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COMPARATIVE STUDY ON CAPACITY ESTIMATION FORAN UNCONTROLLED INTERSECTION OF EXISTINGROADS

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ABSTRACT: Rotary intersection, also known as Roundabout, provided for conventional intersections. This rotary intersection, have traffic calming effect by reducing vehicular speeds using geometric design. Rotaries require less maintenance than traffic signals. A well designed roundabout achieves a balance of safety and efficiency.

In the past years various models have been developed for analyzing the traffic flow on these intersections. These methods are classified in two groups. The first group consist of methods which are purely empirical and based on geometry of intersection. The second group consist of methods which are based on Gap acceptance process.

In this paper, I have worked on the traffic of Srinagar city in Pantha Chowk, for a comparative study for which different models are used for determining critical gap, also the methodologies for extraction of head way, lag, acceptance and rejected gap has been suggested. It has been found that the Lag time utilize by the minor front vehicle and the major front vehicle in case of parallel approach by two vehicles of minor stream in same gap is defined as the front lag in the study. It has also been concluded that the critical gap is dependent of the type of vehicle, and critical gap obtained using Raff's method is highest for two wheeler and lowest for three wheeler. Harder's method, Raff's method and Ashworth's method has been used to determine the critical gap in the present study and the result show that the critical gap value obtained using the accepted and rejected lag gives the lowest value of critical gap. The Ashworth's method which takes into account, the mean and standard deviation of accepted gaps indicates the highest value of critical gap.

I. INTRODUCTION

1.1OVERVIEW

India is being ranked as second most populous country in the world, with over 1.25 billion people. Already containing 17.5% of the world's population, India is projected to be the world's most populous country by 2025. Due to this there is growth in transportation demand, which results in increase in vehicular movement and hence increase in vehicular volume on roads. This increase in vehicular volume affects the level of service (Q, K &V) and safety of road especially at critical locations like intersection of two roads where vehicles moving in different directions compete for the use of same space. In India intersections are comparatively more critical as the traffic composition is basically of heterogeneous nature. All metropolitan cities have busy urban streets, especially during peak period of the day, and the intersection on these streets become the major place of conflicts to the smooth flow of vehicles. The capacity of intersections further gets reduced due to the presence of other road side commercial and social activities. For the purpose of providing solution it is required to provide the intersection with proper mechanism, which can reduce the conflicts, delays, and enhance safety. This mechanism can be in the form of signal system, flyover or roundabout depending on the magnitude of the traffic flow. Flyovers or grade separated intersections can also prove to be appropriate in conditions where flow is high in both the directions but restricting the change in direction is a point of concern here which again needs to be addressed. Under many traffic conditions, an un-signalized roundabout may operate with less delay to users than traffic signal control or all-way stop control. Unlike all-way stop intersections, a roundabout does not require a complete stop by all entering vehicles, which reduces both individual delay and delays resulting from vehicle queues and hence capacity of intersection can be enhanced. A roundabout may also operate much more efficiently than a signalized junction because drivers are able to proceed when traffic is clear without the delay incurred while waiting for the traffic signal to change. These advantages also reduce air pollution from many idling vehicles waiting for traffic lights to change. Roundabouts are also found to be safer than both traffic circles and junctions—having 40% fewer vehicle collisions, 80% fewer injuries and 90% fewer serious injuries and fatalities (According to a study of a sampling of roundabouts in the United States, when compared with the junctions they replaced) (Highway Safety Research and Communication Website). At traditional junctions with stop signs or traffic lights, the most serious accidents are right angle, left-turn, or head-on collisions that can be severe because vehicles may be moving fast and collide at high angles of impact. Roundabouts virtually eliminate those types of crashes because all vehicles travel in the same direction and most crashes are glancing blows at low angles of impact. Roundabouts can increase delays in locations where traffic would otherwise not be required to stop, however, for example, at the junction of a high-volume and a low-volume road, traffic on the busier road would normally not have to stop if the junction were signalized, because the traffic signals would provide a green signal to the busier road the majority of the time. When the volumes on the approach roadways are relatively balanced, a roundabout can reduce delay because each approach would otherwise encounter a red signal greater than half of the time if the junction were signalized and hence can affect the capacity of intersection.

1.2NEED OF STUDY

Roundabout provides orderly continuous traffic flow which reduce the conflict angle. For moderate traffic roundabouts are self-governing and need no control by traffic police for traffic signals. When traffic flows from one or more legs increases to or more than its capacity, then the operation of roundabout becomes difficult and it may get inter-locked and all vehicles in the roundabout may come in standstill condition and need to be controlled by traffic police. By studying the capacity parameters like, weaving phenomenon headway, speed, etc., and developing their relationship with the roundabout capacity, one can increase handling capacity of roundabout. There has been many capacity models developed in countries like United States, Australia, U.K., Germany, which are developed for the homogeneous traffic condition. As in urban India, traffic conditions being heterogeneous with two wheeler as domination mode model developed. Roundabouts have been used worldwide as an efficient intersection control type to improve safety and operational efficiency and hence major research on the capacity of roundabouts has been carried out in several countries including the United Kingdom, Australia, United States, Germany, and France and various models have been developed in past for analyzing the traffic flow on these intersections. These methods can be broadly classified in two groups. The first group consists of methods which are purely empirical and are based on geometry of intersections verses entry width, entry angle, no of lanes in entry and circulation etc. The second group consists of methods which are based on Gap acceptance process. Gap acceptance process depends upon Critical Gap and follow-up time. Since un-signalized intersections give no positive indication or control to the driver which alone must decide when it is safe to enter the intersection, the driver looks for a safe opportunity or Gap in the traffic to enter the intersection. Critical gap can be defined as minimum gap that all drivers in minor stream are assumed to accept at all similar locations, or in other words it is that accepted gap which gives maximum capacity at an intersection. Trout beck and Brilon (2001) defines Critical Gap as the minimum time gap in priority stream that a minor street driver is ready to accept for crossing or entering the major stream conflict zone. They also defined the Follow-up time as the time gap between two successive vehicles from minor stream while entering the conflict area of the intersection during the same major street gap.

1.3ROUNDABOUT

Traffic intersections are complex locations on any road. This is because vehicles moving in different directions want to occupy same space at the same time. In addition, the pedestrians also seek same space for crossing. Drivers have to make split second decision at an intersection by considering his route, intersection geometry, speed and direction of other vehicles etc. A small error in judgment can cause severe accidents. It also causes delay and it depends on type, geometry, and type of control. Overall traffic flow depends on the performance of the intersections. It also affects the capacity of the road.

II. OBJECTIVES

The objectives of the study are as under:

- To study classified gap acceptance behaviour.
- To evaluate efficacy of different methods for estimating critical gaps.
- To study speed Profile of dominating vehicle.
- .To study Headway distribution pattern for Indian condition.

For attaining the above said objective, vehicular movement at weaving zone of un-signalized intersection is closely studied and observation on gap acceptance will be made. From the collected data, value of Headway, Spacing and hence critical gap will be estimated using various methods.

III. REVIEW OF LITERATURE

Hani Mahmassanian d YosefSheffi (1980) Cambridge, Traditional gap acceptance functions have been estimated based on the first gap observed. In this paper we show that the critical gap of drivers is decreasing on the average as they are waiting for an acceptable gap. Our gap acceptance function is based on a prohibit model which assumes a normal distribution of gaps across gaps and drivers. The data includes 203 observations (drivers) collected from roadside observations at various intersections in Berkeley, including all rejected gaps and the accepted one for each observation (406 records were thus used for the estimation).

C. S. FISK (1991), New Zealand, has focused on the problem of estimating traffic performance characteristics like, capacity, queue length, and delay at one and two lane traffic roundabouts. Where drivers have a choice of lane for manoeuvre, a user optimal model is used to allocate flow to alternative lanes. The analysis is suitable for inclusion in traffic assignment models which explicitly represent traffic conflicts at intersections, or in standalone analytically based computer programs which analyze a single roundabout.

Werner Brilon, Ralph Koenig, Rod J. Troutbeck (1999) Australia gives an overview of some of the important methods for determining critical gaps, been used worldwide. These methods are described by their characteristic properties. For comparison purposes a set of quality criteria has been formulated by which the usefulness of the different methods can be assessed. Among these one aspect found in study as to be of primary importance is that the results of the estimation process should not depend on the traffic volume on the major street during the time of observation. Only if this condition is fulfilled, can the estimation be applied under all under saturated traffic conditions at un-signalized intersections. To test the qualification of some of the estimation methods under this criterion, a series of comprehensive simulations had been performed. Further it was also concluded that, the maximum likelihood procedure and the method developed by Hewitt can be recommended for practical application. Moshe A. Pollatschek, AbishaiPolus and Moshe Livneh (2001) Israel, presented a microscopic decision model for driver gap-acceptance behaviour when waiting at an Unsignalized intersection on the secondary road and also to estimate the resulting intersection capacity. The model is based on evaluation of the risk associated with not accepting small gaps against the

potential benefit of their acceptance, which has saved time as a result of shorter waits at the entry line. The model takes into account individual preferences by defining individual critical gap, which is different from the traditional macroscopic critical gap approach. The latter estimates the critical gap for the entire population of drivers. The paper presents the difference between different driver populations (risk loving vs. cautious) and shows how this difference actually results in different capacities on the minor road.
Akcelik R. (2003), 2nd Urban Street Symposium, California, U.S.A. has taken a single lane roundabout as a case study from the United States to compare capacity estimates using gap-acceptance based Australian and Highway Capacity Manual method and the linear regression based UK (empirical) method. Some contradictory results obtained from these models are highlighted and reasons for differences are discussed by the author. Such systematic differences have important design implications.

Author has also discussed the UK roundabout research, and explained why the UK Linear Regression model will underestimate capacity for low circulating flows and overestimate capacity for high circulating flows.
Joewono Prasetijo (2005) Germany, compared the capacity determined by Indonesian Highway capacity Manual (1997) with the modern gap acceptance method since the Indonesian Highway Capacity Manual used empirical relations to determine the capacity of un-signalized intersection. Due to the effect of various conditions such as geometric design of roads, flows and environment which would reduce or increase the actual capacity from the basic capacity and based on the previous data calculated in similar traffic condition, the actual capacity was found to be decreased to certain extent. However, it is rather difficult to get detailed information since there was no information in service time of every stream of every approaches and every type of vehicles.
Sun Yon HWANG Chang Ho PARK (2005) Korea, the gap acceptance model was designed primarily to reflect a drivers' behaviour. After composing and estimating the model, we found that the space gap is a more important variable than the time gap. Because drivers run at their own speed, they tend to be more restrained by space than time. That is, drivers generally consider distance as a more important factor for determining the safety of a certain lane change.
The factors determining gap acceptance include the lead gap, lag gap, front gap, heavy vehicle and the remaining distance. Congestion greatly affects gap acceptance. Whether conditions are congested or not depends on gap acceptance. When there is traffic congestion, we are more likely to observe behaviours such as nosing occurs and provides different results.
Feng Xu (2007), University of Nevada, Reno, has addressed driver's gap-acceptance behaviour characteristics at roundabouts and documents the measurement results of critical headway and follow-up headway based upon selected roundabout sites in California. The maximum likelihood methodology was applied in this study to calculate the critical headway, while the follow-up headway was obtained directly from the extracted time events. Raff's method was used to estimate the critical headway and compared with the result of maximum likelihood method. In addition, the factors affecting critical headway and follow-up headway were also investigated. The conflicting flow rate and the speed of the circulating traffic were found to have a negative correlation with both critical headway and follow-up headway. GUO Ruijun LIN Boliang (2010), China, a frequent confluence and divergence operations at roundabout weaving sections. The author had analyzed some parameter performances, which included the velocity distribution, the distance distribution of lane changing, the headway distribution of confluence vehicles, and vehicles on circulating lanes, as well as the application of accepted headways. Besides, some conclusions were drawn, for example, the vehicle velocity of outer circulating lane is larger than the inner circulating lane; the confluence vehicle is smallest; the divergence operation occurs later than the confluence operation; the confluence vehicle velocity has a tendency to increase with the accepted headway increase; the posterior gap is usually larger than the frontal gap in one accepted headway; the equivalent critical gap of multilane roundabouts is smaller than the critical gap of single-lane roundabouts.

IV. DETERMINATION OF CRITICAL GAP

INTRODUCTION

The value of accepted gap is not constant. It differs from driver to driver and vehicle to vehicle at every particular situation. The critical gap as per various definitions will change with the values of accepted and rejected gap. Hence determining the critical gap itself is a point of concern. Various methodologies and concept have been put up in recent past by various researchers worldwide for determining the critical gap. However, the condition in which they have been derived and used so far is different from the Indian traffic condition since we have heterogeneous traffic condition. Few of those methods have been used for the study area and the results are observed as under.

HARDER'S METHOD

This is a simple method based on the values of Gap. The drivers are assumed to be consistent so as to simplify the method. A consistent driver is assumed to behave or react in the same way in different situations. For determining the critical gap using this method, all Gaps were measured using the frames generated by the videos recorded for the study area. The acceptance and rejection of the gaps has been noted and the time scale is divided into segments of 1 second. The number of observed and accepted Gaps at every interval of 1 second is observed. The ratio of observed and accepted gap for the particular segment is estimated as ai. If the assumption is made that the proportion of drivers who accept a gap of size t seconds is identical to the probability that a driver has critical gap value smaller than t, then,

Pa, Gap= Fc(t)

And if ti is the time at the center of interval i, then

Fc (ti) = ai

This is an approximation of the cumulative distribution function of critical gaps. The mean critical gap is then given as

$tc=\sum^{W} ti.Fc(ti)-Fc(ti-1)$
Where W is the number of intervals of 1 second.
The data for the accepted and rejected Gaps for the study area was utilized to determine the value of critical gap by dividing the segments at an interval of 1 second. The number of observed and rejected Gaps and the calculation of critical gap is shown as under.

Calculation for Harder's Method for Critical Gap

Time (Sec)	Accepted Gaps	Rejected Gaps	Observed Gaps	a_i	$F_c(t_i)-F_c(t_{i-1})$
0-1	23	61	84	3.65	---
1-2	103	35	138	1.33	2.32
2-3	86	5	91	1.06	0.27
3-4	55	0	55	1	0.06
4-5	13	0	13	1	0

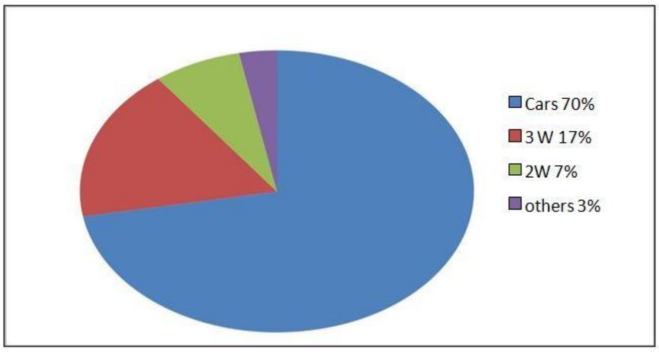
Using the equation stated above, the value of tc is calculated as 1.295 seconds. Brilonet.al. has noted that for practical applications this method has some drawbacks. For the method, in each interval i, a sufficiently large sample should be available and for this, longer observation period is required. Another disadvantage noted is that it only considers the condition where no queuing occurs. An additional problem could be that the critical values can be systematically different from that for the gaps. As a result of all these points, the Lag method is not used in practice.

ASHWORTH'S METHOD

For exponentially distributed major stream gaps with statistical independence between consecutive gaps and normal distributions for ta and tc, Ashworth stated that the average critical gap tc can be estimated from mean of accepted gaps (μa) and standard deviation of
accepted gaps (σa) using the following relation
tc = μa – p. σ2a
Where, p is the major stream traffic volume observed in vehicles per second. The maximum volume at the study section is found to be 60 vehicles per minute and hence the value of p for estimation is taken as 1. The mean value of accepted gap for all type of vehicles is observed to be 2.155 with the standard deviation of accepted gap values as 0.7886. With these values, using the above stated equation, the value of critical gap is obtained as 1.53 seconds.

TRAFFIC VOLUME ANALYSIS
It can be seen that the proportion of car is highest and it is followed by 3-wheelers which is a major mode of public transport in Srinagar city. The Intersection studied connects the Srinagar city with National Highway and hence the pattern of flow to and from residential zone to commercial zone can be observed from the chart below in both morning and evening peak hours.

MORNING PEAK



EVENING PEAK

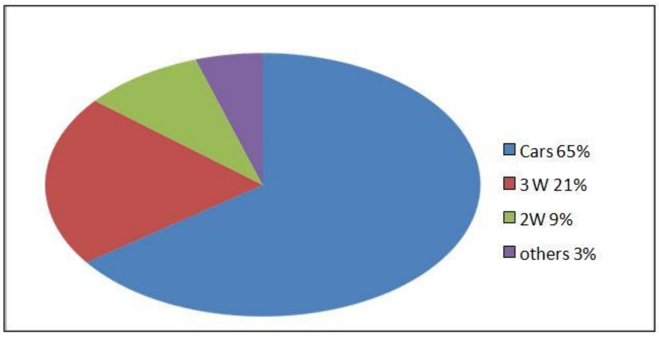
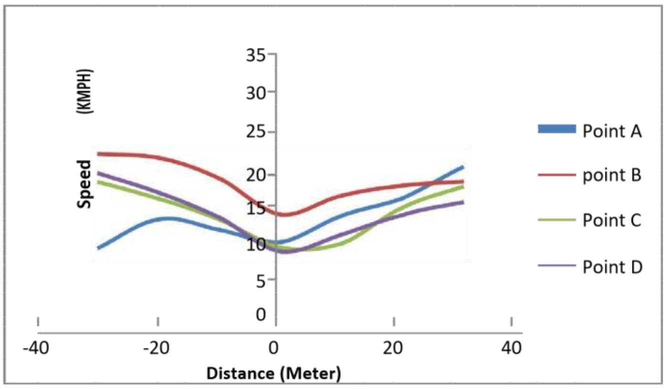


Chart showing the proportion of each vehicle type using the intersection
The major flow in morning peak is observed from leg 1. However the quantity of flow of vehicles entering the intersection in evening peak hours is observed to reduce. The opposite pattern is seen in the chart showing the proportion of vehicles exiting the intersection in morning and evening peak hours.

5.5 SPEED PROFILE
The speeds of the vehicles were observed to reduce when the vehicles approach towards the conflict zone. This is studied from the speed profile plotted using performance box mounted on car as study vehicle.
The vehicles show the similar pattern of speed decreasing towards conflict zone and increasing once the vehicle has passed the conflict zone. The speed of vehicle at conflict zone is observed to be low and ranging between 15 and 20 kmph. The conflict zone B has highest speed since the flow from the nearest leg (Leg 2) is lowest due to which the conflict chances are low and hence the vehicles move at a comparatively higher speed.



Speed profile at conflict points

FOLLOW UP TIME

The follow up time by the vehicles entering the intersection is tabulated below. The average value of combined follow up time for all the legs is found to be 0.48 seconds. This value for leg 2 is highest which can be due to the flow from that leg being lowest.

Follow up time details

Follow up time	Leg 1	Leg 2	Leg 3	Leg 4	Combined
Average	0.52	0.39	0.38	0.45	0.42
Standard Deviatio n	0.25	0.22	0.19	0.24	0.23
Min.	0.18	0.16	0.08	0.17	0.18
Max.	1.28	1.04	0.92	1.16	1.28

The minimum value 0.08 second is observed from the busiest leg that is leg 4. The deviation in the follow up time is found to range between 0.19 and 0.26 seconds and the standard deviation for combined data of all the leg is 0.23 second.

HEADWAY

The headway for each leg was determined using one minute volume count data. The values obtained is summarized in the following table

Headway Time Details

Headway	Leg 1	Leg 2	Leg 3	Leg 4	Combined
Average	2.73	2.14	2.06	4.56	2.87
Standard Deviation	0.97	0.80	0.57	1.57	1.45
Min.	1.43	1.22	0.90	2.14	0.90
Max.	5.45	6.00	5.45	10.00	10.00

The highest value of minimum and maximum headway can be observed in leg 4. The other three legs have these values close to each other. The headway values are analyzed for the distribution. The distribution shows to be best fitted as exponential (negative) with the value ranging from 0.22 to 0.49. The value of lambda for the combined data set of all the legs is found to be 0.35.

LAG TIME

The lag value is seen to have their values close enough for all the legs. The standard deviation for all the legs range between 0.19 seconds to 0.26 seconds

Lag time details

Lag	Leg 1	Leg 2	Leg 3	Leg 4	Combined
Average	0.59	0.73	0.85	0.678	0.718
Standard Deviation	0.19	0.25	0.26	0.21	0.25
Min.	0.24	0.4	0.48	0.24	0.24
Max.	1.12	1.52	1.84	1.4	1.84

The lag values is highest for maximum and minimum lag for the leg 3 and are lowest for those in leg 1. The lag values shown here are excluding the values of front lag.

V. CONCLUSION

The traffic scenario in India has few unique features when compared with the traffic in developed countries. Out of various points, one important basis is the proportion of categories of vehicles. Indian traffic has almost 60 to 80 percent of vehicles as two wheelers. From the classified volume count also it can be observed that the proportion of two wheeler in total traffic using the intersection, ranges from 65% to 70%. Since the traffic condition in India is heterogeneous, a well-defined methodology for data extraction was required. The study presents various methodologies for extracting the data for Gap (Accepted and Rejected), Lag time and Follow up time. These methodologies take into account the condition of typical Indian traffic and decision making by the driver. However for the analysis of data, the driver is assumed to be consistent and homogenous. The traffic is found not observing the Lane discipline and the proportion of forced gap is found to be higher than the accepted gap. Since the vehicles differ in various ways as per their characteristics, the classified gap acceptance behaviour was studied through the estimation of critical gap by each type of vehicle using Raff's Method. The critical gap value is lowest for only 2 wheelers as 1.25 seconds. It is found highest for 3 wheelers as 1.78 seconds. For the same, when cars were considered, the critical gap value obtained is 1.425 seconds. This variation can be related to the vehicular characteristics such as dimensions and acceleration rate due to which they are found to differ from each other. Out of various methodologies available for determination of critical gap, the basic 3 methods viz. Harder's method, Raff's Method and Ashworth's Method have been applied to the data collected from the intersection. The critical gap value obtained using the accepted and rejected lag gives the lowest value of critical gap of 1.29 seconds. The Raff's method which uses the statistical distribution function of accepted and rejected gaps and their intercept, gives the critical gap value of 1.4 seconds. The Ashworth's method which takes into account the mean and standard deviation of accepted gaps indicates the value of critical gap to be 1.53 seconds. The percentage reduction in speed for approaching vehicle at every 10 meter interval is found to be more than the increase in speed by leaving vehicle. This average reduction of speed for all the conflict zones, before and after conflict point is observed to be around 17% in both the cases. It is also observed from speed profile that the drivers tend to slow down well in advance before reaching the conflict zone and they increase the speed at high pace as they leaves the conflict zone. The headway for each leg was determined using one minute volume count data. It indicates that the headway values are dependent on the volume of the traffic and the headway distribution shows that the plot is best fitted as exponential (negative) with the value ranging from 0.22 to 0.49.

FUTURE SCOPE

The study was carried out on four legged dual lane roundabout. Since there is variation in size shape and number of lanes in the intersection, and as a result of time constraint, various aspects have been untouched on which future works can be carried out.

Various methodologies have been put up by various researchers in the recent past to determine the value of critical gap. In the present study, the Lag method, Raff's Method and Ashworth's Method has been applied. Other available methods which can be applied are:

Harder's Method, Logit- Probit method and maximum likelihood method. These methods had been given and used by researchers on the data collected for homogenous traffic condition which is not the same as in Indian condition and hence these methods cannot be applied for the Indian conditions.

Wardrop's Model is being used in India for estimation of capacity of un-signalized intersection.It considers the geometry and flow of vehicles. The researchers around the world have stated that the capacity can be found to be more dependent on the gap acceptance behaviour of the vehicles

Since Wardrop's method does not give any consideration to gap acceptance behaviour, new methodology can be derived for the estimation of capacity at un-signalized intersection using gap acceptance behaviour.

The scope of the present study has been limited to four legged intersection with 2 circulatory lanes. Future study may be carried out considering varied values of number of approach lanes and circulatory lane in the intersection.

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