APP. D.

THE HIGHWAYS AGENCY

TD 40/94

THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT

THE WELSH OFFICE
Y SWYDDFA GYMREIG

THE DEPARTMENT OF THE ENVIRONMENT FOR
NORTHERN IRELAND

Layout of Compact Grade Separated Junctions

British
Department for Transport.

Summary: This Standard sets out the layout requirements for compact grade separated junctions. It gives recommendations for the application of compact grade separation to existing at grade junctions and to new routes incorporating junctions of this type.

1. INTRODUCTION

General

1.1 This Standard sets out the design standards and methodology for the geometric layout of compact grade separated junctions principally for use on rural and inter-urban roads. It is intended that the standard shall be used in those situations which are not appropriate to the full levels of provision covered in **TD 22 (DMRB 6.2.1)**.

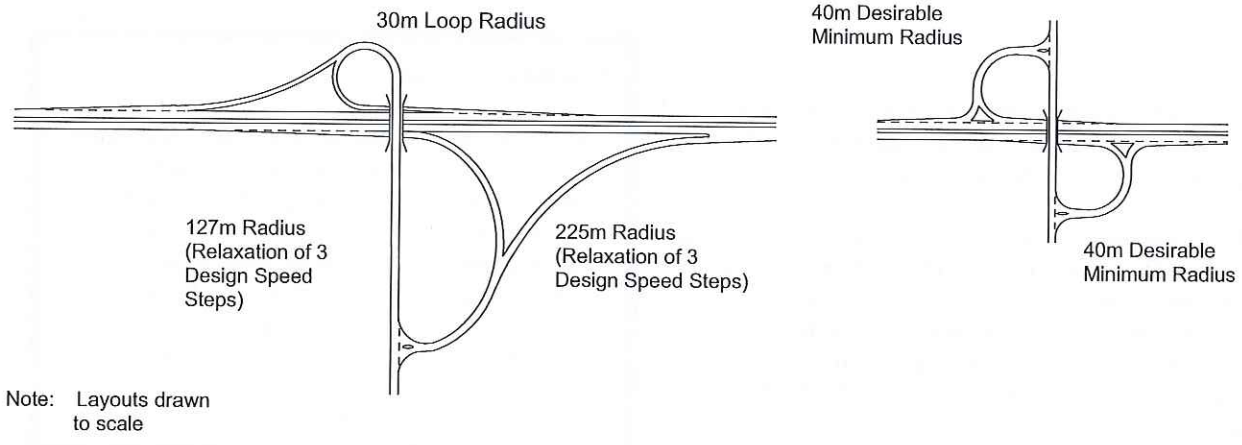
1.2 It has been found that grade separation to the standards contained in **TD 22 (DMRB 6.2.1)** and **TA 48 (DMRB 6.2.2)** can be economically justified at design flows above 30,000 AADT on the main line, depending on turning traffic. Previously, using standards contained within **TA 20 (DMRB 6.2)**, it has normally been possible to justify grade separation to lower design flows of 20,000 AADT on the main line, but again this depended on turning traffic.

1.3 Grade separation should be considered wherever it can be economically justified and environmental constraints can be satisfied. Guidance on the process of choosing a junction type is given in **TA 30 (DMRB 5.1)**. Using those standards compact grade separation as set out here can be justified at flows as low as 12,500 AADT on single lane dual mainline depending on turning traffic and more significantly, accident rates. Attention should be paid to ensuring that there are no major differences in the level of junction provision along a route.

1.4 This standard therefore sets out the level of provision to be considered for low traffic flow situations on the minor road and effectively extends downwards the range of flows and conditions over which grade separation could well be justified economically to around 12,500 AADT on the through route. Further not readily apparent benefits may accrue in accident reductions at other crossings and rights of way, further reduction in severance and the compensation needed to alleviate it, and a reduction in the provision of accommodation bridges.

1.5 Full grade separation on a single carriageway as a general rule is not recommended for reasons of driver perception and therefore reduced safety and should generally be avoided in design. However **TD 9 (DMRB 6.1.1)** makes recommendations about the provision of grade separation at specific junctions on single carriageway roads. The provision of compact grade separations on single carriageways is a permitted alternative provided that the junction layout includes a section of single lane dualling on the mainline.

1.6 Comparisons of the overall size and layouts of grade separated junctions designed to **TD 22** and this standard are indicated in **Figure 1/1**.



a. Grade Separation to TD 22 Standards

b. Example of Compact Grade Separation to TD 40 Standards

Figure 1/1 Examples of the range of Grade Separations

2. DESIGN PROCEDURES

General Principles

2.1 The introduction of design standards for compact grade separation is primarily aimed at improving safety for all road users. At all stages in the design and construction of the junction it is of paramount importance that safety aspects are fully investigated and considered.

2.2 This standard shall be applied in the design process to both the improvement of existing at grade junctions on single and dual carriageways, and to the design of junctions on new single and dual carriageway routes. Compact grade separation requires in all cases the provision of either a section of single lane dualling or a full dual carriageway on the major route.

2.3 The standards for compact grade separation have in most instances been rigorously set in order to minimise the variation in designs to prevent confusion for the road user. Those items which do permit a degree of variation at the discretion of the designer are:

a. Junction configurations;

b. Horizontal radii on compact connector road *(desirable minimum radius with a relaxation of one design speed step)*

c. Vertical Curvature; *(desirable minimum radius with a relaxation of one design speed step)*

d. Carriageway Width; *(three options and a one step relaxation)*

e. Curve Widening. *(three options are permitted for each radius)*

Junction Strategy

2.4 Junction design shall provide an understandable progression of standards for the driver and therefore sequences of junctions should not involve many different layout types. The introduction of a compact grade separation to replace an existing at grade junction will have an effect within the route, beyond the immediate limit of the junction. It is therefore essential to assess the effect upon the network and prepare a junction strategy. The siting of the compact grade separated junction will require careful consideration of the degree of access to be provided.

2.5 On **existing single carriageways** compact grade separation may be applied to a route which consists of a number of priority junctions. The existing priority junctions may consist of a range of layouts from simple T junctions to staggered single lane dualling with priority junctions.

2.6 On **existing dual carriageways** the provision of compact grade separation may be applied to a route which consists of a number of grade separated junctions and roundabouts interspersed with major/minor at grade priority junctions. Introduction of compact grade separation on a route such as this is intended to remove all of the right turn manoeuvres associated with the mainline resulting in a fully grade separated route. Some left-in/left-out junctions may be retained or introduced.

2.7 Where a compact grade separated junction or junctions are being considered the following matters shall be taken into account:-

a. the closure of certain minor road junctions which have very low flows and for which there are alternative routes. The additional journey length, delay and inconvenience resulting from the closure of a route must be considered in the context of the improved safety which will be achieved by the removal of all the right turn manoeuvres;

b. limiting remaining at grade junctions to left in left out only;

c. where there is no alternative route it may be necessary to reconsider the location and number of junctions;

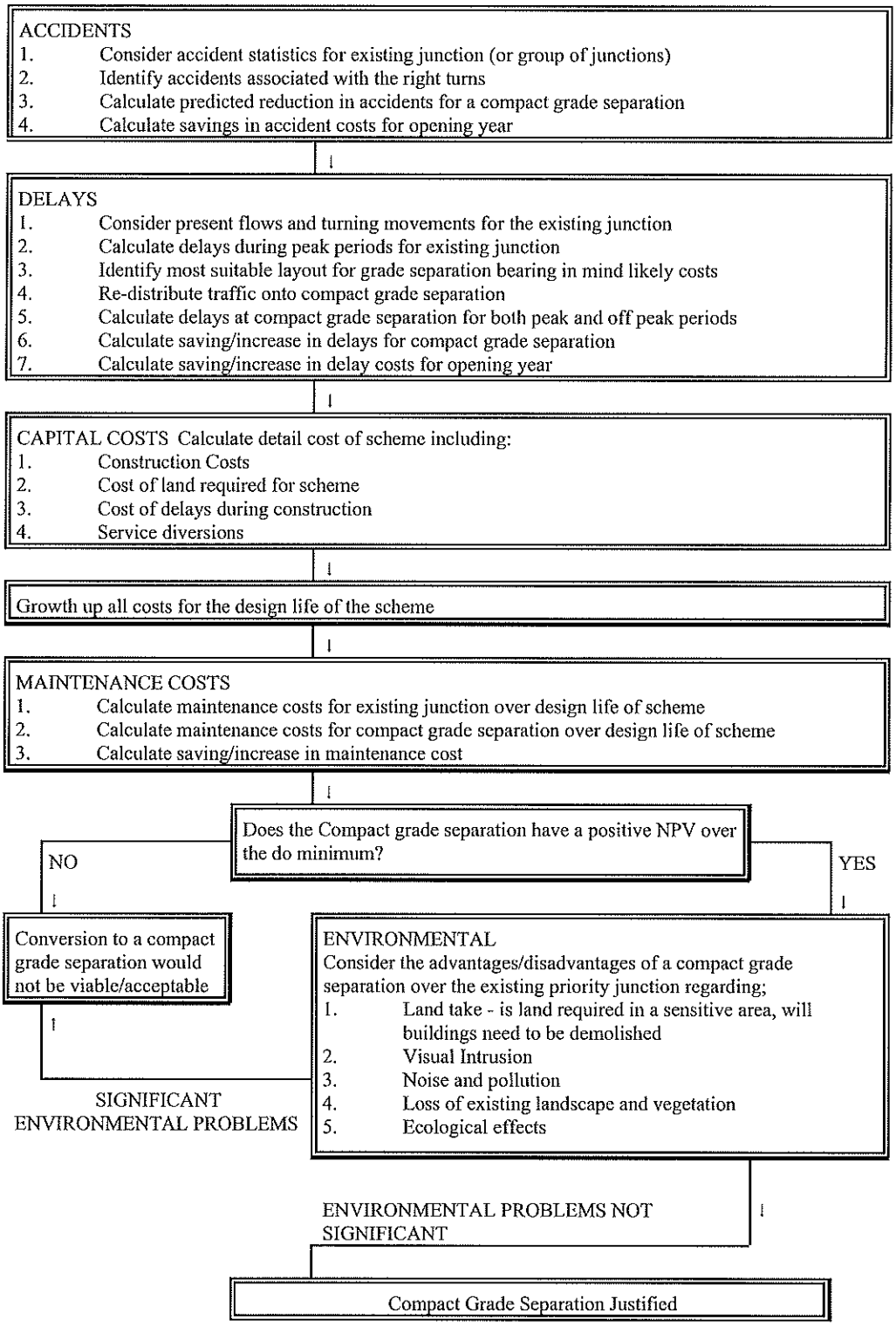


Figure 2/1 Upgrading of existing Priority junction to Compact grade separation.

Value of Time

2.27 To determine time savings (or increases) calculate the total vehicle hours saved (or lost) in the scheme opening year using both high and low traffic/economic growth:-

a. calculate average time savings (or increases) per vehicle for peak and off-peak periods. This will necessitate the calculation of the average time taken through the various links of the grade separated junction making allowances for acceleration and deceleration;

b. calculate the delays at the junction entries and exits during the peak periods;

c. factor the savings (or increases) per day in order to arrive at an annual time saving (or increase) by using the appropriate **M Factor** and **value of time (VOT)** obtained from **COBA (NESA** in Scotland).

2.28 If the local mix of traffic should differ significantly from the trunk road average then the value of time appropriate to the local traffic mix can be substituted.

Vehicle Operating Costs

2.29 Compact grade separation can increase significantly the total vehicle kilometres travelled due to the reassignment of the traffic through the compact grade separation. The total additional distance for each movement and the annual vehicle operating costs can then be determined.

Calculation of Present Value of Benefits

2.30 The accident, time and vehicle operating costs calculated for the scheme opening year (both high and low growth) should each be capitalised over 30 years and discounted back to the base year to give the present value of benefits **(PVB).**

3.5 Taking into account the reduction in the predicted number of accidents and the reduction in accident severity ratios, evidence suggests that annual accident costs for 3 arm priority junctions can be reduced by approximately 60% and for a 4 arm priority junction by approximately 80%, by the introduction of compact grade separation.

3.6 It is intended that compact grade separation shall be used to provide a safe means of crossing high speed routes for all road users, and specific requirements are detailed in **Chapter 4**. The geometrical standards for the compact connector road have been established at a level of provision intended to maintain slow vehicular speeds through their length thereby improving safety for other road users.

3.7 Other positive factors which improve safety as a result of compact grade separation are;

a. removing the possibility of large vehicles which cross central reserve gaps protruding into the offside lane;

b. removal of U turns on the mainline.

Traffic Signs / Road Markings

3.8 The provision and layout of traffic signs and road markings is an integral part of the junction design process and shall be considered at an early stage. Advance direction and warning signs shall be provided on both the major and minor roads. Positioning of signs within the junction and the compact connector road shall be carefully considered so that they do not interfere with driver's visibility. It is essential that there is no over-provision of signing within the compact connector road which may result in unnecessary distractions to drivers negotiating the curves.

3.9 On the approach to the junction from either the major or minor road the junction must be clearly defined by means of appropriate signing indicating the junction as a priority T junction and not as a slip road.

3.10 Where full curve widening is not provided, as identified by paragraphs 6.20, 6.21 and Table 6/3, then regulatory signs shall be provided in accordance with **Chapter 3 of the Traffic Signs Manual** on the compact connector road to advise motorists in one direction that they should give way to vehicles proceeding in the opposite direction. Statutory requirements for regulatory signs are contained in the **Traffic Signs Regulations and General Directions** and **Traffic Signs Regulations (Northern Ireland)**.

3.11 Within the compact connector road it is recommended that signing be restricted to warning signs indicating the nature of the alignment, and the proximity of junctions.

3.12 The application of special surface treatments may be provided as an additional means of highlighting the nature of the geometrical standards for the compact connector road. This can be achieved by the application of a contrasting surface colour (red) within the hatch markings to emphasise the nature of the curve, this should reinforce the meaning and presence of the markings to the driver.

Surfacing

3.13 Given the possibility of steep gradients on the approach to the junctions consideration should be given to the properties of the surfacing particularly with regard to skid resistance and wear.

5. FLOW STANDARDS

General

5.1 The introduction of compact grade separation is intended to extend downwards the range of flows and conditions over which grade separation may be considered. It has been found that using these standards improving existing junctions to compact grade separation can be justified down to flows of around 12,500 AADT on the mainline, depending upon turning traffic.

5.2 Compact grade separation can be used with single carriageways and dual two lane all-purpose roads within Categories 3A, 3B, 4, 5 & 6 of roads as defined in Table 4 of **TD 9 (DMRB 6.1.1)**.

Flow Levels

5.3 Compact grade separated junctions appear to be suitable for use where mainline flows are between approximately 12,500 AADT and 30,000 AADT and are normally associated with very low flows (generally below 10% of mainline flow) on the minor road.

Delays

5.4 Junction delay figures significantly in the economic assessment of alternative forms of junctions and is dependent upon the geometric standards and the traffic conditions. In assessing the delays associated with compact grade separations it is important to include the additional travelling time required to pass through the compact connector roads and to negotiate the additional junction entry and exits. Delays at the major/minor junctions may be significantly reduced during the peak periods; travel time throughout the day will increase due to the additional distance through the junction.

5.5 Alternative layout options for 4 arm junctions should be assessed to determine the most suitable form to minimise the additional delays, which will depend upon the turning proportions. This should be carried out at an early stage in the design when considering the topographical and environmental constraints imposed upon the junction location and form.

Capacity

5.6 Junction capacity is dependent upon the interaction between the various traffic movements within a junction and the geometrical standards of the junction. **TRRL Report SR582** provides guidance for the prediction of capacity based upon investigation of existing junctions. Analysis of capacities for compact grade separations based on this report indicates that the removal of the right turn manoeuvre can result in significant capacity increases.

5.7 In the particular case of 3 arm (T) junctions, conversion to compact grade separation is only likely to prove viable where the existing junction already experiences delay or the junction is an essential element of the route, possibly providing a means of removing right turn manoeuvres at adjacent 3 arm junctions as indicated in **Figure 7/8**.

5.8 Analysis indicates that for the improvement of an existing priority junction to compact grade separation standards an increase in capacity of 80% for some movements can be achieved at the mainline junctions.

5.9 The layout of the compact grade separation should be chosen to suit the traffic movements. In certain conditions the redistribution of the turning traffic can result in significant turning flows at the minor road junction entry and exits. It is important therefore to assess the capacity of these junctions when considering the layout to be adopted.

6. GEOMETRIC STANDARDS

General

6.1 This standard provides a geometric standard for compact grade separation incorporating established design standards for major/minor junctions. The geometric standards contained in **TD 9 (DMRB 6.1.1)** provide for design speeds down to a minimum of 50kph. The geometric standards for compact grade separation are generally based upon the principles contained in **TD 9 (DMRB 6.1.1)** but are for a design speed of 30 kph which is 3 design speed steps below the current minimum.

6.2 The geometric standards for the mainline and for those minor roads which pass directly through a compact grade separation shall be provided in accordance with Standard **TD 9 (DMRB 6.1.1).**

Design Speed

6.3 Design speeds for the mainline and the minor road shall be determined from **TD 9 (DMRB 6.1.1).**

6.4 As a general principle it is intended that the speed of vehicles through the compact connector road shall be limited by its speed through the entry and exit junctions with the mainline and the minor road. For this reason long straight sections within the compact connector road shall be avoided.

6.5 The design standards for compact grade separated junctions relate to a single design speed of approximately 30kph. Junctions shall only be designed to this design speed, higher or lower standards shall not be used. A range of standards would result in driver confusion and uncertainty and problems of perception of the junction with consequent safety implications.

6.6 If speeds markedly in excess of this do occur or are anticipated then speed limits within the junction may need to be considered.

Compact Connector Road

6.7 Compact connector roads shall be designed in accordance with **Table 6/1** except for the special conditions of **paragraph 6.11** when the stopping sight distance may be relaxed further as set out in paragraph 6.11. The stopping sight distances in **Table 6/1** are not related to the design speed but are based upon the requirements to provide adequate stopping sight distance through the compact connector road to show clearly to the driver leaving the mainline the shape of the junction.

STOPPING SIGHT DISTANCES	
Desirable Minimum (m)	70
Relaxation of One Design Speed Step (m)	50
HORIZONTAL CURVATURE	
Desirable Minimum Radius (m) with 5% Superelevation	40
Relaxation of One Design Speed Step(m) with 5% Superelevation	32
VERTICAL CURVATURE	
Desirable Minimum Crest K	3.3
Relaxation of One Design Speed Step Crest K	2.3
Absolute Minimum Sag K with lighting	2.3
Absolute Minimum Sag K without lighting	3.2

Table 6/1 Design Standards for Compact Connector Roads

Cross Sections and Curve Widening

6.19 For the purpose of designing junctions and interchanges, cross sections for the mainline and all connector roads are given in the Manual of Contract Documents for Highway Works, Volume 3 **"Highway Construction Details"** (MCHW 3.1). Different lane marking details and widths of construction for compact connector roads from those shown in **"Highway Construction Details"** are specified in this standard.

6.20 Compact connector roads may be widened on curves in accordance with **Table 6/3**, the widening shall be applied in the form of central hatched markings as illustrated in **Figure 6/1**. The width of curve widening shall be chosen to suit the anticipated level of usage by large goods vehicles. Designers shall take into account the probability of large vehicles regularly meeting on the curve.

6.21 Where no curve widening is applied large goods vehicles will cut across into the oncoming lane, where the minimum curve widening is applied large goods vehicles will cut across into the whole of the hatched area. Where the normal curve widening is provided there will be sufficient width for two large vehicles to pass in opposite directions. Regulatory signs shall be provided when appropriate in accordance with **paragraph 3.10**.

Inner Channel Radius (m)	Width W_H of Hatching at Apex on Curve (m)		
	No Curve Widening	Minimum Curve Widening	Normal Curve Widening
40	0.6	1.90	3.40
32	0.6	2.54	3.74

Table 6/3 Curve Widening on Compact Connector Roads

6.22 Carriageway widths for the compact connector road shall be such that they provide a transitional change in standards from the major carriageway width to the minor carriageway width in accordance with **Table 6/4**.

6.23 The minimum width of carriageway for a compact connector road shall be 6.6m and the maximum shall be 7.9m, excluding curve widening. Where the traffic volumes are particular low and the proportion of large goods vehicles is correspondingly low a relaxation to 6m may be permitted, by either reducing the carriageway width or omitting the central hatched markings.

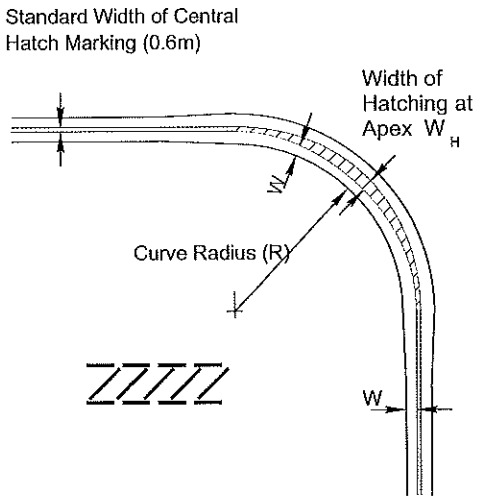
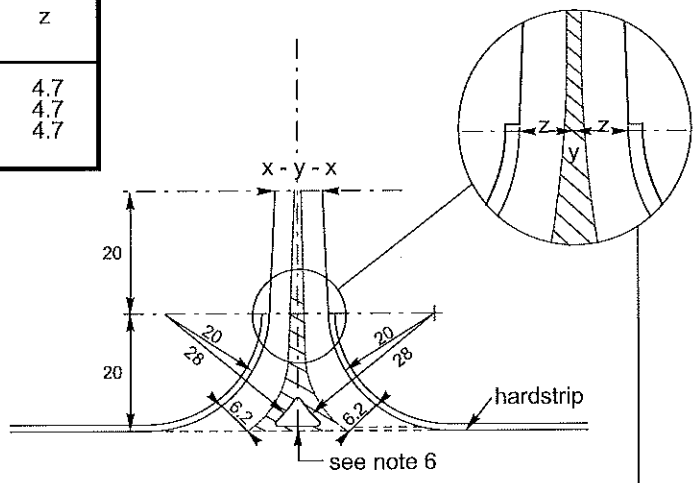


Figure 6/1 Application of Curve Widening

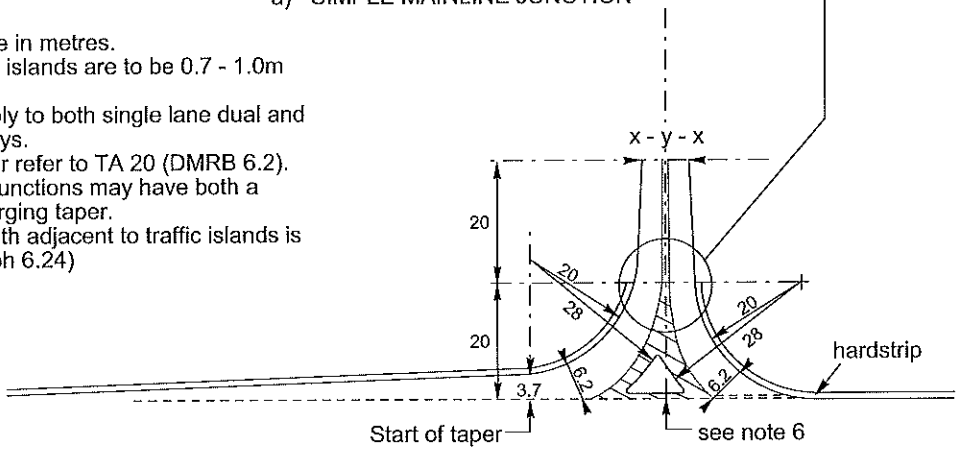
Minor Road Width	x	y	z
< 3.0	3.0	0.6	4.7
3.0 to 3.65	3.3	0.6	4.7
3.65	3.65	0.6	4.7



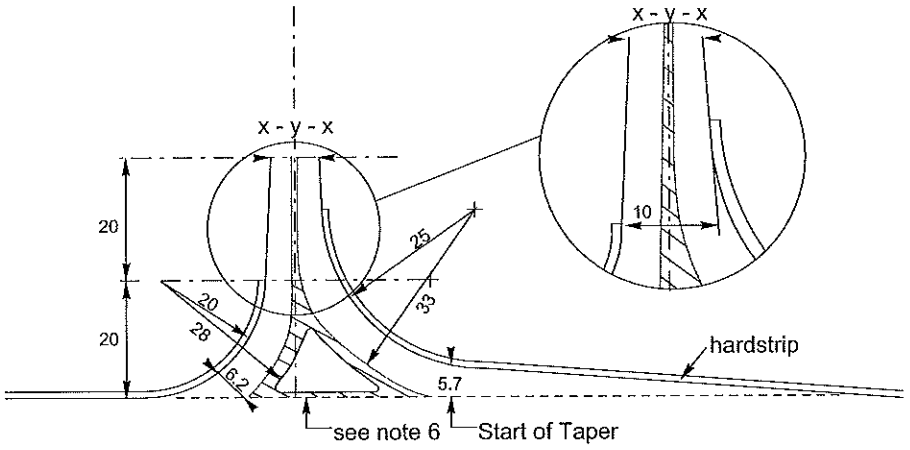
a) SIMPLE MAINLINE JUNCTION

NOTES:

1. All dimensions are in metres.
2. All corner radii on islands are to be 0.7 - 1.0m radius.
3. These details apply to both single lane dual and D2AP carriageways.
4. For length of taper refer to TA 20 (DMRB 6.2).
5. Where required, junctions may have both a merging and diverging taper.
6. The minimum width adjacent to traffic islands is 6m (see paragraph 6.24)



b) MAINLINE JUNCTION WITH NEARSIDE DIVERGE TAPER



c) MAINLINE JUNCTION WITH NEARSIDE MERGING TAPER

Figure 6/2 Modified Major/Minor Junction for Left Turn Only Manoeuvres

(Dimensions are those set out in **TA 20 (DMRB 6.2)** but modified for left in/left out operation. As modified in **paragraph 6.29**, the conditions under which tapers may be provided are detailed in **TA 20 (DMRB 6.2)**)

7. LAYOUT OPTIONS

General

7.1 The layout for the compact grade separation will in many cases be dictated by the constraints imposed by the existing junction to be modified, or site topography in the case of new routes. The formats of these junctions are numerous and it is not possible to provide exhaustive examples. In some cases, underbridges could be considered as an alternative and they may prove practical and justifiable economically. There may be situations, where, due to local topography, this would be preferable in landscape terms. In level and treeless landscapes, overbridges can be visually intrusive and planting may be out of character. Environmental Design is addressed further in **DMRB Volume 10, The Good Roads Guide.**

7.2 Detailed examples of 3 alternative layouts for 4 arm junctions are indicated in **Figures 7/1 to 7/3** and an example of a layout for a 3 arm junction is indicated in **Figure 7/4.** Schematic representations of other layouts are indicated in **Figures 7/4 to 7/8.**

7.3 **Figure 7/9** indicates two method of incorporating a compact grade separation into a section of carriageway which has a series of priority junctions in close proximity. The first option indicates the junctions adjacent to the compact grade separation restricted to left in left out requiring right turning traffic from these junctions to divert to the compact grade separation to complete their manoeuvre. The second option indicates the closure of the adjacent priority junctions and the total diversion of these routes to connect into the compact grade separated junction.

7.4 The preferred locations for the junction of the compact connector road to the mainline are in the 1st and 3rd quadrants as indicated in **Figures 7/1, 7/2 and 7/4,** as they facilitate the provision of required visibilities without the need to widen under the structure.

Typical Sketch Layouts

Figure 7/1 Detailed layout of 4 arm, D2AP carriageway with compact connector roads in preferred location and including both merging and diverging tapers, and free flow on the minor carriageway. For junctions where minor road traffic movement is primarily straight across.

Figure 7/2 Detailed layout of 4 arm, D2AP carriageway with compact connector roads in preferred location without merging and diverging tapers, and free flow on the minor carriageway. For junctions where minor road traffic movement is primarily straight across.

Figure 7/3 Detailed layout of 4 arm, D2AP carriageway with compact connector road forming a loop. For junctions where minor road traffic movement is primarily turning onto and off the major carriageway.

Figure 7/4 Detailed layout of 3 arm, D2AP carriageway with compact connector roads in preferred location and including both merging and diverging tapers.

Figure 7/5 A selection of schematic layouts indicating 4 arm compact grade separations on dual all-purpose carriageways.

Figure 7/6 A selection of schematic layouts indicating 4 arm compact grade separations on single all-purpose carriageways.

Figure 7/7 A selection of schematic layouts indicating 3 arm compact grade separations on dual all-purpose carriageways.

Figure 7/8 A selection of schematic layouts indicating 3 arm compact grade separations on single all-purpose carriageways.

Figure 7/9 Schematic example of compact grade separation and restricted junctions.

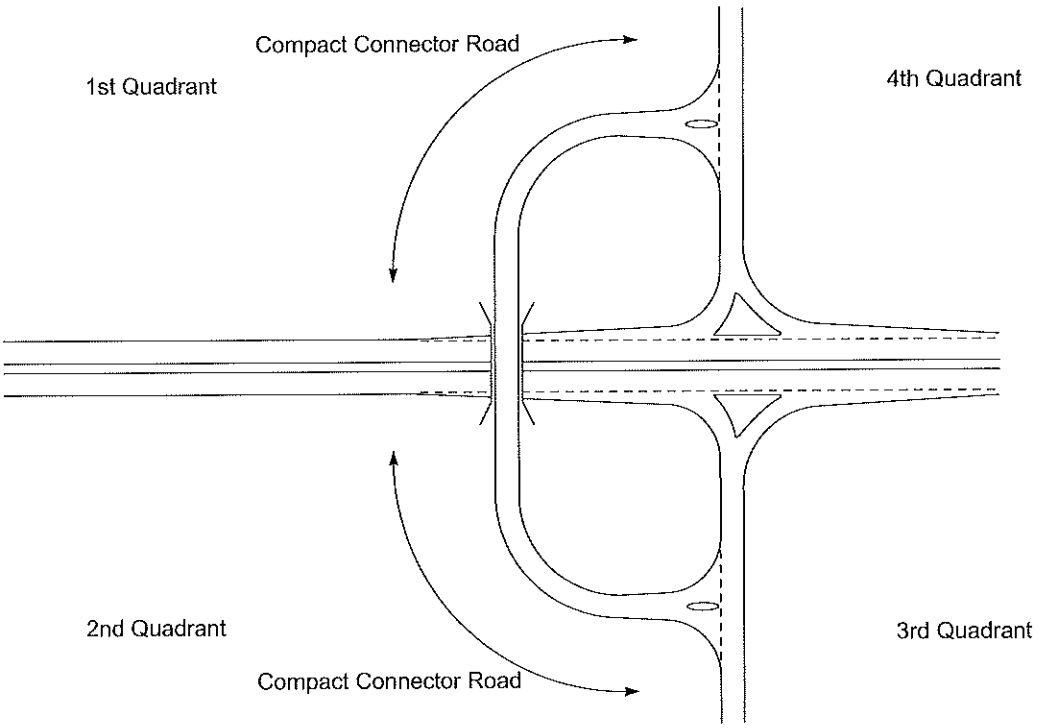


Figure 7/3 **Compact Grade Separation for 4 Arm Junction, Showing Merge and Diverge Tapers**

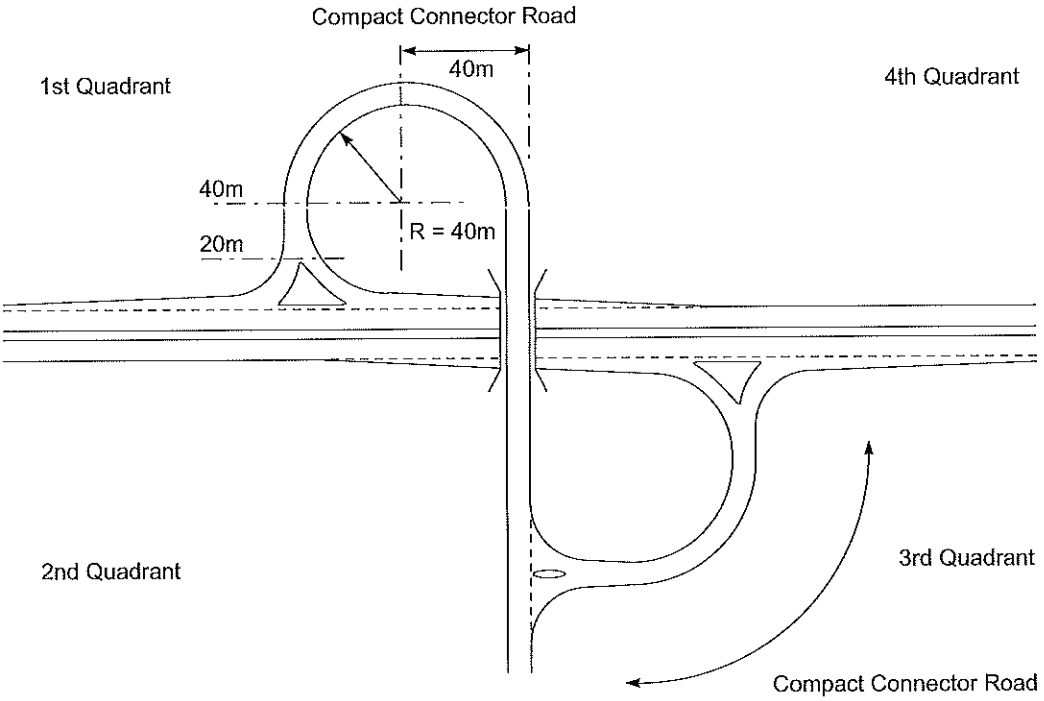


Figure 7/4 **Compact Grade Separation for 3 Arm Junction, Showing Merge and Diverge Tapers**

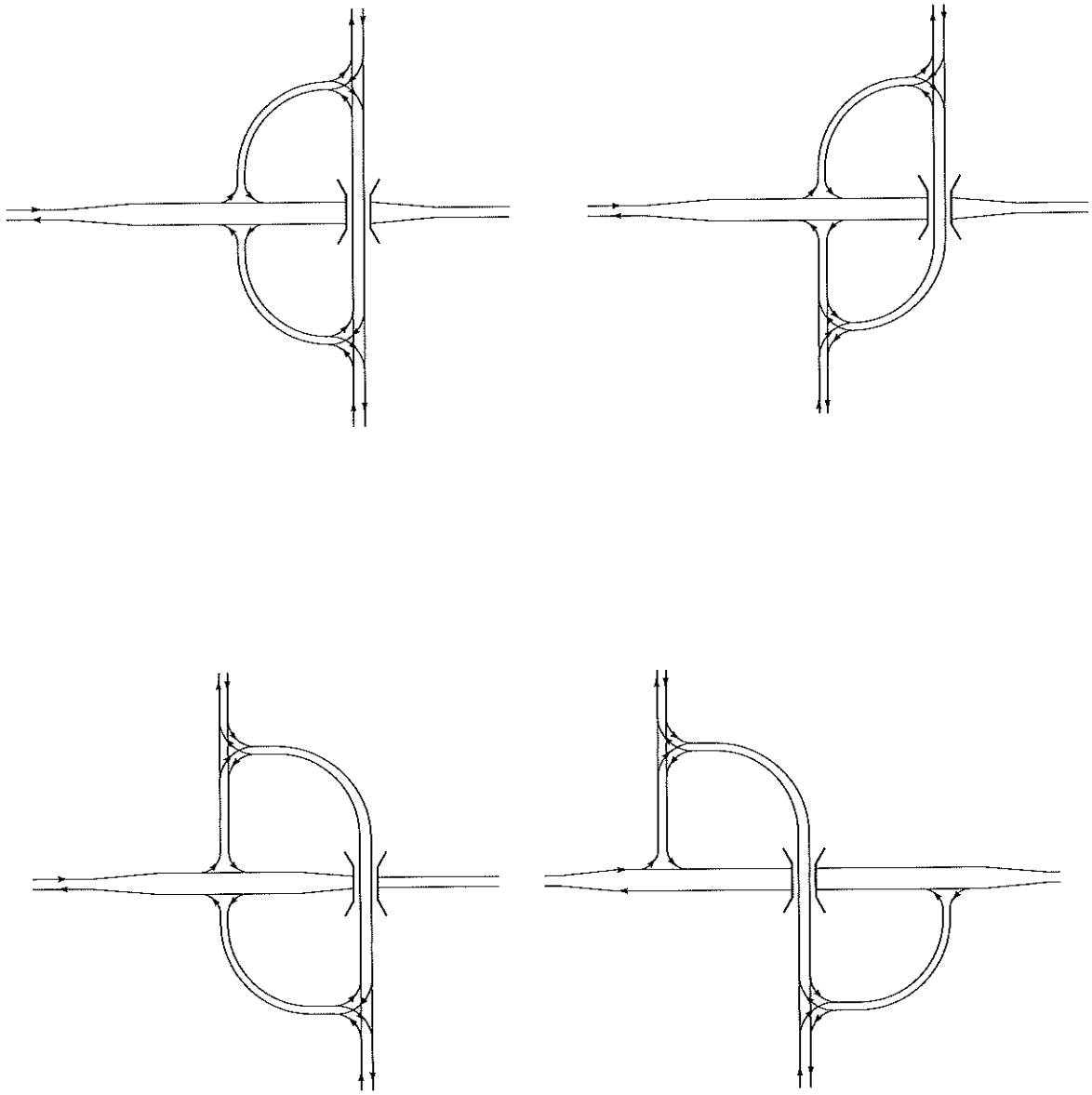
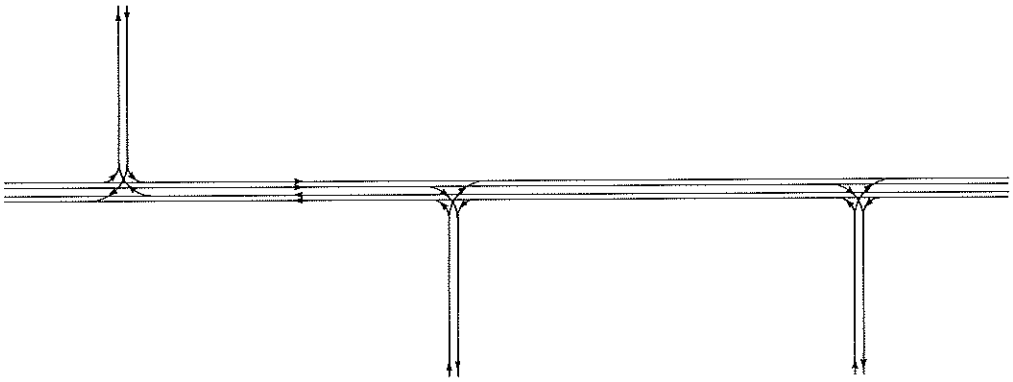
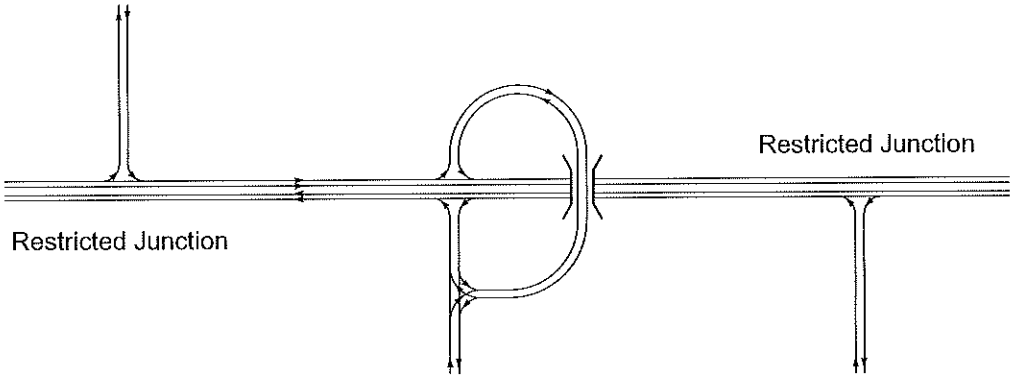


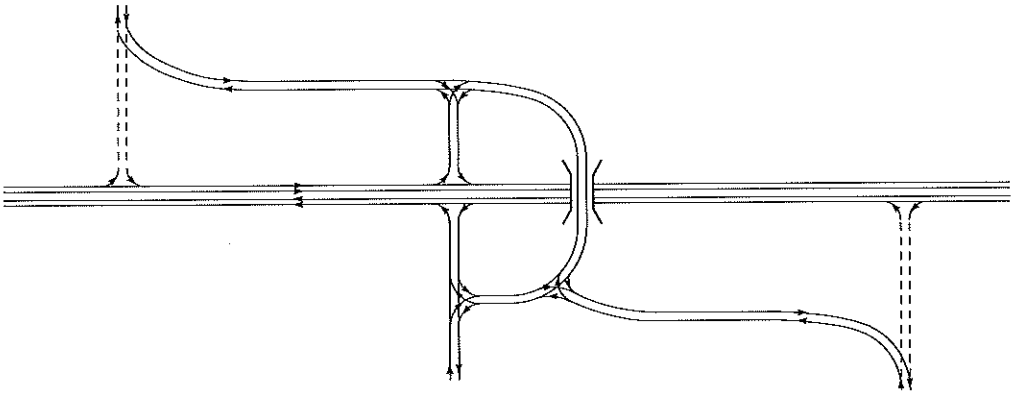
Figure 7/6 Schematic Examples of 4 Arm Compact Grade Separation Single Carriageway



Existing Layout indicating 3 arm junctions



Proposed Layout indicating Compact Grade Separation and Restricted Junctions



Proposed Layout indicating Compact Grade Separation and Total Diversion of Minor Side Roads and/or Accommodation Roads

Figure 7/9 Schematic Example of Compact Grade Separation and Restricted Junctions

9. ENQUIRIES

All technical enquiries or comments on this document should be sent in writing as appropriate to:-

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