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Study and Design of Roundabout at Charkop Market, Kandivali (West)

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***Abstract*— The developing cities are having a lot of traffic problems with increasing rate of vehicles. In present time charkop market and Hindustan naka, kandivali (west) part of Mumbai city, Maharashtra. Traffic problem are due to private vehicles running in this part of city these increased rate of vehicles require space for movement, with safety having enough capacity of roundabout's intersection. So capacity evaluation needs to be done on roundabout intersection for easy operation of traffic. During the past decade major cities have under gone hazard growth of Industrialization, urbanization of country, and kandivali is not exception for that. Traffic is increasing day by day, so it is almost impossible for traffic police to control the traffic manually at the intersection. Although the signals have been provided on both intersection but the traffic congestion has not been reduced effectively. In order to improve the traffic conditions as well as the aesthetic view at the said intersections, we suggest to design the roundabout at these intersections to reduce traffic congestion keeping in view high traffic and conditions favoring the roundabout. For this traffic volume surveys, study and the design is done accordingly.**

Keywords: - Traffic, Roundabout, Charkop Market, Intersection and Kandivali.

I. INTRODUCTION

Table No. 1.1 : Fundamental elements of Roundabouts
Roundabouts are a type of circular intersection or junction in which road traffic flows continuously in one direction around a central island. With the rapid growth of traffic it is experienced that widening of roads and providing flyovers have become imperative to overcome major conflicts at intersections such as collisions between through and right turn movements. In this way, major conflicts are converted into milder conflicts like merging and diverging. The vehicles entering the roundabout are gently forced to move in a clockwise direction. Roundabouts are the efficient intersection design over the signalized intersections depending upon traffic and site data. Depending on the size of circular traffic intersections it may be classified as Rotary, Roundabout, lanes urban compact, compact and Mini-roundabout. Roundabout are suitable when there are more approaches and no separate are available for right turn traffic thus making the intersection geometry complex. 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 the United Kingdom (U.K.), France, United State and Germany since their introduction in the early 1970"s. But from past few year's uses of roundabouts and rotaries with or without signal system is also increasing in India.

A. Types of Roundabouts

- Mini roundabouts
- Urban compact roundabouts
- Urban single lane Roundabouts
- Urban double lane roundabouts

Fundamental elements of all above roundabouts are compare in table no 1.1 below. Components of Roundabouts

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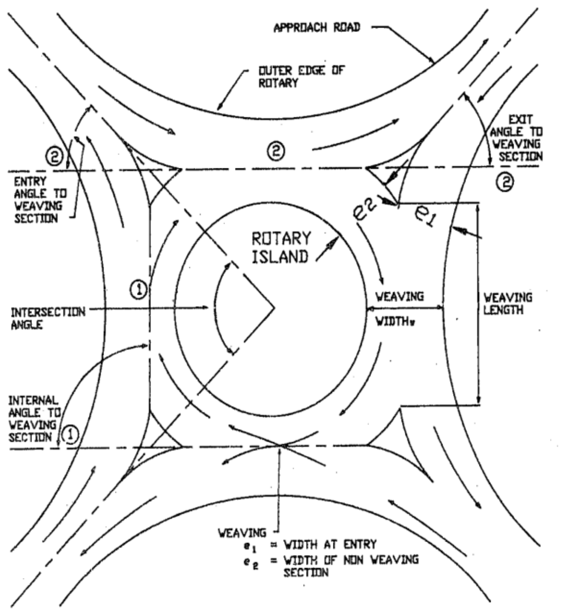
Design element	Mini	Urban compact	Urban single lane	Urban double lane
Recommended max entry design speed	25km/hr	25km/hr	35km/hr	40km/hr
Max no of entering lanes	1	1	1	2
Inscribed circle diameter	13m to 25m	25m to 30m	30m to 40 m	45m to 55m

Fig No. 1.1 Components of Roundabout

B. Components of Roundabouts



- **Design Speed**

All the vehicles are required to reduce their speed at a rotary. Therefore, the design speed of a rotary will be much lower than the roads leading to it. Although it is possible to design roundabout without much speed reduction, the geometry may lead to very large size incurring huge cost of construction. The normal practice is to keep the design speed as 30 and 40 KMPH for urban and rural areas respectively.

- **Entry, Exit and Island Radius**

The radius at the entry depends on various factors like design speed, super-elevation, and coefficient of friction. The entry to the rotary is not straight, but a small curvature is introduced. This will force the driver to reduce the speed. The speed range of about 20 KMPH and 25 KMPH is ideal for an urban and rural design respectively. The exit radius should be higher than the entry radius and the radius of the rotary island so that the vehicles will discharge from the rotary at a higher rate. A general practice is to keep the exit radius as 1.5 to 2 times the entry radius. However, if pedestrian movement is higher at the exit approach, then the exit radius could be set as same as that of the entry radius. The radius of the central island is governed by the design speed, and the radius of the entry curve. The radius of the central island is about 1.3 times that of the entry curve for all practical purposes.

- **Shape of Central Island:**

The shape and disposition of central island (control island) depend upon various factors such the number and disposition of intersecting roads and traffic flow pattern. Islands. The conditions under which a particular shape is favored are discussed below in Table no. 1.2:

Type	Central Island
Circular	Equal importance to all road meetings
Squares with rounded legs	Suitable for predominantly straight ahead flows
Elliptical, elongated, oval or rectangular.	To favour through traffic/to suit the geometry of the intersecting legs/ to provide longer Weaving lengths.
Irregular	Shape is dictated by existence of large number of approaches.

Table No. 1.2 : Shapes of central Island and conditions

- **Width of the Rotary**

The entry width and exit width of the rotary is governed by the traffic entering and leaving the intersection and the width of the approaching road. The width of the carriageway at entry and exit will be lower than the width of the carriageway at the approaches to enable reduction of speed. IRC suggests that a two lane road of 7 m width should be kept as 7 m for urban roads and 6.5 m for rural roads. Further, a three lane road of 10.5

m is to be reduced to 7 m and 7.5 m respectively for urban and rural roads. Traffic rotaries reduce the complexity of crossing traffic by forcing them into weaving operations. The shape and size of the rotary are determined by the traffic volume and share of turning movements. Capacity assessment of a rotary is done by analyzing the section having the greatest proportion of weaving traffic. The analysis is done by using the formula given by the width of the weaving section and it should be higher than the width at entry and exit. Normally this will be one lane more than the average entry and exit width. Thus weaving width is given as,

$$W = weaving = [(e1+e2) / 2] + 3.5m$$

Where e1 is the width of the carriageway at the entry and e2 is the carriageway width at exit. Weaving length determines how smoothly the traffic can merge and diverge. It is decided based on many factors such as weaving width, proportion of weaving traffic to the non-weaving traffic etc. This can be best achieved by making the ratio of weaving length to the weaving width very high. A ratio of 4 is the minimum value suggested by IRC. Very large weaving length is also dangerous, as it may encourage over-speeding.

- **Weaving Length:**

The weaving length determines the ease with which the vehicle can maneuver through the weaving section and thus determines the capacity of the rotary. The weaving length is decided on the basis of the factors, such as, the width of weaving section, average width of entry, total traffic and proportion of weaving traffic in it. It is desirable to prevent direct traffic cuts and this can be achieved by making the ratio of weaving length to weaving width large enough. A ratio 4:1 is regarded as minimum. The minimum values of weaving lengths as recommended by IRC are given below Table No. 1.3:

Design Speed (kmph)	Minimum length of Weaving (m)
40	45
30	30

Table No. 1.3 : Suggestions for weaving length

C. Advantages over Signal System:

• The main advantage of roundabout over signalized system is that the vehicles don't have to halt and can continuously move around roundabout.

• Also electricity can be saved in roundabout over a signalised intersection. As per the survey conducted by Hindustan Times, Rs 6.5lakhs/month is consumed in Delhi for signalised system.

• The conflict points in signal system, for vehicles is 32 and that for pedestrians is 8 that is in all 40 conflict points are provoked. But the same in roundabout is 8 for vehicles and 4 for pedestrians in all 12 conflict points. Shown in figure below

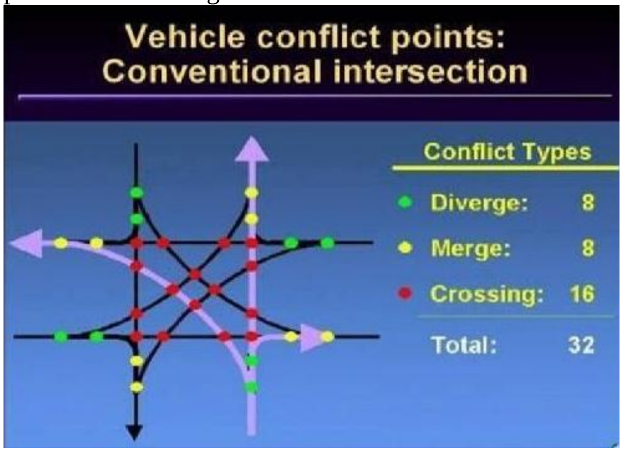


Fig. No. 1.2: Conflict Points at signalized system

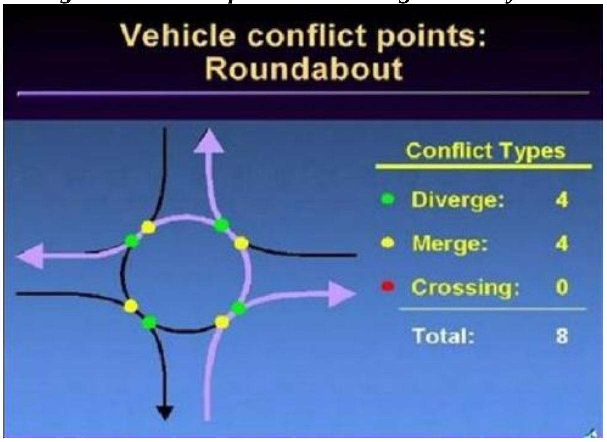


Fig. No. 1.3: Conflicts point at Roundabout

II. LITERATURE REVIEW

From study of previous work done in field of highway design we have found that experts in this field have focused on link between traffic condition, traffic volume and geometric design to see whether designed roundabout is able to perform the desired operational performance. IRC SP 41 and IRC 65-1976 recommends the guidelines, factors on the design of traffic rotaries. S.K. Mahajan, Kruti Jethwa, et al (2013) in their paper have discussed a new geometric concept to design roundabout and a software package has been developed by them to be used in road works. Waheed Uddin (2011) concluded in his paper that Roundabout has proved in increasing the capacity of intersection, decreasing delay and reducing number of crashes and number of injury and reducing vehicle emission. From this he marked roundabout proved beneficial junction increasing traffic flow and decreasing delay. Junaid Yaqoob, & Er. Amir Lone (2016) in their paper stated that rotary are a tool that increases safety along the street, enhances driver attentiveness, reduces automobile idling, and efficiently streams traffic through an area.

III. METHODOLOGY

Traffic surveys at intersection were conducted by manual method. For this method we had first studied about the procedure and collected the required information & forms, then we performed traffic survey at the intersection. Traffic survey was conducted by splitting three field observers at each leg. One observer was appointed to count overall vehicle volume passing through fixed point, while other two were appointed to count left and right turning vehicle volume. Six surveys were carried out at peak hours at study area, charkop market. The traffic flow mainly includes cars, auto-rickshaw, two wheelers, bus, trucks and other light commercial vehicles such as tempos. From survey performed, we preferred survey No. two (morning) for design purpose as it had maximum traffic volume amongst all surveys then calculations of traffic intensity by multiplying with their respective Passenger Car Unit (PCU) had been done. After this we have carried out calculation for weaving length, entry, exit radius etc. and other factors such as radii of Central Island were referred from IRC 65. Obtained data were impart to AutoCAD Civil 3D to design roundabout for specified condition.

IV. LOCATION: CHARKOP MARKET, KANDIVALI (WEST) MUMBAI, MAHARASHTRA

The location selected for designing the roundabout is situated at Charkop Market, Kandivali (West), Mumbai, Maharashtra is pretty much crowded area due to market situated in this region. At the intersection there are four roads namely RPD Road No. 4, RPD Road No. 5, RPD Road No 6 and DR. Babasaheb Ambedkar Road, which are major district roads with 8 meter carriage way. In fig. No. 4.1 exact location of the junction is given. Due to rapid growth and development population of this area has been increased in last decade which also leads to increase in number of vehicles and traffic congestion. All four roads have traffic signals of 30 sec allowance which is not efficiently handling the traffic so to overcome this problem we think that roundabout will be more efficient option and hence we are designing the roundabout for said intersection.

Fig. No. 4.1: Location plan Source: Google maps

V. DATA COLLECTION AND EXTRACTION

To design roundabout we have carried out surveys on morning evening basis. On Tuesday, Friday & Sunday respectively, so that we can cover traffic on weekdays as well as weekends. The survey reports are represented in the bar graph as shown below.

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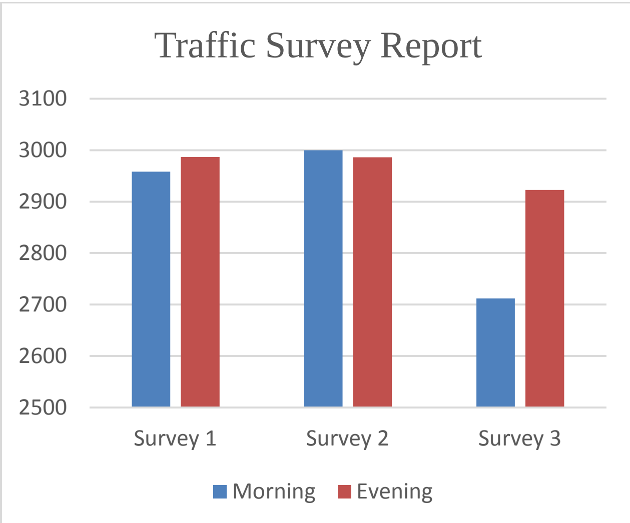

Fig. No.5.1: Representation of Traffic Survey

In Fig. No.5.1 we can see that survey 2 (Morning) had maximum number of vehicles so it is more favorable to take this data for design purpose so that designed roundabout can handle traffic more effectively. Survey 2 (morning) data in shown in the table 5.1 below:

Approach	Leg	Left turning			Straight ahead			Right turning		
		Car / Auto	Two wheeler	Truck/bus	Car/ Auto	Two Wheeler	Truck/bus	Car/ Auto	Two Wheeler	Truck/bus
N	D	86	66	12	123	104	10	114	94	11
E	A	127	156	10	247	76	23	165	102	15
S	C	106	105	18	96	66	6	109	94	14
W	B	137	115	12	184	50	20	202	104	21

Table 5.1: Survey 2 (Morning) data

VI. CONDITIONS AT INTERSECTION AND THEIR SUTABILITY

A. As per IRC 65, a roundabout can handle 3000 vehicles per hour from all leg efficiently. At study area i.e. charkop market we did 6 surveys, 3 in morning peak hours and remaining 3 in evening peak hours, on the basis of this surveys we can firmly say that this intersection does not cross this permissible limit so by considering this point, we can say that this intersection is suitable for roundabout.

B. Also in IRC it is mentioned that if traffic volume with more than 30% right turning then roundabout is suitable in such cases, so we thus calculate total volume of right turning traffic, and it is more than 30% on each leg following calculation from survey 2 (morning), which makes our above statement valid

Leg A = (right turning volume)/(overall volume) =282/921 ×100 = 30.61%

Similarly,

$$\text{Leg B} = \frac{327}{845} \times 100 = 38.69\%$$

$$\text{Leg C} = \frac{217}{614} \times 100 = 35.34\%$$

$$\text{Leg D} = \frac{219}{620} \times 100 = 35.32\%$$

So also from this point of view the intersection is suitable for roundabout.

C. Apart from this pedestrian crossing is also considerably low at this study area which is given below

Leg A = 87 pedestrians/hour
Leg B = 62 pedestrians/hour
Leg C = 79 pedestrians/hour
Leg D = 92 pedestrians/hour

So we can also say that it's suitable from pedestrian point of view too.

D. Roundabout required large area for construction, the concerned intersection have major district roads which are wide enough to construct roundabout. Also all four legs have equal volume of traffic, so this things are also suitable for roundabout. So from above points we strongly recommend roundabout at considered intersection i.e. at charkop market.

VII. DESIGN OF ROUNDABOUT

For designing roundabout different components of roundabout are need be design separately which are entry, exit curve, waving width, radius of central island etc. this components has been discussed already in this paper so now moves towards designing calculations and adoption for roundabout at charkop market.

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a. Design speed

For measuring speed of vehicles at selected intersection we did spot speed study by stopwatch method and the speed we took for design speed as 30 KMPH which is also recommended by IRC 65 for urban areas.

b. Shape of central island

Shape of Central island mainly depends on number and type of roads at intersection. Concerned intersection have four legs which almost 90 degrees angle to each other and also it has relatively equal traffic volume from all four legs so we going to adopt Circular shaped central island.

c. Entry radius (e1)

Entry radius depends upon design speed, and in this case we had already adopt design speed as 30 KMPH. Suggested value for e1 as per IRC 65-1976, page No. 9 table No. 1 is 15 meters to 25 meters so take e1 = 15 meters

d. Exit radius

In IRC it is mentioned that Exit radius should slightly more than entry radius so that driver can increase their speed at exit the recommended value is 1.5 times of e1

So, exit radius = 1.5 × 15 = 22.5 meters.

e. Radius of central island

Radius of central island should be bigger than radius at entry generally it is adopted as 1.33 times of entry radius. Which is also mentioned in IRC 65-1967.

So, Radius of central island = 1.33 × 15 = 19.95 meters say 20 meters.

f. Weaving length

The weaving length determines the ease with which the traffic can merge and diverge. The weaving length decided on the basis of factors such as the width of weaving section, the average width at entry, total traffic and the proportion of weaving traffic in it.

Weaving length from page No. 10 from IRC 65-1967

For design speed 30 KMPH minimum suggested value for weaving length is 30 meters.

So, take weaving length = 30 meters

g. Weaving angle

Weaving angle should be as small as possible but should not be less than 15 degrees.

So take weaving angle = 45 degree

h. Width of carriageway at entry and exit

The carriageway width of the intersection leg is governed by the design year traffic entering and leaving the intersection. Since the maximum width of carriageway of the concerned intersection is 16.76 meters ≅ (17 meters).

Minimum width of entry should be 8 meters so we proposed width of entry 10 meters at RPD road No. 04 & RPD road No. 06, and width of entry at RPD road No. 05 and Dr. Babasaheb Ambedkar road is 8 meters.

i. Width of Non Weaving section (e2)

IRC 65-1967, on page No. 10 recommends that the width of non-weaving section should be equal to the widest single entry into the roundabout and should generally be less than width of weaving section.

Therefore,

e2 = 10 meters (from above point H)

j. Width of weaving section (w)

Width of waving section of roundabout should be one traffic lane wider (3.5 meter) then the mean entry width. i.e.

Mathematically, $w = \frac{e1+e2}{2} + 3.5 = \frac{15+10}{2} + 3.5 = 16$ meters

k. Capacity of Roundabout

Approach	Left turning	Straight ahead	Right turning
Leg D (North)	169.1	229	215.3
Leg C (South)	235.15	162.3	218.7
Leg A (East)	272	368.4	283.5
Leg B (West)	256.85	277.5	338.8

Table No.7.1: Traffic volume in PCU/hr.

The traffic in terms of PCUs from each leg is illustrated in fig No.7.1 below:

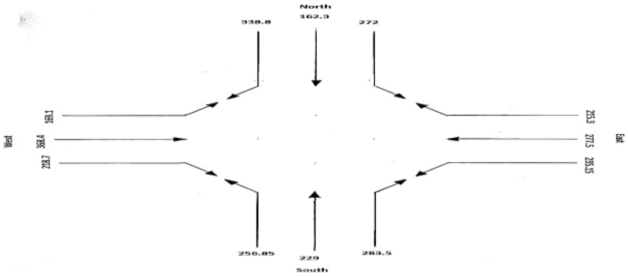

Fig No.7.2: Traffic approaching from each leg to roundabout in PCU/hr.

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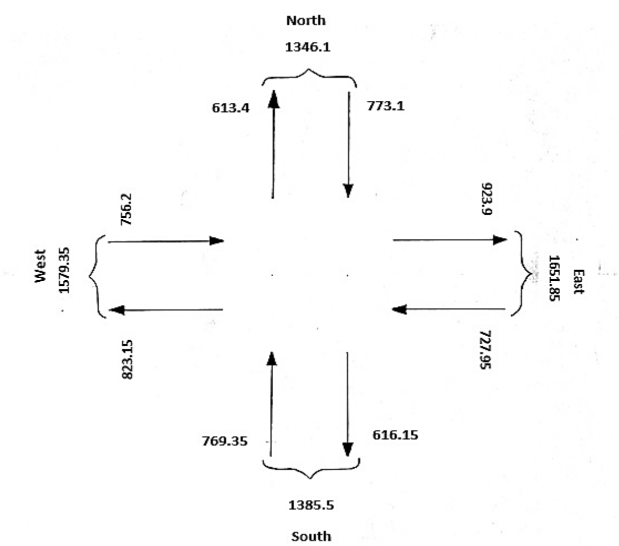
Fig No.7.2.1: Traffic approaching on each leg in PCU/hr.



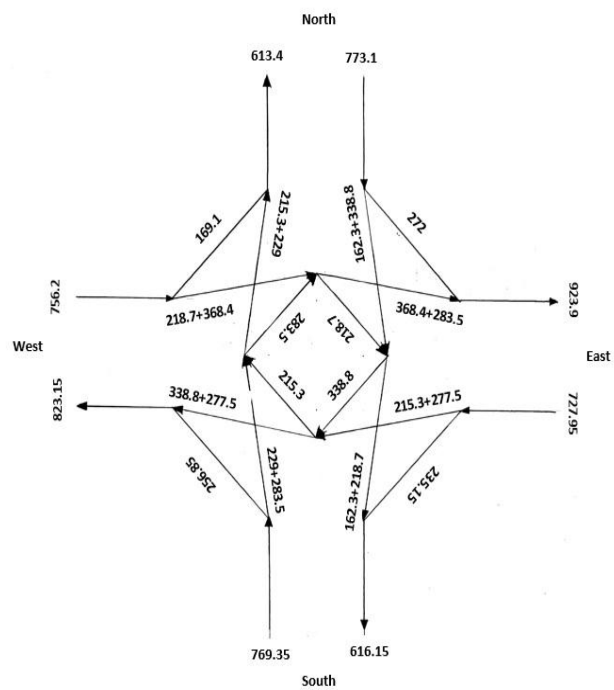


Fig No.7.3: Traffic flow is allocated to the network

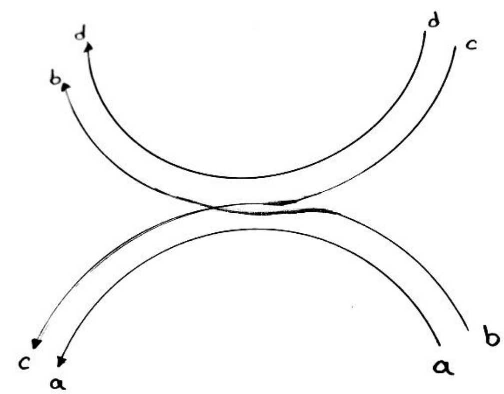


Fig No.7.4 : waving traffic

Weaving traffic from east to south i.e. from Leg A to Leg C
a= 338.8 PCU/hr.
b= (162.3+218.7) = 381 PCU/hr.
c= (215.3+277.5) = 492.8 PCU/hr.
d= 235.15 PCU/hr.
P = (b+c) / (a+b+c+d) from IRC 65-1967 Page No.
Therefore, P = (381+492.8) / (338.8+381+492.8+235.15) P = 0.56

Hence mathematical formula for capacity of roundabout, from IRC 65-1967 Page No.
$Q_p = \{280*w\ [1+ (e/w)]*[1-(P/3)]\} / [1+ (w/l)]$
$Q_p = \{280*16\ [1+(10/16)]*[1-(0.56/3)]\} / [1+ (16/30)]$
$Q_p = 3861.56$ PCU/hr.
Similarly, weaving traffic from West to South i.e. Leg B to Leg c
a= 215.3 PCU/hr.
b= (229+283.5) = 512.5 PCU/hr.
c= (338.8+277.5) = 616.3 PCU/hr.
d= 256.85 PCU/hr.
P = 0.705
$Q_p = 3632.08$ PCU/hr.

Weaving traffic from West to North i.e. Leg B to Leg D
a= 283.5 PCU/hr.
b= (215.3+229) = 444.3 PCU/hr.
c= (368.4+218.7) = 587.1 PCU/hr.
d= 169.1 PCU/hr.
P = 0.695
Qp = 3647.91 PCU/hr.

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Weaving traffic from North to East i.e. Leg D to Leg A
a= 218.7 PCU/hr.
b= (162.3+338.8) = 501.1 PCU/hr.
c= (368.4+283.5) = 651.9 PCU/hr.
d= 272 PCU/hr.
P = 0.701
Q_p = 3638.41 PCU/hr.

Hence consider capacity of designed roundabout is minimum from above four Q_p i.e. 3632.08 PCU/hr.

VIII. RESULT

From above calculations, capacity for RPD road No. 06 (Leg A) to Dr. babasaheb Ambedkar road (Leg C) is 3861.56 PCU/hr. which is maximum from all weaving sections, capacity for RPD road No. 04 (Leg B) to Dr. babasaheb Ambedkar road (Leg C) is 3632.08 PCU/hr. which is minimum of all waving section, capacity for RPD road No. 04 (Leg B) to RPD road No. 05 (Leg D) is 3647.91 PCU/hr. and capacity for RPD road No. 05 (Leg D) to RPD road No.06 (Leg A) is 3638.41 PCU/hr.

IX. CONCLUSION

In our study we performed surveys and accumulate traffic data which was required for designing roundabout, and after studying all necessary requirements and calculation we found that minimum capacity of designed roundabout is 3632.08 PCU/hr. whereas maximum required capacity for concerned intersection is 3026.6 PCU/hr. hence we can conclude that designed roundabout can efficiently handle present traffic flow as well as if in near future if there is slightly increase in rate of traffic flow, designed roundabout is capable for managing the traffic. Apart from this if roundabout is provided at said intersection then traffic congestion will be reduced to some extent as well as the halt time of vehicles at intersection will be minimized. As discussed above roundabout has far less conflict points than signalized intersection so by providing designed roundabout pedestrian safety can also be achieved.

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