Advanced Methods for Critical Gap Estimation in Mixed Traffic at Unsignalized Junctions

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Abstract

An engineering concept known as the critical gap is frequently used to estimate the capacity of individual movements at unsignalized junctions. The majority of studies on critical gap estimation are based on homogeneous traffic situations where the rules of priority and lane discipline are actually followed. Driver behaviour and vehicle interactions at unsignalized junctions in mixed traffic patterns are intricate. Two T-intersections in the southern region of India are used in this work to estimate the critical gap using some of the known approaches, including lag, Harder, logit, probit, modified Raff and Hewitt methods. The findings demonstrate that critical gap estimates have values as low as 1.60 s and that there is a considerable difference (12%–38%) between values calculated using various methodologies. This demonstrates how the current approaches are unable to handle the mixed traffic scenarios. A different method of critical gap estimate is suggested that makes use of vehicle clearing behaviour along with gap acceptance data.

Keywords: *Uncontrolled intersection, Heterogeneous traffic, Critical Gap, Gap Acceptance,*

1. Introduction

Traffic refers to the flow of moving vehicles that are formally organised with junctions, marked lanes, crossroads, regulated signals, and signs, including pedestrians, carriages, lordly trucks, etc. As a network connecting highways in various places, these crossroads are essential. Fewer areas are left without traffic lights, while those that are the most accident-prone are signalised. Uncontrolled or unsignalized junctions are those that lack stop signs or traffic signs. Heavy commercial vehicles (HCV), light commercial vehicles (LCV), two-wheelers, three-wheelers, carts, autos, and bicycles all end up getting into traffic disputes on unsignalized highways. It addresses elements including quantity, speed, capacity, time interval, vehicle category, gap, and headway.

The gap is the amount of time between two successive vehicles in a traffic stream approaching one another, as determined by the front or back bumpers of the vehicles passing in a particular reference line. Headway is the distance between two subsequent moving cars on a road as measured by their fronts. When a car approaches the stop sign from a side street, lag is the first gap they notice. The degree of the lagging that is slowing the vehicle depends on its condition. A critical gap is the smallest distance necessary for a minor street driver to merge with major stream cars. The driver takes into account any gaps that are accepted or rejected. Gap acceptance is the acceptance of the bare minimal amount of gap in the flow of traffic required to safely change lanes. It is based on joining the same line of traffic or cutting across to the appropriate lane. The period between each vehicle should lag due to the constant movement of traffic and the need for space between successively moving vehicles. The concept of the vehicle accepting or rejecting the gap when moving from one mode to another depends on these factors, therefore the gap may be wider or smaller.

2. Literature Reviews

Assuming that the major road's headways follow a negative exponential distribution, the critical gap and accepted gap follow a normal distribution, Ashworth et al. (1968) examined the distribution character of the accepted gap with different flow rates of the major road. They also modelled the average value and variance of the critical gap.

According to different driving activities, Plank and Catchpole (1984) looked at whether different drivers or the same driver at different times had different crucial gaps. Constant and diverse traffic flow is the name for this disparity or dissimilarity.

Vehicles going in the primary stream are prioritized more to cross the crossings than the minor stream, according to Luttinen R. et analysis’s of unsignalized intersections with multiple traffic flows in 1996. Minor Street traffic must wait until there is a significant enough gap on Major Street. The main stream headway is the crucial space during which a vehicle at the minor stream can decide whether to combine with or cross the oncoming traffic. The critical gap is a crucial measure for assessing and predicting traffic volume and capacity, aside from small traffic delays. Besides delay in the minor road. A minor stream vehicle can only join the major stream when the major stream's headway is more than the crucial gap, also known as the "acceptable gap." This headway is used to assess if a minor stream vehicle can enter the major stream. On the other hand, the headway is referred to as the "rejected gap" when the car is unable to cross the junction since it is less than the critical gap.

According to Hamed et al. (1997), the distribution of the crucial gap was correlated with driving experience, drivers' socioeconomic status, waiting time, and journey destination. The conflicting flow, minor road lane count, turn-left lane percentage, and major stream velocity all affect the average value of the crucial gap.

The critical gap at uncontrolled crossings is evaluated using a variety of methodologies**,** Polus et al. (2003) found. They were connected by an s-type curve that could be inferred by an exponential model, and the critical gap decreased with vehicle waiting time**.**

The evaluation of homogenous traffic situations in which road discipline is appropriately enforced was the main emphasis of AshalataR. et al. (2011). At non-signalized junctions with heavy traffic, drivers' interactions and behaviours are composite. In this study, current statistical techniques including Harder's approach, modified Raff’s method, probity, and the logit method are used to observe and record the data of lag, gap, and headway in order to determine the crucial gap. This focuses on how the techniques cannot represent mixed traffic scenarios. The process for determining the crucial gap is based on how cars in the junction behave when clearing the intersection.

3. Methodology

Raff's approach of identifying important gaps seems to be an old strategy. For the computation of the critical gap, Modified Raf's approach requires the values of both gap and lag. The estimation of the rejected and acceptable gaps is accepted using this method. The sum of the probability for the gaps that were rejected and those that were approved is taken to equal 1. The length gap therefore equals the critical gap. It consists of the

measured gap rejection and acceptance distribution function.

The threshold approach is another name for Raff's technique. Because it is straightforward and useful, this strategy is frequently employed in many nations.

$F_{a(t)} + F_{r(t)} = 1$ .... (i)

Where,

t is the headway of the major stream.

Fa(t) is the cumulative probability of accepted gap.

Fr(t) is the cumulative probability of rejected gap.

4. Data collection and Analysis

In order to analyze the driver's gap acceptance behaviour at Minor Street at the uncontrolled junction at Nihal Singh chowk in Keonjhar, this article estimates the critical gap at that intersection. The crossroads is well visible, and each vehicle movement is within standard viewing distance. The presence of traffic lights had no impact on the vehicle's movement. On large roads, traffic volume varies by vehicle per hour, but on smaller roads, it varies by vehicle per hour. On a normal workday (9:00 a.m.–12:00 p.m.), we will gather data utilising video recording techniques and a video shooting camera to gather metrics such as gap, lag, and acceptance. The camera was positioned such that it could collect information on all different types of cars, including their gaps, lag times, etc.

Fig.2 Nihal Singh Chowk

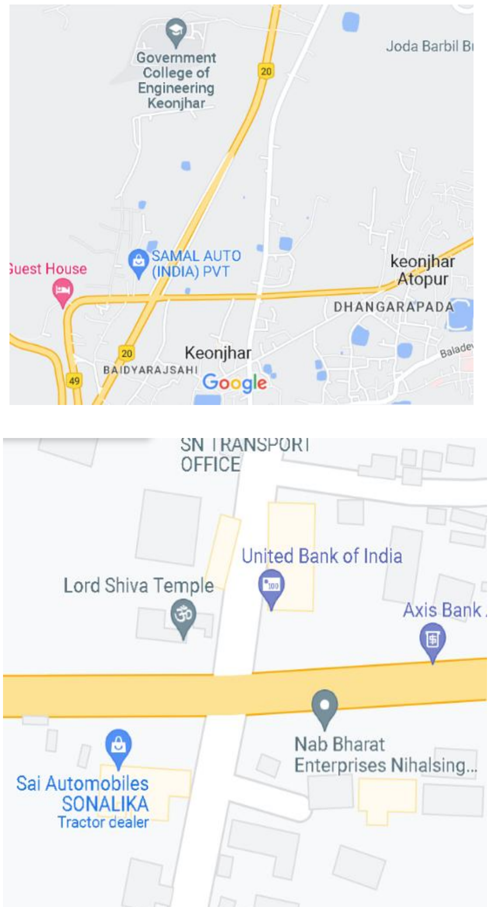

Fig.1 Map view of Nihal Singh Chowk

Table 1 Cumulative accepted and rejected probability for Approach-1

Time interval	Mean	Accepted gap	Rejected gap	Accepted probability	Cumulative accepted	Rejected probability	cumulative rejected probability	1-cumulative rejected
>0-0.6	0.3	1	1	0.142	0.142	0.026	0.026	0.974
>0.6-0.7	0.65	1	3	0.142	0.284	0.078	0.104	0.896
>0.7-1.1	0.9	1	6	0.142	0.426	0.157	0.261	0.739
>1.1-1.8	1.45	1	10	0.142	0.568	0.263	0.524	0.476
>1.8-2.8	2.3	1	7	0.142	0.71	0.184	0.708	0.292
>2.8-5	3.9	1	2	0.142	0.852	0.052	0.76	0.24
>5-6	5.5	1	9	0.142	0.994	0.026	0.786	0.214

Table 2 Cumulative accepted and rejected probability for approach-5

Time interval	Mean	Accepted	Rejected	Accepted probability	Cumulative Accumulative probability	Rejected probability	Cumulative rejected probability	1-Cumulative rejected probability
>0-0.9	0.45	1	0	0.045	0.045	0	0	1
>0.9-1.3	1.1	1	3	0.045	0.09	0.04	0.04	0.96
>1.3-1.7	1.5	1	2	0.045	0.135	0.027	0.067	0.933
>1.7-2	1.85	1	25	0.045	0.18	0.337	0.404	0.596
>2-2.3	2.15	1	6	0.045	0.225	0.081	0.485	0.515
>2.3-2.4	2.35	1	3	0.045	0.27	0.04	0.525	0.475
>2.4-2.8	2.6	1	3	0.045	0.315	0.04	0.565	0.435
>2.8-3	2.9	1	6	0.045	0.36	0.081	0.646	0.354
>3-3.4	3.2	3	6	0.136	0.496	0.081	0.727	0.273
>3.4-3.6	3.5	1	4	0.045	0.541	0.054	0.781	0.219
>3.6-5.4	4.5	3	5	0.136	0.677	0.067	0.848	0.152
>5.4-6.4	5.9	7	8	0.318	0.995	0.108	0.956	0.044

5. Results and Discussion

The eight approaches represented above were used to determine the critical gap through and right turns from a minor road (two-wheeler, three-wheeler, light commercial vehicle, heavy commercial vehicle and cars) at four-legged intersection located at Nihal Singh chock. This result shows many variations in the critical gap parameter estimated by modified raff's method.

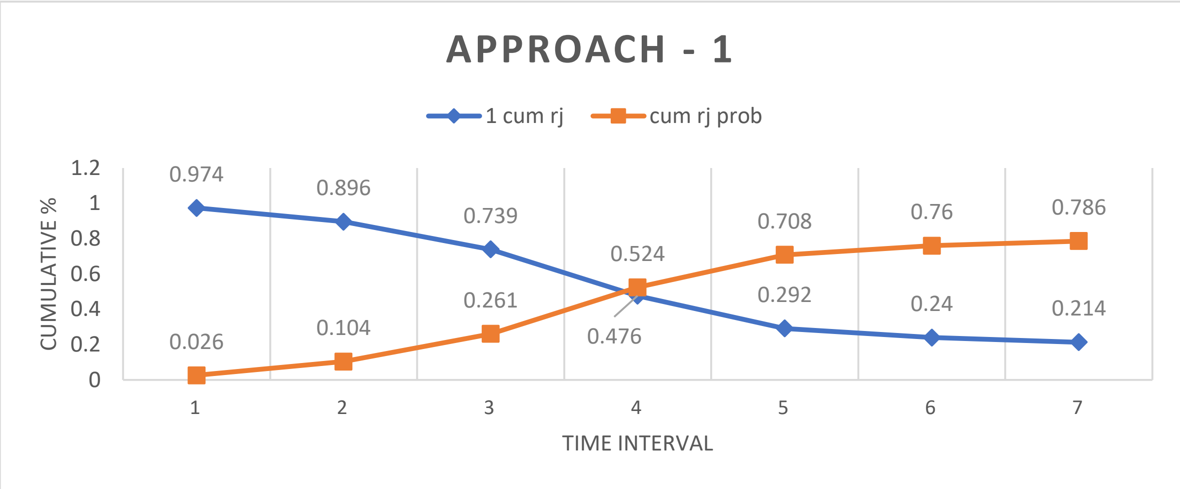

Fig.3 Modified Raff Graph for Approach 1

Fig.4 Modified Raff Graph for Approach 5

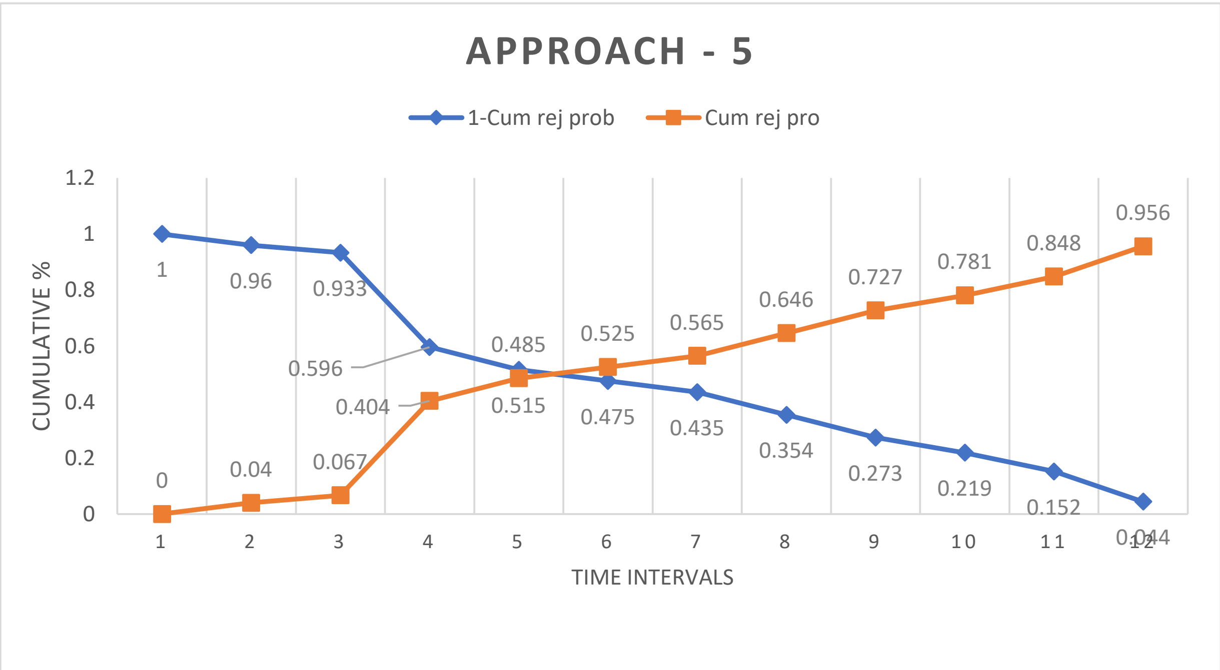

Table 3: Comparison of critical gap between approach-1 and approach-5

Sl. no.	Approach number	Critical gap t_c (in second)
1	Approach-1	4.476
2	Approach-5	5.5

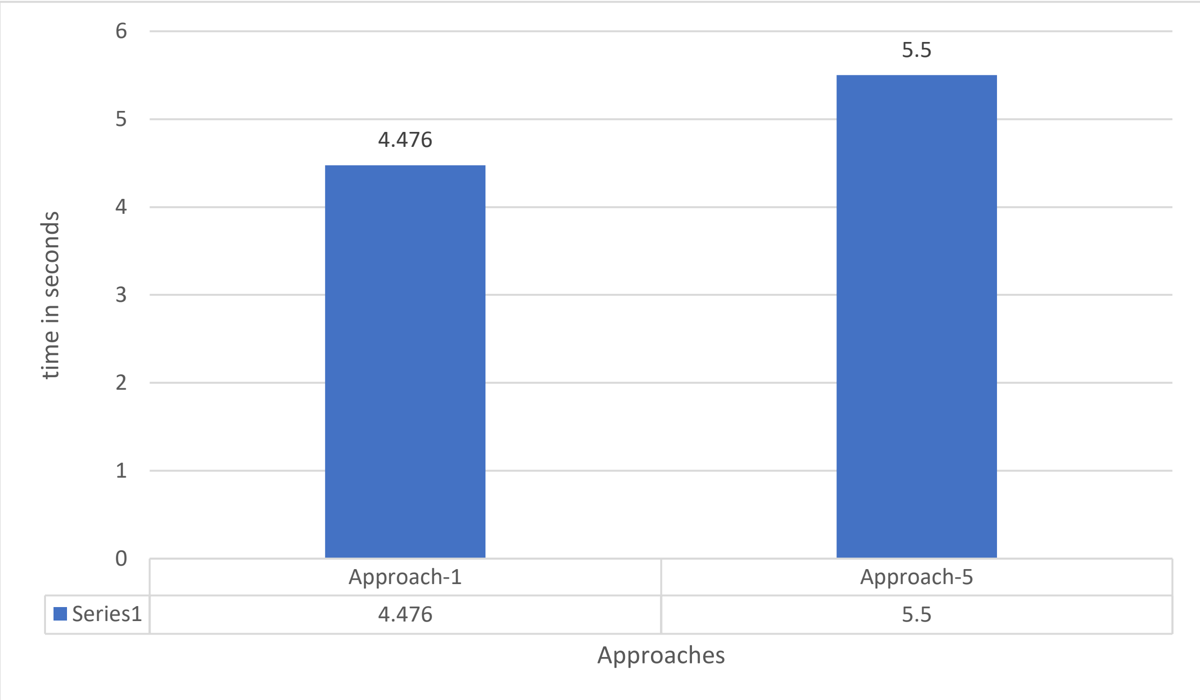

Fig.5 Comparison of Critical Gap

6. Conclusion

In this study, Raff's method is applied to estimate the critical gap, following its extensive use in previous research. The work also highlights the challenges associated with measuring critical gaps at unsignalized intersections. The method provides both the mean and probable values of the critical gap. Traffic movement data were collected from a non-signalized four-legged intersection located at Nihal Singh Chowk, Keonjhar. Critical gap values were analyzed using multiple methodological approaches. The observed critical gaps, obtained under relatively low traffic volumes, were found to be smaller across different estimation techniques due to the heterogeneous nature of traffic.

The concept of accepted and rejected gaps in mixed traffic was examined using various procedures applied at the four-legged intersection. It was observed that the resulting distribution graphs of cumulative accepted and rejected gaps did not behave in an ideal or expected manner, indicating inconsistencies in driver behaviour under mixed traffic conditions. Generally, critical gap estimation is essential for determining intersection capacity and the lag intervals of approaching vehicles in mixed-flow traffic. Therefore, understanding gap-acceptance behaviour is valuable for traffic engineers and can support the development of reliable traffic models for both heterogeneous and homogeneous conditions.

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