A Model for Estimation of Capacity and Critical Gap at Unsignalized Intersections in Hyderabad city.

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Abstract:

Traffic congestion on urban road network is a result of increase in vehicular traffic as it is characterized by slow speed, longer trip lengths, and longer delays. Unsignalized intersections are provided for to low volume traffic flow and its performance is used to evaluate urban road networks .Delay is considered as the important parameter and evaluation of unsignalised intersections is achieved through Gap acceptance behavior. Gap acceptance behavior is an important parameter for determination of capacity at unsignalized intersection.

This article explicitly presents the overview of estimation of capacity of unsignalised intersection using Indo HCM 2017 for better identification of traffic characteristics. Estimation of critical gap, occupation time and delay are some of the major factors considered for the analysis. Data is collected through video graphic techniques at 2 locations in Hyderabad city. Traffic Parameters like volume, approaching vehicle type, accepted and rejected gaps were extracted. The study has also examined the variables associated with occupancy factor, vehicle type and socio demographic features. It is observed that the capacity of pragathi nagar T intersection is 845vehicles /hour and critical gap is 4.29 seconds and the capacity of bahadurpally (4 legged) Intersection is 647 vehicles / hour and critical gap is 4.02 seconds.

Keywords: Critical gap, stratified sampling technique, conventional methods, and occupancy factor.

1.0 Introduction:

Traffic congestion is a condition on road networks occurs as use increases, and is characterized by slower speeds, longer trip times, and increased vehicular queuing. U.S.A, alone bears a congestion cost of $ 305 billion every year. In India just in 4 metropolitan cities the congestion cost is $ 22 billion every year**.** India is a developing country and cities have has rapid urbanization and modernization as result there is an immense growth in road traffic following heterogeneous traffic causing delay and congestion to road users . This leads to longer trip lengths, slower speeds of vehicles, increased vehicle queuing and vehicle operation cost. (pande, 2012) Generally in semi urban and urban scenarios unsignalised intersections are primary locations where a conflict occur. Diesel and petrol consumption in city is nearly 2.4 Mega liters/day and 1.7 Mega liters/day respectively. The average time spend by any driver in traffic jam is 102 hours /year. Approximately there are 1.3 million deaths and 20-50 million fatalities takes place in a year globally. Unsignalised intersection are implemented to regulate low volume traffic flow. Based on relative importance of two roads, they are generally designated as major and minor roads.

Capacity of an intersection affects the total capacity of road network due to traffic movements like merging, diverging and conflicting. An intersection is considered as node in a traffic network of urban roads. (prasad, 2014).In mixed traffic conditions roads carry different modes of vehicles like Heavy commercial vehicles HCV, low commercial vehicles LCV, cars, 2 wheelers, 3 wheelers, animal driven carts and cycles leading to complex behavior of interaction between the vehicles.There are several

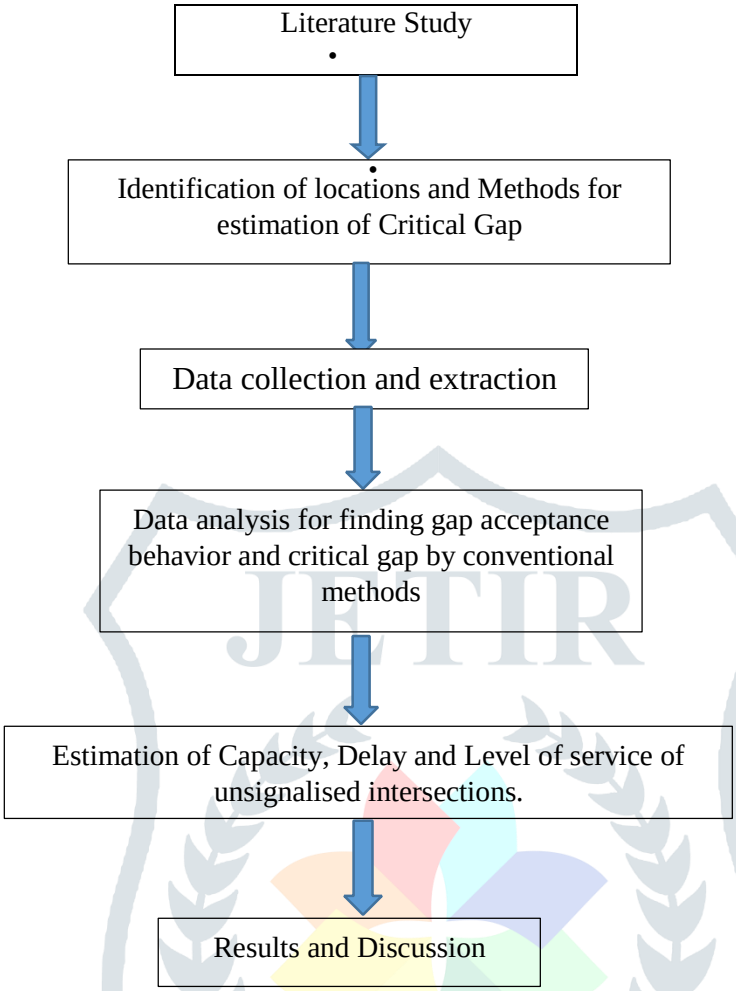
techniques for estimation of capacity of unsignalised intersections. conflict model or modified tanners model which is based on critical gap and follow up times of vehicles from minor road traffic has mathematical relation of interaction and impact between flows at intersectionVehicular interactions are complex at unsignalised intersections, a driver must find a safe moment for moving into intersection area. Drivers intending to enter an unsignalised intersections have a series of gaps between vehicles in a stream, where they cross or merge.

Conflicts in traffic are created when two or more roads cross and they results in delay and congestion. The capacity at an unsignalised intersection is important for evaluation of road network capacity (Mourya, 2016).Gap acceptance is an essential skill for safe driving and determines the delay and capacity at an unsignalised intersection. Gap acceptance behavior explains the road user behavior in traffic stream and develops training and technology to lower risk of crashes (Guler, 2017). Critical gap as explained in Indo HCM is as the shortest time interval on the major approach that allows the minor stream vehicles go into the intersection. Therefore, the driver's critical gap is the lowest gap that would be acceptable. (Harsh.J, 2015) A specific vehicle would reject any gaps smaller than the critical gap and would accept gaps larger than or equal to the critical gap. Critical gap is an important aspect of driver's behavior which is considered in the design and analysis of intersections. Transportation Research Board (2000) suggested that driver's critical gap can be calculated based on the observations of the greatest rejected and lowest accepted gap for a given intersection. (Astalatha.R, 2011) Critical gap is an important parameter for calculation of capacity which cannot be measured directly on field .Rejected and accepted gaps of single vehicle in a minor stream can be analyzed and some statistical methods are used for estimation of critical gaps by conventional methods like Raff's ,Maximum Likelihood Method ,Probability Of Equilibrium Method ,Ashworth , Greensheild , Logit ,Harder ,Wu ,Acceptance Curve Methods etc. (Wu, 2012).Estimation of delay, capacity ,Gap acceptance behavior are extensively studied at unsignalized intersections. The effect of Delay on critical gap is calculated by considering the average delays of vehicle to that of critical gaps in second (Tian, 2015).The distribution of Accepted and rejected gaps are divided into different ranges according to movements on major and minor roads. (Sahraei, 2016).

2.0 **Objective:** The objective of Present study is to determine

- To determine capacity of intersection using Gap acceptance capacity model and Indo HCM 2017 • To determine gap acceptance behavior, critical gap of priority junction using conventional methods.

3.Methodology:



4.0 Data Collection: Traffic data is collected through video graphic technique at the selected site. In the present study traffic data was collected for 9 hours for a week i.e. from 19.11.2018 to 25.11.2018 from traffic police department and at each intersection peak hour traffic is determined. At all locations the peak hour was observed to be 18.00-19.00P.M.on Friday. .

- Vehicle Classification
- Turning movements Direction

of travel

Study location: Intersection was selected in such a way that they have fair geometry and least interference by pedestrians and parked vehicles.

Major traffic problems occurring at unsignalised intersections in Hyderabad city were identified

1. Pragathi Nagar –T intersection
2. Bahadurapally Intersection.(4 legged Intersection)

Figure 1: study locations

4.2 Site selection criteria: Intersections consisting major and minor road on an urban road in Hyderabad city were selected. At these intersections following are major factors considered

1. There are few pedestrian and cyclists
2. Roads are two lane divided
3. There is no road side parking adjacent to the lane
4. Intersections are located in educational, recreational and residential areas

Figure 2 : Pragathi Nagar

Figure 3 : Bahadurpally

4.3:Road Inventory Data: Road geometric data like carriage way width, parking facilities, type of intersection, bus bay, median width, footpaths and street lights are taken from selected junctions.

Road geometric data		
Facility	**Location 1 Pragathi Nagar**	**Location 2 : Bahadurpally**
Carriage way Width	17	15.5
Type of intersection	T – Intersection	4 legged intersection
Bus Bay	No	Yes
Median Width	1 Meter	0.5 Meter
Foot Path	No	No
Street Light	Yes	Yes

Table 1: Road geometric Data At study locations.

4.4 Volume count study: Traffic Volume Survey is an essential part of Town Planning, in a road network. It includes counting the number of vehicles passing through the selected intersection. The study of Classified Traffic Volume Count is to understand factors that form the basis of:

Establishing the use of the road network by vehicles of different categories, traffic distribution, and PCU. .Need of median shifting or road widening. The peak hour volume of locations 1 and 2 i.e. pragathi nagar and bahadurpally are given in the above figures. It is noted that the peak hour volumes are 4106 PCU and 4243 PCU respectively. Peak Hour flow was calculated by video data collected from Police department, Hyderabad. The accepted and rejected gaps from the video are extracted by stratified sampling technique for analysis and determination of capacity and Critical gaps.

S.no	Leg	Movement	P.H.V 1	P.H.V 2
1	3	Bachupally-Gandimaisamma	1298	1322
2	5	Gandimaisamma-Bachupally	889	986
3	1	Bachupally-Pragathinagar	323	496
4	4	Pragathi nagar – bachupally	405	429
5	2	Pragathinagar- gandimaisamma	514	606
6	6	Gandimaisamma-pragathinagar	469	514

Table 2: Traffic volume count of pragathi nagar T intersection

S.no	Leg	Movement	P.H.V 1	P.H.V 2
1	3	Gandimaisamma –Bahadurpally	294	460
2	1	Gandimaisamma –Pragathinagar	170	184
3	2	Gandimaisamma-suraram	192	213
4	5	Suraram –gandimaisamma	421	462
5	6	Suraraam-Pragathinagar	490	509
6	4	Suraram-Bahadurpally	86	95
7	9	Pragathinagar-Gandimaisamma	301	326
8	8	Pragathinagar –Bahadurpally	190	230
9	7	Suraram-Bahadurpally	570	609
10	10	Bahadurpally –Gandiamaisamma	256	323
11	12	Bahadurpally-Suraram	402	498
12	11	Bahadurpally-Pragathinagar	320	334

Table 3 : Traffic volume study at Bahadurpally Intersection

5.1 Critical Gap Estimation by Indo HCM Method: *Indo HCM 2017* Define critical gap as "The minimum major stream headway during which minor street vehicle can make a maneuver", uses occupancy factor method for calculation of critical gap and it considers drivers behavior. Data containing Geometry of road and classified volume count of peak hour traffic is taken. The following are the steps to calculate critical gap and capacity of an unsignalised intersection by Indo HCM method.

1. Input Data (Geometry of road and traffic volume)
2. Convert the volume of traffic into PCU
3. Calculate conflict traffic flow
4. Determine Critical Gap
5. Capacity of Turning Moments

The critical gap for any movement can be obtained by the equation

$$T_{c,x} = t_{c,base} + f_{LV} * \ln(P_{LV}) \quad \ldots\ldots\ldots\ldots 1$$

Where

P_{LV} = Proportion of Heavy Vehicles

F_{LV} = Adjustment factor for proportion of Large vehicles in conflicting Traffic Stream

$T_{c,base}$ =base critical gap for various movements

Capacity of each turning movement is given by the equation

$$C_x = \frac{a * V_{c,x} * e^{-V_{c,x}(t_{c,x} - b)/3600}}{1 - e^{-v_{c,x} t_{f,x}/3600}} \quad \ldots\ldots\ldots\ldots 2$$

The Base critical gap for four lane divided and the adjustment factor for heavy vehicles are taken from Indo HCM.

Adjustment Factor	Base critical Gap	Leg	Critical Gap Formula	tc (sec)
0.46	2.7	Bachupally To Pragathi Nagar (1)	tc=2.7+0.46*ln(0.17)	1.9
0.58	**3.8**	**Pragathi Nagar To Gandimaisamma (7)**	**tc=6.8+0.58*;ln(9.46)**	**4.29**
0.88	6.8	Gandimaisamma To Bachupally (5)	tc=3.8+0.88*ln(1.76)	8.1

Table 4: critical gap for location 1 –Pragathi Nagar

Movement	Base Critical Gap	Adjustment Factor for light and heavy vehicle F_{LV}	Proportion of Heavy veh in conflicting stream	Critical gap
Gandimaisamma –Pragathinagar(1)	**2.7**	**0.457**	**17.98**	**4.02**
Suraram-Bahadurpally(4)	2.7	0.457	12.19	3.84
Suraram-Bahadurpally (7)	3.8	0.885	15.06	6.2
Bahadurpally- Gandiamaisamma (10)	3.8	0.885	18.02	6.35
Pragathinagar-Bahadurpally (8)	6.8	0.583	19.05	8.51
Bahadurapally-Pragathinagar (11)	6.8	0.583	20.87	8.56

Table 5 : Critical gap for location 2 – Bahadurpally

5.2 Capacity and LOS estimation using Indo HCM 2017 :

Highway **capacity** is defined by the Highway **Capacity** Manual as the maximum hourly rate at which persons or vehicles can be reasonably expected to traverse a point or a uniform segment of a lane or roadway during a given time period under prevailing roadway, traffic and control conditions. **Level of service** (LOS) is a qualitative measure used to relate the quality of motor vehicle **traffic service**. LOS is used to analyze roadways and intersections by categorizing **traffic** flow and assigning quality **levels** of **traffic** based on performance measure like vehicle speed, density, congestion, etc.The following tables explain the capacity and level of service at each leg of both intersections.

Movement	$T_{c,x}$	Follow up Time	Conflicting flow	a(Adjustment factor)	b(adjustment factor)	Capacity c_x	v/c	LOS
Movement 1	1.9	1.14	514	0.8	1.3	769.68	0.66781	D
movement 7	**4.29**	**2.574**	**622**	**1**	**2.16**	**825**	**0.753939**	**D**
movement 5	8.1	4.86	986	0.9	1.971	1200	0.821667	E

Table 6: Capacity and LOS of intersection 1 Pragathi nagar

Movement	critical Gap	Follow up time	conflicting Flow	Adjustment Factor' a'	Adjustment Factor 'b'	Capacity	volume	v/c	LOS
1	**4.02**	**2.412**	**498**	**0.8**	**1.3**	**645.02**	**345**	**0.535**	**D**
4	3.84	2.304	230	0.8	1.3	359.23	298	0.830	E
7	6.2	3.72	1263	1	2.16	571	173	0.303	B
10	6.35	3.81	1139	1	2.16	604.36	128	0.212	B

8	8.51	5.106	1388	0.9	5.04	425.5	217	0.510	C
11	8.56	5.136	1873	0.9	5.04	740.6	599	0.809	E

Table 7 : Capacity and LOS of intersection 2 bahadpally

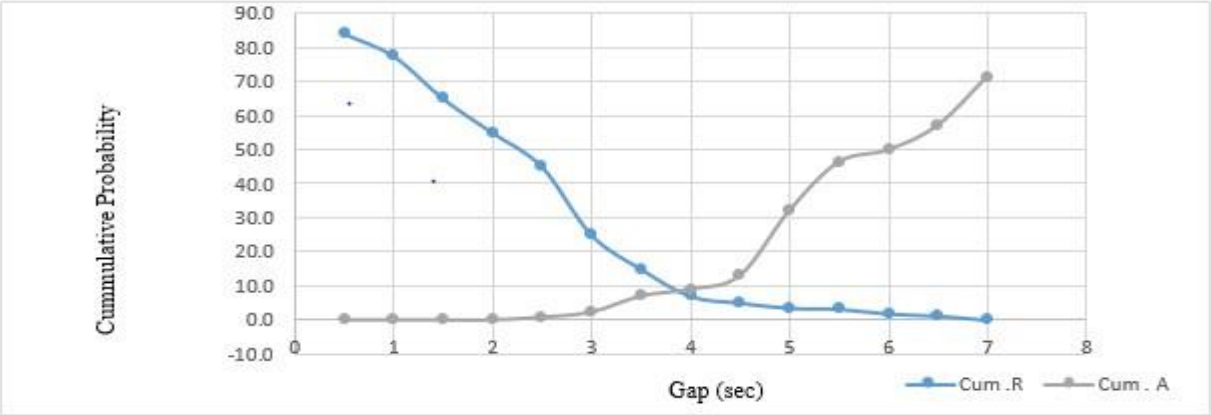


Figure 4 : critical gap of bahadurpally intersection (4 legged)

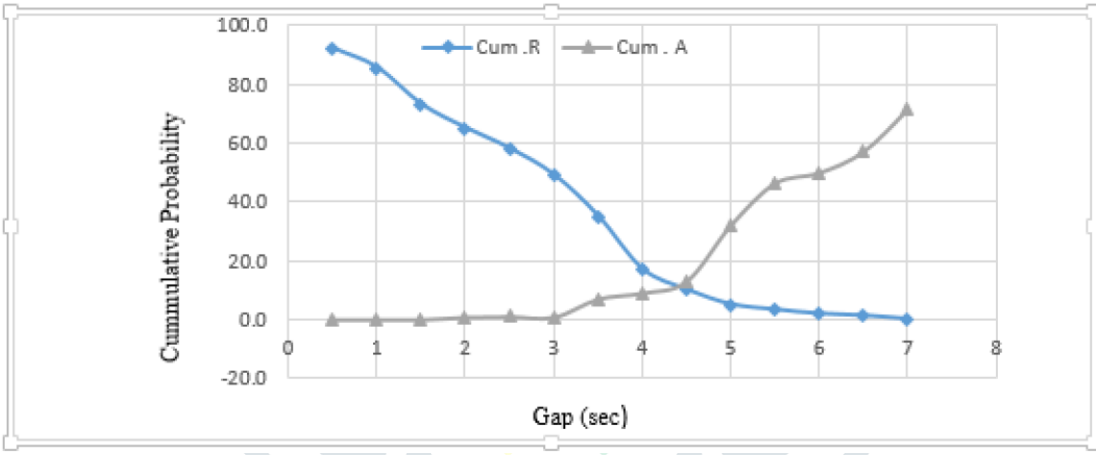


Figure 5 : critical gap of pragathi nagar intersection (T intersection)

6. Results and Discussion:

The paper provides detailed notes on determination of critical gap using Indo HCM method and Raff's Method .The stepwise analysis of collection of data, extraction of traffic volume, accepted and rejected gaps calculation and plotting the critical graph, Capacity estimation and determination of LOS explains the procedure of Indo HCM method .Both Indo HCM method and Raff's method were analyzed to investigate the potential factors of the methods and compared. The following are some of the observations made during the investigation process.

- The peak hour traffic of the 3 legged pragathi nagar intersection is 4102 PCU and 4 legged intersection is 4323 PCU under mixed traffic conditions.The capacity and LOS of intersection 1 calculated from Indo HCM method is 845 veh/hr with v/c ratio as 0.753 and LOS D
- The capacity and LOS of intersection 2 calculated from indo HCM method is 647veh/hr and V/C ratio as 0.535 and LOS D .The critical gap of intersection 1 and intersection 2 were observed as 4.29 and 4.02 sec respectively for vehicles travelling from minor road to major road right turns.
- Raff's method explains the critical gap of intersection 1 and intersection 2 as 4.35 and 3.90 respectively for vehicles travelling from minor road to major road right turns.It is observed that both Indo HCM 2017 and Raff's method provides similar results and Indo HCM method is accurate method compared to Raffs's method under mixed traffic conditions.

Geometry	**T int ersection (Pragathi Nagar)**		
Movement	Major Left (1)	Major Right(7)	Minor Left(5)
Adjustment For Base Critical Gap	2.7	3.8	6.8
Critical Gap	1.9	4.29	8.1s

Heavy Vehicle Adjustment Factor	0.46	0.58	0.88
Adjustment Factor 'a'	0.8	1	0.9
Adjustment Factor 'b'	1.3	2.16	6.8
Capacity	770	825	1200
V/C	0.67	0.75	0.82
LOS	D	D	E

Table 6 : Results Of location 1 Pragathi Nagar intersection

Geometry	**4 legged Intersection (Bahadurpally Intersection)**					
Movement	Major Right (1)	Major Right (4)	Minor Right(7)	Minor Right(10)	Major Through (8)	Major Through (11)
Adjustment For Base Critical Gap	2.7	2.7	3.8	3.8	6.8	6.8
Critical Gap	4.02	3.84	6.2	6.38	8.51	8.56
Heavy Vehicle Adjustment Factor	0.457	0.457	0.885	0.885	0.583	0.583
Adjustment Factor 'a'	0.8	0.8	1	1	0.9	0.9
Adjustment Factor 'b'	1.3	1.3	2.16	2.16	5.04	5.04
Capacity	345	298	173	128	217	599
V/C	0.535	0.83	0.303	0.212	0.51	0.809
LOS	D	E	B	B	C	E

Table 7 : Results of location 2 bahadurpally Intersection

7.References

1. Brilon. (1999). Useful estimation procedures for critical gaps. *Transportaation Research Board (TRB) ,National Research council,Washington* .

2. Guler, S. (2017). Methodology for estimating capacity and vehicle delays at un signalised multimodal intersections.

3. J., H. (2015). A Review of Critical Gap Estimation Approaches at Uncontrolled Intersection in case of Heterogeneous Traffic Conditions.

4. Mourya, A. K. (2016). Estimation of critical gap for through movement at four legged uncontrolled intersection. *ELSEVIER*, 203-212.

5. pande, P. M. (2012). Evaluation of Delay and LOS for Signalised intersection. 372-377.

6. R., A. (2011). Critical Gap through clearing Behaviour of drivers at Unsignalised intersection. *springer*, 1427-1434.

7. Sahraei, M. A. (2016). Determination of Gap Acceptance at Priority Junctions. *Elsevier*.

8. Tian, Z. Z. (2015). A further investigation on critical gap and follow up time. *Interanational symposisum on Highway Capacity* (pp. 397-408). USA: Transportation Reasearch CIrcular.

9. Wu, N. (2012). Estimating Distribution Functions of Critical Gaps at unsignalised intersections based on Equilibrium of probabilities. 1-25.