

Analysis of Gap Acceptance, Capacity and Level of service at Unsignalised ‘T’ Intersection under Mixed Traffic Condition

Bhagyalaxmi A¹, Dr. D. Rajashekar Reddy²

^{1,2}*Civil Engg. Department, Osmania University, dudipalars@yahoo.com*

Abstract— The analysis of gap acceptance, capacity and level of service at uncontrolled unsignalised intersection is very important in developing countries like India. In developed countries such as USA, these intersections are controlled by using stop sign because their existed individual lanes for different class of vehicles and uniform traffic conditions. But in India, this was totally different due to all type of vehicles are using same lane which is considered as mixed traffic condition. Under this condition, each driver’s behavior is different while taking decision to maneuver the intersection safely. Generally, signals are installing instead of stop signs at these intersections because, day to day the traffic is increasing continuously and there are no rules and regulation followed by different drivers to avoid accidents and conflict movements. Installing such signals at every unsignalised intersection is very expensive. So, before installing signals it is necessary to analyze these intersections to know the present service of roads. For the present study two uncontrolled unsignalised intersections at Peerzadiguda X road and Chengicherla X road both NH-163 were selected because, these two intersections are tackled more congestion as increasing daily traffic. The video graphic survey was carried out to estimate the gap/lag, arrival rate, approaching vehicle types, waiting time etc.. Based on this data, further parameters like critical gap, follow-up times, capacity and level of service were estimated accurately using different field techniques like Modified Raff’s method, Harder Method, Greenshield method and Clearing time method etc..which were old and latest methods and also used HCM 2010 as a reference manual. Finally, the results were compared at these intersections to give further solutions like improving of intersection, installing signals, extent of roads, providing medians, providing stop sign etc. to provide better service for future trends.

Keywords— *Unsignalised intersections, Critical gap, Field technique methods, Capacity, Level of service, HCM 2010*

I. INTRODUCTION

Two-Way Stopped-Control (TWSC) intersections are common type of intersections. A three-legged intersection was considered as a standard type of TWSC intersection. This type of intersection consisted a minor street road and vehicles are used to merge or cross the major street road with stop signs installed on minor road. The service of these intersections based on relative priorities of the conflicting movements where lower priority movement must yield to higher priority movement. At these intersections merging, crossing, diverging of traffic was very difficult. The performance of an unsignalized intersection was strongly influenced by the delay caused by low-priority movements on minor roads. So the study of such intersections was very risky and challenging one.

The gap was expressed in terms space or time. That means, the distance between the two vehicles considered then gap was expressed in terms of space. When time elapsed between arrivals of vehicles was considered then gap expressed in terms of time.

Gap acceptance was a process by which a minor stream vehicle accepts an available gap to maneuver. Gap acceptance was a behavior of the driver’s decision. This depends on the performance of the drivers. It was a choice (or) decision chosen by young and old drivers to accept or reject gap. This was a decision process of human brains.

The minimum major-stream headway during which a minor-street vehicle can make a maneuver. That means, the minimum gap required in major stream for minor stream vehicle to cross the intersection safely. So, the driver’s critical gap was minimum and must be acceptable. All the drivers rejected the gaps which are less than the critical gap and accepted the gaps more than critical gap.

The maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or a roadway during a given time period under prevailing roadway, traffic and control conditions. Capacity is a quantitative parameter. This was estimated based on HCM manual by choosing input parameters like critical gap and follow-up time. It was necessary to analyze the capacity at uncontrolled intersections to improve the service of intersections.

Delay is a fundamental parameter for highway investments. This was an extra time consumed by vehicle than reference values. Or the additional travel time experienced by a driver, passenger or pedestrian. At these intersections, the minor street vehicles or low priority vehicles were consumed some extra time and considered as delay. This was the inverses of capacity.

Level of Service (LOS) is defined as a qualitative measure describing the operational conditions within a traffic stream and their perception by motorists and or passengers.

This document is a template. An electronic copy can be downloaded from the Journal website. For questions on paper guidelines, please contact the journal publications committee as indicated on the journal website. Information about final paper submission is available from the conference website.

II. LITERATURE REVIEW

The gap was defined differently by various researchers. According to them the details of gap and lag was defined briefly below.

According to Ashworth and Green (1966) gap measured from the rear of one vehicle to the front of the following vehicle. Adibesi (1982) gap was defined as the major stream headway wholly available to a waiting vehicle from the minor road. Based on Polus (1983), it as the time interval between two successive vehicles in the major road stream.

The lag is measurement between two vehicles on different roads. The number of studies done on measuring of gap, lag and critical gaps. Gap acceptance studies done at unsignalised intersections with priority of vehicles concept includes, Hawkes (1968), Ashworth(1969), Ashton(1971), Miller(1974), Polus et al(2003), Davis and Swenson(2004), Kay et al.(2006), and Xu and Tian (2008).

According to Greenshields et al. (1947) , critical gap is the acceptable average minimum time gap. Later, in 1950 maiden applied regression analysis which is a empirical method to estimate critical gap. In 1950, Raff and Hart defined critical gap as the lag for which the number of accepted shorter gaps is equal to the number of rejected longer than it.

Ashalatha et al (2011) carried out a study on critical gap by clearing behavior of drivers at unsignalised intersections under mixed traffic condition. In his study, video recording technique was used for data collection. The method was simple and applicable to mixed traffic conditions.

Sai et.al (2014) found that the capacity of any uncontrolled intersection of Indian, was highly depends on the gap acceptance behavior. In his study, a micro second difference in gap measurement leads to considerable error in capacity estimation. So, they concluded that the majority of the gaps were between 0-2 sec.

In 1991, Heidemann analysed formulas for the calculation of mean queue lengths and average delays for vehicles on the minor roads at priority intersections. In 1999 Troutbeck observed the limited priority situations such that minor street vehicles were entered into a major stream. Troutbeck developed the relationships to estimate capacity and maximum delay for minor street vehicles. Kaysi and Alam in 2000 developed a simulation technique to understand the driver behaviors such as aggressiveness, impatience, experience and traffic stream intersection at normally priority unsignalised intersections. In 2007, Wan Hashim et.al showed that critical gap acceptance procedure is still widely used for estimating vehicle capacity of unsignalised intersection.

III. OBJECTIVES OF THE STUDY

1. To decide critical gap by various methods like Raff's Method, Harder method, Greenshield method & Clearing time method which are old and latest methods.
2. To find out the control delay, queue lengths and level of service of minor and major streams.
3. To scrutinize the capacity and level of service of minor and major turns of selected intersections using HCM 2010.
4. To judge against the results at selected uncontrolled intersections under heterogeneous traffic conditions.
5. To ascertain the present condition and service of intersections based on the analysis.
6. To provide alternative solutions for better service of intersections.

IV. STUDY AREA AND DATA COLLECTION

For the present study two “T” intersections were selected one at Peerzadiguda X road near to Boduppall and another at Chengicherla X road near to Medipally of Hyderabad for estimating critical gap and analyzing LOS. These intersections are controlled traffic police.



Fig. 1 Layout of Chengicherla X Road and Peerzadiguda X Road

The video graphic technique was used to determine all parameters. The preliminary survey was conducted to know the geometric conditions of chosen intersections. The video camera was fixed at a side of intersections to observe all movements through major as well as minor streams. The survey was conducted for one week on Monday, Wednesday and Friday during morning 8-10A.M to extract traffic data by using video editor tool.

From the video graphic survey the various parameters like, gap, accepted or rejected, follow-up times, clearing time etc., were measured from major right turn as well as minor right turn for both intersections. In this study, only two directions were chosen as conflict movements.

Table 1 Input Data from the field for LOS Analysis

No	Minor to Major				Major to Straight						
	Vehicle type (A)	Entry time (B)	Start time (C)	Exit Time (D)	Vehicle type (E)	Entry time (F)	Clearance of area time(G)	Gap (H)	A/R (I)	Follow-up time	Clearing time
1	Bike	00:22:110	00:23:010	00:28:820	Bike	00:22:360	00:23:760	1.65	R		5.81
					Bike	00:26:360	00:27:970	2.6	A		
2	4W	02:01:230	02:07:420	02:16:180	Car	02:01:360	02:03:440	2.21	R	1.69	8.76
	Bike	02:08:430	02:08:430	02:13:420	Car	02:03:660	02:06:480	0.22	R		4.99
	Bike	02:09:330	02:09:330	02:14:490	Car	02:07:720	02:09:800	1.24	R	1.07	5.16
					Bike	02:11:700	02:16:270	1.9	A		

The critical gaps are measured from raff’s , harder method, Greenshield method and clearing time methods and are used as input values to estimate capacity from HCM 2010. In clearing time method, the capacity for mixed traffic (by Ashalatha and Chandra) was measured by analyzing capacities for individual class of vehicles. Based on capacities, movement capacity, pedestrian impedance, vehicle impedance, queue lengths, average delays and LOS etc., were estimated based on HCM 2010 manual.

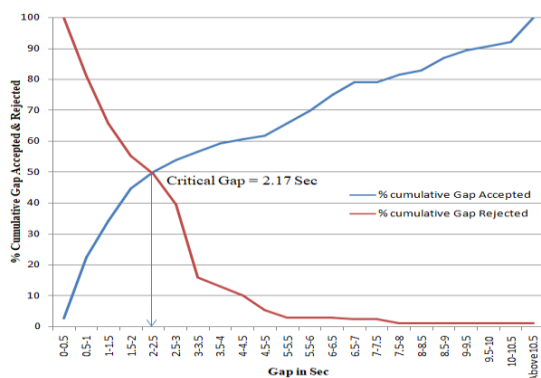


Fig.2 Critical gap by Raff’s Method

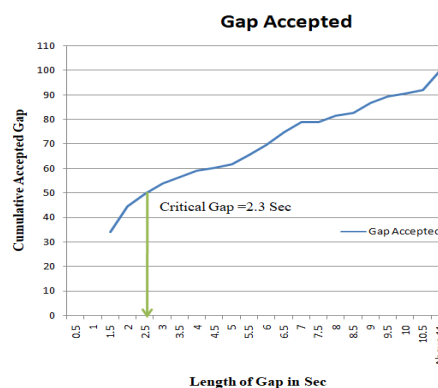


Fig..3 Critical gap by Harder Method

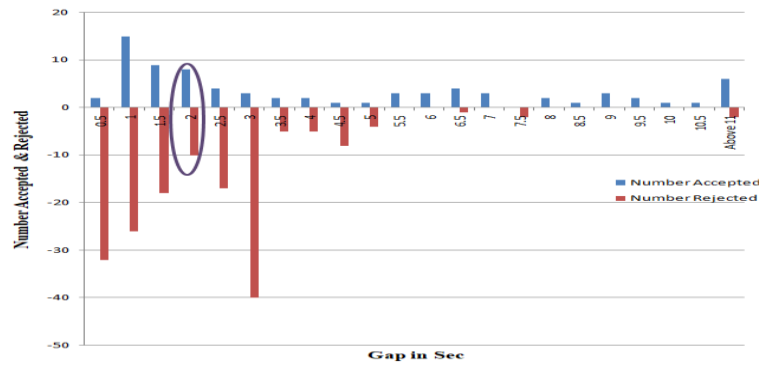


Fig. 4 Critical Gap by Greenshield Method

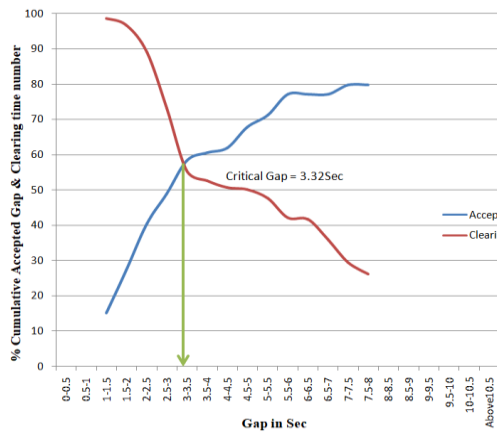


Fig. 5 Critical Gap for 2W by Clearing Time Method

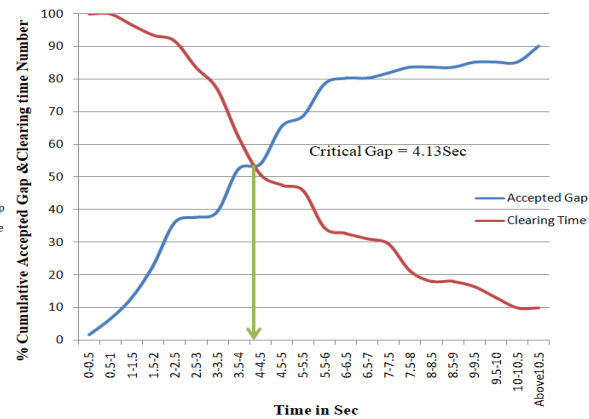


Fig. 6 Critical Gap for 3W by Clearing Time Method

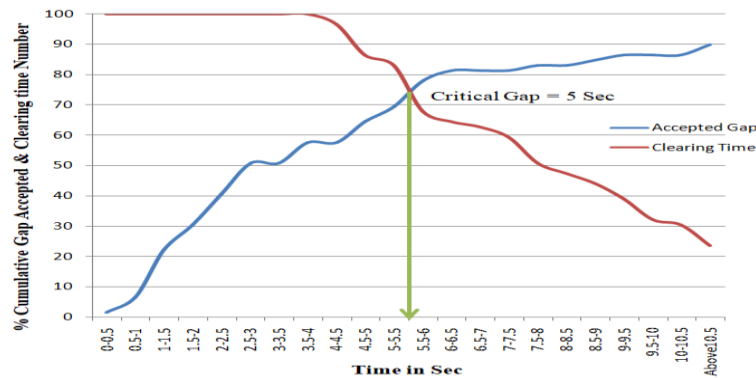


Fig.7 Critical Gap for 4W by Clearing Time Method

V. RESULTS

5.1 Results of Critical Gaps and Follow up times

From the below table, the critical gaps were slightly varied from all methods. The critical gaps from all methods was more than 2 sec but less than 3 sec at Peerzadiguda X Road. At Chengicherla X road the critical gap was varied from 2 Sec to 4 Sec. The Critical gap was increased as increasing vehicle size at both intersections. Follow-up time for major Right turn was lesser than minor Right turn at Peerzadiguda X road because, more queue condition existed through major Right turn. The follow-up time for Major Right turn at Chengicherla X road was slightly lesser than Minor Right turn because, minor queue condition existed.

Table 2 Critical Gaps and Follow-up Time for Peerzadiguda (A) & Chengicherla X Roads

Area	Movement	Raff's	Harder	Green shield	Clearing time		Follow-up time	
A	Minor RT	2.17Sec	2.3 Sec	2 Sec	2W	2.81 Sec	1.34 Sec	2.13 Sec
					3W	-	1.36 Sec	
					4W	4.4 Sec	3.514 Sec	
	Major RT	2.045 Se	2.94 Se	3 Sec	2W	3.32 Sec	1.084 Sec	1.507 Sec
					3W	4.13 Sec	1.46 Sec	
					4W	5 Sec	2.725 Sec	
B	Major RT	2.0775Sec	2.625Sec	4 Sec	2W	3.36 Sec	1.3 Sec	2.24 Sec
					3W	4.13 Sec	1.4 Sec	
					4W	5 Sec	2.7 Sec	
	Minor RT	2.27 Sec	3.31 Sec	3.5 Sec	2W	3.29 Sec	1.83	2.923 Sec
					3W	5.72 Sec	2.48	
					4W	5.76 Sec	3.10	

5.2 The Results of LOS for Minor RT at Peerzadiguda

Table 3 The results of LOS for peerzadiguda Minor Right Turn

Method	Capacity		Queue length	Delay Sec/veh	LOS
Raff's Method	826 Veh/hr		<2	10.56	B
Harder Method	795 Veh/ hr		<2	10.85	B
Greenshield Method	860 Veh/hr		<2	10.29	B
Clearing time Method	2W	886 Veh/hr	880Veh/hr	<2	10.14
	3W	-			
	4W	378 Veh/hr			

From the above results, it was observed that the capacity varied from 795 to 880 Veh/hr. For all the methods, the queue lengths are less than 2, this indicates that 1 or 2 vehicles are under queue conditions throughout delays. Delays also varied with less difference. The Level of service from all methods was "B". This indicates that traffic was stable flow, minor delays experienced through Peerzadiguda minor right turn.

5.3 The Results of LOS for Major RT at Peerzadiguda

Table 4 Results of LOS for Major Right turn

Method	Capacity		Queue length	Delay (Sec)	LOS
Raff's Method	748 Veh/hr		<2	13	B
Harder Method	523 Veh/ hr		<4	20.73	C
Greenshield Method	509 Veh/hr		<4	21.74	C
Clearing time Method	2W	512 Veh/hr	367Veh/hr	<8	24
	3W	326 Veh/hr			
	4W	181 Veh/hr			

From the above results, It was observed that the capacity varied from 367 to 748 veh/ hr. From all the methods, the queue lengths are higher except Raff's method . This indicates that more than 4 vehicles but less than 8 vehicles are under queue conditions throughout delays .

Delays also varied with less differences. The Level of service from all methods was "C" except by Raff's method. Because, the delays obtained from the Raff's method was lesser than other methods. This indicates that traffic was less congested flow, higher delays experienced throughout peerzadiguda minor right turn.

5.4 The Results of LOS for Major RT at Chengicherla X Road

Table 5 The Results for Chengicherla X Road Major Right Turn

Method	Capacity	Queue length	Delay	LOS		
Raff's Method	638 Veh/hr	<5	19.11	C		
Harder Method	504 Veh/ hr	<8	32.83	D		
Greenshield Method	401 Veh/hr	<12	72	F		
Clearing time Method	2W	459 Veh/hr	422Veh/hr	<11	59.35	F
	3W	320 Veh/hr				
	4W	170 Veh/hr				

From the above results, It was observed that the capacity varied from 422 to 638 veh/ hr. From all the methods, the queue lengths are higher except Raff's method . At this intersection more than 5 vehicles but less than 12 vehicles are under queue conditions throughout delays .

Delays also varied with higher differences. The Level of service from Greenshield and clearing time methods was "F" as compared to Raff's method & Harder Method. Because, the delays obtained from above methods was higher. This indicates that traffic was more congested and forced flow, higher delays experienced throughout chengicherla minor right turn.

5.5 Results of LOS for Minor RT at Chengicherla X Road

From the below results, It was observed that the capacity varied from 610 to 770 veh/ hr. From all the methods, the queue lengths are less than 2. This indicates that 1 or 2 vehicles are under queue conditions throughout delays. Delays also varied with less differences. The Level of service from all methods was "B" & "C". This indicates that traffic was stable flow to slight congested flow and minor delays experienced through peerzadiguda minor right turn.

Table 6 The Results for Chengicherla Minor Right Turn

Method	Capacity	Queue length	Delay (Sec)	LOS		
Raff's Method	770 Veh/hr	<2	12.86	B		
Harder Method	632 Veh/ hr	<2	16.24	C		
Greenshield Method	610 Veh/hr	<2	17.06	C		
Clearing time Method	2W	827 Veh/hr	768Veh/hr	<2	12.9	B
	3W	437 Veh/hr				
	4W	391 Veh/hr				

VI. CONCLUSIONS

The conclusions of this study are listed below

1. In this analysis, it was found that as increasing in vehicle size the critical gaps also increased. It was concluded that critical gap is depends on space occupied by vehicle category.
2. The obtained critical gaps for 4W vehicles at Peerzadiguda X road were lower than HCM 2010. Because, more queue condition was existed at this section.
3. From the analysis, follow-up times for Chengicherla X road through major right turn was higher than Peerzadiguda X road because, some queue condition was existed at this section.
4. The critical gap for minor right turn at Peerzadiguda X road for 3W was zero because, 3W vehicles are not existed sufficient quantity for this analysis.

5. It was concluded that the obtained critical gaps by all methods are varied in little differences.
6. At Chengicherla X road, obtained LOS was “F” which indicated the forced flow. To improve the service of this intersection, the signals are provided to minimize conflicts for safe movement of traffic.
7. At Peerzadiguda X road, the obtained LOS was “B” by all 4 methods. It was concluded that along minor right turn, the slight delays are getting which was a stable flow.
8. In this analysis, at Peerzadiguda X road through major right turn LOS was “C” mostly by all methods except Raff’s Method because, a slight differences in obtained delays.
9. At Peerzadiguda X road the LOS by minor right turn was better than major right turn.
10. To improve the service of these intersections, the signals were installed with proper rules and regulations at both intersectons. Because, this area was very congested and there was no alternative routes and space to divert the traffic, to extend the roads.

REFERENCES

- [1] Highway Capacity Manual (HCM), “Highway Capacity Manual.” Chapter 16 and 17, Transportation Research Board, National Research Council, Washington D.C., 2000
- [2] Ashalatha, R., and Chandra, S., “Critical Gap Through Clearing Behaviour of Drivers at Unsignalized Intersections.” *Journal of Civil Engineering*, 15(8), 1427-1434, 2001
- [3] Chandra, S., Agarwal, A., and Ashalatha, R., “Microscopic Analysis of Service Delay at Uncontrolled Intersections in Mixed Traffic Conditions.” *Journal of Transportation Engineering*, 135(6), 323-329, 2009
- [4] Karthika P T, and Dr. Bino I Koshi., “ Gap Acceptance Behavior of Drivers at T-Intersections.” *International Journal of Engineering Research & Technology*, ISSN :2278-0181, 2014
- [5] B.Someshwara Rao, T. Rambabu, and Dr.G. Venkata Rao, “Analysis of Capacity and Level of Service at Uncontrolled Intersections under Heterogeneous Traffic Conditions.” PP. 181-190, Volume 8, Issue 8, 2017
- [6] Jayant P.Sangole, Gopal R. Patil, Prasad S. Patare , “ Modelling Gap Acceptance Behavior of Two-Wheelers at Uncontrolled Intersection Using Neuro-Fuzzy.” *Procedia Social and Behavioral Sciences* 20 (2011) 927-941, 2011
- [7] M. Hemavathy, S. Kalanaadhi, Dr. K. Gunasekharan, Dr. Mukti Advani & Dr. S. Velumurgan, “Assessment of Critical Gap at Uncontrolled Intersections under Heterogeneous Traffic Conditions.” *Indian Journal of Transport Management*, 2015
- [8] Per Solberg, “A Study of Lag and Gap Acceptance at Stop-Controlled Intersections” , Joint Highway Research Project, 8-4-28, 1964
- [9] Wan Hashim WAN Ibrahim and Mohd Erwan SANIK, “Estimating Critical Gap Acceptance for Unsignalised T-Intersection under Mixed Traffic Flow Condition.” *Proceedings of the Eastern Asia Society for Transportation Studies*, Vol. 6, 2007
- [10] Mithun Mohan, Satish Chandra , “ Review and Assessment of Techniques for Estimating Critical Gap at Two-way Stop- Controlled Intersections.” *European Transport*, 2016, Issue 61, ISSN 1825-3997.
- [11] Adebisi, O, “Driver gap acceptance phenomena”. *Jornal of Transportation Engieering*, ASCE, Vol. 108, No, pp. 676-688, 1982
- [12] Velan, S. M. and Van Aerde, M.V., “ Gap acceptance and approach capacity at unsignalised intersection.” *ITE Journal*, Vol. 66, No. 3, pp. 40-45, 1996
- [13] Gattis, J.L. and Low, S. T., “ Gap acceptance at a typical stop controlled intersectionoins.” *Journal of Transportation Engineering ASCE*, Vol. 116, No. 2, pp. 153-166, 1999
- [14] Catchpole, E. A. and Plank, A.W., “ The capacity of a priority intersection.” *Transportation Research*, Vol. 20 B, No. 6, pp. 441-456, 1986
- [15] Hewitt, R. H., “ Measuring critical gap.” *Transportation Science*, Vol. 17, 1983
- [16] Hewitt, R.H., “A Comparision between some methods of measuring critical gap.” *Trafic Engineering and Control*, Vol. 26, No. 1, pp. 13-22, 1985

- [17] Brilon, W., and Wu, N., “ Capacity at Unsignalized Intersections Derived by conflict Technique.”
Transportation Research Record, 1776, 82-90, 2001
- [18] Brilon, W., Koenig, R., and Troutbeck, R.J., “ Useful Estimation Procedures for Critical Gap.” *Transportation Research Part A: Policy and Practice*, 33(3-4), 161-186, 1999
- [19] B.D. Greenshields, D. Shapiro, E.L. Erickson, *Traffic Performance at Urban Street 4 Intersections*, Technical Report 1, Bureau of Highway Traffic, Yale University, New Haven, 1947
- [20] M.S Raff, J.W. Hart, *A Volume Warrant for Urban Stop Sign*, Traffic Engineering and Control, 5/1983, pp.255-258, 1950