

HIGHWAY DESIGN REPORT

Appendix 2

Proposed Design Principles for Modern Roundabouts



June 2000

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1 Introduction

1.1 Purpose

The purpose of this report is to:

- describe in short the general design and safety performance of modern roundabouts,
- present a proposal for design principles for modern roundabouts in Turkey.

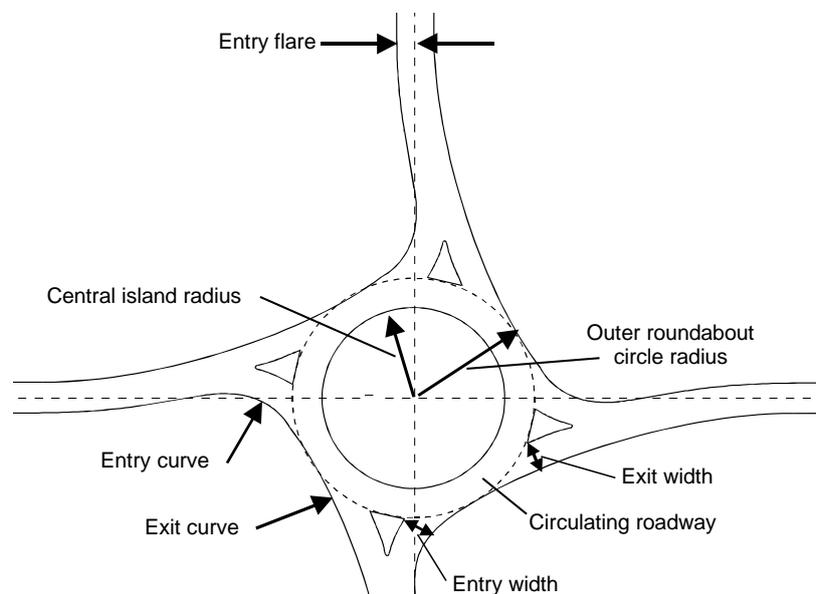
The report is focused on safety issues. In addition, there are a number of issues that must be included in future guidelines, for example, capacity and delay calculations and design of crossfall and drainage.

The objective is to incorporate modern roundabouts as a standard intersection type in new comprehensive Turkish design guidelines. To work out new design guidelines is however a long procedure. It is suggested, therefore, that the proposed design principles are adapted to Turkish conditions and used for the introduction of modern roundabouts in Turkey.

1.2 Terminology

To distinguish from “traffic circles” in general and the “rotaries” already used in Turkey, it is suggested that the term **modern roundabout** is used for roundabouts designed and controlled according to the principles in this report.

The main design elements of a modern roundabout are shown in the figure below.



Main design elements of a modern roundabout

1.3 General description of modern roundabouts

1.3.1 Characteristics

Compared to “traffic circles” in general the most important characteristics of modern roundabouts are the yield at entry and deflection of traffic.



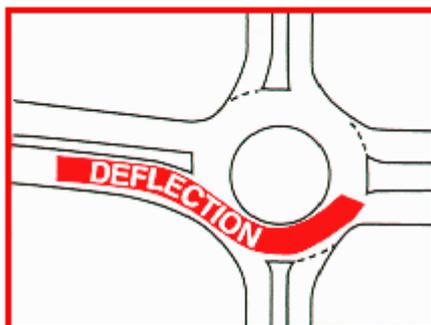
Yield-at-Entry

Modern Roundabout

Vehicles entering a roundabout on all approaches are required to yield to vehicles within the circulating roadway.

Traffic Circle

In traffic circles sometimes stop or signal control or give priority to entering vehicles is used.



Deflection

Modern Roundabout

The speed at which a vehicle is able to pass the roundabout is controlled by the location of the central island with respect to the alignment of the right entry curb. (This feature is responsible for the improved safety record of modern roundabouts).

Traffic Circle

Some large traffic circles provide straight paths for major movements or are designed for higher speeds within the circulating roadway.

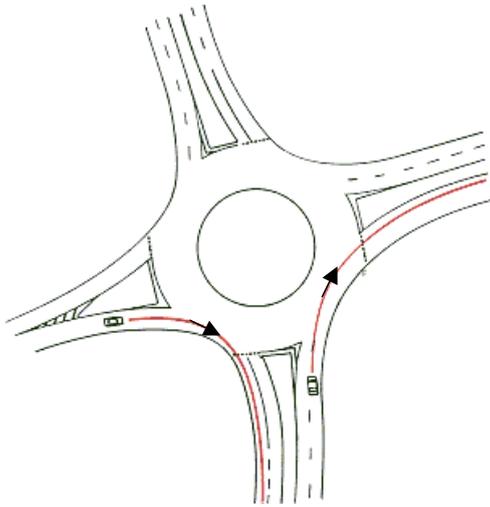
Some small traffic circles do not achieve adequate deflection for speed control because of the small central island diameter.

Some other important characteristics are:

- ❑ No stop or parking is allowed on the circulating roadway.
- ❑ No pedestrian activities take place on the central island.
- ❑ Traffic islands are required.

1.3.2 Operation

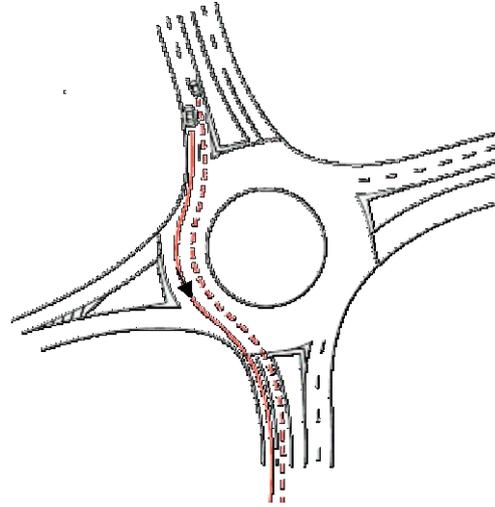
The basic operation of a modern roundabout is shown in the figures below.



Right turn

Approach on the right, stay on the right in the roundabout and leave on the right.

Display your right turn indicator on the approach and through the roundabout.

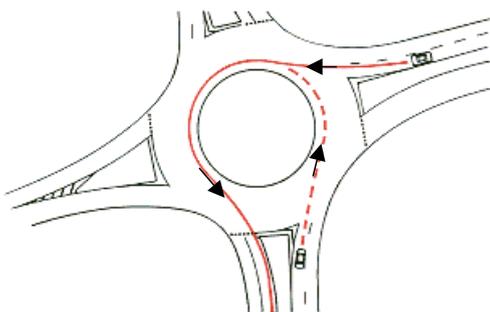


Straight ahead

Approach in the right lane and stay in that lane through the roundabout (solid line).

If the right lane is blocked due to dense traffic or road obstruction, then approach and continue through the roundabout in the left lane (broken line).

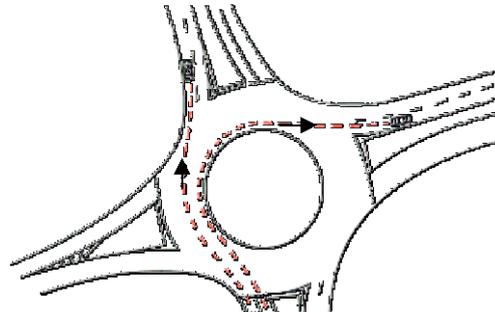
In both cases, display your right turn indicator just past the exit prior to the one you plan to take. (No signal is required on the approach to the roundabout).



Left turn and U-turn

Approach in the left lane, displaying your left turn indicator before entering the roundabout and maintain this signal.

Change to your right turn indicator just past the exit prior to the one you plan to take.



Exit positions

When exiting a roundabout, (whether travelling straight ahead or turning left) continue in the same lane you are using in the roundabout.

Always use the right turn indicator prior to exiting.

1.3.3 Advantages and disadvantages

Compared to priority controlled and signalized intersections, some of the **advantages** and **disadvantages** with roundabouts are pointed out in the tables below.

Advantages

| | Priority controlled intersections | Signalized intersections |
|------------------------------------|--|--|
| <u>Safety</u> | Reduced number of conflict points compared to uncontrolled intersection. Lower speeds reduce frequency and severity of both vehicle-vehicle and pedestrian-vehicle accidents. | |
| <u>Capacity</u> | Traffic <i>yields</i> rather than <i>stops</i> , often resulting in the acceptance of smaller time gaps. | Roundabouts should normally give higher capacity/lane due to the omission of lost time (red and yellow) at signalized intersections. |
| <u>Delay</u> | Overall delay will probably be less than for an equivalent volume signalized intersection. | |
| <u>Cost</u> | Accident costs are low due to the low number of accidents and severity. | |
| | Less right-of-way is generally required. | Maintenance costs are generally lower for roundabouts. |
| <u>Pedestrians/ bicyclists</u> | Low speeds reduce frequency and severity of pedestrian-vehicle accidents. | |

Disadvantages

| | Priority controlled intersections | Signalized intersections |
|------------------------------------|---|--|
| <u>Capacity</u> | | In a coordinated signalized network a signalized intersection can increase the overall capacity of the network. |
| <u>Delay</u> | | Signals may give shorter total delays in intersections with very skew traffic distribution (very high volumes on some entries and very low on others). |
| <u>Cost</u> | In some locations, roundabouts may require more road/street lighting. | |
| <u>Pedestrians/ bicyclists</u> | Longer paths increase travel distances for both pedestrians and bicyclists. Roundabouts may increase delay for pedestrians seeking time gaps to cross. | |
| | | There is no stopped phase with the safety and security of a signal. |

1.4 Safety performance

1.4.1 General

In a comprehensive study in Sweden, roundabouts with the speed limit 50 km/h were found to be even slightly safer than grade separated intersections. Both accident rate, injury rate and number of injured per accident were found to be influenced by:

- local speed limit in the roundabout,
- the general speed limit on the road compared to the local speed limit in the roundabout,
- the number of legs,
- the number of lanes in the roundabout.

The effect of the radius of the central island is uncertain, but it seems that roundabouts with radii between 10 and 25 meters have the lowest risk.

1.4.2 Accident and injury rates

Based on the Swedish study, prediction models have been developed for accident and injury rates. The models take into account the speed limit, number of legs and number of lanes in the roundabout. The models give the following rates per million incoming vehicles.

| Local speed limit | General speed limit | 4- leg | | 3- leg | |
|-------------------|---------------------|--------|--------|--------|--------|
| | | 1-lane | 2-lane | 1-lane | 2-lane |
| 50 km/h | Same as local | 0.113 | 0.133 | 0.109 | 0.127 |
| 70 km/h | "- | 0.208 | 0.244 | 0.200 | 0.234 |
| 50 km/h | Higher than local | 0.159 | 0.186 | 0.152 | 0.178 |
| 70 km/h | "- | 0.292 | 0.341 | 0.280 | 0.328 |

Accident rates (accidents/1 million vehicle) for Swedish roundabouts

| Local speed limit | General speed limit | 4- leg | | 3- leg | |
|-------------------|---------------------|--------|--------|--------|--------|
| | | 1-lane | 2-lane | 1-lane | 2-lane |
| 50 km/h | Same as local | 0.022 | 0.028 | 0.020 | 0.026 |
| 70 km/h | "- | 0.058 | 0.074 | 0.054 | 0.069 |
| 50 km/h | Higher than local | 0.037 | 0.048 | 0.035 | 0.045 |
| 70 km/h | "- | 0.099 | 0.128 | 0.093 | 0.120 |

Injury rates (injured/1 million vehicle) for Swedish roundabouts

Comments:

- The accident and injury rates are based on accident statistics from 182 roundabouts (mostly urban and sub-urban).
- Roundabouts on roads with a higher general speed limit than the local speed limit through the intersection have higher accident and injury rates. This can be interpreted as an effect of different driver behavior or expectations on rural and urban roads.
- It was found that the number of accidents is almost directly proportional to the measured speeds.
- The traffic volume was found not to influence the accident and injury rates. (In the study there were roundabouts with over 40 000 incoming vehicles/day).

2 Proposed design principles

2.1 The use of modern roundabouts

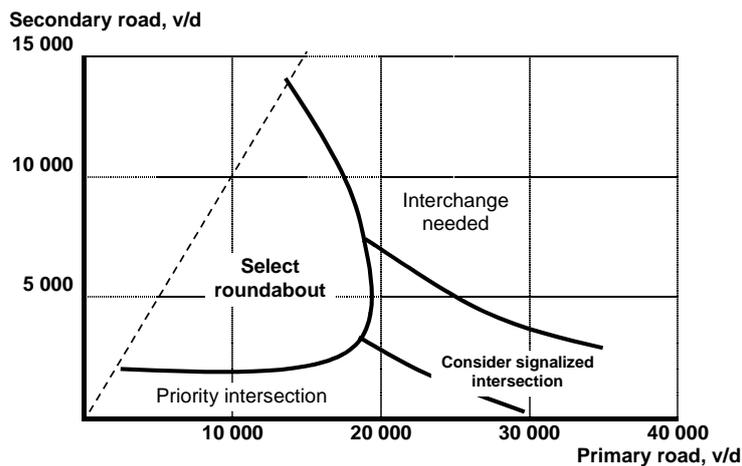
According to recent studies *roundabouts are safer than signalized intersections. Consequently, for safety reasons roundabouts should be selected if priority intersections cannot be used.*

Roundabouts generally can be accepted on all roads and in all locations where control intersections are accepted. The following table shows an example on a policy for the acceptance of roundabouts.

| Location | Road class | | |
|----------|-------------------|--------------------|-------------------------------|
| | State road type I | State road type II | Provincial road type I and II |
| Rural | - | Accepted | Accepted |
| Suburban | Accepted | Accepted | Accepted |
| Urban | Accepted | Accepted | Accepted |

Example of policy for the acceptance of roundabouts for different road classes in different locations

Roundabouts can be used for both high and low traffic volumes. The diagram below shows for which traffic volumes roundabouts can be used and generally are socio-economic favorable compared with signalized intersections.



Example of diagram showing when to select roundabout and when to consider signalized intersection

However, a roundabout may not be possible, for example, depending on the available space or the alignment of the connecting roads. In some planning conditions, a signalized intersection ought to be selected and for high traffic volumes a signalized intersection can be socio-economic favorable. (See Appendix 1 “Proposed Principles for Selection of Intersection Type”)

2.2 Basic design

2.2.1 Basic design principle

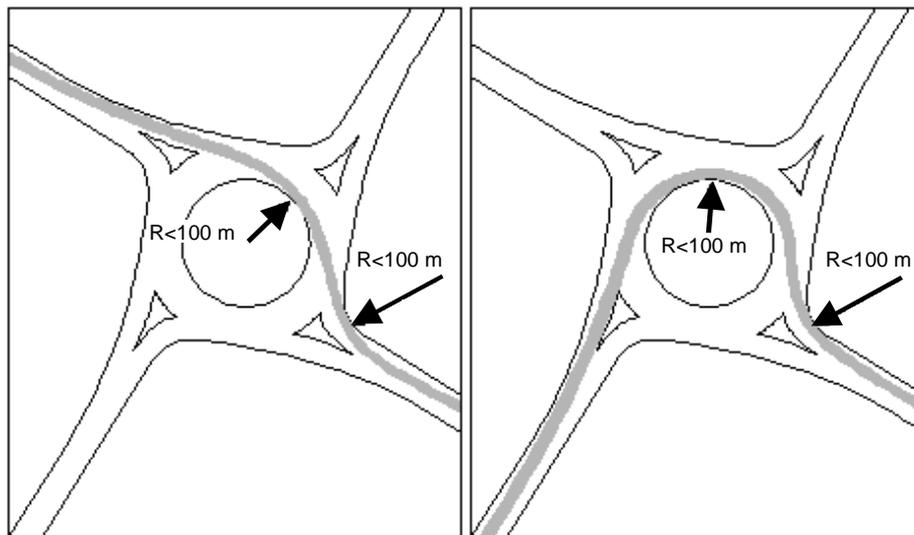
General requirements

The following features are generally considered necessary for a roundabout to perform safely and efficiently:

- ❑ They must be easily identified in the road system.
- ❑ The layout must be clearly visible and marked appropriately.
- ❑ The layout must encourage drivers to enter the intersection slowly and keep a low speed through the roundabout.
- ❑ Adequate sight distances must be provided at all entry points to enable the driver to enter the intersection and to observe the movements of pedestrians and bicyclists.
- ❑ Adequate lighting must be provided for safe operation at night.

Speed control

To keep the speed down, possible driving paths for a passenger car should not have radii more than 100 meters (Swedish guidelines) at the entry and through the roundabout.

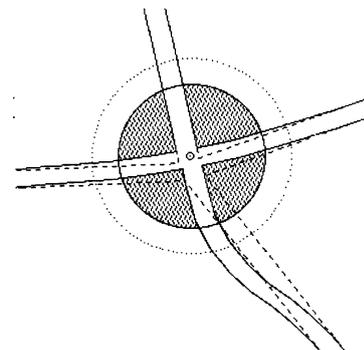


Maximum radii for possible passenger car driving paths

Alignment

To get a good overview of the roundabout the parts of the central island between the connecting roads should have approximately the same area.

The alignment of the roads should be adjusted to lower the speed and to improve the placement of the central island. The picture shows how the existing alignments (dotted lines) can be adjusted

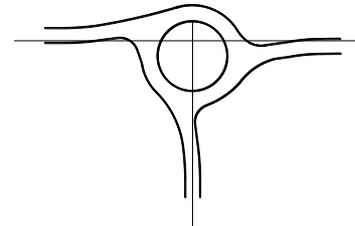


Number of legs

Normally roundabouts are applied at four leg intersections. Roundabouts can, however, also be used for three and five leg intersections.

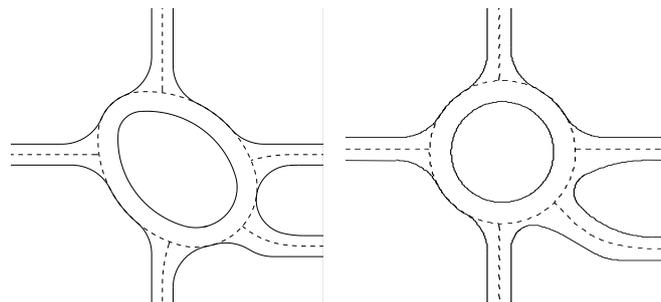
In three leg intersections, the angles between the legs can be adjusted by:

- ❑ displacement of the central island from the intersection point of the center lines of the connecting roads,
- ❑ deflection of the road alignments.



In five legs intersections, the needed space for the extra connection can be created by:

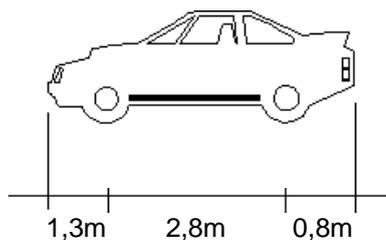
- ❑ making the central island egg shaped (left figure),
- ❑ increasing the radius of the central island to at least 20 m (right figure).



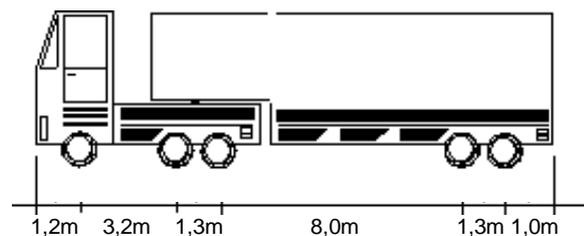
Design vehicles

A roundabout should be designed to give good accessibility for the type of vehicles which normally use the roundabout and to be able to pass with special vehicles. Some Swedish design vehicles are shown in the pictures below. (Note that the semi-trailer is rather similar to the semi-trailer C50 in the Turkish guidelines from 1965).

Example of normal design vehicles

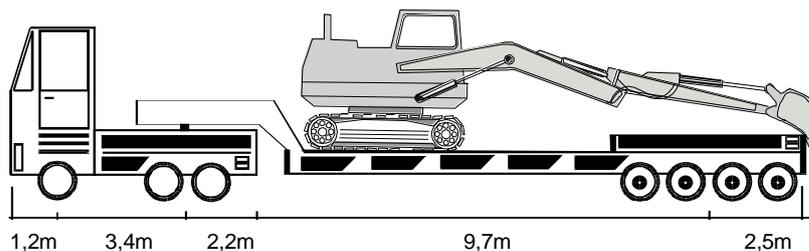


Passenger car, total length 5,0 m



Semi-trailer, total length 16,0 m

Example of a special design vehicle



Special trailer, total length 19,0 m

2.2.2 Basic design elements

The basic design elements, which determine the size of a roundabout, are:

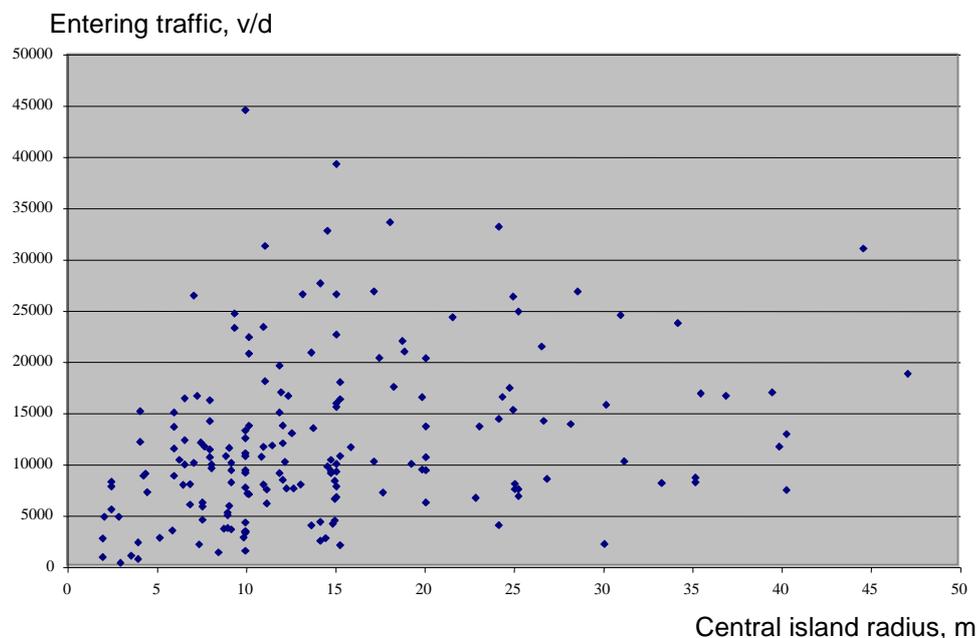
- the radius of the central island,
- the number of lanes,
- the width of the circulating roadway.

Radius of the central island

The central island radius for a *normal roundabout* should generally be between 10 and 25 meters. For two lanes roundabouts it should be at least 15 meters.

In some European countries *small roundabouts* with a central island radius between 2 and 10 meters and mini-roundabouts with central islands less than 2 meters are used in urban areas. These types are generally not suitable on rural roads and city passings since they cannot be used by all long vehicles. Consequently, these types are not suggested to be used on KGM roads.

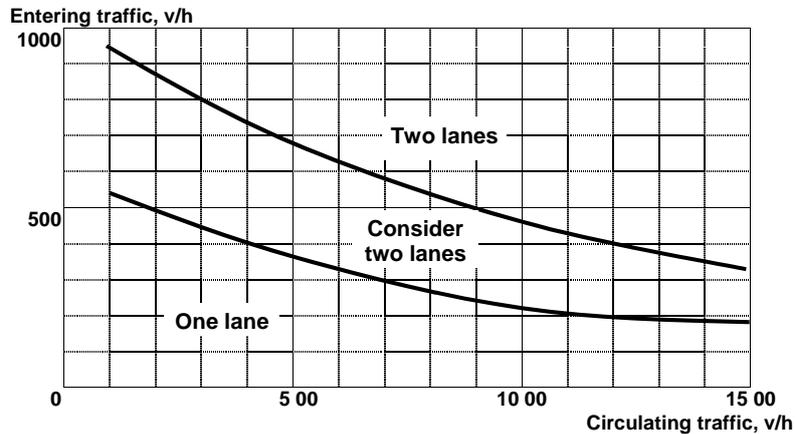
There is no simple relation between the central island radius and the (possible) capacity. The capacity is also depending on other design parameters, such as the width of the circulating roadway and the entry and exit angles and widths. This can be understood by the figure below which shows present traffic volumes (not capacity) for about 180 existing Swedish roundabouts. However, roundabout with bigger central islands have higher capacity because both the time gaps between vehicles and the lengths of the weaving sections are longer.



Existing traffic volumes in Swedish roundabouts with different central island radii.

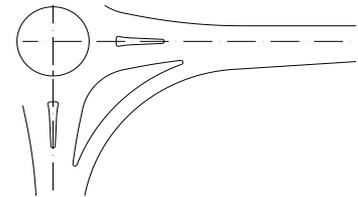
Number of lanes

If traffic volumes permit, the circulating roadway for safety reasons should only have one lane (See section 1.4.1). For higher traffic volumes, a 2-lane circulating roadway may be necessary. The diagram below shows the need for two lanes according to Swedish guidelines.



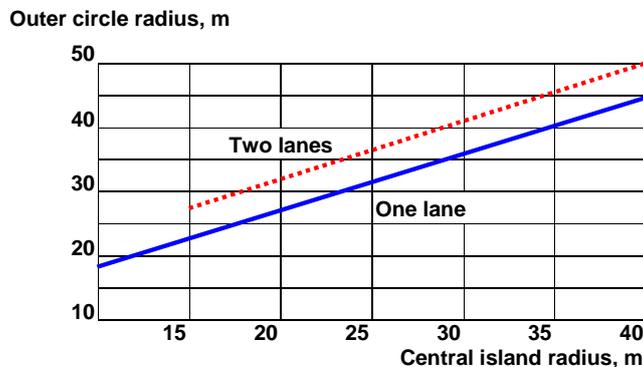
Number of lanes in the circulating roadway according to Swedish guidelines

The need for two lanes must be checked for each entry. If two lanes are necessary for one entry, the whole roundabout should be designed with two lanes. An alternative design to increase the capacity for one entry can be to use a separate right turn lane according to the figure.



Width of the circulating roadway

The width of the circulating roadway should be determined for the *design traffic situation* defined by the *design vehicles* using the roadway at the same time. A one lane roundabout, for example, should be designed for a semi-trailer and a two lane roundabout for a semi-trailer plus a passenger car. According to Swedish guidelines, the width of the circulating roadway is determined by use of the diagram below.



Width of the circulating roadway according to Swedish guidelines

2.3 Detailed design

From a safety point of view, the most important design elements are:

- entries,
- exits,
- pedestrian and bicycle crossings.

Normal design of these elements is shown in the examples in chapter 3.

2.3.1 Entries and exits

The entry should be designed to encourage the drivers to lower their speeds. This is done by choosing a suitable design of the entry curve and in some cases by a flare of the entry.

The exit should be designed to give smooth traffic flow.

Entry flare

The purpose of a flare of the entry is to reduce the speed. Consequently, it should be used where the speed on the connecting road is high before the roundabout, primarily in rural areas with a speed limit of 70 km/h or more.

The size of the flare is depending on the alignment of the entry and should normally be about one lane wide (3.75 m).

Entry curve

The entry curve should be designed like an entry curve in an ordinary priority intersection. The main radius should normally be around 15 meters.

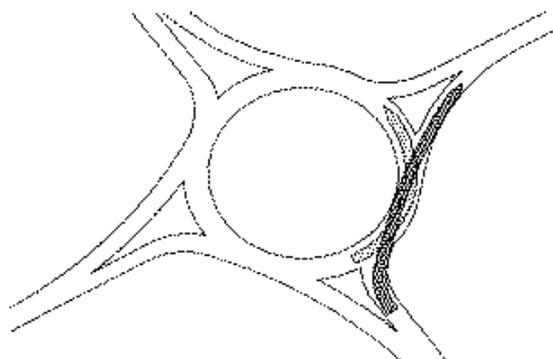
Exit curve

The main radius in the exit curve should be between 100 and 200 meters for a normal symmetric roundabout. If there is a pedestrian crossing, the radius should be smaller.

Combination of exit and entry curves

The alignment of the connecting roads can make it necessary to adjust the exit and entry curve radii. If larger radii than normal are used, it must be checked that there are no possible driving paths for passenger cars with a radius more than 100 meters according to the figure on page 8.

If possible, between the entry and the following exit, there should be no part of the outer roundabout circle. For roundabouts with big central island radii or long distances between entry and exit, this can be difficult to avoid. If possible, the alignment of the connecting roads should be adjusted.



Connection between entry and exit radii that should be avoided

Entry and exit widths

The entry width is depending on the entry radius. The following entry and exit widths are used in the Swedish guidelines for one and two lanes roundabouts respectively.

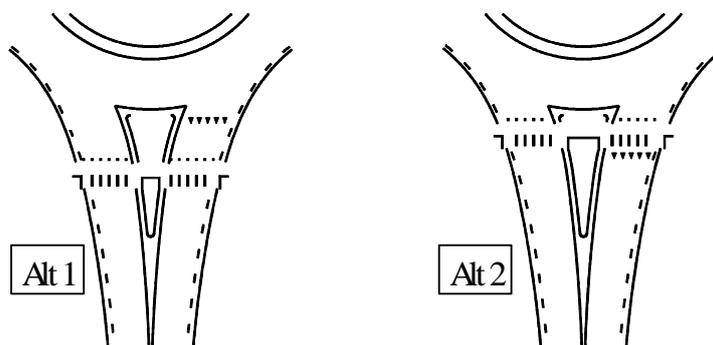
| Number of lanes | Design vehicle(s) | Entry widths | | Exit widths |
|-----------------|------------------------------|---------------------|---------------------|-------------------------|
| | | Entry radius < 15 m | Entry radius > 15 m | Exit radius 100 – 200 m |
| 1 | Semi-trailer | 6,5 m | 6,0 m | 5,5 m |
| 2 | Semi-trailer + passenger car | 10,0 m | 9,5 m | 7,0 m |

Example of entry and exit widths

For entries, the transition to normal lane width should be at least 30 meters long. For exits, the transition to normal lane width should be 75 - 100 meters long.

2.3.2 Pedestrian and bicycle crossings

Pedestrian/bicycle crossings are normally placed according to one of the two alternatives shown in the figure below.



Example of location of pedestrian/bicycle crossings

In Alt 1 (alternative 1) the yield line is placed after and in Alt 2 before the pedestrian/bicycle crossing. The advantages and disadvantages with the two alternatives are mainly the following:

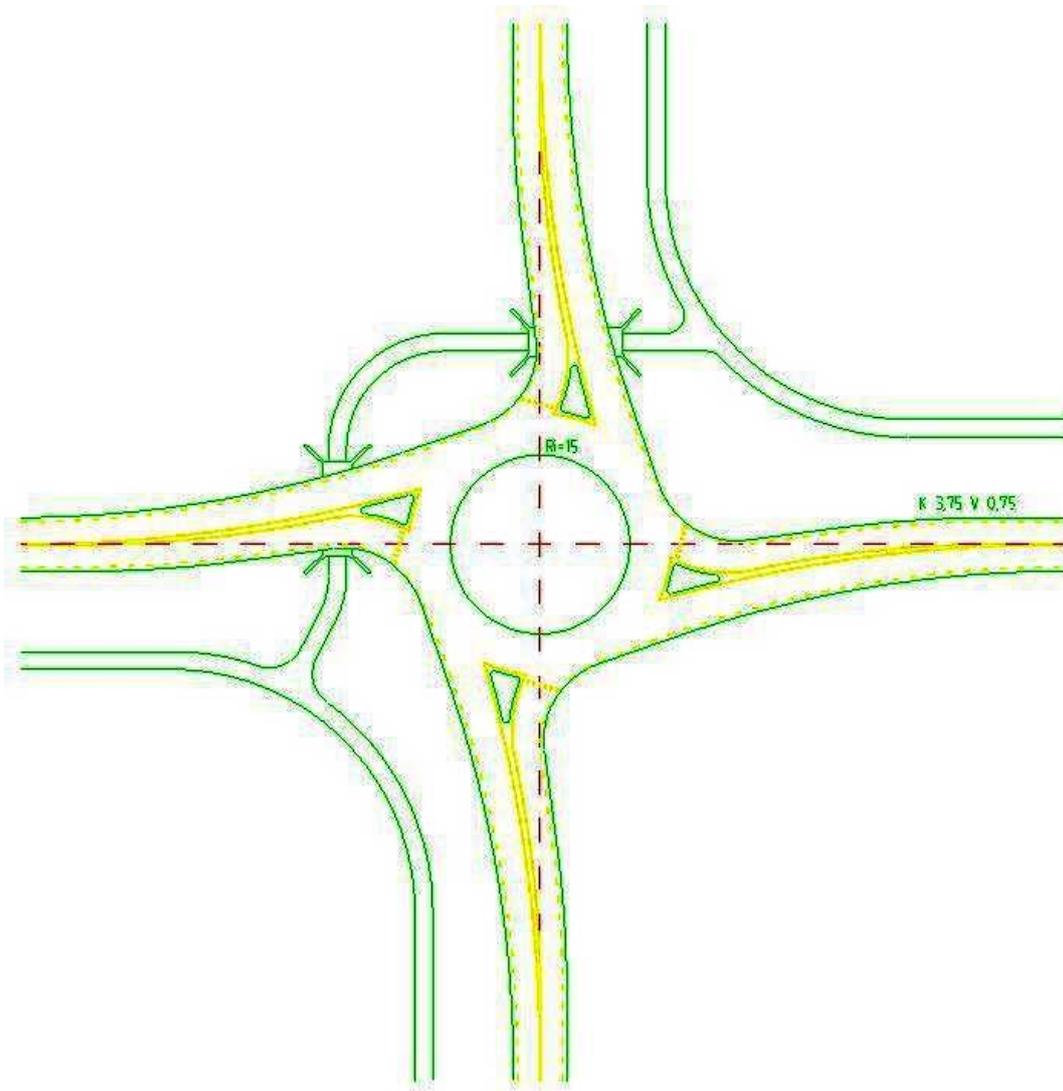
- In Alt 1, with a distance between the crossing and the yield line, vehicles can yield for the crossing and the roundabout separately. This is safer and easier to handle, especially at high traffic volumes.
- In Alt 2, with the yield line closer to the roundabout, the interaction between drivers in entering and circulating vehicles is easier.

3 Examples

The following examples are a few of the simplified standard drawings in the Swedish guidelines.

3.1 One lane rural roundabout

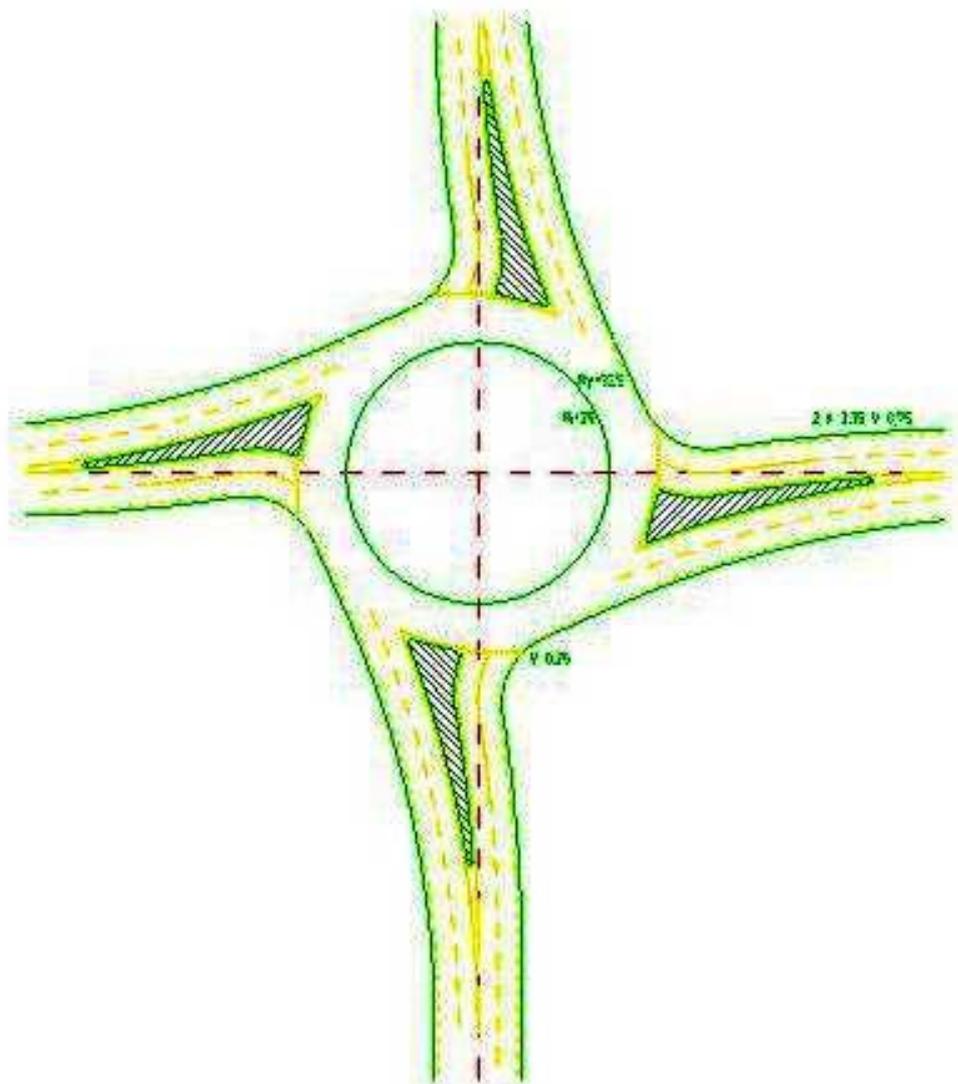
| | |
|------------------------|-------|
| Central island radius: | 15 m |
| Outer radius: | 22 m |
| Entry radius: | 15 m |
| Exit radius: | 150 m |



Normally, there should be no pedestrian crossings in a roundabout in a rural area. This is indicated in the drawing by the grade separated pedestrian crossings.

3.2 Two lanes rural roundabout

| | |
|------------------------|--------|
| Central island radius: | 25 m |
| Outer radius: | 33,5 m |
| Entry radius: | 15 m |
| Exit radius: | 150 m |



3.3 One lane urban roundabout with pedestrian crossings

Central island radius: 15 m (included 1 m driving area for heavy vehicles)

Outer radius: 21 m

Entry radius: 15 m

Exit radius: 50 m

