Estimation of Critical Gap at Uncontrolled Three legged Intersections

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Abstract: - The capacity of any unsignalized junction is a measure of overall performance of urban traffic scenario. Various parameters are responsible for performance of unsignalized intersection like geometrical parameters, composition of traffic, traffic movements and volume etc. In recent past many researchers have worked on effect of critical gap on performance of such Intersection for heterogenous traffic. The critical gap is the most important parameter to understand the gap acceptance behavior of drivers and to estimate the capacity of an individual movement. Critical gap is a stochastically distributed value and it cannot be measured using field measurements and it varies with drivers, time, movements and traffic conditions. In this study two uncontrolled T-Intersections were selected at the urban area of Ahmedabad for estimating critical gap at such junction in heterogenous traffic. The primary data was collected by videography method on a typical weekday in the morning peak hours. The critical gap value was estimated for right turning vehicles from minor stream using Occupancy time method, Raff's method Harder's method and Logit method for two-wheelers, three-wheelers and four-wheelers and the results will be compared and analyzed.

Keywords: **Critical gap, Gap Acceptance, heterogeneous traffic, Uncontrolled Intersection**

I. INTRODUCTION

To analyse the traffic flow at an uncontrolled intersection has always been an area of interest for traffic engineers due its complex operational behaviour. The driver who is on the minor street has to make an approximate estimation of the gap to cross or merge the intersection conflict area safely. The decision to enter into the conflict area is influenced by driver behaviour, intersection characteristics, vehicular characteristics, opposing flow, type of control, etc. The complexity is further increased in the case of heterogeneous traffic conditions that normally prevail in developing countries, where the rules regarding priority of lanes are very often neglected.

Critical gap is the most significant parameter in the gap acceptance process. A consistent driver will accept all gaps which are more than his critical gap and will reject all other gaps which are less than his critical gap. The determination of capacity at unsignalized intersections is based on critical gap. The Highway Capacity Manual of USA (HCM, 2000) has defined critical gap as the minimum time difference between the arrivals of minor street vehicle during which a minor street vehicle can make its entry into the intersection.HCM (2010) replaced critical gap with critical headway and defined it as the minimum headway in the major traffic stream that will allow the intersection entry of one-minor street vehicle. The term critical headway is basically applicable to conditions of uniform traffic, but when there exists a wide variability in the operating traffic as in the case of heterogeneous conditions, it is meaningful to consider critical gap instead of critical headway.

Critical gap is a parameter which cannot be directly measured from the field, but is estimated on the basis of accepted and rejected gaps. It can be confidently assumed to lie in between the accepted gap and maximum rejected gap. This estimation process become complicated when applied to heterogeneous traffic conditions which are characterised by lack of lane discipline, absence of movement priority, forced entry of lower priority movement, zig-zag crossing of the intersection area etc. The variations in the static and dynamic characteristics of the operating traffic further complicate the estimation process. This paper proposes a new approach for critical gap estimation which can be usedfor bothhomogeneous and heterogeneous traffic conditions.

II. RESEARCH OBJECTIVE

To estimate critical gap for right turning from minor street at an unsignalized T-intersection using Occupancy time method, Raff's method,Harder,s method and Logit Method and to compare the results obtained from above methods.

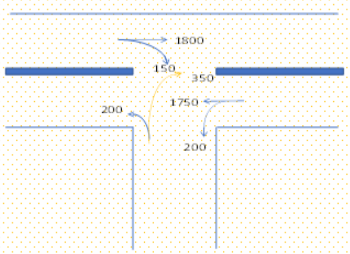
III. STUDY AREA

In order to estimate critical gap parameter at uncontrolled intersection, two three-legged intersection are selected in the urban area of Ahmedabad. The T-Intersection were selected keeping the following points in mind:

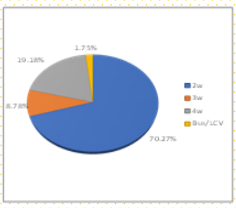
- Pedestrian and cyclist activity should be minimal.
- There should a convenient location for placing the video camera to cover all movements on intersection.
- Encroachment should be minimal near the intersection.
- Bus stop and parking should not be placed near the intersection.
- There should be no speed breakers on any aproach of the intersection within 75 m from the centre of intersection

Intersection No. 1 near sahjanand chowk

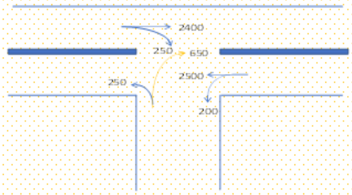
Intersection No. 2 at Narnapura



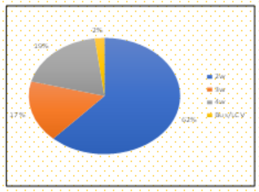
Traffic Flow Details (Vehicle/hour) of Study Intersection No. 1



Entry Flow from Minor Street of Intersection no. 1



Traffic Flow Details (Vehicle/hour) of Study Intersection No. 2



Entry Flow from Minor Street of Intersection near No. 2

IV. DATA EXTRACTION

Extraction of Gap timings:

To extract the data the recorded tape was played on the big screen to extract and analyze the gap acceptance data with the help of the AVS video editor software. All minor road vehicles were divided into three categories (car, 2-wheeler & 3-wheeler) and the gap data were extracted for right turn from minor road. AVS Video Editor software is used in the extraction process because it shows the time in miliseconds as well as it can draw lines in video also.To estimate the critical gap with different methods the values of accepted and rejected gaps offered to the every subject vehicle on the minor street by the major stream traffic and occupancy time for every subject vehicle were needed.To get the above values time instants for every subject vehicle were calculated as shown in the sample excel work sheet.

			Gap 1 = Ei - Di		Gap 2 = Gi - Fi		Gap 3 = Ii - Hi		Gap 4 = Ki - Ji		Gap 5 = Mi - Li			
		Conflicting Vehicle No.												
Sample no.	Ts	1		2		3		4		5		6		To
		Front	Back	Front	Back	Front	Back	Front	Back	Front	Back	Front	Back	
1	27.508	30.36	30.558	30.844	30.982	36.126								34.302
2	10.768	11.439	11.759	12.126	12.462	13.52	14.166	15.926						20.936
3	2.439	4.582	5.182	7.278	7.6	10.956								9.421
4	21.784	27.184												26.504
5	31.463	32.017	32.341	33.223	33.503	35.608								36.365
6	40.224	40.784	41.025	41.459	41.744	47.383								46.225
7	58.384	58.934	59.247	59.282	59.696	0.759	0.845	1.21	1.36	2.265	2.424	10.042		6.921
8	42.929	44.943	45.185	48.905										49.729
9	44.224	44.943	45.185	48.905	49.224	51.06	51.463	52.418	52.689	53.624	53.935	58.488		0.785
10	6.136	10.301	10.54	11.943	12.224	14.848								13.064
11	30.545	30.263	30.773	31.663	32.094									41.063

Occupancy time = To-Ts

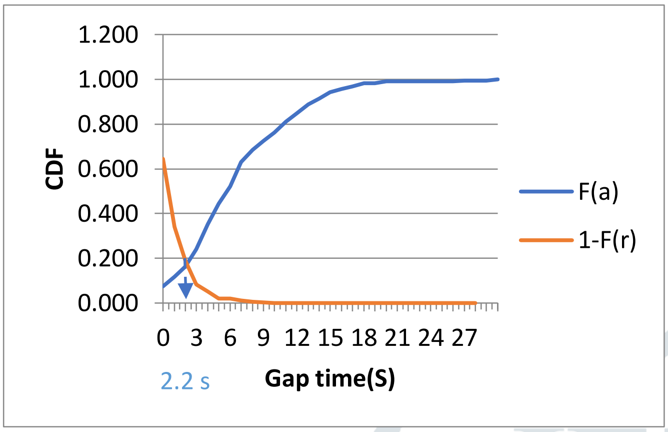
Accepted Gap = Last gap in the row and other gaps are rejected gaps.

V. ESTIMATION METHODS FOR CRITICAL GAP

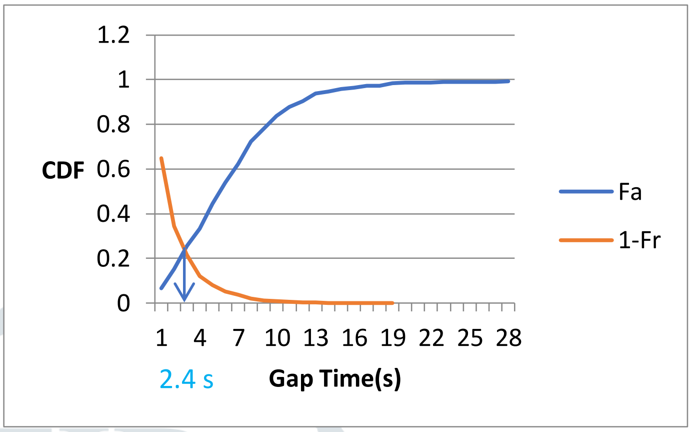
1. Raff method

Raff method is based on macroscopic model and it is the earliest method for estimating the critical gap which is used in many countries because of its simplicity. According to Raff method, critical gap is the gap at sum of cumulative number of accepted gaps Fa and maximum rejected gaps Fr is equal to 1. In other words, the number of rejected gaps larger than critical gap is equal to the number of accepted gaps smaller than critical gap.

$$Fa = 1 - Fr$$



Critical Gap Estimation for 2-W by Raff Method for Intersection no. 1



Critical Gap Estimation for 2-W by Raff Method for Intersection no. 2

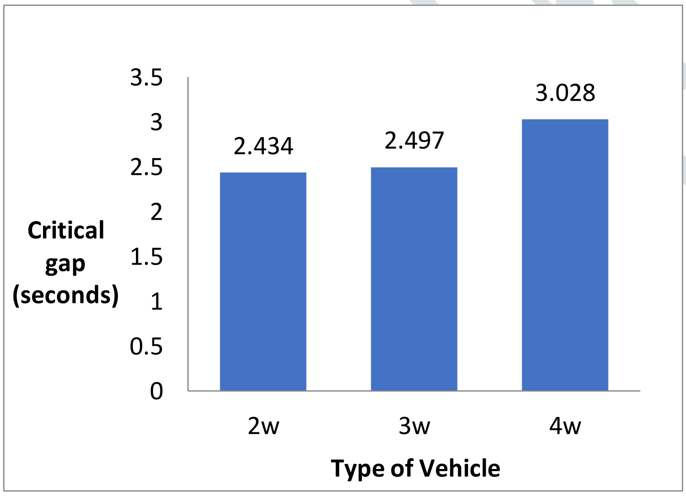
2 Harder's method

Harders (1968) have developed a method for tc estimation that has become rather popular in GERMANY. The method only makes use of gaps. For Harder's method, lags should not be used in the sample. The time scale is divided into intervals of constant duration, e.g. Δt = 0.5 secs. The center of each time interval i is denoted by ti. For each vehicle queuing on the minor street, we have to observe all major stream gaps that are presented to the driver and, in addition, the accepted gap. From these observations we calculate the following frequencies and relative values:

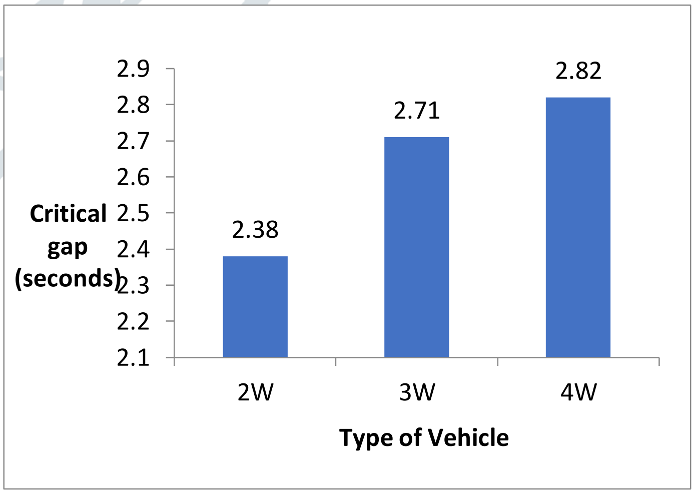
Ni = number of all gaps of size i, that are provide to minor street vehicle; Ai = number of accepted gaps of size i;

$$ri = Ai / Ni$$

Now, these ai values can be plotted over ti. The curve generated by doing this has the form of a cumulative distribution function of critical gaps. It is treated as the function Fc(t). However, nobody has provided any conclusive mathematical concept that this function ai= function (ti) has real properties of Fc (t).



Critical Gap As per Vehicular Category by Harder,s Method for Intersection no. 1



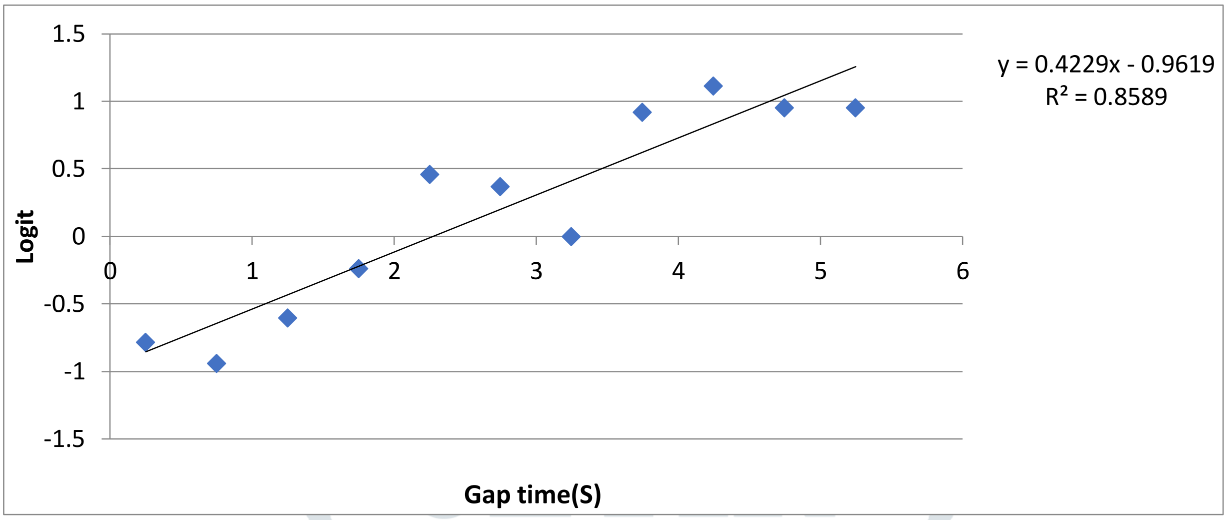
Critical Gap As per Vehicular Category by Harder,s Method for Intersection no. 2

3 Logit method

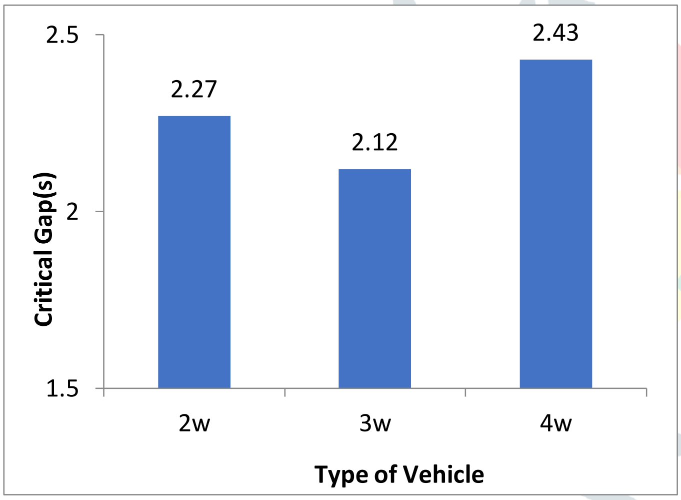
Logit model is basically a weighted linear regression model with a mathematical form as shown in below equation.

$$P(a) = (1 + e^{-(\beta_0 + \beta_1(i))})^{-1}$$

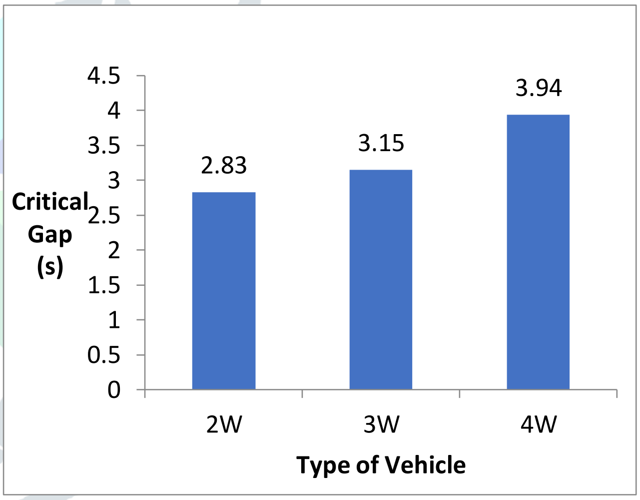
Where P(a) is the probability of accepting a gap of size i; β_0 and β_1 are regression coefficients. A fitted linear line can be plotted on the chart to see the time that offers 0.5 probabilities of acceptance of a gap size. This technique is often accustomed to verify the influence of different independent attributes in the critical headway, such as the waiting time, Avg. speed, etc.



Linear regression Logit Model for 2W for Intersection no. 1



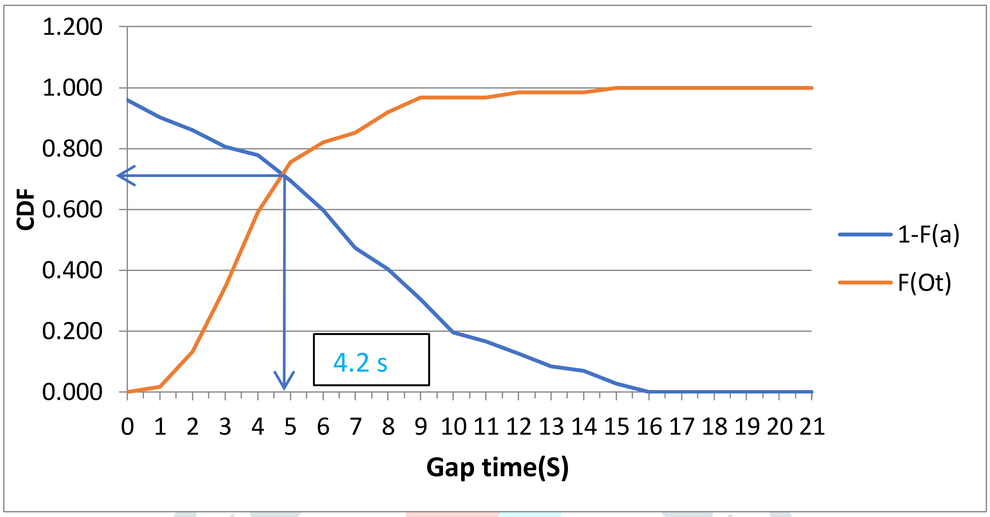
Critical Gap As per Vehicular Category by Logit Method for Intersection no. 1



Critical Gap As per Vehicular Category by Logit Method for Intersection no. 2

4 Occupancy Time Method

In the gap acceptance process, a driver would accept a gap in the conflicting stream which will allow him to complete the required manoeuvre before the arrival of the next conflicting vehicle in the manoeuvre area. Therefore, the amount of time a vehicle spends within the conflict area is a good measure for the estimation of driver's critical gap. Conflict area marks the region within the intersection area where two traffic streams interact with each other. The occupancy time (OT) of a vehicle is defined as the time interval between the arrival of the front of a vehicle in the conflict area and the departure of its rear from the conflict area. This will depend upon driver behaviour, intersection geometry, type (size) of the subject vehicle, opposing vehicular traffic and the manner a driver would clear the conflict area. Occupancy Time concept is advantageous especially in situations where drivers do not follow a definite path to clear the intersection owing to poor lane discipline. Occupancy time indicates the time gap required by a driver between the vehicles in the conflicting stream to perform therequired manoeuvre.



Critical gap for 2-wheeler by Occupancy Time Method for Intersection no. 1

5.Critical Gap from Indo HCM 2017:

Base Critical Gap Value (seconds)
Four lane divided intersection

Movement	2w	3w	4w
Right turning from minor to major street	3.5	3.7	3.8

$$t_{c,x} = t_{c,base} + f_{LV} \times \ln(P_{LV})$$

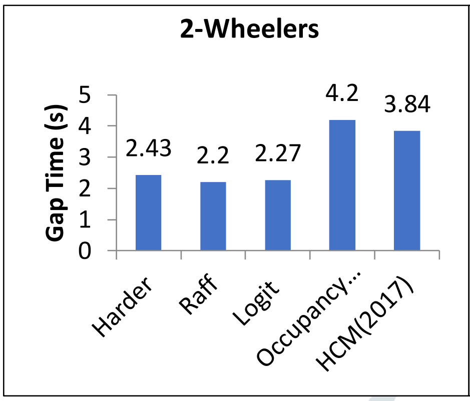
Where, **$t_{c,x}$** is the critical gap (s) for vehicle type x, **$t_{c,base}$** is the base critical gap value for corresponding vehicle type executing the same movement, **f_{LV}** is the adjustment factor for large vehicles *(vehicle larger than cars)* and **P_{LV}** is the proportion of large vehicles in the conflicting traffic stream. Table gives the large vehicle adjustment factors for different vehicle types at intersections..

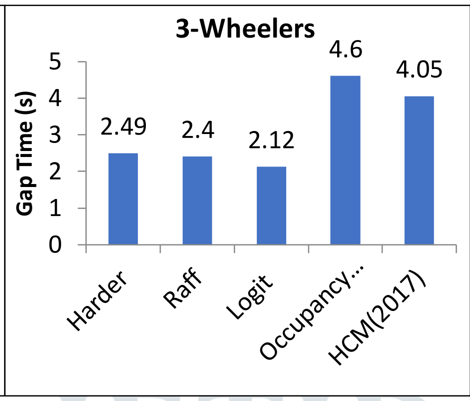
Adjustment Factor for proportion of Large Vehicles in Conflicting Traffic Streams

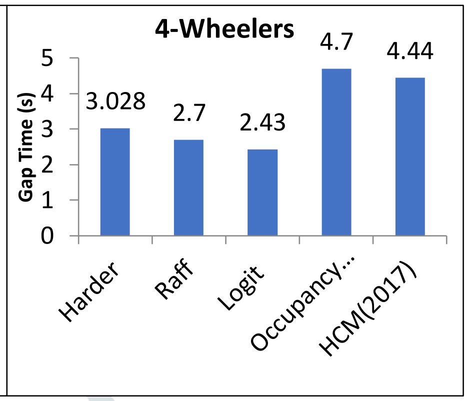
Movement	2w	3w	4w
Right turning from minor to major street	0.61	0.64	0.88

Critical Gap values by different Methods for Intersection no. 1

Vehicle Category	Critical Gap (s) Estimeted by Different Methods				
	Harder	Raff	Logit	Occupancy time	IHCM(2017)
2w	2.43	2.2	2.27	4.20	3.84
3w	2.49	2.4	2.12	4.60	4.05
4w	3.02	2.7	2.43	4.70	4.44

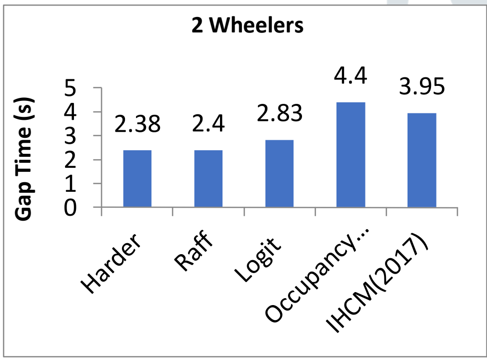


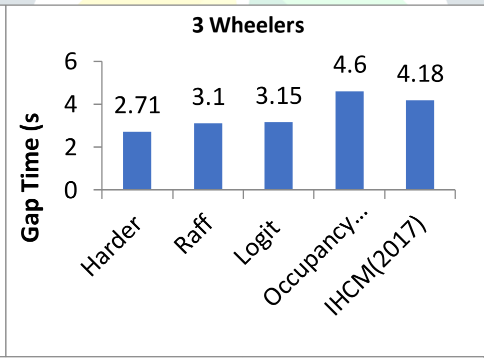


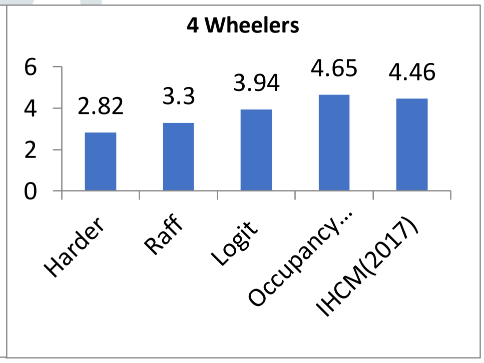


Critical Gap values by different Methods for Intersection no. 2

Vehicle Category	Critical Gap (s) Estimeted by Different Methods				
	Harder	Raff	Logit	Occupancy time	IHCM(2017)
2w	2.38	2.40	2.83	4.40	3.95
3w	2.71	3.10	3.15	4.60	4.18
4w	2.82	3.30	3.94	4.65	4.46







III. CONCLUSION

Capacity analysis of an unsignalized intersection is basically depends upon gap acceptance behaviour. Estimation of critical gap is a first step of this process. In this paper many methods to estimate critical gap is studied which were used by the researchers in their past studies. The conceptual differences among the methods provide different values for estimated critical gaps. In this paper it is also shown that the difficulties and complexities in the estimation of critical gap. It is concluded that the some methods gives the mean value of the critical gap and some methods gives the total distribution of the critical gap. In this study critical gap value for the vehicles taking right turn from minor street is estimated for seperately for two-wheelers, three-wheelers and four-wheelers at two three-legged intersections located at the urban area of ahmedabad. Four methods were used to estimate the critical gap value such as Raff's method, logit method, Harder's method and Occupancy time method. The results obtained for the both intersections from these methods were compared to the values derived from the Indo HCM 2017 for the right turning from the minor street movement. Estimated critical gaps are found to be with a wide deviation among the results obtained by these four different approaches. This is due to the inborn fault of these methodologies to account for the heterogeneous traffic conditions as they evolved under fully homogeneity. However, concept of clearing Occupancy time approach which has been evolved for mixed traffic conditions produces quite reasonable results for right turning from minor movements.

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