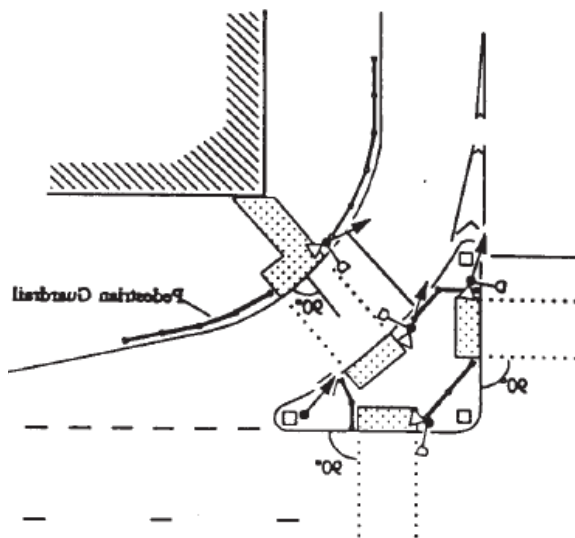


Figure 5.4.2 Pedestrian Crossing Facilities on Separation Island

5.4.5 Specific Measures for Cyclists

Cyclists shall be discouraged from sharing the carriageway with motorised traffic and provided with adjacent facilities. Where cycle facilities are provided adjacent to signalized junctions, controlled crossings shall be provided across the side roads, with suitable dimensions to accommodate cyclists and other non-motorised users.

Controlled crossing for cyclists and pedestrians may be combined.

Alternatively grade separation may be provided for cyclists and pedestrians.

5.4.6 Bus Lanes

Various traffic management methods may be used to assist buses at signal-controlled intersections. These include:

- **with flow** bus lanes which are terminated in advance of the “Stop” line to ensure that the full width of the “Stop” line is available to all traffic during the green period, thereby minimising delays to other traffic and accommodate right turns;
- **turning exemption**, allowing buses to make a turn which is prohibited to other traffic;
- **selective detection** giving priority to buses, further detailed in QTCM fitted with a transponder which is recognised by the signal controller;
- on with flow bus lanes, **separate traffic signals** can be installed at the termination of the bus lane, in advance of the main junction inter-visibility zone, providing a **bus advance area** between the two sets of signal control.

Contra flow bus lanes shall not be provided, unless these are physically separated from the main traffic flow for their full length.

Other classes of vehicles which may be permitted to use bus lanes in certain circumstances include emergency vehicles, motor cycles, taxis and goods vehicles.

5.5 Signalized Roundabouts

5.5.1 General

Guidance on the provision of traffic signals at roundabouts is contained in the QTCM and discusses the specific traffic problems associated with roundabouts which may be resolved by the application of traffic signals, with or without the need for geometric changes. Where roundabouts require signals on most or all entries, computer programs are usually employed for modelling purposes.

When the flows using a roundabout circulatory carriageway exceed a level where the self-regulating nature of the intersection breaks down, the throughput of particular entries can be restricted by the difficulty of finding gaps in the circulating traffic. The provision of traffic signals at one or more of the arms can produce the necessary bias in favour of the affected entries and particularly:

- where delays are excessive, due to imbalanced flows, signals can alter the natural priority to a more desirable one;
- where throughput is inadequate because of high circulating speeds (rather than high flows), signals can achieve an overall improvement in throughput; and
- where it is possible to co-ordinate the circulatory carriageway as part of an overall UTC network (usually fixed-time UTC), signals can reduce overall delays by taking out the random element of “Give-Way” control.

By a combination of physical improvements, road markings and signalling it may be possible to increase capacity, provide better balance of queues, reduce speed and improve safety (particularly for cyclists) at roundabouts. Lane control at signalized roundabouts may be also improved by the effective use of route indications on the external and internal approaches to direct traffic to the appropriate exit arms, as illustrated in Figure 5.5.1. Where referenced in this standard, the external approach shall relate to approaches on arms connecting into the roundabout, and the internal approach shall relate to approaches within the circulatory carriageway.

Under normal priority control at each entry, roundabouts operate in a self-regulating manner. However, signalized roundabouts have signal control on one or more of the external approaches (entry arms) and may also have signal control on one or more internal approaches (circulatory carriageway). Signalized roundabouts may also operate in a self-regulating manner to a varying degree, depending upon a combination of the extent, method and duration of the signal control conditions and the size of the roundabout (see sub-Sections 5.4.1 to 5.7.3).

No two signalized roundabouts will be alike and, as a consequence general guidance only can be provided on the geometric design for various forms of signalized roundabouts.

5.5.2 Pedestrian Crossing Facilities

This sub-Section provides advice with regard to larger roundabouts located in rural areas where pedestrian movements are infrequent or non-existent. In urban locations, particular care should be taken to cater for pedestrians and where pedestrian usage is frequent, crossing facilities should be designed in accordance with the advice contained in sub-Section 4.

The provision of signals for traffic on the entry approaches of a circulatory carriageway provides a natural focal point for pedestrians and it is relatively easy to provide a pedestrian phase. The route provided for pedestrians across the rest of the circulatory carriageway needs to be related to the pedestrian desire lines and will affect the signal system that is adopted. Pedestrians may be signalled onto the central island of the roundabout or crossing facilities provided on the exits to the roundabout. Crossings at exits need to be located sufficiently far away from the circulatory carriageway to minimise the likelihood of queuing vehicles interfering with circulating traffic. This will depend on traffic flows, overall circulatory carriageway and the length of stop time for traffic at the pedestrian signals.

The provision of traffic signals on entries to the roundabout also assists in separating the conflict between vehicular and pedestrian movements. When signal-controlled pedestrian crossing facilities are incorporated on the exit arms, designers should ensure that adequate storage length is provided to avoid traffic queuing back onto the circulatory carriageway.

5.5.3 Geometric Design Standards

This sub-Section provides guidance on the application of geometric design standards for signalized roundabouts.

The geometric design standards contained in Section 6 should be applied to external and internal approaches which operate in a self-regulating manner at any time (i.e. those approaches without signal control and those with part-time signal control). The standards contained Section 6 should also be applied to those approaches with indirect signal control (see 5.6.2).

The geometric design standards contained in sub-Sections 1 to 4 (inclusive) should be applied to external approaches which operate with direct full-time signal control (see 5.6.1). The standards should also be considered for those external approaches which operate with direct part-time signal control, however the standards contained in Section 6 take priority under these circumstances.

For signalized roundabouts the junction inter-visibility zone on the circulatory carriageway should be measured to a point 2.5m beyond the secondary signal, as indicated in Figure 5.5.1.

The requirements for junction inter-visibility shall be applied to all internal and external approaches which operate under signal control at any time.

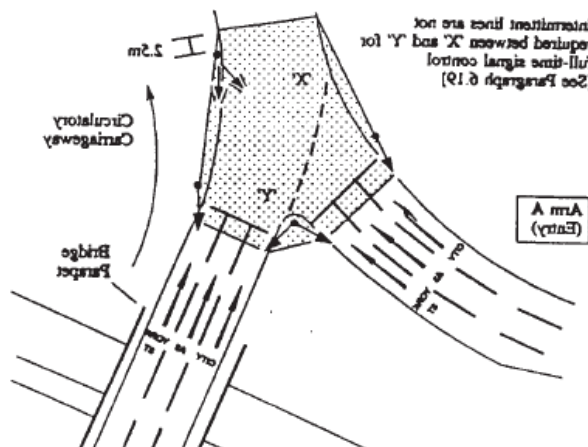


Figure 5.5.1 Junction Control Area

5.5.4 Size

The engineering problems posed in the design of a signalized roundabout are usually more challenging for a small roundabout than for a large roundabout. This is due to the physical constraints imposed on the internal link lengths between each signal-

controlled approach, which affect the interaction between the individual approach signals.

5.5.5 Extent of Signal control

Fully controlled is the condition where signal control is provided on all internal and external approaches (i.e. the direct method of signal control).

Partial-control is the condition where one or more of the approaches remain under priority control. Partial-control can be used where traffic congestion does not occur on all external approaches. It can be easier to coordinate the signals of a four-arm roundabout if one of the arms is priority controlled

5.5.6 Methods of Signal control

Direct signal control is the condition where the signals are situated on one or more of the external approaches and the internal approach immediately to the left of each signal-controlled entry. Figure 5.5.2 illustrates an example of a large signalized roundabout with partial, direct signal control, where traffic flows on the minor roads (Arms B and C) are light and continue to operate in a self-regulating manner under normal priority control.

Indirect signal control is the condition where the signals are situated at such a distance away from the roundabout entry that the entry continues to operate in a self-regulating manner under normal priority control. Figure 5.5.3 illustrates an example of a signalized roundabout with indirect signal control on each entry arm.

Indirect signal control may be used where an entry arm with a very heavy traffic flow is preceded by (i.e. is to the right of) an entry arm with a very light traffic flow. The heavy flow may often proceed virtually uninterrupted, possibly with high circulatory speeds. This causes an unbalanced traffic flow which adversely affects the capacity of the roundabout and can lead to excessive queue lengths (and substantial delays) to other external approaches which in turn may result in congestion at preceding junctions or on slip roads.

The installation of indirect signal control (see Figure 5.5.3) can be introduced to control entry flows on one or more approaches and can provide a gap in the circulatory traffic, to favour those entry arms which were previously subjected to excessive delays and queues. In this way the capacity of the entry arms can be balanced, however increases in vehicle gap distances may be detrimental to cyclists and pedestrians crossing the arms.

5.5.7 Duration of Signal control

Full-time control is the condition where signals are permanently operating. Under full-time signal control the "Give Way" road marking across any signalized entries to the roundabout should not be provided (see Figure 5.5.1). Installing signals for full-time control often involves making geometric modifications, as an integral part of achieving throughput improvements, in ways which might not necessarily be effective or safe on

a roundabout with priority control. These modifications are detailed in sub-Section 5.8.

Part-time control is the condition where signals are switched on at set times (generally peak flow periods) or under certain traffic conditions by queue detectors. When traffic flows are light the roundabout operates in a self-regulating manner under normal priority control. In some cases, where the traffic flows are strongly tidal, signal control can be employed on different arms at different times of day.

Part time control often gives lower off peak delays, but it provides limited scope for making geometric changes as part of the signal installation, since a physical layout that is still suitable for priority control must be retained. Part time control can also introduce some confusion, due to the need for associated permanent signing and lining, which can lead to an increase in collisions when the signals are not in use. Full time control should always be considered as the preferred alternative to part time control. Part time control is not suitable where any of the following apply:

- a requirement for pedestrian crossing facilities on the circulatory carriageway;
- a potential benefit from incorporation in a linked system; and
- significant queues arise at various times of the day.

The examples illustrated in Figure 5.5.2 and Figure 5.5.3 could both operate under full-time or part-time signal control.

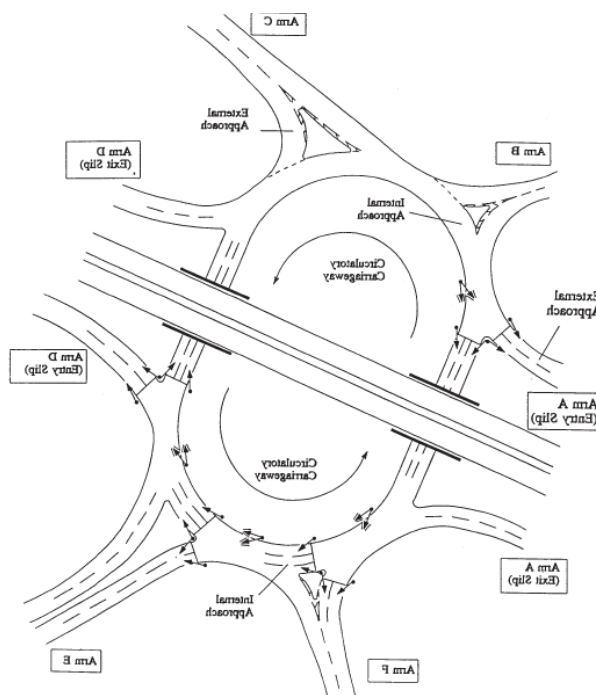


Figure 5.5.2 Example of Large Signalized Roundabout with Partial, Direct Signal Control

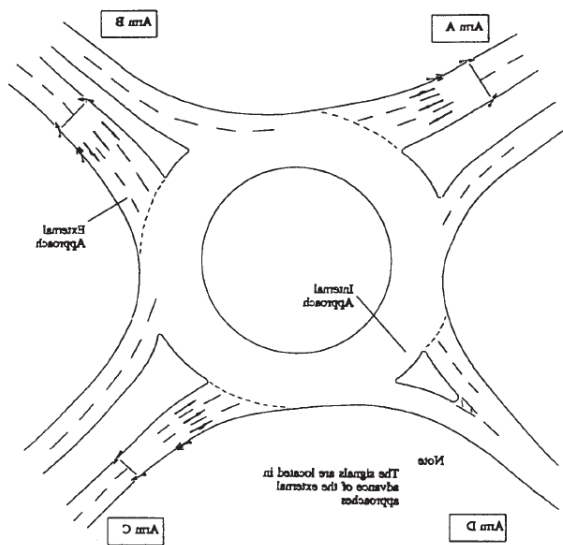


Figure 5.5.3 Signalized Roundabout with Indirect Signal Control

5.5.8 Geometric Modifications

Geometric modifications may be required to roundabouts in order to:

- increase capacity on external approaches;
- increase capacity on the circulatory carriageway;
- accommodate queues at internal “Stop” lines on the circulatory carriageway;
- improve forward visibility and inter-visibility in the junction inter-visibility zone;
- provide alignment improvements and lane control measures;
- provide specific measures for pedestrians, cyclists and buses.

These modifications may take the form of:

- additional nearside or offside approach lanes;
- additional internal approach lanes within the circulatory carriageway;
- increasing the size of splitter islands in order to achieve longer internal approaches;
- segregated facilities or signalled crossing facilities.

5.5.9 Offside Approach Lane

The provision of an additional offside external approach lane, as illustrated in Figure 5.5.4, is appropriate where:

- sufficient space is available on the offside, within the central median;
- a nearside approach lane would result in inadequate internal queuing capacity on the internal approach to the right;
- it does not significantly reduce the queuing capacity on the internal approach to the left.

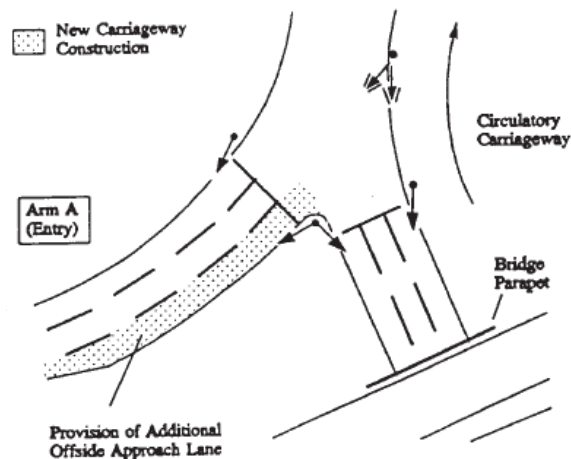


Figure 5.5.4 Provision of Additional Offside Approach Lane (to be reversed for RHD)

5.5.10 Nearside Approach Lane

The provision of an additional nearside external approach lane as illustrated in Figure 5.5.5 is appropriate where:

- sufficient space is available on the nearside;
- an offside external approach lane would result in inadequate queuing capacity on the internal approach to the left;
- it does not significantly reduce the queuing capacity on the internal approach to the right.

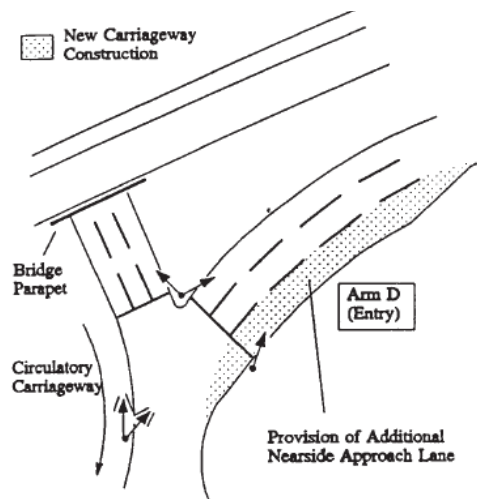


Figure 5.5.5 Provision of Additional Nearside Approach Lane (to be reversed for RHD)

5.5.11 Internal Approach Lanes

In Figure 5.5.2 the internal queuing capacity on the circulatory carriageway to the left of Arm E is limited by the width of the median on the dual carriageway approach. Similarly, to the left of Arm F the internal queuing capacity is severely limited by the size of the deflection island. Internal approach lanes less than 15m in length may result in the blockage of the exit arm, particularly where Large Goods Vehicles are

present and the effect of these internal queues should be considered when assessing the performance of the roundabout.

Under full-time signal control the capacity on the internal approaches to Arms E and F could be improved by geometric modifications (see Figure 5.5.6) to these external approaches by significantly reducing the entry radii. Under part-time signal control however the scope for geometric modifications is reduced due to the requirements for the design to be in accordance with Section 6.

Figure 5.5.6 illustrates how the queuing capacity on the internal approach to the left of Arm F may be improved by increasing the size of the splitter island and realigning the external approach arm.

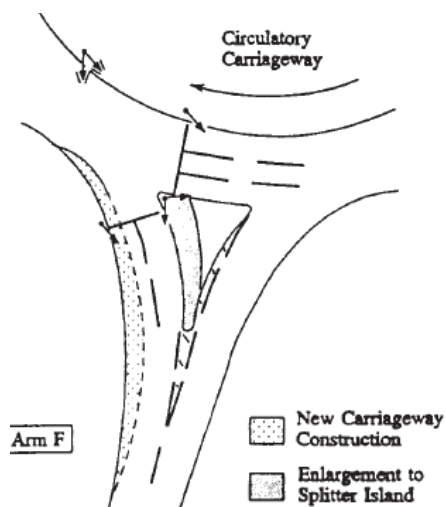


Figure 5.5.6 Improvement to Internal Queuing Lanes (to be reversed for RHD)