Modification of Roundabout to Avoid Interlocking During Heavy Traffic Condition: A Case Study

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Abstract

A roundabout intersection is a specialized form at grade intersection laid out for movement in one direction around a central island. Since most of the roundabouts are situated in urban CBD areas, the intersection region could not be expanded to deal with increasing traffic. The objective of the study was to estimate the capacity of roundabout and compare it with present traffic. The video data was collected for 5 hours to observe the traffic behavior of vehicles at selected roundabout. The volume count was performed by observing four different class of vehicles namely Cars (small as well as large), motorized 2-wheelers and 3- wheelers as well as Heavy vehicles (buses and trucks). The capacity was estimated using Wardrop's formula by calculating weaving traffic proportion (p) for each weaving section. For maximum weaving traffic proportion, the capacity was estimated as 3163 pcu/hr which is very less compared to total volume present during peak hour i.e. 17341pcu/hr. Hence, converting the roundabout into signalized roundabout intersection is proposed which requires proper designing of traffic signals. At final stage, the designed signals would be implemented to avoid roundabout interlocking in future.
Keywords: Roundabout; Capacity; Signal; weaving section; Proportion Value

I. INTRODUCTION

Across the world, rapid increase in traffic volume and congestion remain to outperform the growth in highway capacity. A great amount of this congestion generally occurs at the intersections, rather than along the highways between intersections. Therefore for overall improvement of any roadway system, intersections are the most vital nodes for efficient traffic operations. The improvement of intersection's performance by use of every available technique is utmost important for traffic engineers. There are several kinds of intersections available for safe and efficient maneuvering of vehicles. This study discussed about the inaptness of roundabout intersection having high traffic volume in urban areas.

A roundabout is a type of circular intersection or junction in which traffic flows in circulating path around a central island in one direction. The modern form was standardized in United Kingdom. Generally roundabouts are designed to have a free flow of circulating traffic, so that sufficient gap should be maintained from entering traffic. Roundabouts are the good option for urban and sub-urban areas, where there is demand of channelizing the heavy traffic volume.

Congestion is an inevitable condition on roads nowadays. It can be defined as the impedance and delay enforced by vehicles on each other. The occurrence of congestion affects the travel cost by delaying the people, freight and vehicles. It also increases the operating cost of vehicles including fuel and maintenance costs. In this case study, the site selected is situated in an urban area where surrounding space of the roundabout is almost fully developed i.e. there is no scope of widening of roundabout further. This kind of problem is very common nowadays at most of the roundabout situated in urban areas. To overcome such situation where provision of widening cannot be implemented, signalization of roundabout can be proved as an efficient measure. Signalising the roundabout will help in maintaining the free flow of circulatory traffic as well as avoiding the interlocking of it.

II. LITERATURE SURVEY

This chapter reviews the research work carried out by various researchers on roundabout capacity throughout the world. In the US, the first design guideline for a roundabout (called rotary) was published in 1942 by the American Association of State Highway Officials (AASHO). A rotary was defined as an intersection where all traffic merges into and emerges from a one-way road around a central island. The general concept was that large radii gave long weaving sections, on which both high speeds and high capacities could be maintained.

Fundamentally, three methodologies can be used to assess the capacity of roundabouts. These three methodologies are: interweave theory model, gap acceptance theory, and regression analysis theory.

Wardrop (1973) formula is considered to be a typical representative of this model. Based on the weaving theory, the model of capacity on weaving segment is established to reflect the capacity of roundabouts. However, with the development of the off-side priority rule, this formula has no theoretical foundation. Prior to the rule, conventional roundabouts performed as a weaving section between two streams: circulating and entering flows. With the new rule, entering traffic now has to give way to circulating traffic and enter when accepted gaps are available. The operational basis is measured by the number of vehicles entering the roundabout. Capacity is measured in terms of the entry capacity, rather than of weaving section capacity. Because drivers enter the roundabout only when the gap in the circulating traffic is large enough, the capacity of the roundabout will depend primarily on the circulating flow and the availability of gaps.

Tanner (1997), formula is considered to be a typical representative of this model. Based on the gap acceptance theory, it calculates the capacity of roundabouts by utilizing information about entry vehicles mainly. Later, there are some modified models.

Hagring (2001), Analysed the influence of mixed circulating and exiting flow on the capacity of entering flow.

Troutbeck (1992), Analysed the limited priority merging at non-signalized intersections.

DENG W (2005),Made a contrastive analysis for two roadways uncontrolled intersection of capacity by motorcade analysis method.

Allsop (2001),Raised the definition of the reserve capacity, that is a new calculation method of capacity of roundabout--settled proportion interweave section volume restrict method, and then applied in non-signalized intersections (1996). Based on this method, the capacity of roundabouts is the sum of the entry capacity in all directions. For the third model, based on macro data, the capacity of the roundabout will depend on the circulating flow and the entry flow.

Kimber (1989), Conducted a research study on using a multiple linear regression method to derive the relationship between the circulating flow and the entry flow. The dependence of entry capacity on circulating flow is known as the entry/circulating flow relationship, and depends on the drivers' interaction and roundabout geometry.

The HCM 2000, Provides some findings about the capacity of the entry flow when buses pull in the circulating flow. The effort of weaving section is not taken into account or simply not considered by the HCM. In summary, based on the literature review, there has been a good deal of research on the capacity of roundabouts utilizing information about entry and exiting vehicles. However, little research specifically focusing on the weaving section is found in capacity estimation.

Wang, 2012, They give highest priority in the capacity analysis. The purpose of this research is to estimate the capacity of roundabout by modelling weaving gap acceptance at the weaving sections

III. METHODOLOGY

The capacity of the roundabout depends primarily on the circulating flow and the availability of gaps. Since entry stream of movement decreases if the circulating flow increases, because there are fewer gaps for vehicles entering roundabout. Therefore, the addition of each entry capacity should not be considered equivalent to the capacity of roundabouts. The concept of Wardrop's formula was applied for calculating the capacity of roundabouts. The substance of this concept is that when the stream of vehicles at the weaving section achieves the capacity and becomes the bottleneck of the roundabout, the sum of all flows at weaving sections in all directions is the capacity of roundabouts.

A. Site Selection

The site selected in the study in situated in Dehradun city of India. It is located at one of the busiest place in the city. Since the area surrounding the considered roundabout is built up, the widening of roundabout is almost impossible. The roundabout is having three approaches having almost similar angles between all of them. The widths of weaving sections are very less. The image of the selected site of roundabout is shown in Figure 1.

Fig. 1: Image of the selected site of roundabout at Clock Tower, Dehradun, India

B. Field Data Collection

Video recording technique was used to record the traffic flow characteristics including volume. The data of traffic volume was collected for more than six hours of heavy traffic conditions on a normal weekday during daytime having clear visibility. The video camera was placed at an elevated place in such a manner that the whole intersection could be captured in a single frame. It had made the extraction and analysis easier. The distance between the installed digital video camera and the roundabout was around ranges 15 to 20 meters which was appropriate to collect the required information. The length and width of weaving sections were measured manually using measuring tape. The measurements of length and width of all the three weaving sections are mentioned in Table 1.

Table – 1
Geometric dimensions of weaving sections

Weaving Section	*Length (m)*	*Width (m)*
Darshan Lal - Chkrauta	*38*	*11.5*
Chkrauta - Rajpur	*42*	*11.5*
Rajpur – Darshan Lal	*45*	*11*

C. Data extraction

Data extraction was performed manually in laboratory by playing the recorded video on computer. Location of the roundabout is in an urban area where there are relatively high volumes of traffic on the roads and congestion at the roundabout. Traffic studies were carried out to determine the traffic volume, composition of traffic stream selected sites. The vehicles category considered in the study are motorized two wheelers and three wheelers, Cars (big as well as small) and Heavy vehicles (Buses and Trucks). The volume count of each category of vehicle was done for each of the approach individually. Total volume for any particular hour is the addition of number of vehicles from all the three approaches. The extracted volume is presented in the Table 2

Table – 2
Traffic volume for every hour from each approach

Approaches	*First Hour (13:30 to 14:30)*	*Second Hour (14:30 to 15:30)*	*Third Hour (15:30 to 16:30)*	*Fourth Hour (16:30 to 17:30)*	*Fifth Hour (17:30 to 18:30)*
Rajpur	*5791*	*9148*	*9560*	*9610*	*11352*
Darshanlal	*5363*	*8081*	*6889*	*7556*	*7653*
Chkrauta	*5891*	*8476*	*9093*	*9607*	*9706*

From above table, it can be seen that number of passenger vehicle is very high. It is due to presence of maximum number of 2 Wheelers

IV. DATA ANALYSIS

A. Determination of volume

The volume data was extracted from the collected video recording. The classified volume count was done for each approach separately. The volume was counted hourly for continuous 5 hours. The combined volume from all the three approaches for every individual hour was estimated around 16000PCU/Hour. The hourly variation of volume is shown in Figure 1.

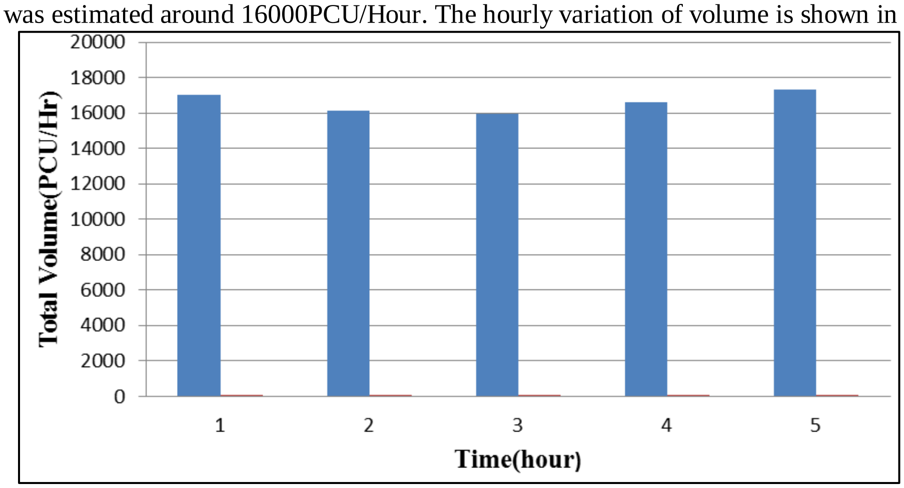

Fig. 1: Variation of total traffic volume per hour(PCU/Hr)

B. Estimation of Capacity

The capacity was calculated with the help of wardrop's formula. In this, the capacity of roundabout depends on the capacity of weaving sections. More will be the weaving traffic lesser will be the overall capacity of roundabout. For calculating the capacity, determination of weaving traffic proportions are required for every approach. The proportion of weaving traffic can be defined as the traffic having weaving movements divide by total traffic at the particular weaving sections. The weaving traffic proportion i.e. p was calculated by using equation (1).

$$p = \frac{b+c}{a+b+c+d}$$

…. Equation (1)

Where 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.
The values of weaving proportions calculated by above mentioned equation are given in Table Below.

Weaving Section	*Flow of Directions*					
	A	*B*	*C*	*D*	*Proportion Value (P)*	*Maximum Capacity (Q)*
Rajpur-Darshanlal	*5235*	*6996*	*4890*	*456*	*0.68*	*3137*
Darshanlal-Chakrata	*4124*	*3395*	*6996*	*0*	*0.72*	*3170*
Chakrata-Rajpur	*2653*	*5950*	*4259*	*456*	*0.77*	*3163*

As discussed earlier, the capacity of the considered roundabout was calculated by Wardrop's formula. The maximum value of proportion value i.e. p was used for determination. The maximum value of p suggested that the weaving section having maximum p value dealt with maximum weaving traffic. While the weaving traffic reduces the capacity of that section, it also reduces the overall capacity of roundabout. The wardrop's formula is expressed in the following equation (2).

$$Q_w = \frac{280w[1+\frac{e}{w}][1-\frac{p}{3}]}{1+\frac{w}{l}}$$

….. Equation (2)

Where, Q_w = Capacity of roundabout
w= width of weaving section
e = Entry width
p = Weaving traffic proportion
l= length of weaving section

Since the Chakrata- Rajpur weaving section having maximum weaving traffic proportion (p), the geometric dimensions of that particular section was measured manually. After putting the required measured values in above mentioned equation, the capacity calculated was 3163pcu/hr.

C. Comparison of Volume and Capacity

The volume for the considered roundabout was around 16000pcu/hr. However the peak hour volume determined was estimated 17341pcu/hr. While the capacity calculated by using the required information was only 3163 pcu/hr. Here it can be easily observed that the present volume maneuvering the roundabout is far greater than its capacity. This huge difference between volume and capacity clearly demonstrates the present of scenario of traffic condition at the roundabout. During peak hours, the congestion problem is quite obvious and mostly leads to interlocking of roundabout. Since the roundabout lies in fully built up area, hence widening could not be possible. Therefore to overcome this problem there should be installation of signals which would facilitate the safe and smooth movement of vehicles particularly in peak hours

V. CONCLUSION

The analysis shows that the volume during peak hours is much higher than the capacity of the roundabout. Since the roundabout situated in an urban area, the provision of providing the signals would be a good option for avoiding congestion. During peak hours, the interlocking of roundabout could be avoided by using signals at approaches' entrance. To control the pedestrian effects on roundabout capacity and performance, the development of sidewalks with control access for pedestrian movement should be provided. Moreover, there might be a requirement of dedicated pedestrian signal also particularly during evenings.

VI. SCOPE OF FUTURE WORK

Congestion is an unavoidable condition as there will be scarcity of resources always. Therefore a certain amount of restraints on traffic has to be applied before the situation will become worse. In this study, the volume of roundabout was extremely high than its capacity. This kind of situation is quite common among the roundabouts located in built up areas. Hence similar conditions could be performed on these roundabouts. Since the collected data was limited only for peak hours, data collection of non-peak hours is also essential to investigate the problems more clearly. Signalizing the roundabout can be adopted as a future measure to reduce the frequency of congestion.

REFERENCES

[1] Hagring, O.Derivation of Capacity Equation for Roundabout Entry with Mixed and Circulating and Exiting Flows, Transportation Research Record 1776, Transportation Research Board, Washington, D.C. , pp. 91-99, 2001
[2] Troutbeck, R. J. Estimating the critical gap acceptance from traffic movements. Physical Infrastructure centre. Research 92-5, Queensland University of Technology, Australia, 1992
[3] Kimber, R.M. Gap-Acceptance and Empiricism in Capacity Prediction, Transportation Science, Vol. 23, No. 2. 1989.
[4] Weiqi Wanga, *, Xiaokuan Yangb Research on Capacity of Roundabouts, Social and Behavioral Sciences 43 157 – 168 2012