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Capacity Analysis and traffic performance of roundabout in heterogenous traffic conditions

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ABSTRACT

The current condition of roundabouts in india is highly congested and unoperational during peak hour period. The result of congestions results in high traffic delays and extra fuel consumption. There is an urgent need to analyse the parameters such as the design and geometrics of the roundabouts. In the current study, the capacity of roundabouts is evaluated using different roundabout models which are TANNER MODEL, NCHRP MODEL and GERMAN MODEL.

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.

KEYWORDS

Introduction

A roundabout is a conventional form for intersection traffic management. Roundabouts are normally circular in structure, distinguished by giving way on entry and circulation around a central island. Roundabouts are suitable for accident prone zones, traffic delays, and approaches with relatively average traffic flows. Roundabouts can really help in mitigating traffic congestion and traffic delays. In roundabouts, the traffic volume on one approach is significantly higher that it prevents vehicles at any other approach from entering the roundabout particularly at a downstream approach or the next following approach. Calculation of junction capacity of roundabouts is very important because many factors are associated with it such as traffic delays, operational cost, environmental problems, level of service and accidents. There are three legs, four legs, five legs and six legs roundabouts in Varanasi and most of them have served more than 15 years. The amount of attention paid on the geometrics of roundabouts is very less so it is hard to evaluate the capacity and level of service.

Tanner model uses the gap-acceptance theory (or critical headway) to simulate the behavior of vehicles circulating within the roundabout and vehicles entering the roundabout. Finding a safe gap (or headway) within circulating traffic stream entering a roundabout is the controlling variable that determines the ability of approach vehicles to enter the roundabout. Ongoing research works on roundabout models mostly focuses on evaluating the capacity of an approach based on the circulating and entering flows. Approach capacity is evaluated as a mathematical function of follow-up headway and critical headway. This method is not sensitive to roundabout geometric functions such as inscribed circle diameter, entry angle, etc. The level of traffic stream performance itself can have an impact on driver behavior and increasing the complexity of modeling roundabout operations.

Follow-up headway and critical headway are two important factors to conduct the capacity analysis of roundabouts. Critical headway at roundabouts defined as the minimum time interval in circulating flow when an entering vehicle can safely enter the roundabout. when faced with any headway equal to or greater than the critical headway a driver would enter the roundabout. Follow-up headway is defined as the minimum headway between two entering vehicles, which can be calculated by the average difference between passage times of two vehicles entering and accommodating the same mainstream headway under a queued condition. That is to say the follow-up headway is equal to the inter-vehicle headway on an approach at capacity. On increasing the follow-up time and critical gap which results in the decrease of its capacity.

Roundabouts can be classified into two broad categories – empirical and theoretical. The Tanner model is based on gap-acceptance theory with gap-acceptance criterion. Giving importance to the gap-acceptance theory the Highway Capacity Manual (HCM 2010) roundabout tanner capacity model is a logical (exponential regression) model.

Therefore, road authorities and other concerned bodies need to have a thorough check on capacity and delay study of every roundabout, so they can come up with the solutions for the traffic congestions, traffic delays, queue length, Degree of Saturation and level of services.

Vehicle Safety:

Roundabouts have less conflict points than conventional intersections and also involve lower operating speeds for both the driver entering the roundabout and the driver driving in the roundabout. A conflict point is defined as the location where the paths of two motor vehicles or a vehicle and pedestrian queue, diverge, merge, or cross each other. The following figure is used to illustrate the reduction in conflict points:

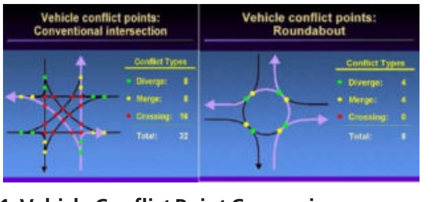


Figure1-1: Vehicle Conflict Point Comparison

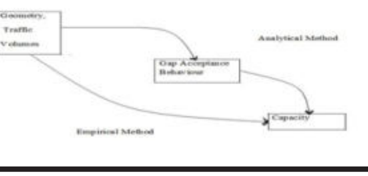
At four-way stop roundabouts have about a 75% decrease in vehicle conflict points compared to a traditional intersection. Three types of conflicts are defined in the report: merge and diverge conflicts, and crossing conflicts. Crossing conflicts are frequently the most serious in terms of vehicular injuries and fatalities. At a traditional intersection accidents are frequently happen when a driver neglects to stoplight or stop sign. By eliminating crossing conflicts, roundabouts were designed dramatically lower the incidents of injuries and fatalities associated with conflict points.

2 Methodology

There are two different theories or methodologies to assess the capacity of the roundabouts. These theories are:

(i) Analytical methods

(ii) Empirical methods



Analytical method includes the:-
- Tanner Capacity Model HCM 2010 model

Empirical method includes the:-
- UK model and NCHRP report model
- German Model

Study area and data collection

3.1 Study area

Varanasi is one of popular city in india in the state of Uttar Pradesh known for its culture and tourism. This city contains more population and more traffic problems so we can reduce traffic flow with increase capacity of roundabouts. The essential geometric and peak hour traffic data are collected at roundabouts. That roundabouts are chosen based on the principle of possible representative of the target population of roundabouts regarding size and numbers. Varanasi has many roundabouts and the chosen roundabouts have three legs and four legs in order to fully represent the size of the roundabouts. Actually, most of these roundabouts were built before 15 years ago when rotary and traffic circles are popular but now the drivers have to operate in accordance to modern roundabout traffic rules. Since tanner model does not depend on geometric elements, but they are more dependent on traffic rules. So that collecting traffic data and observing some geometric features possible to carry out the capacity analysis.

The chosen roundabouts for traffic study are:-
- Bhu Gate Chauraha
- Girjighar Crossing

Bhu Gate Chauraha

Girjighar Crossing

3.2 Data Collection

Gap acceptance/rejection, follow-up time and free-flow speed are collect from the video for the roundabouts. Any unusual driver behaviour such as gap-forcing behaviour, violation of the right-of-way, and unnecessarily tentative drivers was noted. All the data is collect manually. The traffic data collected should indicate the existing peak hour traffic conditions. Data are collected with the aid of a video camera to record the entry and exit of vehicles at two roundabouts in Varanasi. The video enabled information on volume, delay and speed and gap acceptance to be determined. The use of a video camera is noteworthy because it permits the use of the minimum number of personnel and the tapes can be reviewed several times to obtain the most accurate information. The video is used to determine the rejected gaps or lags of drivers approaching the roundabout and eventually the accepted gaps or lags that the drivers used to merge into the roundabout plus the follow-up times in instances where there is a queue.

The vehicles summarized as shown in table 3-1 on approach leg and in table 3-2 on intersection. The data is collected for one hour or 60 minutes duration.

Table 3-1 Summarized vehicle volume on each leg at peak hour

Round about	Leg No.	Heavy Vehicles	Light Vehicles			Total Number of Vehicles	Traffic (PCU)
			Cars & autos	Motor cycles & bicycles	Total		
BHU Gate	E	23	125	377	502	525	394
	W	16	82	369	451	467	323
	N	35	284	653	937	972	733
	S	29	337	557	894	923	717
Girjaghar Crossing	E	18	91	196	287	305	252
	W	4	47	135	182	186	129
	N	159	517	2219	2736	2895	2183
	S	112	398	1076	1474	1586	1328

Table 3-2 Summarized vehicles volume on intersections at peak hour

Round about	Leg No.	Heavy Vehicles	Light Vehicles			Total Number of Vehicles	Traffic (PCU)
			Cars & autos	Motor cycles & bicycles	Total		
BHU Gate	103	828	1956	2784	2887	2167	4
Girjaghar Crosing	293	1053	3626	4679	497	3892	6

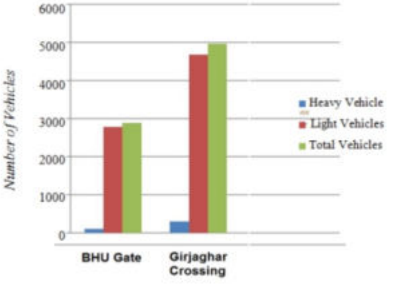


Figure 3-1Maximum Peak Hour Vehicles Volume Distribution on Intersections

Figure 4-1 clearly shows the maximum and the minimum numbers of vehicle traffic at junction of roundabouts. The reason for this can mostly be attributed to land use. The maximum number of vehicles occurs at Girjaghar Chauaraha and minimum number of vehicles occurs at BHU Gate chowk.

Data analysis and Results

4.1 General

Taking in to consideration all the above summarized data, we can proceed to the capacity analysis using tanner formula based on HCM 2010 and model proposed in NCHRP Report 572. However, some extra data is required to represent driver behaviour.

Gap-acceptance parameters, critical gap and follow up headway were measured during the traffic flow count. So better results are obtained and it is good to do it simultaneously with the traffic count. When it is measured with the traffic count on different legs at the same roundabout, different results of critical and follow up headway can be observed. Critical and follow up headway collected from roundabouts which is attached in the APPENDIX-A and also show in table 4-1

Table 4-1 Critical gap and follow up time of each leg of round about

Leg No.	N		S		E		W	
Round about	Critical gap(sec)	Follow up time (sec)	Critical gap(sec)	Follow up time (sec)	Critical gap(sec)	Follow up time (sec)	Critical gap (sec)	Follow up time (sec)
BHU Gate	4.01	2.5	3.83	2.6	3.64	2.93	3.4	3.6
Girjaghar Crossing	3.13	2.41	3.10	2.7	3.75	2.68	4.87	3.24

Table 4-2 Capacity estimation of roundabouts following Tanner's Model

Round about	Total Vehicle Flow	Capacity	Degree of Saturation(V/C)

BHU Gate	2167	3928	0.55
Girjaghar Crossing	3892	3569	1.09

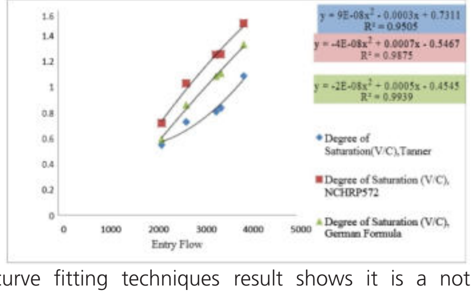
Table 4-3 Estimation of Capacity using Model proposed in NCHRP REPORT 572

Round about	Total Vehicle Flow	Capacity	Degree of Saturation(V/C)
BHU Gate	2167	3023	0.72
Girjaghar Crossing	3892	2593	1.50

Table 4-4 Capacity estimation of roundabouts following German linear Model

Round about	Total Vehicle Flow	Capacity	Degree of Saturation(V/C)
BHU Gate	2167	3637	0.595
Girjaghar Crossing	3892	2914	1.335

There is polynomial relationship between total entry flow at intersection and degree of saturation (v/c) at intersection of roundabouts. Figure 5-2 clearly shows the relationship entry flow and degree of saturation (v/c) with a reasonable R-squared or coefficient of determination



The curve fitting techniques result shows it is a not linear relationship but it is a polynomial one. The polynomial curve root mean square (coefficient of determination) does not have significant result which is 0.9. Even if the curve does not fit from the distribution of the values, we can observe that there is an increase the degree of saturation when the entry flow increases

From Table 4-5 it is seen that 1 roundabout has very low effective capacity compared to their entry flow. That is within the range of F LOS. Actually the intersection performance or capacity depends on the approaches or legs performance and always their v/c ratio is taken from the maximum v/c ratio of the approaches.

Table 4-5 Summarised analysis results on the intersection based on tanner model

Round about	Total Vehicle Flow	Capacity	Delay	Queue length	Degree of Saturation	Level Of Service (LOS)
BHU Gate	2167	2998	7.03	3.65	0.55	A
Girjaghar Crossing	3892	3569	179.42	191.13	1.09	F

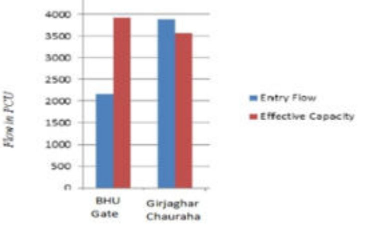


Figure 4-3 Peak Flow Vs Effective Capacity

Figure 4-3 shows peak flow or entry flow verses effective capacity and it clearly shows the maximum flow occurs at the Girjaghar Chauaraha and minimum flow occur at BHU Gate chowk ,minimum capacity occur at Girjaghar Chauaraha.

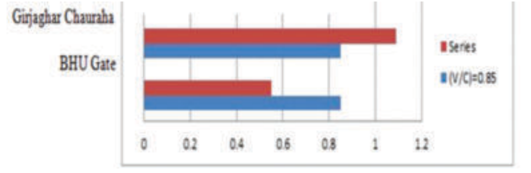


Figure 4-4 Degree of Saturation at Intersection

To give a clear picture of the result Figure 5-4 also presents degree of saturation with 0.85 being the recommended limit by HCM.

Girjaghar Chauaraha has higher entry flow at their intersection more than 3500 and their v/c ratio is very high and more than 1. From this we can observed that their higher traffic flow may lead to higher (v/c) ratio however it is so ahead of schedule there is no option choose without observing other parameters and legs capacity analyses results. For all intersection, lane-by-lane capacity has been done and capacity at legs, degree of saturation and opposing circulatory flow has been summarized as shown in Table 5-8

Before we investigate the reason for their inadequacy it is better to see the assumption on the theory in respect of direct relationships of capacity at legs and opposing circulatory flow. Capacity at legs is influenced by the average entry lane width and number of entry lane. Since it was first developed considering opposing circulatory flows vs capacity at legs relationship as it was mentioned using curve fitting techniques. The developed relationship is indicated in figure 4-5 below.

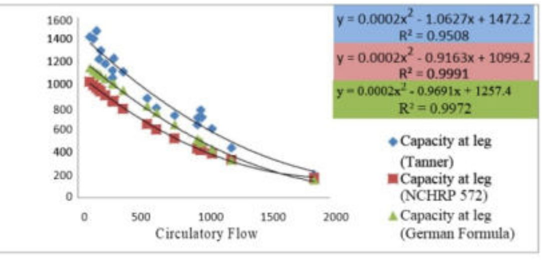


Figure 4- 5 Opposing circulatory flow vs Capacity at leg

The curve fitting techniques result shows it is a not linear relationship but it is a polynomial one. The polynomial curve root mean square (coefficient of determination) does not have significant result which is 0.9. Even if the curve does not fit from the distribution of the values we can observe that there is decrease the capacity when the circulating flow increases.

5. Conclusion

Varanasi roundabouts capacity analysis results indicate the legs of roundabouts are in serious problems or over saturation. Based on observed actual field conditions it is common to see that at peak hours, the traffic police need to regulate the traffic at these roundabouts since traffic control devices cannot function or regulate the traffic. As the study uncovered the real issues are identified with deficiency of number of entry lanes, number of circulatory lanes, high traffic flow and unbalanced traffic on the approaches o roundabout. Besides most of the roundabouts were built more than 15 years ago with obscure service limits.

All the input parameters of empirical method for capacity analysis do not exist at Varanasi Roundabouts. Thus only analytical method was carryout the capacity analysis with parameter using Tanner Formula based on HCM 2010.

High traffic entry flows at Girjaghar Chauaraha roundabout was found to be more than 3500. This traffic is very high to be accommodated by the roundabout. In addition there is also high traffic flow (2183) at north leg of Girjaghar Chauaraha that show high percentage of traffic volume share (56%), which is not recommended for roundabouts. There is an urgent requirement to look over the geometrics and design parameters of studied roundabouts in coming time otherwise consistent traffic congestion would paralyse the commuters ride.

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