

REVIEW PAPER ON DEVELOPMENT OF GUIDELINES FOR THE DESIGN OF ROUNDABOUT

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DOI: <https://www.doi.org/10.58257/IJPREMS39354>

ABSTRACT

The meeting area of two or more roads is called an intersection. The traffic movements like through, turning and crossing traffic are present at the intersection which lead to different conflicts. These conflicts may be handled in different ways depending on the type of intersection and its design. The safety, efficiency, speed, capacity and economy of a road depend upon the intersection design. Roundabouts are special form of channelized circular intersection in which traffic moves in one direction around a central island before exits to various intersecting roads. It is a major form of at-grade junction featuring yield control on all entry lanes, one-way flow around a central island and appropriate geometric curvature to keep circulating speeds low. Depending on the size of circular traffic intersections it may be classified as Rotary, Roundabout and Mini-roundabout. Rotaries are suitable when there are more approaches and no separate lanes are available for right turn traffic thus making the intersection geometry complex. Rotaries were designed in the 1940's or earlier and work well at low volumes, but very poorly under heavy traffic conditions. Under low traffic conditions, a roundabout offers higher capacity as compared to a two-way stopped control or an all-way stop-controlled intersection. Roundabouts were developed in the 1960's and able to handle heavy traffic. Mini-roundabouts are best suited to areas with low speeds and there is no feasibility to use roundabout with a raised central island. Mini-roundabouts are common in United Kingdom (U.K.), France, United State and Germany since their introduction in the early 1970's.

Keywords: Roundabout, Rotaries, Geometric curvature, pedestrian,

1. INTRODUCTION

The researchers have focused on the relationship between geometric design and traffic conditions for achieving the required operational performance of roundabout. The literatures related to operational analysis and design of roundabouts are discussed.

IRC:65-1976(Recommended practice for traffic rotaries) by Indian Road Congress provides the guiding principles for the design of traffic rotaries. The code does not cover the recommendations for the design of 'mini-roundabout'. According to the code the minimum traffic volume should be about 500 vehicles per hour and highest volume of the rotary may be taken about 3000 vehicles per hour. Capacity of the rotary depends upon both geometry and weaving traffic data. The speed limit in the rotary is limited to 40 kmph. Separate pedestrian crossing and cycle tracks should be provided suitably.

The UK standards for roads i.e. Design manual for Roads and Bridges (TD 16/07) lays down the guidelines for the design of roundabouts. The code gives recommendations for the selection of type of roundabout like Mini, Normal, Compact, Grade Separated etc., geometric layout, crossfall and visibility requirements depending on the design speed of approach roads and different type of traffic flow. According to code the widening localised at the point of entry is called entry flaring which helps in increasing capacity of the roundabout.

2. LITERATURE REVIEW

The UK standards for roads i.e. Design manual for Roads and Bridges (TD 54/07) focuses on the design standards and advice for the design of mini-roundabouts. It states that for the use of mini-roundabout the flow on any approach should be more than 500 vehicles per day. The design speed of mini-roundabout should not exceed 30mph and the numbers of arms should be limited to four. It gives suggestions for the geometric design features, the safety of mini-roundabouts and a flow chart for assessing mini-roundabout.

Federal Highway Administration of U.S. Department of Transportation (FHWA-SA-10-007) lays out technical summary for the planning, analysis, and design of mini-roundabouts. It recommends the total daily entering traffic should not exceed 15000 vehicles for a mini-roundabout and size of inscribed circle diameter should be less than 30m. Due to less maintenance of mini-roundabouts, they have longer service lives as compared to signalized intersections. It suggests benefit-cost analysis for programming purposes.

Satish Chandra and Rajat Rastogi (2012) proposed a simple empirical method for determination of the entry capacity from the flow conditions alone after comparing the results of UK model, US method, German Model, Swiss model and Indian model. The capacity estimated by IRC model gave maximum value whereas US model gave minimum capacity for four selected roundabouts of Chandigarh city. The proposed method estimates roundabout capacity by considering circulating flow only and the result is comparable with German capacity model.

Alex Ariniello and Bart Przybyl (2011) pointed out that the use of roundabouts instead of signalized intersection will result in fewer crashes and lower delay. It will also help in reducing greenhouse gas emissions and energy consumption. According to the study the crash rate can be reduced by 8.6% per year, energy consumption by 45,000 gallons of gasoline per year and emissions of CO₂ by 400 metric tons per year. Considering safety benefits and significant reduction of emissions, roundabouts may be treated as an important sustainable measure of traffic control.

The procedure to use Highway Capacity Manual (HCM 2000) for roundabouts in Turkey was discussed in the paper "Determining the capacity of Single-lane Roundabouts in Izmir, Turkey" by Serhan Tanyel et al. (2005). Only two intersections were taken into consideration for the research and the results obtained for follow-up time and critical gap are close to HCM 2000 lower and upper bound values. The paper concluded that as an initial approach HCM 2000 can be used for the design of roundabouts.

S. Anjana and M.V.L.R. Anjaneyulu (2014) developed crash modification factors (CMFS) and Crash prediction models for the safety at roundabouts located in the state of Kerala. He tried to co-relate safety with geometric features of roundabout by developing models. He suggested that accident rates can be reduced by increasing circulatory roadway width, splitter island and exit angle.

S.K. Mahajan et al. (2013) discussed a new geometric design concept of rotaries and developed one software package using global math application for use in road networks. With less observation data the software can determine the quantity of earthwork, can check the earthen embankment stability and can able to design rotaries.

3. DESIGN GUIDELINES

GENERAL

The present chapter deals with the guidelines given in IRC:65:1976 and the guidelines followed in UK and USA. The following sections present these guidelines.

GUIDELINES OF IRC:65-1976

At-grade intersection is defined as the meeting area of all roads at the same level. The traffic operations like merging, diverging and weaving are present in the intersection at-grade. Traffic rotary is a specialised form of at-grade intersection where vehicles from the converging arms are forced to move round a central island in one direction in an orderly and regimented manner and weave out of the rotary movement into their desired direction. This 'Recommended Practice for Traffic Rotaries' provides the guidelines for the design of traffic rotaries. The recommendations laid down here do not include the guidelines for 'mini-roundabout'.

General Guidelines for Selection of Rotary Intersection

Rotaries are not suitable for intersections carrying very low traffic. Selection of rotary at an intersection depends on the geometric layout of the site, traffic characteristics and proportion of right turning traffic. Rotaries are adopted for intersections with three or more legs and require quite larger area also. Direct conflicts are neglected at rotary by weaving traffic and right turning traffics have to travel some more distance.

- a) For the consideration of rotary intersection the lowest traffic volume should be about 500 vehicles per hour.
- b) Rotaries are more suitable where the traffic volumes entering from different approaches of the intersection are nearly equal.
- c) Traffic rotary can handle maximum traffic volume of 3000 vehicles per hour entering from all the legs of intersection.
- d) Rotaries are more adaptable in locations with high right turning traffic.
- e) A rotary is advantageous if sufficient space is not available for handling the queues.

Shape of Rotary Island

The various factors upon which rotary island depend are the traffic flow pattern, layout and number of intersecting roads. Depending on the layout of intersecting roads the various shapes of Rotary Island are circular, turbine, elliptical and tangent shapes. Sometimes asymmetric shapes like combination of both curves and straight may serve the desired purpose. One or more intersecting roads may be realigned for achieving the required intersection angle and weaving length. Before finalising the final shape of rotary island minimum weaving length should be achieved between two intersecting roads.

Some rotary islands of various shapes are discussed below.

Circular

When all the four intersecting roads placed symmetrically i.e. two roads of equal importance meet roughly at right angle, a circular shape central island is suitable. Regular and constant flow can be achieved in a circular shape rotary island.

Squarish with rounded edges

This is combination of four large radii curves or four straights roughly producing four sides of a square and small radii curves at four corners. This type of central island is preferable for straight head flows.

Complex Intersection with many approaches

If numbers of approaches are more at an intersection, then the layout of the island.

Radii of Curves at Entry and Exit

Entry curve radius depends upon the design speed, coefficient of friction and amount of superelevation. The value of coefficient of friction may be taken as 0.47 and 0.43 for the design speed of 30 and 40 kmph. Suggested values of radius of curves at entry vary from 20 to 35 metres and 15-25 metres for the design speed of 40 kmph and 30 kmph respectively. To pick up the vehicle speed it is expected to provide larger radii of the curves at exit with respect to radius of curve at entry and central island. So it recommends the radius of exit curve equal to 1 to 2 times the radius of curve at entry. Variations may be allowed considering the practical traffic situations like pedestrians, cyclist etc.

Radius of Central Island

The recommended value for radius of central island is 1.33 times the radius of curve at entry though it should be equal to radius at entry theoretically. The reason for quite larger value of central island is to give priority to the traffic already present on the rotary and to slower the speed of approaching traffic.

Weaving Length

The various factors upon which weaving length depend are the average width of entry, width of weaving section, proportion of weaving traffic and total traffic. Capacity of rotary intersection depends on the weaving length. Weaving length value may be kept at least 4 times larger than the width of the weaving section. The recommended values of minimum weaving length are 45 and 30 metres for the design speed of 40 and 30 kmph respectively. To avoid the high speeding of vehicles inside weaving section, the maximum weaving length is limited to twice the values mentioned above.

Width of Carriageway at Entry and Exit

The governing factors for the carriageway width are amount of traffic volume entering and leaving the rotary. The predicted future growth of traffic should be taken into consideration for deciding the width of carriageway at entry and exit. The recommended values for width of carriageway at entry and exit of a rotary intersection entry. Variations may be allowed considering the practical traffic situations like pedestrians, cyclist etc.

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Entry and Exit Angles

It is desirable to keep entry angles greater than exit angles and if possible it should be nearer to 60 degree. Exit angles should be kept small with respect to entry angles. even tangential also allowed.

Capacity of the Rotary

The factors upon which capacity of rotary depend are weaving section width (w), average entry width (e), weaving length (l) and proportion of weaving traffic (p). The following formula is being used to calculate the capacity of rotary intersection.

$$280w(1+p)(1-3Q_p) = (1+p)$$

Where

Q = Practical capacity of the weaving section of a rotary in Passenger Car Units (pcu) per hour.

w = Width of weaving section (6 to 18 m)

e = Average width of entry i.e. average of e_1 and e_2 (e/w to be within a range of 0.4 to 1.00)

l = Length of weaving section between the ends of channelizing islands in metre for the range of $w/l = 0.12$ to 0.40

p = proportion of weaving traffic

b+c a+b+c+d

a = left turning traffic moving along left extreme lane

d = right turning traffic moving along right extreme lane

b = crossing/weaving traffic turning towards right while entering the rotary

c = crossing/weaving traffic turning towards left while leaving the rotary

Outer Curb Line

IRC says "the external curb line of weaving sections should not normally be re-entrant, but consist of a straight or large radius curve of the same sense as the entry and exit curves as explained. This type of arrangement will help in eliminating waste area.

Pedestrians and Cyclists

IRC:11-1962 (Recommended practice for the Design and layout of cycle tracks) should be followed for the cyclists and pedestrian crossing to be provided. "According to IRC, where the channelizing island is short, as indicated at 'A' in the figure, the cycle track should lead behind its tail. But where the island is long, as at 'B' in this figure; a gap should be left in the island to accommodate the cycle track. It is desirable to provide flashing signals to warn about pedestrian and cyclist-crossings at rotary legs".

Signs and Markings

"Rotaries require to be adequately designed both for day and night travel. A red reflector about one metre above the road level or a vertical cluster of such reflectors at a height of 0.3 to 1.0 m high should be fixed and the nose of each directional island and on the curb of the central island facing the approach roads".

"Curbs of the central and channelizing islands should be painted with vertical black and white strips, each 500 mm wide, to improve visibility. All pedestrian and cyclist crossings should be provided with sustainable pavement markings in accordance with IRC:65-1970 (Code of Practice for Road Markings)".

Illumination and Landscaping

"Illumination of the rotary junction at night is very desirable. If the central island is small, viz. Less than 20 m in diameter, satisfactory result is obtained by a single lantern having symmetrical distribution and mounted centrally at a height of 8 metres or more, mounting height of 9-10 m is often advantageous".

"A rotary provides ample scope for effective development of the landscape. But all such development should only be ancillary to the essential object of traffic control, viz., the reduction in the speed of vehicles and advance indication of the paths to be followed by vehicles".

Drainage

Water should not be allowed to accumulate within rotary intersection and for which proper attention should be given for drainage.

UK STANDARD FOR ROUNDABOUTS

Design Manual for Roads and Bridges (DMRB) lays down different standards for roundabouts. TD 16/07 deals with the advice and design standards for the geometric design of roundabouts. The updated version of TD 16 made changes in

design hierarchy, location of pedestrian crossings, new compact roundabout, entry deflection, outward sloping crossfall, visibility to the right, truck rollover, signing and marking.

The software like RODEL and ARCADY can be used to estimate safety performance and capacity of roundabout.

According to DMRB "roundabouts are junctions with a one-way circulatory carriageway around a central island and vehicles on the circulatory carriageway have priority over those approaching the roundabout". Proper geometric layout of roundabout helps in minimising delay for all road users whilst maintaining safe passage of vehicles through the intersection. Flare sharpness and entry width are the important factors for estimation of capacity, whereas safety of roundabout depends upon entry deflection as vehicle speed is governed by it. Capacity and safety of a roundabout are also associated with road markings and traffic signs.

Types of Roundabouts

The roundabouts may be classified as Normal, Compact, Mini, Signalised, Grade Separated and Double Roundabouts. It is recommended that the minimum diameter of Normal roundabout should be 4m. The approach roads may be single or dual carriageway roads. The roundabout in which all arms having single lane entry and exit is known as a Compact Roundabout. The speed limit for Compact Roundabout is 40 mph or less. According to DMRB "mini-roundabout does not have a kerbed central island and in its place is a flush or domed circular solid white road marking between 1 and 4 metres in diameter, capable of being driven over where unavoidable". To link flyovers, underpasses and multiple level junctions a grade separated roundabout is used. The roundabout installed along with traffic signals is known as signalised intersection. The combination of two roundabouts with a separation of short link at a junction is called Double roundabout. The roundabouts can be Normal, Compact or Mini.

4. CONCLUSIONS

The dissertation entitled 'Development of Guidelines for the Design of Roundabouts is taken up with a view to introduce some guidelines which are not included in Indian guidelines. Based on literature review it is noted that different countries have their own design guidelines and capacity models for roundabout intersection. The main conclusions drawn from the study are as follows.

In this study a flow chart has been prepared for deciding whether a given intersection is to be designed as rotary, roundabout or mini-roundabout using the preliminary geometric and flow data of the intersection by comparing IRC, UK and FHWA guidelines.

Various design parameters of rotary, roundabout and mini-roundabout as given in IRC, UK & US guidelines have been compared.

IRC method is based on critical weaving section and not on entry flow method as is the case with HCM or any other method. That is why IRC gives capacity of the least loaded weaving section and it assumes that intersection will get saturated when the flow in the critical weaving section reaches capacity, IRC model always gives very high value of capacity compared to other models, whereas US capacity model gives lowest capacity among all.

Two new capacity models have been proposed for quick calculation of capacity which give the capacity value close to IRC capacity model. New capacity models are simple to use as they require very less geometric and traffic data.

The capacity calculated using the data of different roundabouts by IRC, UK, US, PM 1 and PM 2 are tabulated and compared graphically to show the variations:

5. REFERENCES

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