11

chapter 11 Roundabouts

11.1 Introduction

The main function of a roundabout is to allow the safe interchange of conflicting traffic movements with the minimum of delay to road users. This is achieved by a combination of geometrical layout features related to the volume, type, and speed of traffic using the junction. The needs of all road users should be taken into account. Traditional roundabout design with flared approaches and wide circulatory carriageway widths is dominated by motor vehicle capacity objectives and this has caused problems for pedestrians and cyclists. On all but the busiest urban roads it is more appropriate to produce designs that are cycle and pedestrian friendly. Where possible continental style roundabouts (see Chapter 11.2) should be used in urban areas. These are smaller roundabouts with single lane entry, circulatory and exit geometry. These help to keep speeds low.

Roundabouts operate most effectively when turning movements are well balanced. This helps to avoid particular traffic streams dominating the roundabout, which can result in delays and drivers taking less safe gaps to get through the junction. Roundabouts are good at coping with high numbers of right turning vehicles and reducing vehicle speeds (if they are well designed).

Roundabout designs need to cope with widely different types of traffic flow and volume. In an urban location, it can be more difficult to meet the full geometric requirements for roundabouts owing to restrictions on available land and vulnerable road users such as pedestrians and cyclists are likely to be present in greater numbers. In a rural location there are normally fewer physical constraints but the traffic will be travelling at higher speeds. The environment where the roundabout is proposed must be assessed to determine if it is the appropriate facility for the location. In an urban situation where traffic signal junctions are the main type of control and a linked traffic signal control system (UTC) is in operation, a roundabout may be totally inappropriate as it could break up a carefully controlled traffic progression plan.

In many European countries roundabouts are increasingly being used as speed reduction measures as well as a tool to denote a change in the road environment such as from dual carriageway to single carriageway, or from a rural to an urban road layout.

This chapter gives general information and advice on the design of roundabouts, which can be used for new junctions or improvements to existing ones. A full roundabout design guide is beyond the scope of the manual but a number of references and sources of information are given in Chapter 11.7.

11.2 Types of roundabout

Four types of roundabout are used:

- Semi-Rural roundabouts (referred to as normal in the Traffic signs manual)
- continental style urban roundabouts
- mini-roundabouts
- double (or multiple) roundabouts

Roundabouts can also form part of grade-separated junctions. Larger roundabouts can be signalled (see Chapter 10.13) if there are congestion problems.

Semi-Rural roundabouts (Diagram 11.1) have a kerbed central island preferably with an 8m to 15m diameter (absolute minimum diameter of 4m) with approaches that flare at the entry to provide sufficient capacity. They usually have 3 or 4 arms. Some roundabouts have 5 or more arms, but the size of the island required to accommodate them often creates problems with the speeds of circulating vehicles. Double roundabouts can be considered as an alternative in such circumstances.
It should be noted that semi-rural roundabouts are so called to distinguish them from Continental style

urban roundabouts. In addition to being suitable for use in certain rural and semi-rural locations, semi-rural roundabouts may also, in certain circumstances, be appropriate for use on Primary Distributor roads in urban and suburban locations.

Continental style urban roundabouts (Diagram 11.2) usually have single lane entries, exits and circulatory areas with a smaller overall size than normal roundabouts. They are more cycle and pedestrian friendly than normal roundabouts because the absence of flaring and reduced widths control entry and circulating speeds more effectively. They are suitable for traffic flows up to a maximum of 20,000 vehicles per day on the major road. Conflicts on the circulatory area and at the exits are reduced. The central island can incorporate a 1.5m wide strip, which can be overrun by long vehicles. Further guidance on designing urban roundabouts is given in Provision of Cycle Facilities, National Manual for Urban Areas.[5]

Mini-roundabouts (Diagram 11.3) have a painted central island (between 1m and 4m in diameter) which can be overrun by long vehicles. These islands are dealt with in detail in Section C.

Double/multiple roundabouts (Diagram 11.4) are combinations of either the normal or mini-roundabout type located closely together. They can also be used in the grade-separated context with a bridge across the main carriageway forming the link between them.

11.3 Principles of roundabout design

Most medium and large roundabouts are designed on computer software packages, which allow the detailed design of both the horizontal and vertical alignment. Roundabouts should be designed to reduce the entry speed of vehicles so that drivers can judge gaps in traffic and can negotiate the junction safely. Roundabouts must also be able to cope with the volumes of traffic that use them. This balance is achieved by a series of geometric layout factors, which are outlined below. Whilst the roundabout geometry is the most influential safety factor, other factors such as signing, road markings, lighting, landscaping and the provision of facilities for pedestrians and cyclists also have an important role (see Chapter 11.6).

Diagram 11.1 Semi-Rural roundabout

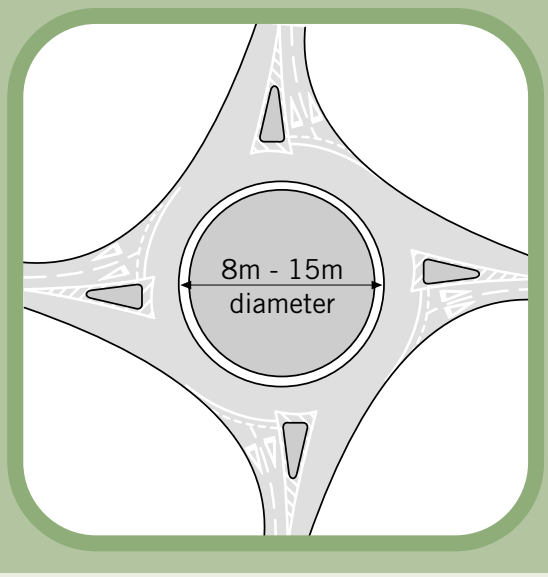


Diagram 11.2 Continental style Urban roundabout

The information in this chapter should be read in conjunction with TD16/93[1] – Geometric Design of Roundabouts and NRA addendum, and the relevant section of Provision of Cycle Facilities, National Manual for Urban Areas.[5]

Continental design roundabouts[5] are the recommended type of roundabout for urban areas for roads with less than 20,000 vehicles per day (subject to a capacity assessment).

Size and shape

The central island of a roundabout should be circular in shape. The size of a roundabout is measured by its outside diameter and this is referred to as the Inscribed Circle Diameter (ICD). This should meet all the kerb lines at the entry points. A constant circulatory width should also be achieved where possible. Traffic on non-circular roundabouts does not flow smoothly, braking and accelerating is accentuated and can lead to accidents.

Continental design roundabouts have a smaller ICD (25m–40m) than normal roundabouts. This makes it easier to achieve geometric requirements.

On roads requiring a higher traffic capacity junctions, an ICD of between 45m and 60m, with 2 or 3 circulating lanes (8m to 12m) is needed. For layouts with 5 or more arms, the roundabouts increase in size markedly. Experience at larger roundabouts has shown that too wide a circulating width can result in excessive speed, driver confusion and resulting safety problems. It is conventional practice to design the circulatory width to a ratio of between 1.0 to 1.2 times the maximum entry width. A maximum circulatory width of 12m is generally considered to be the safe upper limit unless other design factors, such as signalised entries or special circulatory markings, are proposed.

Vehicle entry path curvature (Semi-Rural roundabouts only)

Vehicle entry path curvature (Diagram 11.6) on the approach to the roundabout has a major influence on safety as together with the entry width it controls the speed at which a vehicle enters the roundabout.

Diagram 11.3 Mini-roundabout

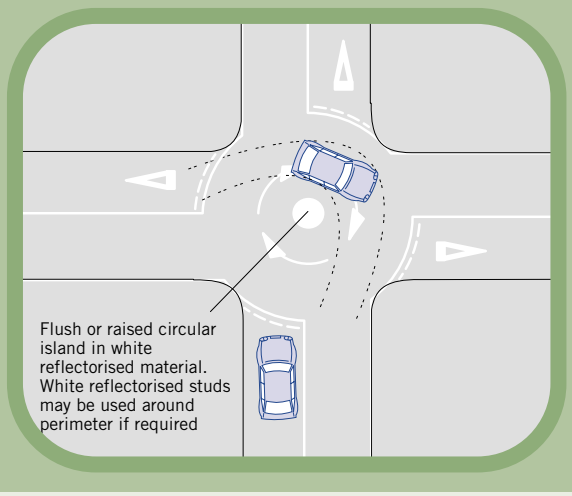


Diagram 11.4 Double roundabout

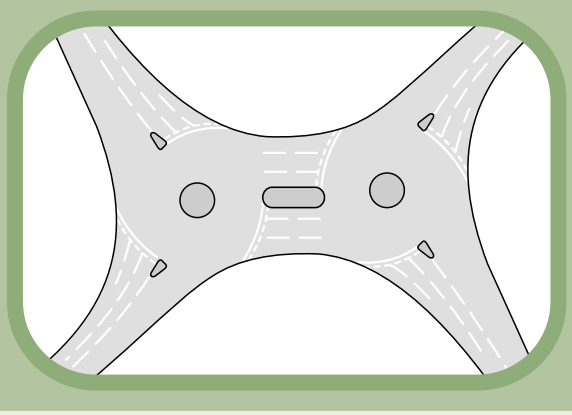
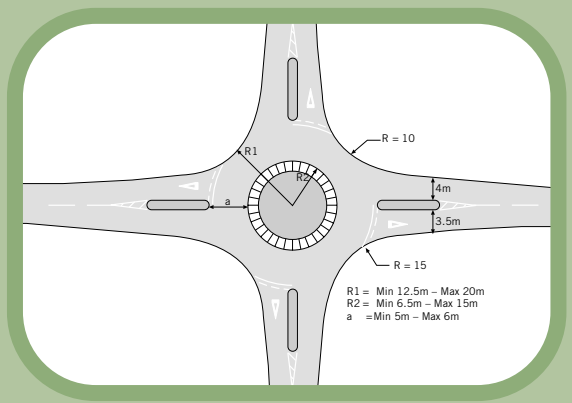
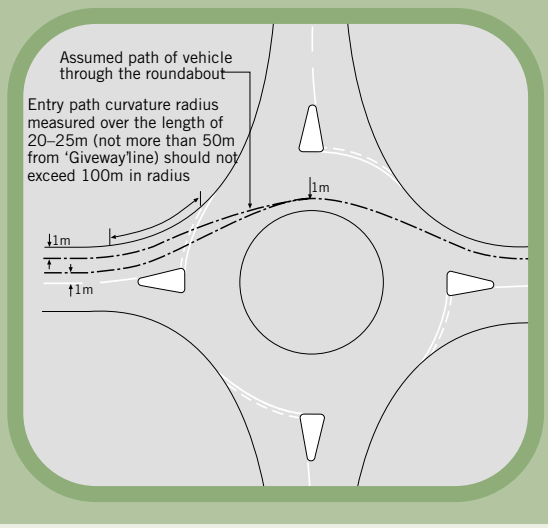


Diagram 11.5 Basic dimension of continental design roundabout



Entry path curvature is a measure of the amount of deflection to the left that the driver is forced to take when entering the roundabout. A vehicle path with a radius of not more than 100m is recognised as achieving the appropriate minimum amount of deflection. It is essential that this deflection be achieved at the entry point to the roundabout. If the entry path curvature is too severe it can result in vehicles losing control and mounting the central island. Similarly this can make it difficult for drivers to merge with traffic on the circulatory carriageway as they may be brought on at such an angle as to make speed and gap assessment difficult.

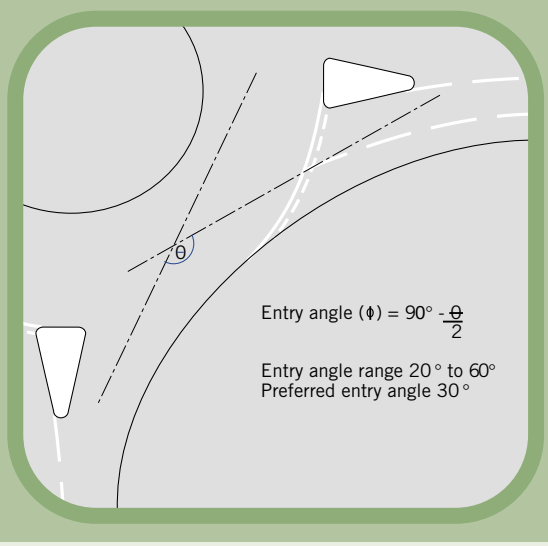
Diagram 11.6 Entry path curvature for a semi-rural roundabout



Entry Angle (Semi-Rural roundabouts only)

The entry angle (Diagram 11.7) is the angle of a vehicle approaching a roundabout in relation to the angle of traffic circulating. Too sharp an entry angle can reduce capacity whilst too shallow an angle can lead to faster entry speeds. An entry angle of 30 degrees is the optimum but this can vary from 20 degrees to 60 degrees, depending on design constraints.

Diagram 11.7 Entry angle for a semi-rural roundabout



Methods for measuring entry path curvature and entry angle together with examples for different types of roundabouts are given in TD16/93[1] – Geometric design of roundabouts and NRA addendum.

Entry width, lane width and corner radii (Semi-Rural roundabouts only)

The entry width is the width of an approach as it enters the roundabout circulatory area. Traditional roundabout design allows for localised widening on the entry arms from 1 to 2 lanes or from 2 to 3 or 4 lanes to improve capacity. Care needs to be taken that the entry width provided is not excessive as this can make it difficult to achieve the required entry path deflection. Drivers are often reluctant to use this extra width for fear of being involved in weaving collisions as they enter the circulatory carriageway.

Capacity calculations from computer models (see Chapter 11.5) may suggest the need for three (or more) lanes at an entry for a particular design year flow. In the early years of operation this width may be unnecessary and some of it may not be used. In such cases it is appropriate to restrict entry width by white lining until growth in traffic flow requires the extra width. Wide approaches also disadvantage pedestrians attempting to cross at

the junction and encourage high entry speeds in light traffic conditions. Where more than one lane is provided, lane widths should be between 3m and 3.5m at the entry yield line.

Splitter Islands

Splitter islands should be provided on approaches (where possible) as they assist pedestrian crossing movements and can accommodate signing to direct traffic. The recommended width between kerbs should be approximately 4m for continental style roundabouts and 6m for normal roundabouts. Care needs to be taken that the signs do not block the visibility of pedestrians.

The recommended kerb radii at entry and exit on a semi-rural roundabout are summarised in Diagram 11.8

Visibility

There are a number of visibility requirements for good design and safe operation:

- Advance visibility (Diagram 11.9) of the roundabout for drivers on the approach (see Table 11.1) is essential for drivers to anticipate the exact location of the roundabout. If drivers cannot see the roundabout because it is hidden over a crest or around a curve then they may not be able to yield at the entry.
- Visibility to the right (Diagram 11.10) and across the circulatory area for vehicles at the yield line is essential in order for drivers to detect safe gaps in traffic. If drivers are unable to see sufficiently then they may be hit by circulating vehicles as they enter the roundabout. However, being able to see to the right from too far back on the approach can encourage drivers to enter the roundabout too quickly. In order to counteract this the required visibility to the right should only be available from a point some 15m back from the yield line. In the UK some authorities have erected fencing or provided landscaping on the approaches to limit visibility.

Further advice on visibility distances is given in TD 16/93[1] and NRA addendum.

Diagram 11.8 Entry width, lane width and corner radii for semi-rural roundabout

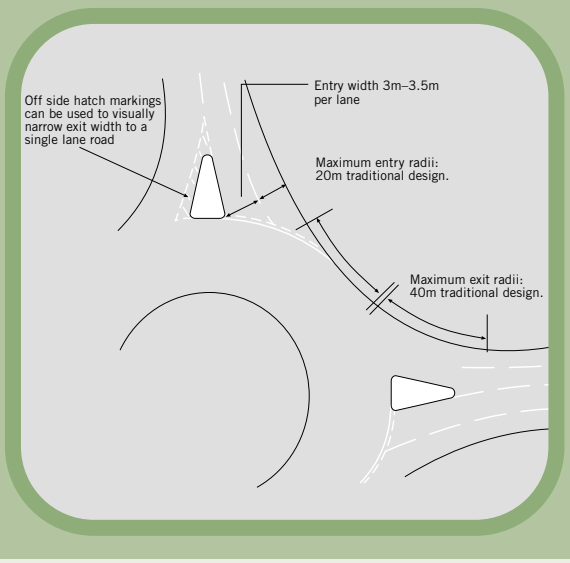


Diagram 11.9 Advance visibility required

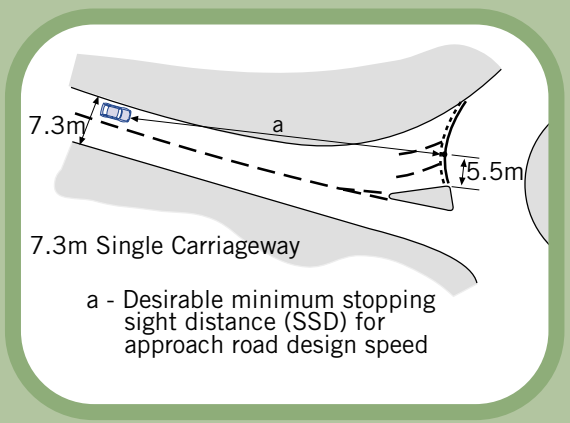


Table.11.1 Recommended advance and forward visibility distances

85% APPROACH SPEED (KPH)	DESIRABLE MINIMUM VISIBILITY DISTANCE (a) (metres)
40	40
50	70
60	90
80	145
100	215
120	295

11.4 Road markings and signing

It is necessary to provide adequate signing and road markings to warn drivers of the presence of a roundabout as they approach it. This is achieved by providing adequate visibility of the roundabout (Chapter 11.3) and the associated signs and road markings. The central island of the roundabout should have 'turn left' and 'sharp change of direction' signs facing each entry in addition to the required lane and yield markings. On the approaches, map-type direction signs (accurately reflecting the layout of the junction) should be used in advance of the roundabout. These should be supplemented by 'roundabout ahead' warning signs, where appropriate.

For roundabouts with high-speed approaches and those where the required advance visibility distance cannot be obtained a number of additional measures can be considered:

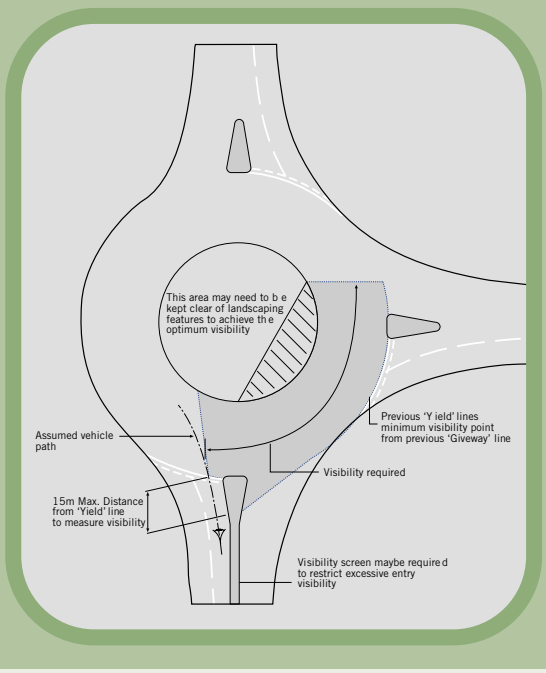
- the inclusion of 'reduce speed now' supplementary plates with the roundabout warning signs
- the use of 'III, II, I' countdown marker posts on the approach
- the use of coloured rumble strips on the approach
- the use of 'slow' markings on the carriageway

These signs and road markings can help to reduce accidents.

Road markings can help drivers to get into the correct lane on the approach to the roundabout. Larger roundabouts or those with three or more circulating lanes can be confusing for drivers in the absence of lane use guidance. It may also be advantageous to provide lane markings on the circulatory area to promote good lane discipline. TA 78/97[2] – Design of road markings at roundabouts shows examples of how circulatory markings can be used at roundabouts (see Diagram 11.11).

Advice on the use of signs for roundabouts is given in the Traffic Signs Manual.[3]

Diagram 11.10 Visibility to right and across circulatory area



Transverse strips on roundabout approach

11.5 Capacity issues and computer models

In capacity terms, new roundabouts are designed to cater for flows in a 'design year' some 10 or 15 years in the future (taking into account traffic flow growth). However as traffic increases it is increasing difficult to accommodate this, especially in urban areas. Often the best that can be achieved at a particular site is to optimise the capacity of the junction within the constraints imposed by available land, services diversion costs and the available budget. The latter approach can lead to pressure to compromise some of the geometric layout features essential for safe operation of the roundabout (such as entry path deflection and entry angle). Such pressures should be resisted and alternatives such as the use of overrun areas and alternative forms of junction should be considered.

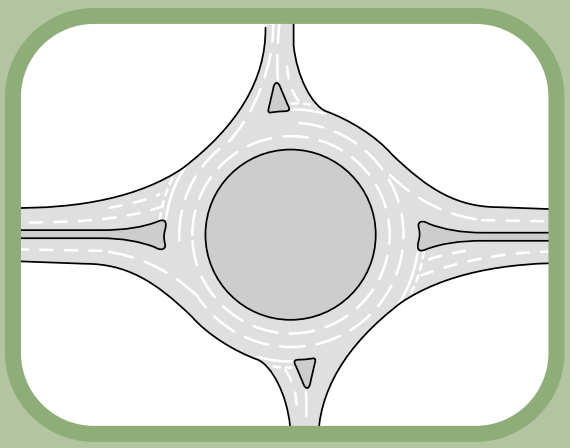
Capacity calculations for semi-rural roundabouts are undertaken using computer software packages. The two main software packages in use are ARCADY and RODEL. These operate in a similar way but ARCADY is more commonly used and can produce predictions of accidents (based on UK experience). Both of these packages use a number of geometric parameters to enable roundabout designs to be modelled against a range of predicted traffic flows to ensure that it will operate satisfactorily. The models output information on queues, delays and capacity (RFC – Ratio of Flow to Capacity) for each arm of the junction. Ideally the RFC value for each arm should be less than 0.85 to produce an efficient design. One or more of the following can achieve improvements in capacity:

- widening the approaches
- increasing the length over which the widening is developed (flare length)
- increasing the size of the roundabout (ICD)

The computer models allow these effects to be tested to optimise the capacity of a particular design.

As with all computer models, care is needed with the interpretation of the results and it is necessary to check that the overall design still produces safe and acceptable operating

Diagram 11.11 Example of circulatory markings on roundabout



Roundabout without adequate entry deflection

characteristics. It is not acceptable to provide a roundabout that has adequate capacity but does not have safe operating characteristics in order to minimise cost.

Unfortunately, neither of these computer models consider the needs of vulnerable road users in the design process and any outputs of accident rates should be checked against local control data to ensure that they are applicable to local conditions.

11.6 Safety issues

Well-designed roundabouts have a good safety record.[4] However, there can be financial and site constraint pressures to provide layouts that may not perform as safely.

The most common accident types at roundabouts involve either a vehicle entering the roundabout into the path of a circulating vehicle or nose to tail shunts on the approaches. Many accidents are related to the speed at which traffic enters a roundabout. High entry speeds lead to high circulating speeds. The most significant design factors, which lead to this, are:

- insufficient entry deflection (Chapter 11.3)
- shallow entry angles (Chapter 11.3)
- inadequate advance visibility of the roundabout and to the right at roundabout yield markings (Chapter 11.3)
- excessive visibility on approaches (Chapter 11.3)
- excessive approach speed (Chapter 11.4)

Other safety problems at roundabouts include:

- high proportion of accidents involving two-wheeled vehicles (around 50% in the UK), leading to consideration of continental style design as a more acceptable solution.
- inadequate surface skidding resistance on the circulatory and approaches – these areas are subject to high braking and turning forces and require the provision of a surface with a high skidding resistance
- large roundabouts (ICDs greater than 80m) with five or more arms have significantly more accidents than smaller ones.
- on some roundabouts sharp changes in crossfall (often combined with tight entry or exit radii) can lead to trucks shedding loads or overturning.

Two-wheeled vehicles are vulnerable and have a very poor injury accident record at all types of roundabouts. The reduction of entry speeds at roundabouts can help to improve safety but consideration should be given to the provision of specific facilities for cyclists at roundabouts. Advice on this is given in 'Provision of Cycle Facilities, National Manual for Urban Areas[5]'.

Roundabouts should not be used in areas of high pedestrian movement unless specific controlled crossing facilities are provided on the approaches. Where crossing facilities cannot be justified, splitter islands should be provided on approaches to assist pedestrian crossing movements. Care needs to be taken that any signs on these islands do not block the visibility or desire lines of pedestrians.

Landscaping can help make a feature of roundabouts and integrate them into the surrounding urban scene, provided that essential visibility elements, traffic signs and other features are not obstructed.

Roundabouts are excellent gateways and are a useful map reference particularly if designed as recognisable urban landmarks.

Road safety audits should be carried out on the designs of all new roundabouts and roundabouts that are being improved significantly.

11.7 References

1. TD16/93 – Geometric Design of Roundabouts and NRA addendum – NRA addendum available from NRA, St Martin's House, Waterloo Road, Dublin 4, Ireland. Tel 01 660 2511 Fax 01 668 0009. TD16/93 available from The Stationery Office, Telephone orders +44 870 600 5522, Fax orders +44 870 600 5533

2. TA78/97 – Road markings at roundabouts – Highways Agency (UK), Available as part of Design Manual for Roads and Bridges, Volume 6 from The Stationery Office, PO Box 276, London SW8 5DT. Tel +44 870 600 5522, Fax +44 870 600 5533

3. Traffic Signs Manual – Department of the Environment, (Available from Government Publications Sale Office, Sun Alliance House, Molesworth Street, Dublin 2, or by mail order from Government Publications, Postal Trade Section, 51 St. Stephen's Green, Dublin 2, Tel 01 6476879; Fax 01 6476843)

4. Laboratory Report 1120, TRRL-1984, Accidents at 4-arm roundabouts – UK. (Details of prices from the Transport Research Laboratory, Crowthorne, Berkshire RG11 6AU, Tel +44 1344 770783/84)

5. Provision of Cycle Facilities, National Manual for Urban Areas – DTO/DoELG. (Available from Government Publications Sale Office, Sun Alliance House, Molesworth Street, Dublin 2, or by mail order from Government Publications, Postal Trade Section, 51 St. Stephen's Green, Dublin 2, Tel 01 6476879; Fax 01 6476843)

6. State of the Art Review, The design of Roundabouts – Mike Brown, TRL – UK. (Details of prices from the Transport Research Laboratory, Crowthorne, Berkshire RG11 6AU, Tel +44 1344 770783/84)