
VOLUME 6 ROAD GEOMETRY

SECTION 2 JUNCTIONS

PART 3

TA 78/97

**DESIGN OF ROAD MARKINGS AT
ROUNDBOUTS**

SUMMARY

This document gives advice for the design of road markings at roundabouts to improve traffic operation and safety.

INSTRUCTIONS FOR USE

This is a new document to be inserted into the Manual.

1. Insert TA78/97 into Volume 6 Section 2.
2. Archive this sheet as appropriate.

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THE HIGHWAYS AGENCY



THE SCOTTISH OFFICE DEVELOPMENT DEPARTMENT



**THE WELSH OFFICE
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**THE DEPARTMENT OF THE ENVIRONMENT FOR
NORTHERN IRELAND**

Design of road markings at roundabouts

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REGISTRATION OF AMENDMENTS

Amend No	Page No	Signature & Date of incorporation of amendments	Amend No	Page No	Signature & Date of incorporation of amendments

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1. INTRODUCTION

General

1.1 Departmental Standard TD 16/93 (DMRB 6.2.3) sets out the Overseeing Organisations' design standards and methodology for the geometric design of roundabouts.

1.2 A well designed roundabout to TD 16/93, with reasonably balanced traffic movements, will operate effectively without additional markings on the approaches or the circulatory carriageway. On "in service" roundabouts where existing traffic flow patterns have changed since design, the use of road markings can improve throughput at high traffic levels, help cater for particularly high turning movements, assist with smooth flow at roundabouts with irregular geometry, and can improve safety.

1.3 A recent study by the Highways Agency has shown that increases of between 6% and 18% in throughput can be achieved on critical arms during peak periods, together with a reduction in conflict between vehicles on the approach to, and the passage through, the junction.

Scope

1.4 This Advice Note provides guidance on the use and design of road markings on the approaches to, and the circulatory carriageway of roundabouts, to enhance traffic operation and safety. It is intended to be read as an addendum to TD 16/93. The advice is primarily for inservice roundabouts, but may also be applicable to new roundabouts in constrained locations if the application of markings is beneficial to operation.

1.5 The Advice Note sets out the general principles for determining whether to use road markings at roundabouts. Advice is also given on road marking options and the design principles to be followed when preparing markings layouts.

1.6 This document does not cover the provision of cycle lanes at roundabouts. Advice on these can be found in Local Transport Notes.

1.7 Any road marking scheme developed by applying the principles offered within this document should only use prescribed road markings. Their use must be in the manner and in accordance with the provisions of the Traffic Signs Regulations and General Directions.

Implementation

1.8 This Advice Note should be used forthwith on all schemes for the management, improvement and maintenance of trunk roads, currently being prepared provided that, in the opinion of the Overseeing Organisation, this would not result in significant additional expense or delay progress. Design Organisations should confirm its application to particular schemes with the Overseeing Organisation.

2. GENERAL PRINCIPLES

2.1 Road markings may be used to channelise traffic and, where required, indicate a particular lane use on in service roundabouts. The use of road markings may prove to be beneficial operationally by increasing the utilisation of the available road space.

2.2 There are two main areas in the operation of in service roundabouts that may lead a Design Organisation to consider the use of road markings. These areas are safety and throughput.

2.3 In designing a set of road markings to address operational difficulties of either safety or throughput, Design Organisations should be aware that both factors are interlinked, and that concentrating a design on one factor may have an effect on the other. The design, therefore, must be sensitive to the way in which the roundabout is used by all road users.

Safety

2.4 The use of road markings may be beneficial in reducing three types of accident at roundabouts:-

- a) side-to-side collisions on the circulatory carriageway,
- b) drivers being forced onto the central island; and,
- c) collisions between entering and circulating vehicles.

2.5 In each case, markings can assist in guiding drivers on the approach and around the circulatory carriageway. This in turn reduces weaving on the circulatory carriageway and can reduce the uncertainty experienced by a driver at the give way line as to the path and destination of circulating vehicles, particularly at larger roundabouts.

Throughput

2.6 Some improvements in throughput can accrue at congested roundabouts with road markings since gap acceptance is slightly improved.

2.7 Approach and entry markings can enhance throughput if there is an underuse of one or more entry lanes, since drivers may be encouraged to make full use of all of the entry lanes.

Specific Examples

2.8 The following paragraphs contain specific examples of design or operational difficulties which may give rise to safety and/or throughput concerns, and which may be alleviated by the use of road markings.

Irregular Geometry

2.9 If the geometry of the roundabout is irregular, it will be more difficult for drivers to use it efficiently and driver behaviour will be more difficult to anticipate. This can be a particular problem at roundabouts where entries and/or exits are very close, where deflection provided by the splitter islands is not tangential to the central island, where there is no easily identifiable straight ahead movement, or where the major flow is required to turn, such as at the end of town by-passes. These features can lead to increased conflicts between adjacent vehicles or imbalanced queues and underuse of entries, and are particularly noticeable where there is a high proportion of drivers unfamiliar with the area, such as on holiday routes.

2.10 Many of the problems at such junctions are caused by driver uncertainty. Approach markings and circulatory division lines and markings can reduce this uncertainty and provide drivers with positive guidance through the roundabout. Markings can assist in maximising the efficient use of the available road space, and reducing the likelihood of vehicular conflicts.

Uneven Approach Queuing

2.11 Uneven approach queuing on one or more arms is particularly noticeable where there is a very dominant movement in either the straight ahead or right turn directions. Drivers' natural behaviour and direction signing often lead drivers to align themselves in either the nearside/centre entry lane, or offside entry lane respectively. This occurs regardless of the absence of queues in other lanes. Dumbbell roundabouts can experience such operational difficulties.

2.12 In these circumstances, provided there is an exit with at least two lanes to cater for the dominant movement, more than one entry lane should be used and drivers encouraged to circulate two or more abreast. The use of road markings on the approaches as well as those on the circulatory carriageway will ensure that queues are more evenly balanced between approach lanes. This can increase the opportunity for vehicles making the dominant movement to find gaps and enter the roundabout.

Wide Circulatory Carriageways

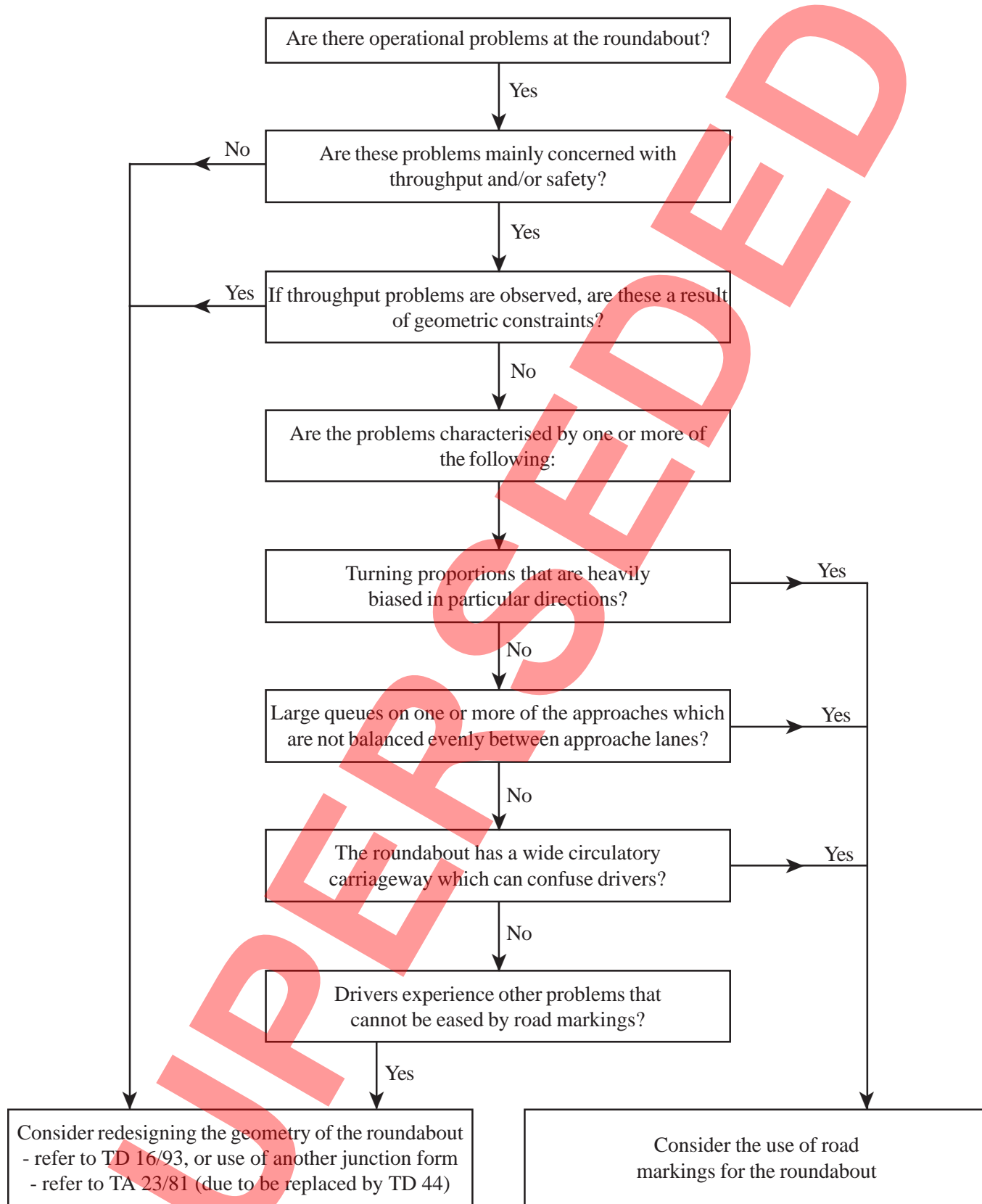
2.13 Drivers may become confused at roundabouts where the circulatory carriageway is wide and there is no guidance on the path they should take. In many cases, drivers will take the most direct path through the junction, which may bring them into conflict with other drivers on the roundabout. Markings can reduce confusion on wide circulatory carriageways, and provide drivers with well defined paths through the junction.

2.14 On very large roundabouts, particularly grade separated, drivers may take a path in the middle of the circulatory carriageway. In these cases, the use of road markings will achieve a more efficient use of the circulatory width available.

Application of Principles

2.15 A flow chart summarising these general principles is given at Fig 2/1. The chart shows the series of concerns or operational difficulties that may lead a Design Organisation to consider using road markings at a particular roundabout. It is not recommended that Design Organisations consider the use of road markings for new roundabouts, save for those with wide circulatory carriageways.

2.16 Some roundabouts may be subject to operational difficulties that cannot be alleviated by the use of road markings alone. In such circumstances, consideration should be given to geometric changes, see TD 16/93 (DMRB 6.2.3), or even a review of the type of junction provided, see TA 23/81 (DMRB 6.2).



Flow Chart Illustrating General Principles (para 2.15)
Figure 2/1

3. ROAD MARKING OPTIONS

3.1 The term road markings is used in this document principally to mean lane division line markings, but other markings such as lane indication arrows, route numbers and destinations may also be used to supplement lane markings. Markings can be applied on the approaches to roundabouts, at the entries and exits, and on the circulatory carriageway.

3.2 Since each roundabout is different in its geometric and operational characteristics, there is no standard layout for roundabout markings. Each site has to be considered on its merits. There are four basic configurations of road markings that can be used on the circulatory carriageway at roundabouts.

3.3 Concentric. Concentric markings trace a complete path around the circulatory carriageway, dividing it into the number of circulating lanes that the carriageway width will allow (Fig 3/1).

3.4 Partial Concentric. Partial concentric markings vary from concentric in that their continuity around the circulatory carriageway is broken, usually adjacent to the entries and/or exits of the roundabout (Fig 3/2).

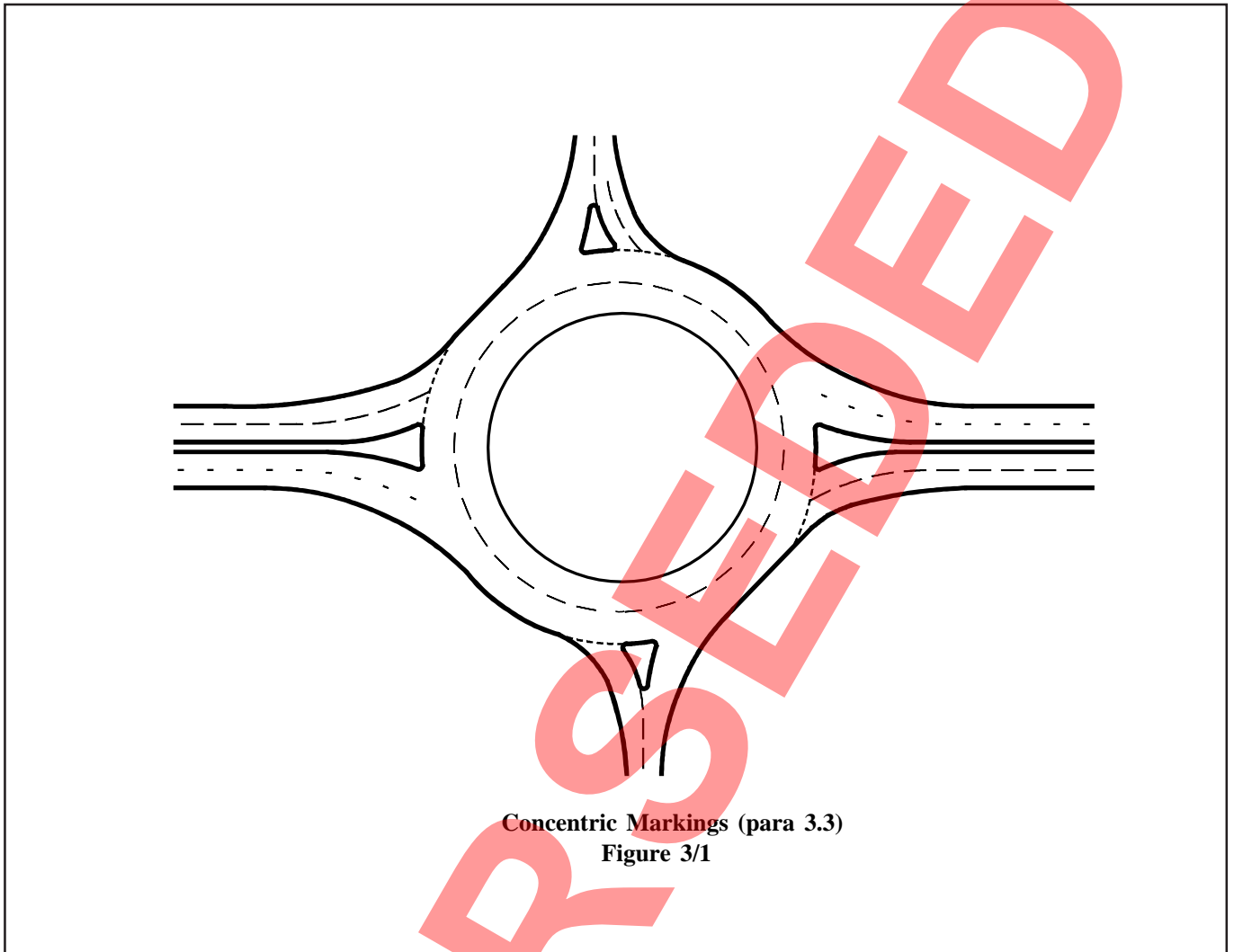
3.5 Concentric-Spiral. This type of marking is a hybrid. The purpose is to direct off the outermost circulating lane or lanes, where the exit width allows, by running the circulatory marking smoothly into the existing road markings on the exit concerned (Fig 3/3).

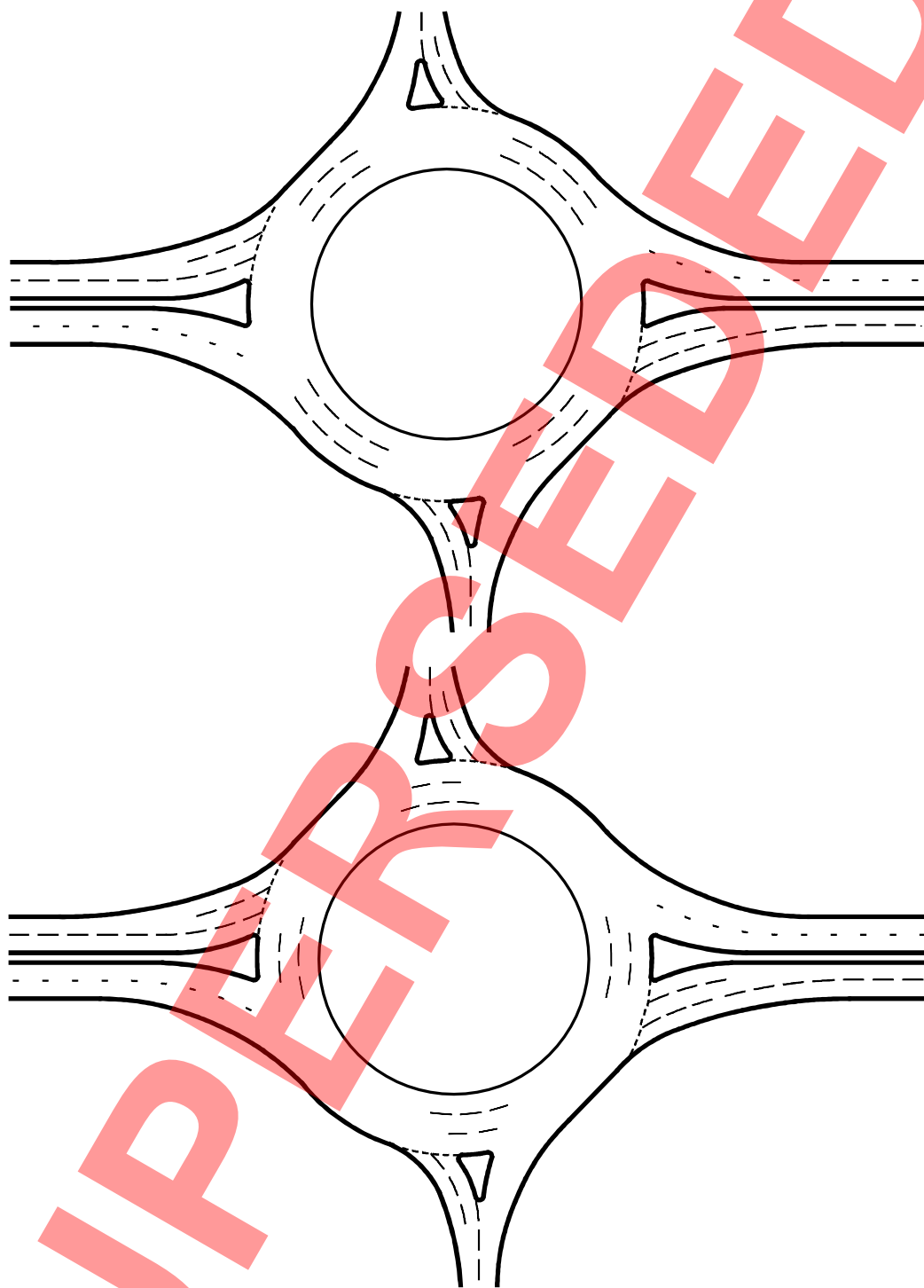
3.6 Spiral. A spiral marking system involves a series of lane gains and lane drops around the circulatory carriageway so that drivers enter in the lane appropriate for their desired exit, and follow the lane around the roundabout to be led off at that exit (Fig 3/4). The width of a particular exit will determine how many circulating lanes lead off the roundabout.

3.7 The spiral markings may be developed from the central island by means of line markings, or by hatch markings until a full lane width is available. Line markings are appropriate on normal roundabouts, but where the inscribed circle and central island are small and/or the number of arms is high, the first two or three markings leading to the full lane width may be omitted. Hatch markings are appropriate on larger diameter normal roundabouts or grade separated roundabouts where the number of circulating lanes is to be varied to aid general operation.

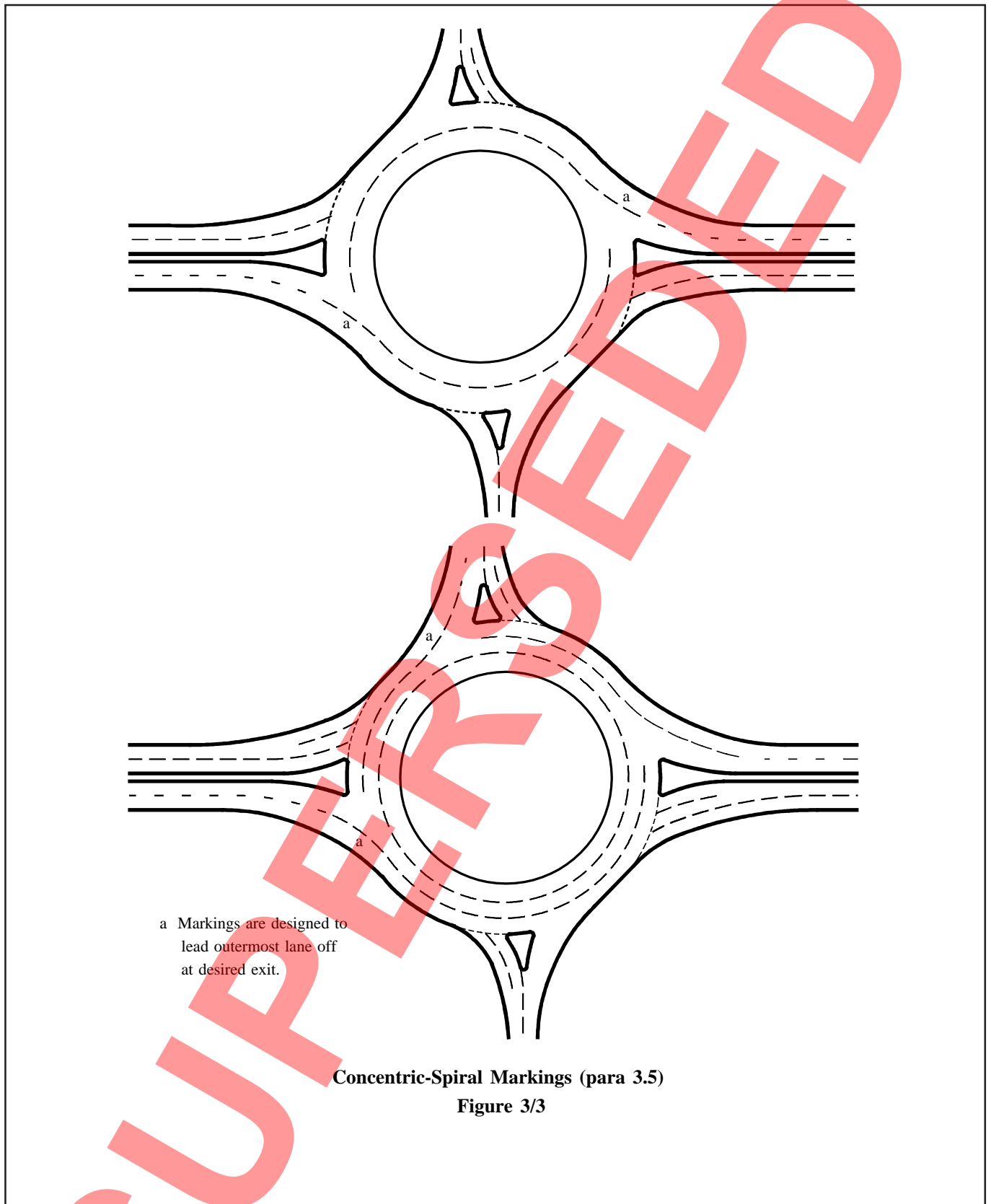
3.8 The markings may also be broken adjacent to the roundabout entries so that drivers entering the roundabout are not required to cross the markings.

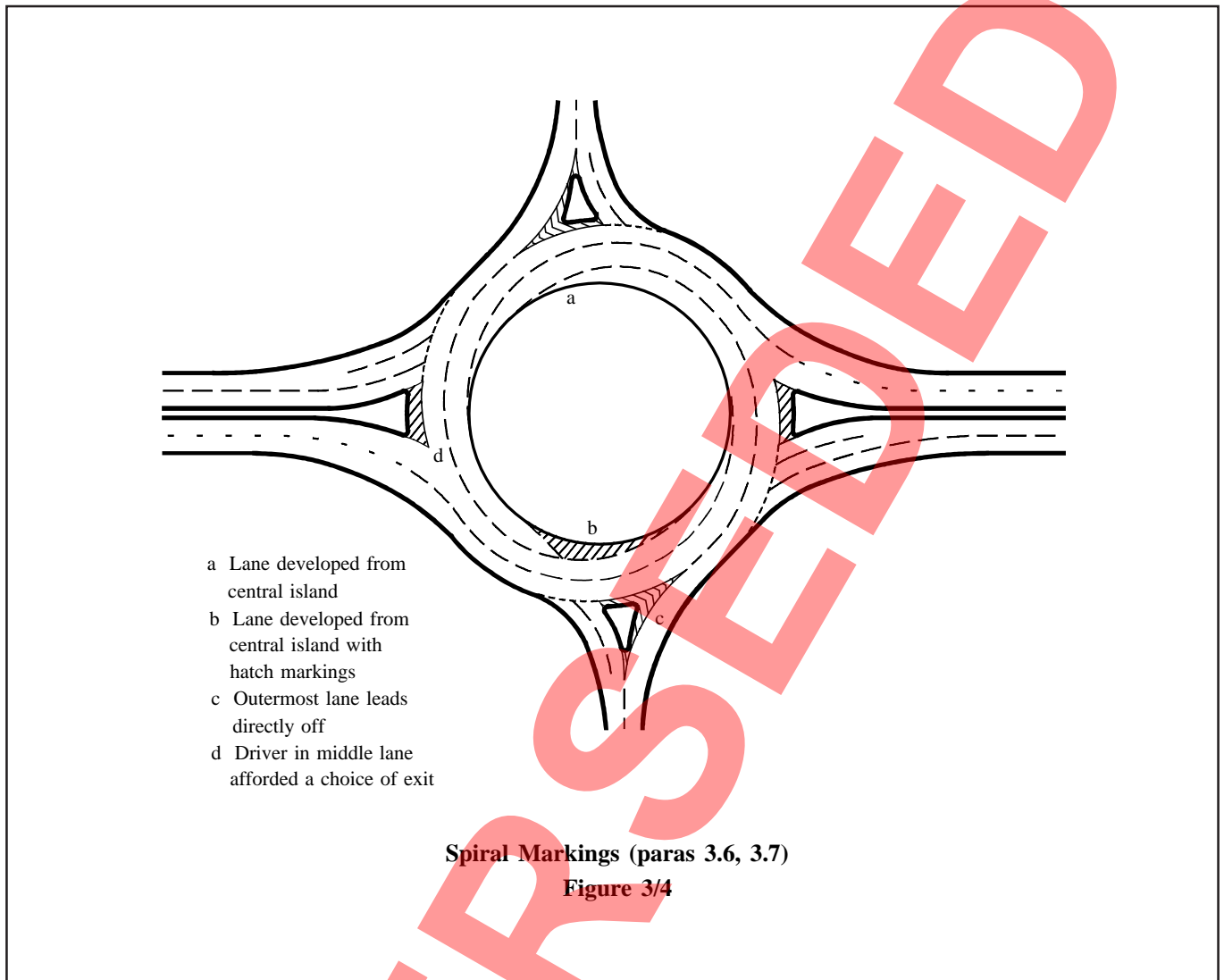
3.9 This is not intended to be an exhaustive list of the types of markings available. Other configurations may be developed using a combination of the main elements of those described above. The choice of which type to use, and any variations, will depend upon the identified operational difficulties at each location.





Partial Concentric Markings (para 3.4)
Figure 3/2





4. DESIGN PRINCIPLES

General

4.1 The design principles for the geometry of roundabouts are set out in TD 16/93 (DMRB 6.2.3). This chapter outlines the main features of the design of road markings at roundabouts which a Design Organisation should consider. Many of the features are dealt with separately, but Design Organisations should bear in mind that the features are closely related and that the design of road markings at roundabouts is an iterative process, as illustrated by the flow chart in Fig 4/1.

Basic Data

4.2 The design of road markings, although closely related to one of the four basic configurations, is site specific. Therefore, it is important for Design Organisations to have a sound understanding of the operation of the roundabout from the outset of the layout design process. In assembling the basic data from which to work, Design Organisations should consider the following:

- a) Visual observations of the operation of the roundabout under the various traffic conditions. Such observations can provide Design Organisations with an indication of driver behaviour, vehicle types and turning proportions, the use of approach and entry lanes, gap acceptance at entries, the use of the circulatory carriageway and any conflict areas. From the observations it will be possible to determine any traffic data collection requirements. High mounted video cameras have been found to be particularly useful in providing a permanent record of junction operational characteristics as well as a record of traffic data.
- b) Vehicle turning counts classified by vehicle type, for a suitable length of time to give a clear representation of the roundabout operation during the periods of heaviest traffic demands. The periods over which counts are required will be determined from the visual observations. A minimum count duration of two hours will be required to determine the traffic profile before, during and after each "peak" situation. Under congested conditions the upstream demand flows should also be determined.

- c) Queue length surveys. If congestion at some time during the day is evident, then Design Organisations should obtain queue length observations for the congested period to determine both the length and distribution across entry and approach lanes.
- d) Accident data indicating the type, frequency and location of accidents over at least the preceding three years.

Application of Markings

4.3 One of the most effective means of increasing the throughput at a roundabout is to ensure the efficient use of the entries. Entry use can be influenced by the approaches to the roundabout and the use of the circulatory carriageway after entering.

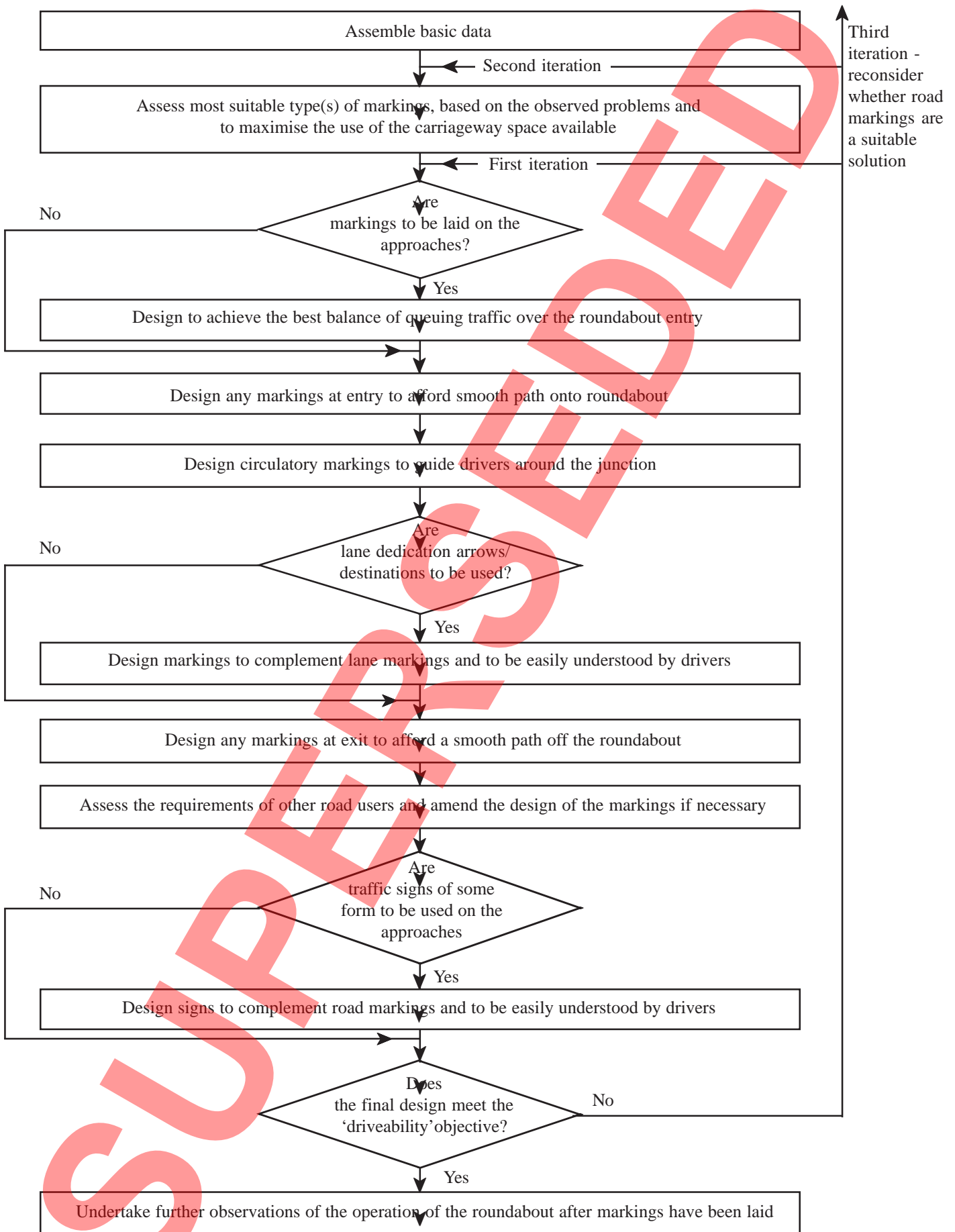
Entries

4.4 The design of entry markings should be undertaken with the aim of leading traffic onto the circulatory carriageway in as smooth and efficient means possible. Drivers should not be expected to undertake unduly sharp or unnatural manoeuvres on entering the junction, as this may lead to some drivers disregarding the markings and increasing vehicular conflict.

4.5 If lane direction markings have been, or are to be, used on the approaches of a particular arm, then the direction markings within the entry lanes should be an extension of those markings in a logical and consistent manner, using the same designation system as those upstream (Figs 4/2a and 4/2b). If no approach markings have been employed, then the entry markings should be designed to give an even balance of any queuing traffic over the entry lanes whilst affording a smooth path onto the roundabout. Arrow markings and route destinations can be particularly beneficial for larger, more complex roundabouts, especially those that have more than four entry/exit arms.

Approaches

4.6 Road markings on the approaches to roundabouts can further complement entry markings. Approach lane markings should be laid a distance back from the "Give Way" line sufficient for them not to be obscured by queuing vehicles, and in a manner which best balances the traffic between approach lanes.



Flow Chart Illustrating Design Principles (para 4.1)
Figure 4/1

4.7 If the geometry of the roundabout lends itself to the safe identification of the exits, then lane direction arrows may be used and / or the use of route numbers, or destinations.

4.8 Approach and entry markings may be used with or without markings on the circulatory carriageway.

Circulatory Carriageway

4.9 The circulatory carriageway line markings should be designed to create smooth paths around the junction for all movements, avoiding any sharp turns, whilst maximising the use of the circulatory carriageway width wherever possible. The markings should provide a smooth link between any entry and exit markings to guide drivers safely around the junction.

4.10 Design Organisations should make an initial assessment of the most suitable type of marking to address the identified main problems. There are some elementary guidelines which assist in this choice.

4.11 Concentric markings are useful to encourage drivers to enter and circulate in two or more adjacent lanes. This increases the potential throughput in locations where this does not ordinarily occur.

4.12 Concentric markings which divide the carriageway into more than two lanes have limited use on wide circulatory carriageways since they have been found to encourage the “tramline” effect. In this case, a driver may remain in a particular lane until reaching the desired exit, and then deviate across other circulating movements in order to leave the roundabout. This behaviour can increase the potential for side-to-side vehicular conflict on the circulatory carriageway.

4.13 Partial concentric markings can assist on wide circulatory carriageways by presenting drivers with clearly defined lanes within which to pass around the junction, and reduce the likelihood of drivers in the offside entry lane being forced towards the central island. The breaks in markings continuity allow vehicles to change lanes in advance of exits.

4.14 At very large roundabouts, Design Organisations should take care to ensure that continuity between successive partial concentric markings and the number of circulating lanes is maintained in order to minimise driver confusion.

4.15 Concentric-spiral markings are useful in reducing conflicts between vehicles at the exits, where more than one exit lane is provided. This type of marking can be used with any number of circulating lanes.

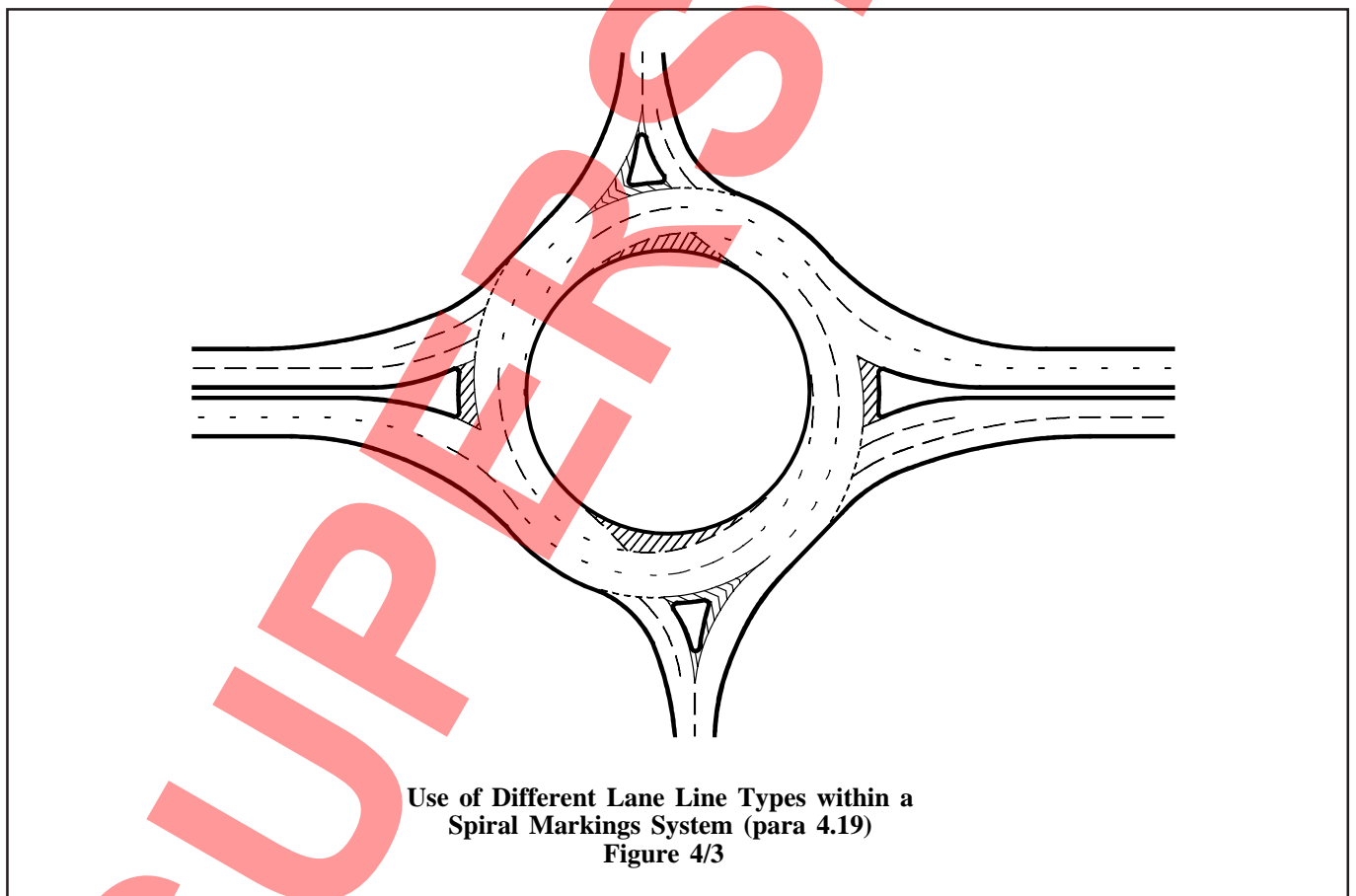
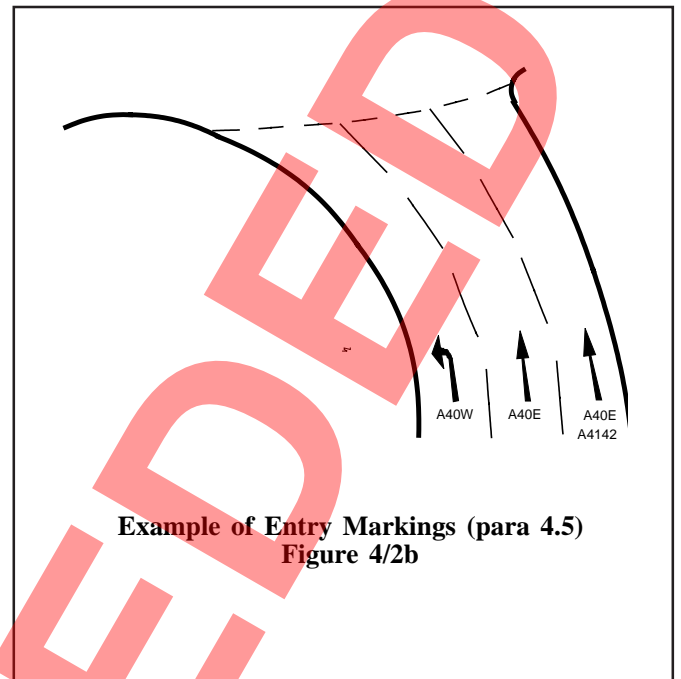
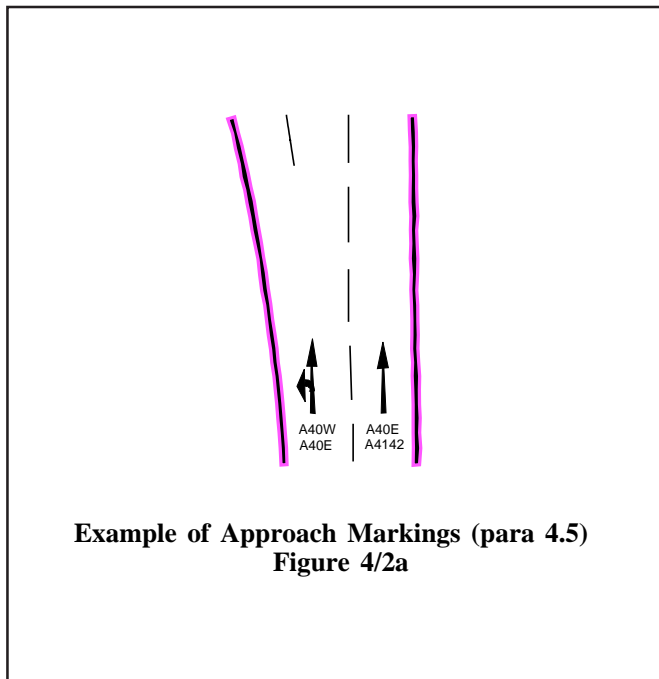
4.16 Spiral markings are more appropriate on large roundabouts where they can be used to guide drivers around the roundabout to their desired exit, whilst maximising the use of the circulating space and reducing potential conflict between adjacent vehicles. The markings can also cater for heavily biased turning proportions, since the circulatory width may be divided according to traffic demand.

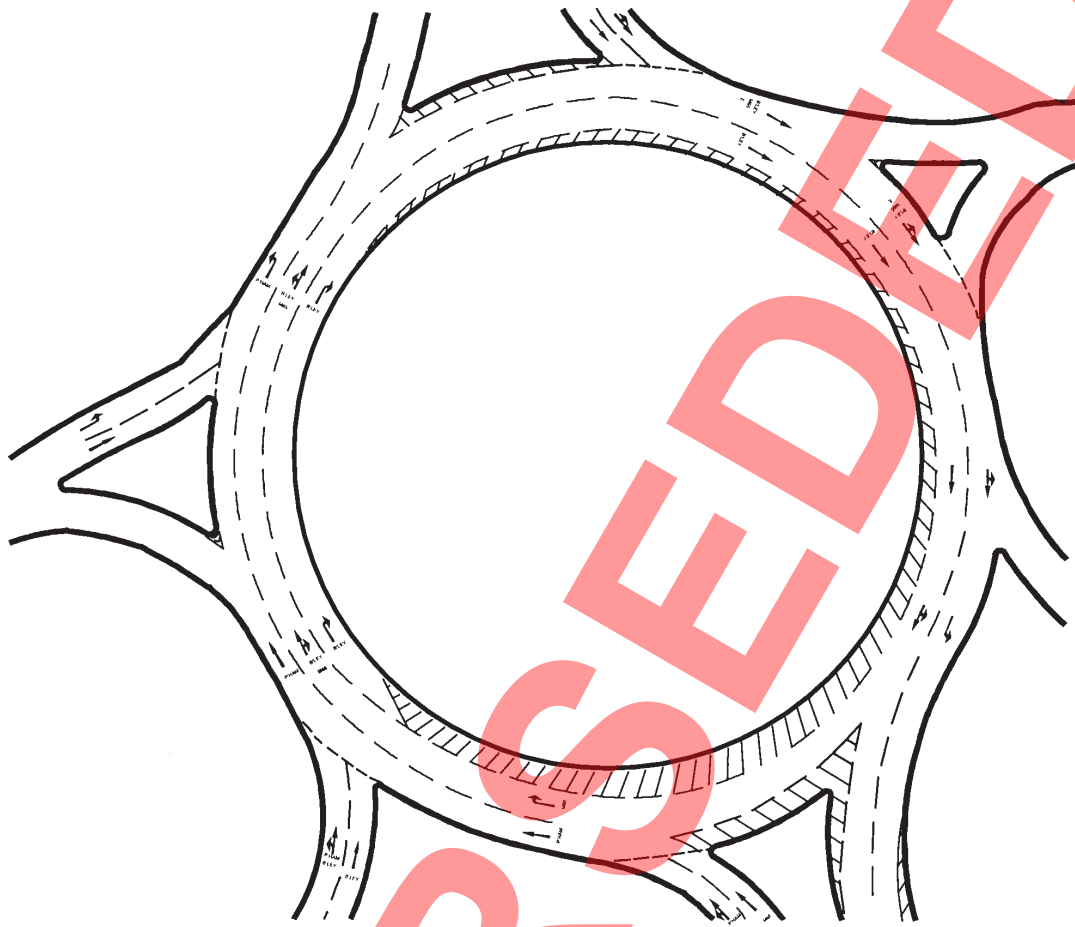
4.17 Their use should only be considered where the circulatory carriageway has sufficient width to cater for two or more lanes of traffic. Where the size and shape of the roundabout is such that sharp manoeuvres would be required between successive entries and exits when following the lanes, spiral markings may not be appropriate.

4.18 U-turning vehicles are required to change lanes with spiral markings. Where there is a significant proportion of U-turning vehicles, hatching at the commencement of the spiral markings may be omitted.

4.19 The circulatory markings should be positioned so that the circulating lanes are visible from each entry to offer drivers a clearly defined position on the circulatory carriageway to which to direct their vehicle, thereby reducing potential conflict. Lane markings placed across or opposite entries are liable to become worn in a short time due to the traffic crossing them. In such circumstances, consideration may be given to markings less susceptible to wear (Fig 4/3).

4.20 Lane direction arrows may be used on the circulatory carriageway, to be visible to both entering and circulating drivers, although the driver’s perception of what is represented by “left”, “straight ahead” and “right” arrows is less clear when circulating. For this reason, “straight ahead” and “right” arrows may be used to denote lanes that continue to circulate (Fig 4/4). Lane direction arrows denoting a left turn immediately prior to an exit may prove beneficial to signify that a lane drop around the circulatory carriageway is approaching.





Use of Carriage Markings on Circulatory Carriageway (paras 4.20, 4.23)
Figure 4/4

4.21 The use of route numbers and/or destinations may also assist drivers' understanding, although Design Organisations should take care not to clutter the circulatory carriageway or make the markings unduly confusing, as may happen where destinations are seen to change between circulatory lanes.

Exits

4.22 Any exit markings associated with the concentric-spiral, or spiral type of markings should be designed so as to afford a smooth exit from the circulatory carriageway. In those instances where traffic is required to merge after exiting, sufficient distance should be provided from the exit to allow the merging manoeuvre to take place in a safe and efficient manner.

4.23 The use of lane direction arrows, route numbers and destinations at exits is not normally recommended since these markings may confuse drivers and clutter the circulatory carriageway. Such markings can be useful on larger roundabouts where a driver in a circulatory lane is presented with the choice of either exiting the roundabout, or continuing to circulate (Fig 4/4).

Other Road Users

4.24 Design Organisations should ensure that the requirements of other road users are not adversely affected by the proposed markings. This is particularly applicable if any at-grade crossings for cyclists or pedestrians are located close to the junction on any of the arms.

4.25 If significant numbers of other road users are present at the junction, and there is no specific provision for them, then consideration should be given to providing other forms of control by reference to TD 36/93 (DMRB 6.3.1); TA 57/87 (DMRB 6.3); TD 28/87, TA 52/87 (DMRB 8.5) and Local Transport Notes.

Traffic Signs and Road Markings

4.26 Lane destination signs using direction arrows, route numbers or destinations can be particularly effective as a supplement to markings on the approaches to a roundabout. Where traffic signs are used, lane and route identification on the signs should be consistent with the lane markings.

4.27 Details of traffic signs are given in the Traffic Signs Regulations and General Directions.

Compatibility of Design Elements

4.28 The junction design should be checked to ensure that the layout suits the traffic pattern under various traffic conditions which may differ by time of day, with the principal movements being afforded the easiest paths. Markings which do not follow natural vehicular paths tend to confuse drivers and may not achieve the expected improvements.

4.29 Design Organisations should aim to achieve the best balance between the design components in order that, overall, the junction works safely and efficiently. This is what is termed the "driveability" objective in design.

4.30 If the driveability objective is not satisfied then Design Organisations should first consider redesigning some of the component elements, and second, a reassessment of the type of markings used. If problems are still experienced in producing a satisfactory design, then Design Organisations may have to reconsider whether road markings are a suitable solution for the site concerned.

4.31 A short assessment of route consistency should also be undertaken if a series of adjacent roundabouts is under consideration. Although each design is site specific, which may lead to differing solutions, drivers may be confused if successive roundabouts along a short section of a route are marked differently, since each will require a different driving technique. Such situations may also lead to a change in the type of markings chosen at one or more of the roundabouts in the series.

Refinement of Markings

4.32 The initial layout of a set of road markings will have been designed following a series of operational observations at the roundabout without markings.

4.33 It is important to realise that a change in the operational layout of the junction may also change the driver behaviour at the modified junction. Therefore, Design Organisations should undertake further observations of driver behaviour, throughput, accidents and roundabout operation once the initial markings have been laid.

4.34 This process serves two purposes. First, it allows an estimate to be made of the effectiveness of the chosen design in mitigating the initial operational difficulties.

4.35 Second, it will allow Design Organisations to assess whether any change in driver behaviour requires a refinement to the original marking layout. Any amendments considered appropriate should then be undertaken and subsequently reviewed. Such a consideration emphasises the iterative nature of the design of road markings at roundabouts. Roundabout markings may need to be refined several times in response to changes in traffic patterns and driver behaviour to achieve the optimum arrangement.

SUPERSEDED

5. REFERENCES

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Volume 6 Road Geometry, Section 2 Junctions, Part 3, TD 16/93 (DMRB 6.2.3) Geometric Design of Roundabouts.

Volume 6 Road Geometry, Section 2 Junctions, TA 23/81 (DMRB 6.2) Determination of the Size of Roundabouts and Major/Minor Junctions. (Due to be replaced by TD 44).

Volume 6 Road Geometry, Section 3 Highway Features, Part 1, TD 36/93 (DMRB 6.3.1) Subways for Pedestrians and Pedal Cyclists. Layout and Dimensions.

Volume 6 Road Geometry, Section 3 Highway Features, TA 57/87 (DMRB 6.3) Roadside Features.

Design Manual for Roads and Bridges, Volume 8 Traffic Signs and Lighting, Section 5 Pedestrian Crossings, TD 28/87 (DMRB 8.5) Pedestrian Crossings: Pelican and Zebra Crossings.

Volume 8 Traffic Signs and Lighting, Section 5 Pedestrian Crossings, TA 52/87 (DMRB 8.5) Design Considerations for Pelican and Zebra Crossings.

2. Traffic Signs Regulations : Stationery Office Ltd

SI 1994 No 1519 - The Traffic Signs Regulations and General Directions 1994, HMSO.

3. Local Transport Notes : Stationery Office Ltd

Local Transport Note 1/86 Cyclists at Road Junctions and Crossings.

Local Transport Note 2/86 Shared Use by Cyclists and Pedestrians.

6. ENQUIRIES

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

Head of Roads Engineering and Environmental Division
The Highways Agency
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St Christopher House
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The Deputy Chief Engineer
The Scottish Office Development Department
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