Roundabout Operational Analysis Under Mixed Traffic Conditions

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ABSTRACT

This paper addresses the most important element of operational performance of roundabout traffic intersections in Jalandhar on capacity analysis. The movements of the vehicles were observed at 5 roundabouts. Gap acceptance and follow up time were estimated for cars for one-hour analysis. The relation between a roundabout performance measure and capacity is expressed in terms of degree of saturation (volume – Capacity ratio). The capacity analysis is done based on gap acceptance method that is adopted by Tanner based on the HCM 2010. The 5 roundabouts are directly related to their approach leg numbers. Approach entry capacity has been analysed for all 5 roundabouts at their legs. Effective capacity verses entry flow relationship has been developed in order to find out the causes of their over Saturation (v/c ratio greater than 0.85) And the result indicates; number of entry lanes, number of circulatory lanes and high traffic flow are the major causes of their over saturation. Tanner models use the gap-acceptance theory (or critical headway) to simulate the behaviour of entering vehicles and vehicles circulating within the roundabout. Current research work on round about models mostly concentrates on determining the capacity of an approach based on the entering and circulating flows. Capacity analysis results indicated that out of 5 roundabouts 1 of them has greater than 0.85 degree of saturation and this roundabout has critical for traffic flow because this has degree of saturation more than 0.85. This 0.85 value is recommended by analysis procedure of tanner model. So, roundabouts are designed to operate at less than 85 percent of their estimated capacity.

Keywords: Roundabout, Capacity, Gap acceptance, Queue length, LOS, Degree of Saturation.

1. INTRODUCTION

Roundabout is a circular intersection with yield control of all entering traffic, channelized approaches, and appropriate geometric curvature, such that travel speeds on circulatory roadway are typically less than 50 km/h (30 mph). Generally, a roundabout is an alternative form of intersection traffic control. Evaluation of junction capacity of roundabouts is very important since it is directly related to delay, level of service, accident, operation cost, and environmental issues. There are three legs, four legs, five legs & six legs roundabouts in Amritsar, & most of them served more than 15 years. Since little attention have been paid to the design & capacity evaluation of the roundabouts, no one knows their capacities & level of services.

Tanner model uses gap acceptance theory (or critical headway) to simulate the behaviour of entering vehicles and the vehicles circulating within the roundabouts. Finding the safe gap (or headway) within the circulating traffic stream to enter the roundabout is the controlling variable that determines the ability of approach vehicles to enter the roundabouts. Current research works on roundabouts model mostly concentrates on determining the capacity of an approach based on the entering & circulating flows. Approach capacity is calculated as a mathematical function of a critical headway and follow up headway. Critical headway and follow up headway are two important parameters to perform operational analysis of roundabouts.

Figure 1 Milap Chowk Roundabout in Amritsar

The Highway Capacity Manual (HCM 2010) roundabout Tanner capacity model is an analytical (exponential regression) model with clear basis in gap – acceptance theory. The NCHRP Report 572 model is based on empirical exponential regression capacity model with no explicitly. Therefore, road authorities and other concern bodies need to conduct a comprehensive capacity & delay study of every roundabout, so they can think with solutions for traffic congestions, traffic delays, queue length, degree of saturations and level of services.

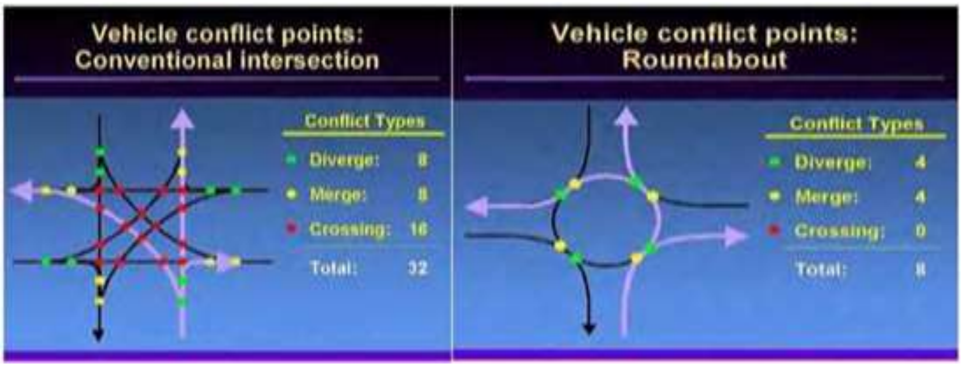

Figure 2 Vehicle Conflict Point Comparision

Now days it is common to see traffic congestions at intersections of roundabouts in Amritsar at peak hours in morning and evening. Therefore, it is necessary to evaluate the capacity of roundabouts for proper traffic operation.

Some of the problem related to capacities of roundabouts are:

- Necessarily geometric features of roundabouts such as flare and apron do not exist.
- In few roundabouts, there arises visibility problems caused by plants or elevated masonry.
- This causes the entering driver to delay on entering the circulating traffic and affecting the capacities of the roundabouts.
- Central islands of roundabout are accessed by pedestrians.
- Absence of road marking signs.
- Absence of traffic signs.
- Absence of lights for illumination purpose of the roundabout islands especially in the night driving from motor vehicle.

The specific objectives of this research were:

- To study regarding the various capacity analysis of roundabouts through literature review.
- To select the appropriate methodology to evaluating the capacities of roundabouts for a mixed sized city in Indian context.
- To define the capacities and service levels of roundabouts junctions for a mid-sized cities in Indian context.

2. LITERATURE REVIEW

Polus and Shmueli (1999) examined and evaluated the capacity model previously developed in their 1997 study. In addition, the study estimated a gap sized above which gaps are not relevant to gap acceptance process and evaluated the gap acceptance behavior of drivers entering roundabouts as their waiting time on the approached leg increased.

Al-Masaeid and Faddah developed an empirical model for estimating entry capacity as a function of circulating traffic and geometric characteristics in 1997. Ten roundabouts located throughout the Jordan were studied. Regression analysis was used to developed the entry capacity model and its performance was then compared with results of German, Danish, and French capacities models.

Hagring proposed a two-capacity model for two lane roundabouts based on previous studies (Hagring 1996, 1998) at Swedish roundabouts on the effect of Origin - Destination (OD) flows. The developed models tested on two synthetic data sets and compared with another Origin – Destination (OD) model proposed by Akcelic-et-al (1997) and Akcelic (2003). Akcelic (1998) write gap acceptance method presented in his report improves capacity prediction during heavy flow conditions and especially about multilane roundabouts with uneven approach demands.

In Kimber's initial laboratory report (1980) he states that the dependence of entry capacity of on circulating flow depends on the roundabout geometry. Kimber defines five geometric parameters which have an effect on the capacity. These are entry width and the flare, the inscribed circle diameter (a line that bisects the center island and the circulating lane twice) and the angle and radius of entry. In Kimber's 1989 paper he states that gap acceptance is not a good estimator of capacity in the United Kingdom. He also states that single-lane entries are the basis for the simplest case for gap acceptance models, while empirical models apply also to multilane entries.

Cassidy-et-al (1995) state that it is not possible to directly observe the main critical gap. This report also states that there is no evidence that a single-valued gap acceptance function cannot be used to model driver behaviour reliably to a stop sign. Tian-et-al (1999) consider the many variables that can affect critical gap and follow up time. They state that geometry, turning moments, vehicle type and approach grade were found to affect these parameters. The Federal Highway Administration (FHWA) (2000) states that it is not desirable to locate roundabouts were grades are greater than four percent. Therefore, it is assumed that most roundabouts will not deal with grade as a factor.

The Transportation Research Board (HCM 2000) presents its critical gap range as 4.1 to 4.6 seconds, and the follow up time as 2.6 to 3.1 seconds. These values are for only single lane roundabouts. It is determined that the average critical gap to be from 2.8 to 4.0 seconds and follow up time to range from 1.8 to 3.7 seconds.

3. DATA COLLECTION, ANALYSIS AND RESULTS

Study Area: The Jalandhar city is a vast city. This city (Jalandhar) composed of large amount traffic problems and also the city's population is high. So, we reduce the flow of traffic which causes congestion such that with increase capacity of roundabouts. Hence to carry out some traffic analysis and traffic data collection we have to observe some geometrics features to find out capacity analysis. The roundabouts which we have chosen for data collection and capacity analysis are enumerated below-: 1. Sardar chowk 2. PEP chowk 3. BSF chowk 4. Milap chowk 5. BMC chowk. The data collected according at peak traffic time of the day around these traffic roundabouts.

Data Collection: Data like gap reduction, gap acceptance, free flow speed and follow up time for the roundabouts were collected. Any unintended and unusual driver's behaviour such as gap forcing behaviour, violation of the right of way and unnecessarily tentative drivers was noted. Here we have collected all the data manually. The video is used to find out the lags of driver or the rejected gap or the driver who are approaching the roundabout and the lags that the drivers used to merge into the roundabout or eventually the accepted gaps plus the follow up time in instances were a formation of queue or platoons of vehicles have been observed. The vehicles like heavy vehicles and the light vehicles are summarized in the Table 1 below on the approaching leg. We should mention that the time duration of the data collected is taken as one hour.

Table (1): Vehicle volume on each leg at peak hour

Roundabouts	Heavy Vehicle	Cars & Autos	Motorcycles & Bicycles	Total No. of Vehicles	Total PCU	% of Heavy Vehicles
Sardar Chowk	107	832	1960	2899	2187	4 %
PEP Chowk	297	1057	3629	4982	3913	6 %
BSF Chowk	157	991	2326	3474	2704	5 %
Milap Chowk	276	1240	2254	3770	3333	8 %
BMC Chowk	219	1230	2872	4321	3434	2 %

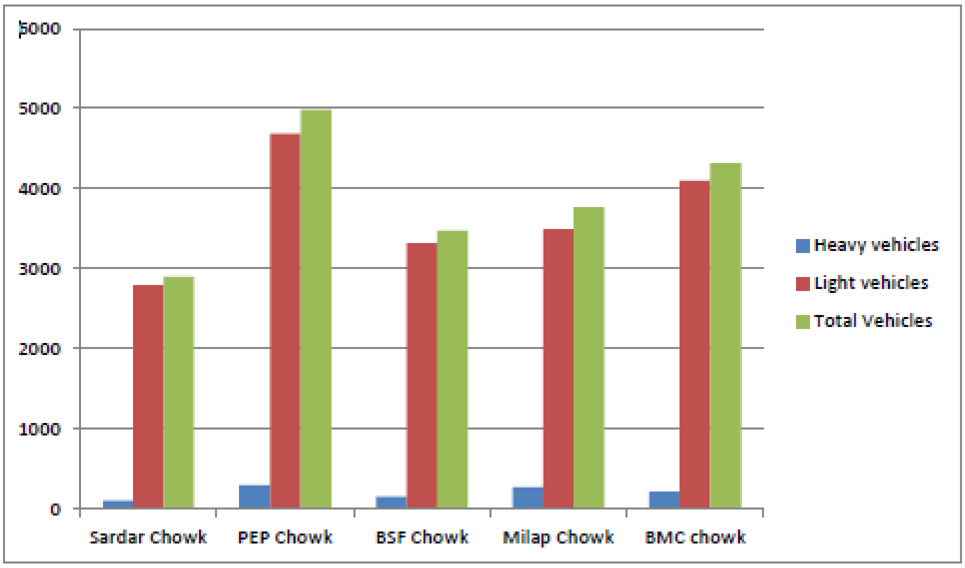

Figure 3 Maximum Peak Hour Vehicles Volume Distribution on the Intersections

Data Analysis: The data which we have calculated above if we take it into the consideration of all summarized data then by using the Tanner formulae which is basically based on HCM 2010 and model proposed in NCHRP report 572 should be used for the computation of capacity analysis. Now with the help of Tanner capacity model the results are obtained. Now this performance is measured with the help of volume-capacity ratio (or) degree of saturation and level of service based on HCM manual. If we have to estimates the capacity on the approach legs of roundabouts by using the Tanner model, NCHRP report 582 proposed model and GERMAN LINEAR model as shown below in the Figure 4. From theories given by Tanner and HCM manual there is a relationship or more specifically say a polynomial relationship exist between entry flow at leg and capacity at leg with reasonable R-squared or the coefficient of determination. The techniques (or) the curve fitting techniques result shows that it is not a linear relationship that the techniques justify and shows that relationship is polynomial relationship. The polynomial curve root mean square (also known as coefficient of determination) does not have significant result which is 0.8 even if the diagram the curve doesnot fit the distribution of values we can see that or we can observe that there is an increase in the capacity when the entry flow increases to 1500 after it decreases.

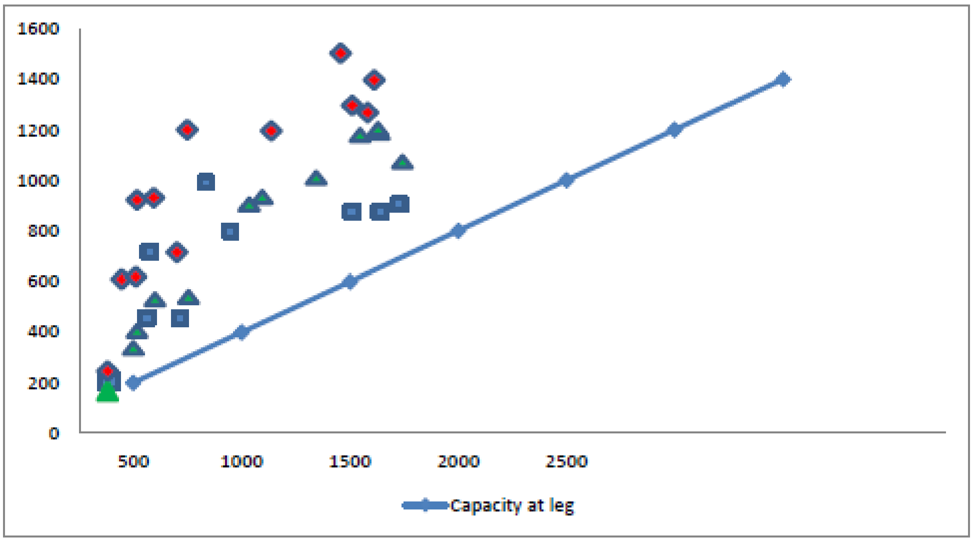

Figure 4 Leg Capacity

There is a polynomial relationship exist between the total entry flow at intersection and degree of saturation (V/C) at intersections of roundabouts. The Figure 5 clearly shows the relationship entry flow and degree of saturation (V/C) with a reasonable R-squared or the coefficient of determination.

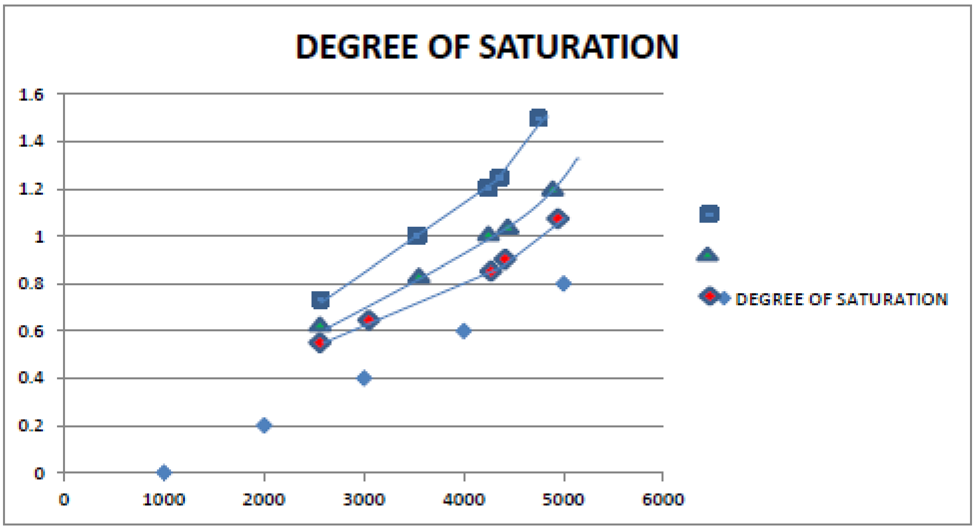

Figure 5 Entry flow vs degree of saturation

From the Table 2 it is seen that one roundabout has a very low effective capacity as compared to their entry flow. Now that is within the range of FLOS, actually the intersection performance or the capacity depends upon the approaches or legs performance and always their volume to capacity ratio is taken from the maximum volume to capacity ratio of the approaches.

Table (2): Entry flow vs degree of saturation

Roundabout	Total Traffic Flow (PCU)	Capacity	Delay	Queue Length	Degree of Saturation	Level of Service (LOS)
Sardar Chowk	2187	3657	7.01	3.66	0.55	A
PEP Chowk	3913	3924	180	190.13	1.09	F

BSF Chowk	2704	3125	9.60	6.58	0.73	A
Milap Chowk	3333	3062	10.57	12.57	12.5	A
BMC Chowk	3434	3081	14.85	22.34	0.89	B

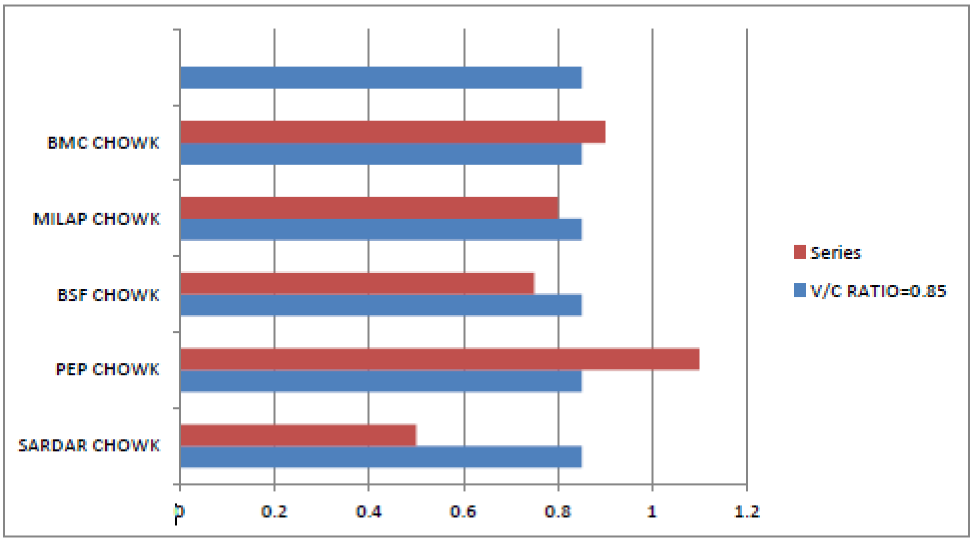

Figure 6 Degree of Saturation at Intersection

As in here Figure 6 shows that degree of saturation with 0.85 being recommended limit by HCM manual (2010). PEP chowk has a higher entry flow at their intersection more than 3500 and also their V/C ratio is very higher and it is more than one. From the figure it can be observed that their higher traffic flow may lead to higher volume capacity ratio. However it is or this is so ahead of the schedule and there is no option choosing without observing other parameters and by capacity analysis result.

4. SUMMARY

As it is based upon the literature reviewed every country in the world would not have same methods of capacity analysis it must be different in each country or different countries must have their own methods of capacity analysis which is set and sent by so many different researchers, but after this theory we can categorize them into the totally roundabout geometry which depends upon approach leg that is the empirical method. In the analytical method many different types of method included such that gap acceptance approach that driver behavior, entering splits and circulating splits, type of vehicle and conflicting circulatory flow are included into the analytical method.

5. CONCLUSION

Jalandhar roundabouts capacity analysis indicates that most of intersecting legs of roundabouts are over saturated and are in serious problem. As based upon on observed actual field condition it is common to see that at the peak hours their traffic police have to intervene and regulate the traffic at these roundabouts since in this situation traffic control devices cannot function or regulate the traffic. Also, this study cannot cover all the real issues which are identified with the deficiencies of number of entry lanes, high traffic flow, number of circulatory lane and unbalanced traffic on the approaches of the roundabout. Also, it has been mentioning earlier that most of the roundabouts were built more than 15 years ago with all the obscure service limit. All the input parameters which are required for capacity analysis of the empirical method do not exist at the Jalandhar roundabouts. That is why we have only analytical method was carried out in the capacity analysis with the parameters using the Tanner formula based on HCM 2010 manual. As we can see that high traffic entry flow at the PEP chowk roundabout was found to be more than 3500. Now it is the high traffic to be accommodated and serviced by any a roundabout. In addition, there is a high traffic flow at the north leg of PEP chowk that shows high percentage of traffic volume share which is very high as compared to the recommended unit and thus this limit value is not recommended by the roundabout. Also, we have made calculated conclusions that maximum capacity occurs at the Milaap chowk and the minimum flow occurs at Sardar chowk and also minimum capacity occurs at the PEP chowk. Now the east leg of BSF chowk, and north and south leg of PEP chowk, Milaap chowk and the BMC chowk roundabout have very low effective capacity than their entry flow. They are within the range of E to F LOS. So, these legs are in the critical condition, the entry lane of east leg of the BSF chowk, north and south leg of Milaap chowk are not adequate. The circulatory lane of south leg of PEP chowk, north and south leg of BMC chowk are not adequate.

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