

# Multi Vehicle-Type Right Turning Gap-Acceptance and Capacity Analysis at Uncontrolled Urban Intersections

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## Abstract

Intersections are the critical zones where conflicting, merging and diverging movements influence the intersection capacity. Uncontrolled intersections in particular pose dangerous situations to vehicular traffic. During peak vehicular flow, the unpredictable crossing behavior of minor stream vehicles induces delay and reduces the capacity of the intersection. Capacity at uncontrolled intersections is typically measured either by gap acceptance method, empirical regression approaches and conflict technique. Gap acceptance is an important characteristic for analyzing uncontrolled intersections. The behavior of different vehicle types and gap of subject vehicle type from minor street taking right turn to merge with major traffic stream is analyzed using gap acceptance method. The objective of the current study is to analyze the effect of major stream vehicle type combinations on the minor stream vehicle gap-acceptance behavior and to determine the capacity of the minor stream taking into account the influence of the right turning vehicles. The capacity of minor stream calculated using Highway Capacity Manual (HCM) 2010, Luttenin's model, and Tanner's model are compared. It is observed that two wheelers are more aggressive than three wheelers for most of the major stream vehicular combinations observed in this study.

## Keywords

capacity, critical gap, gap acceptance, uncontrolled intersection, vehicle type

## 1 Introduction

At uncontrolled intersections the interaction between vehicles is very complex. Gap acceptance is widely used to analyze the behavior of driver at uncontrolled intersections. Gap acceptance is the method in which a vehicle from the minor street accepts the gaps available in the major street. Driver approaching the intersection from the minor street tries to find a safe gap to cross the intersection. It is the decision made by the driver either to accept or to reject the gaps available in the major street under the given conditions. Several researchers have defined the critical gap as “Critical gap is the minimum gap that is acceptable to a driver, intending to cross a conflicting stream” (Ashalatha and Chandra, 2011). Similarly, “critical gap is defined as the size of the gap whose number of accepted gaps shorter than it is equal to the number of rejected gaps longer than it” (Raff and Hart, 1950). Older version of Highway Capacity Manual (HCM, 2000) defines critical gap as “the minimum time in seconds, between successive major-stream vehicles, in which a minor-street vehicle can make a manoeuvre”.

However, latest version of HCM (2010) defines critical headway ‘ $t_c$ ’ as “the minimum time interval in the major street traffic stream that allows intersection entry for one minor-street vehicle”. Estimation of critical gap is difficult under mixed traffic conditions compared to homogeneous traffic conditions. The smaller vehicles approaching from a minor road while attempting to cross a major road try to accept narrow gaps available between the larger-sized vehicles. In mixed traffic conditions, especially as observed in this study at the uncontrolled urban intersections in a medium-sized Indian city, many times a number of small-sized vehicles accept the available narrow gap and move parallel to each other in the process of crossing the major road, after which these vehicles move one after the other in a single line. During the process of crossing the major road, minor road vehicles do not follow the “priority rule” and the major stream vehicles are forced to reduce the speeds to give way to minor stream vehicles. Gap acceptance is affected by various factors which includes, vehicle type and vehicle

arrival rate. It is necessary to determine the effect of major stream vehicle type combinations on gap acceptance by the minor stream vehicles.

## 2 Literature review

In the last few decades, several researchers focused on determining the gap acceptance with main emphasis on homogeneous traffic conditions. Based on the literature review it is observed that there are several methods to estimate the critical gap. Generally, for estimating the critical gap, accepted and rejected gaps are used. This section briefly presents the review of research work performed to analyze the gap acceptance and capacity estimation at uncontrolled intersections. Initial part of the literature deals with critical gap estimation while the later part focuses on capacity estimation for uncontrolled intersections.

Several methods are available to estimate the critical gap including Siegloch's method, Greenshield's method, Raff's method, acceptance curve method, lag method, Ashworth's method, Harder's method, logit procedure, probit procedure, Hewitt's method, maximum likelihood procedure, clearing behaviour, and equilibrium of probabilities. In early 1980's, researchers developed gap acceptance models by comparing existing methods of critical gap estimation and obtained satisfactory results using Ashworth method (Miller, 1972) and maximum likelihood technique (Miller, 1972; 1974). Later, binary logit model was developed (Hamed et al., 1997) to determine the drivers gap acceptance probabilities. The probabilities of accepting or rejecting a gap for each driver can be determined using a binary probit model which is used in the calculation of critical gap for all the drivers. This method can be used to calculate critical gaps of individual drivers and also the mean critical gap at a particular intersection. It was observed that critical gaps differ between the two major lanes. Comparison between various methods of critical gap estimation continued even in late 1990's (Gattis and Low, 1999; Brilon et al., 1999). It is important to note here that the conclusion made by the researchers was essentially based on the relative comparison between the methods they considered. On comparing acceptance curve, Greenshield's, logit, Raff, and Siegloch's methods, it was observed that Raff's method yielded lower critical gap values and logit method yielded higher critical gap values (Gattis and Low, 1999). On comparing Ashworth, Harder, Hewitt, lag, logit, maximum likelihood, probit, Raff, and Siegloch's methods based on the condition that critical gap estimation shall

be independent of major approach traffic volume, it was observed that Hewitt and maximum likelihood methods are considered to be best for evaluation of critical gaps (Brilon et al., 1999). Maximum likelihood method was also used in the past to estimate critical gaps for two major lanes and it was observed that critical gaps can be different in two major lanes (Hagring, 2000). Recently, critical gap was estimated using a new method termed "clearing behaviour of vehicles" in concurrence with gap acceptance that can be used to estimate entry capacity. Using the existing critical gap estimation methods including lag, Harders, logit, modified Raff and Hewitt methods, it was reported in the literature that the critical gap can be as low as 1.6 s (Ashalatha and Chandra, 2011). New critical gap estimation methods were also proposed in the recent years based on a survey method for accepted and rejected gaps. It was observed that exponential model representing the rejected proportion is better than the linear model (Guo and Lin, 2011). Gap forcing behaviors were also analyzed in the past in an attempt to differentiate from conventional gap acceptance models (Xiao et al., 2011). However, these studies are focused on modeling driver's behaviour. Recently, works are also reported on modeling gap acceptance behaviour of right turning vehicles at partially controlled three-legged intersections using adaptive neuro-fuzzy interface system and found that the predictions for major right turning ranged from 75 % to 82 % whereas for minor right turning, it is 87 % to 89 % (Sangole and Patil, 2014).

Capacity of uncontrolled intersections is normally estimated using either empirical or gap-acceptance models. Considering the advantages of the gap-acceptance models, several researchers have focused on identifying the parameters affecting the capacity of uncontrolled intersections. Gap acceptance model was developed based on limited priority for the major stream (Troutbecka and Kakob, 1999) and it was reported that there would be an increase in major stream headways due to the merging vehicles especially at higher traffic flows. An alternate method is also reported in the literature called addition of conflict stream for determining the capacity of unsignalized intersections (Brilon and Wu, 2001). Driver's behavior while waiting on the minor road at unsignalized intersection was also considered to estimate the capacity of the intersection (Pollatschek et al., 2002). It was observed that vehicles will enter on to the main road only when the risk is lower than the benefits and different populations will have different entry capacities. Mixed vehicular

flows considering only heavy and light vehicles were also considered to determine the capacity of unsignalized intersections especially taking into account Chinese traffic conditions (Li et al., 2003). The influence of Non-Motorized Traffic (NMT) and pedestrians on motor vehicles was also considered to estimate the movement capacity of urban unsignalized three-legged intersections using gap acceptance concept (Li et al., 2009).

From the literature it can be said that critical gap for different types of movement is dependent on the availability of the gaps at the intersection. Critical gap and follow up time depends on the type of vehicles crossing the intersection. Different gap acceptance methods include mathematical calculations of critical gap, follow up time, conflicting flow and proportion of vehicles. Similarly, methods developed to find the capacity of unsignalized intersection are mainly based on the calculation of critical gap and follow up time. Behavior of driver manoeuvring the intersection has influence on the delays, headways and capacity of the intersection. In addition, for various types of vehicles the accepted and rejected gaps will be different. Thus, the effects of combinations of major stream vehicle-types on the gap-acceptance behaviour of the minor stream vehicle need to be studied. The study finds its importance that in given traffic conditions, the driver has to accept a gap in the conflicting stream and this decision is influenced by certain behavioural conditions of the driver. Generally the type of vehicle on the major stream influences this behaviour. Also, the types of turning vehicle also influence the gap acceptance behaviour in the traffic stream. Thus, it is necessary to relate the vehicle types to analyze gap-acceptance behaviour. The findings of this study are expected to improve the accuracy with which the capacity of an urban uncontrolled intersection can be estimated. The influence of critical gaps significantly affects the delays and in turn affects the capacity of an intersection. The present study analyzes the effect of vehicle types on the possibility of gap acceptance of minor stream vehicles and calculates the capacities of minor stream vehicles using HCM 2010 method, Luttenin’s model, and Tanner’s model.

### 3 Data collection

Data was collected from two All-way-stop-controlled (AWSC) intersections in Warangal city, Telangana state, India. Both the intersections consist of four-lane divided major streets and two-lane undivided minor streets. Intersections were selected such that there is a clear difference in the proportion of heavy vehicles. For intersection-1,

proportion of heavy vehicles is less compared to intersection-2. The choice has been made to analyse the clear difference between the gap acceptance behaviour because of heavy vehicles and other vehicle types on the major road. For these intersections, several parameters were extracted from the captured video which includes: gap between the vehicles, rate of arrival of vehicles, clearing time of each vehicle type, traffic volume, and time headway. The line diagram with geometrical information and turning traffic volume for both the intersections are shown in Figs. 1 and 2.

The video-graphic data was captured from elevated positions for a period of four hours during weekdays on each location. The peak hour distribution of the traffic which includes two-wheelers (2w), three-wheelers (3w), four-wheelers (4w), light commercial vehicles (LCV), buses, bicycles, heavy vehicles (HV), tractors for both the intersections is shown in Table 1. Figs. 3 and 4 show the composition of traffic for all vehicle types for both the intersections. It can be observed that the proportions of

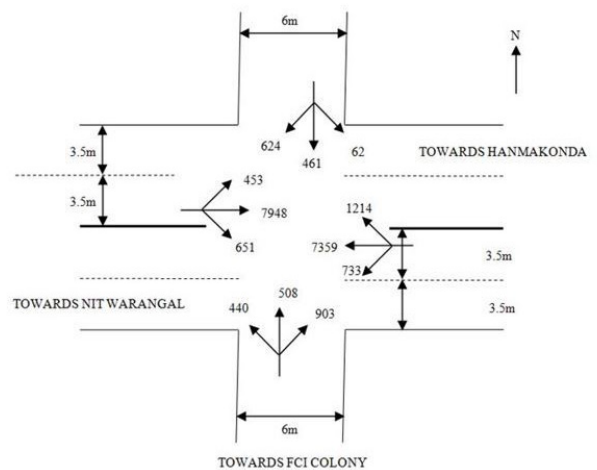


Fig. 1 Line diagram for intersection-1

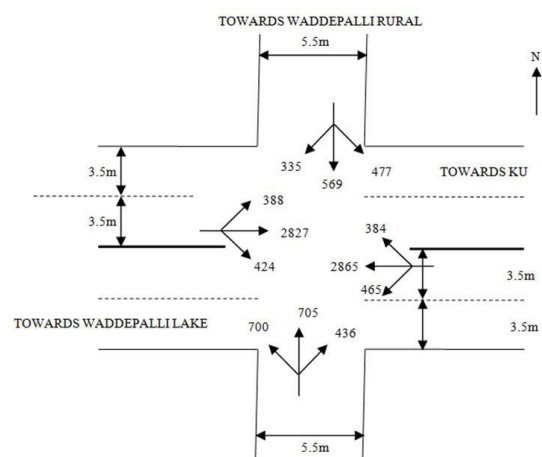
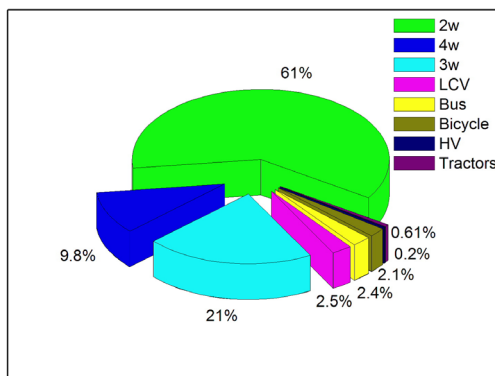


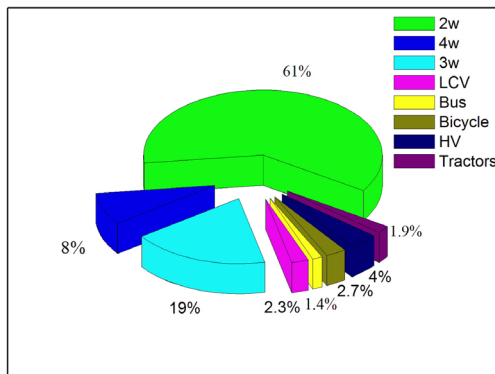
Fig. 2 Line diagram for intersection-2

**Table 1** Peak hour distribution of traffic for both intersections (veh/h)

Different legs of Intersection	Intersection-1			Intersection-2		
	Left turn	Through	Right turn	Left turn	Through	Right turn
East Bound (EB)	733	7359	1214	465	2865	384
West Bound (WB)	453	7948	651	388	2827	424
North Bound (NB)	62	461	624	477	569	335
South Bound (SB)	440	508	903	700	705	436



**Fig. 3** Modal share for intersection-1



**Fig. 4** Modal share for intersection-2

two and three wheelers are very high compared to other modes due to the location of intersection closer to residential area. The clearing time of each vehicle type is shown in the Table 2.

Gap accepted and rejected, follow-up time for each vehicle type was extracted from the video. In addition, the effect of gap available for each vehicle type and with other vehicle types in the stream was extracted from the video. HCM (2010) defines follow up headway as the time between the departure of one vehicle from the minor street and departure of the next vehicle using the same major-street headway, under a condition of continuous queuing

**Table 2** Clearing time for minor stream vehicles

Vehicle type	Clearing time, s	
	NB	SB
2w	11.127	13.817
3w	13.133	18.341
4w	16.221	22.627
LCV	14.166	24.221
Tractor	18.328	19.107
Bus	25.832	-
SB	-	19.100
HV	12.388	-
Bicycle	-	15.124

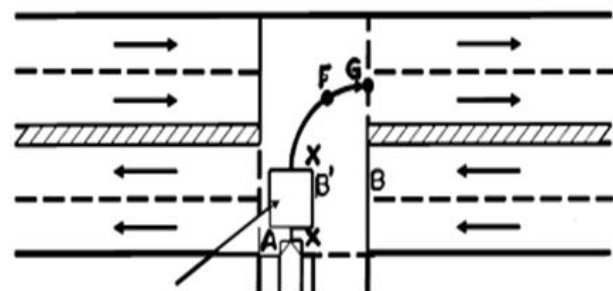
on the minor street. The follow-up time is measured from the field as the average of the total readings.

Considering the heterogeneous traffic conditions in India, the minor street vehicles were found to move about half of the lane width into the intersection area from the stop line as shown in Fig. 5. Position A is considered as the reference line for recording the arrival of minor street vehicles.

Lag was measured as the time interval between the arrivals of a vehicle on the minor road at position A and the arrival of the vehicle on the major street. The video was played with media player classic. Whenever the vehicle reaches point A, the time is noted. The time for the arrival and departure of the vehicles are noted at point G in Fig. 5. For major stream vehicles, readings were taken at point B which is considered as the reference line for the major stream vehicles.

#### 4 Methodology

The methodology includes suitable site selection for the field survey, collection and extraction of field data, identification and statistical analysis of factors leading to gap acceptance. For collecting the gap acceptance data, combination of vehicles are prepared for the major stream traffic. The gap-acceptance study is done only for



**Fig. 5** Representative area for gap-acceptance measurement (Ashalatha and Chandra, 2011).

vehicles which are taking right turn from minor to major stream. The time for the arrival, departure and exit time for each vehicle type are noted for minor stream vehicle. For the major stream vehicles, the readings are taken at the reference line for the major stream vehicle. The gap values obtained from the video are then extracted. As for the first intersection, the left turning traffic is not predominant. Further, left turning traffic is quiet smooth as there is no gap acceptance involved. It is simply a process of merging, in case of left turning traffic. Whereas, for right turning vehicles, gap acceptance phenomenon is influential. Therefore, the data was collected for the right turning vehicles. Through movement is outside the scope of this study.

Further, the major stream vehicles are divided into different combinations. As the percentage of share of 2w, 3w, and 4w are higher, the combinations are prepared. The major combinations that are observed on the traffic are 2w-2w, 3w-3w, 4w-4w, 2w-3w, 3w-2w, 2w-4w, 4w-2w, 3w-4w, 4w-3w and other combinations. Other combinations consist of mix of LCVs, buses, tractors and HVs with 2w, 3w, 4w which are very less in number. For each type of minor stream vehicle the gaps accepted, gap rejected by the major stream vehicle combinations are calculated. Example, for 2w in a minor stream, the gap accepted and gap rejected for different combinations of major stream was noted. Further, the combination of gap accepted vehicles and gap rejected vehicles are matched and the critical gaps for those combinations for particular minor stream vehicles are determined. The critical gap was calculated for each vehicle type in the minor stream taking right turn with respect to the major stream vehicles. The critical gaps obtained from both the intersections are compared. The variation of the critical gap for each combination of major stream vehicle is analyzed.

The critical gaps are determined using the Raff's method and clearing behavior of the vehicles. Clearing time is the total time taken by the vehicle to cross the intersection. The intersection clearing time is affected by the pattern in which a vehicle accepts the available gap. The clearing time of each vehicle type was obtained through the data extracted from the video recording. A plot is generated depicting the cumulative frequency distribution for clearing time on abscissa and cumulative percentage lag and gap accepted on the ordinate. The intersection point of the curves will give the critical gap for the corresponding vehicle type. The critical gap values obtained from clearing behavior are compared with Raff's method.

Capacities of the minor stream vehicles for both the intersections are determined using the Luttinen's model and Tanner's model. The capacity and level of service calculations for each intersection are made using HCM 2010. According to HCM method, movements in each direction are calculated. Volume and lane adjustments are done as the traffic flow is not lane based. The saturation headways for each direction of traffic for each lane are calculated using the percentages of heavy vehicles and turning volume in each direction of traffic. Departure headways are calculated using the saturation headways. Control delay per vehicle is computed for each lane and each approach. The capacity and level of service for the intersection is determined. Similar procedure is applied for intersection-2. The calculation takes into account peak hours in each direction. For both the intersections, the volume of the 2w and 3w are in majority. Percentages of HV are higher for intersection-2 as compared to intersection-1. The traffic volumes observed for first intersection are higher than second intersection. Therefore, the delay and capacity values obtained for first intersection are higher as compared to second intersection.

**5 Results and discussion**

Critical gap values calculated by clearing behavior method are shown in Table 3. Clearing time is the total time taken by the vehicle to cross the intersection. Clearing time will depend upon the manner in which the vehicle enters a gap. The clearing time for each type of vehicle is extracted from the video. The typical cumulative frequency distribution curve for clearing time (Fct) of different types of vehicles from minor street at intersections is plotted. The plot between cumulative percentile lag and gap accepted (%) vs clearing time will give the intersection point. The intersection point indicates a situation when clearing time is just equal to the gap and lag accepted, which is the minimum time gap for the vehicle

**Table 3** Critical gap observed using the clearing behavior of vehicles (in seconds)

Vehicle type	Intersection -1	Intersection -2
	Minor to major	Minor to major
2w	4.84	4.03
3w	7.08	6.53
4w	8.59	7.69
LCV	9.90	6.97
Tractor	11.48	9.98
Bus	-	8.60

to enter the intersection, considering the safety aspect. This point will be considered as the critical gap. The values of critical gap obtained by clearing behavior method gives the safest critical gap values for the vehicle to cross the intersection without any associated risk. The value is valid for any traffic type condition for that particular intersection. For each intersection, the values of critical gap increased with the size of vehicle. For intersection-1, critical gaps are higher as compared with intersection-2, which indicates that for higher major stream flow, the safe critical gap values are higher.

For intersection-1, the critical gap obtained for both North Bound (NB) and South Bound (SB) minor stream

is 2.45 s. From the values, it can be said that, for higher traffic volume the critical gaps are almost similar for each approach of the intersection. For intersection-2 the critical gap obtained for NB and SB minor stream are 3 s and 4.35 s, respectively. For estimating the critical gap estimated using Raff’s method, the accepted and rejected gaps are sorted by gap length and the cumulative numbers of gaps accepted and rejected are tabulated. A graph is plotted using these two data sets. The intersection point of these two curves gives the critical gap ( $t_c$ ) value.

Figs. 6 to 11, shows the critical gap values for various minor stream vehicles with the major stream combinations for intersection-1.

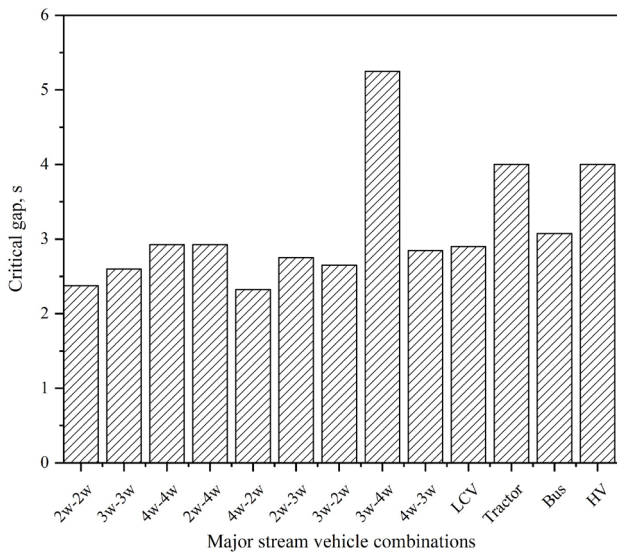


Fig. 6 2w in minor stream for intersection-1

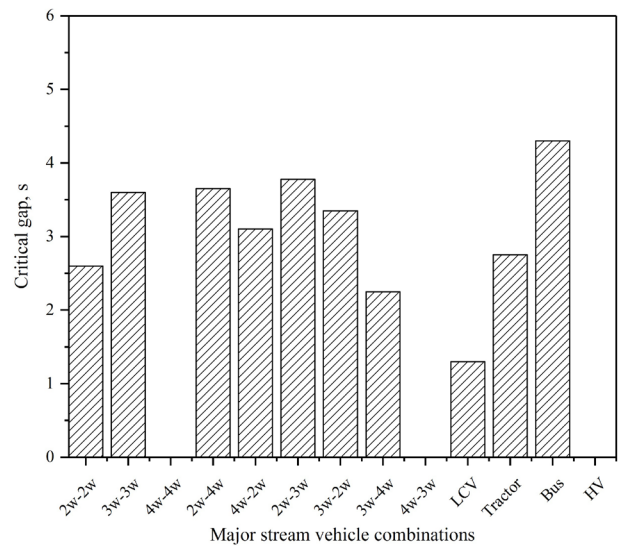


Fig. 8 4w in minor stream for intersection-1

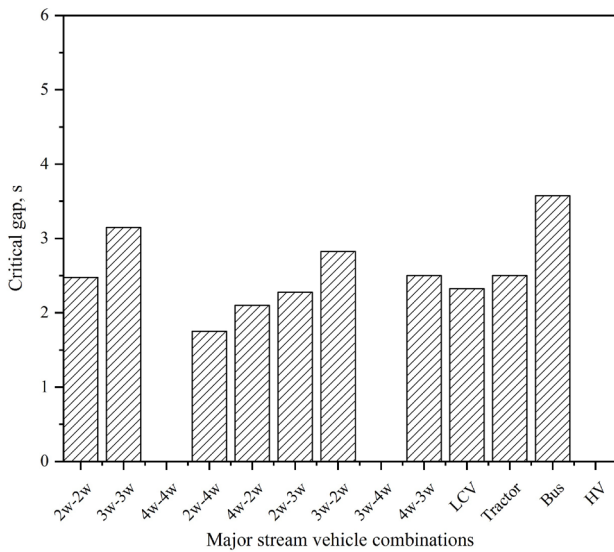


Fig. 7 3w in minor stream for intersection-1

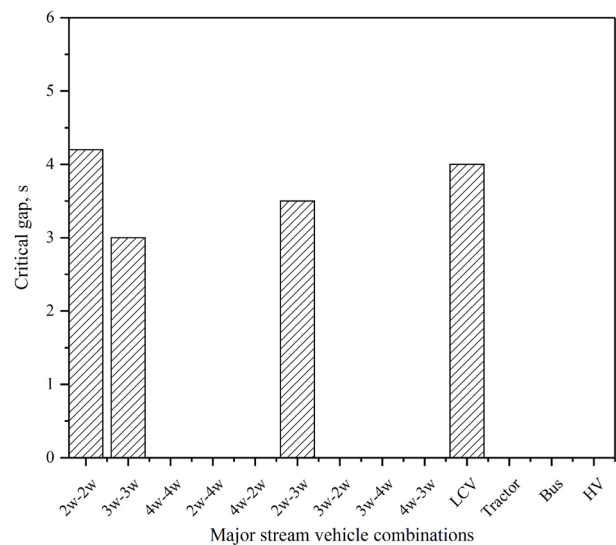


Fig. 9 LCV in minor stream for intersection-1

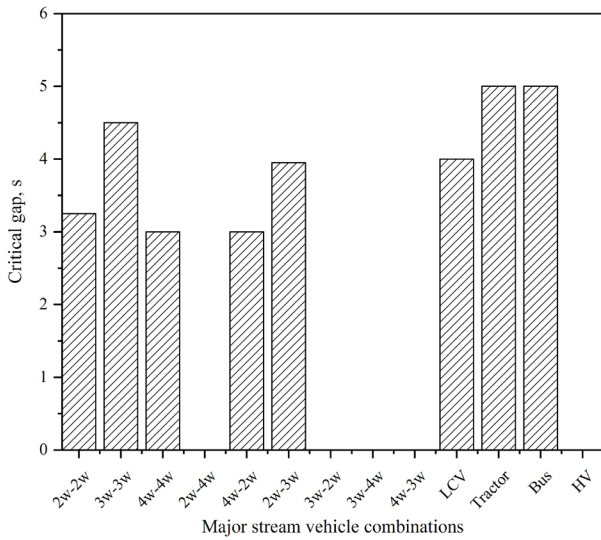


Fig. 10 Tractor in minor stream for intersection-1

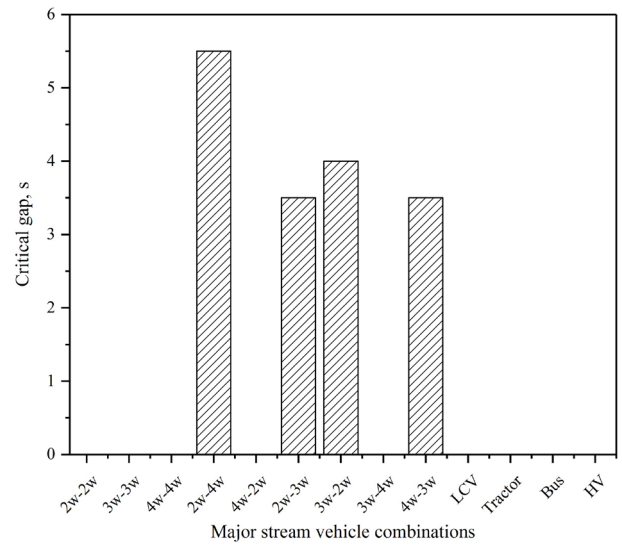


Fig. 11 Bus in minor stream for intersection-1

Figs. 6 to 11 show that for 2w and 3w, the critical gaps for major stream vehicle combinations are lesser as compared to the other vehicles. For buses, the sample data is not sufficient to analyze the behavior. For major stream vehicle combinations, 2w-2w and 2w-3w has been readily accepted by each type of vehicle. For LCV, Tractor and Bus, most of the major stream combinations were not observed since the sample size is very small. The relation between 2w in the minor stream and major stream vehicle combination is plotted as shown in Fig. 5. For 3w-4w combination, the value of critical gap is almost double that of other major combinations. Also, for tractors and HV, it is 60% more than 2w-2w combination.

Figs. 12 to 14 show the critical gap values for various minor stream vehicles with the major stream combinations for intersection-2.

For intersection-2, the traffic volume is less which results in higher value of critical gap for each vehicle type. Having lower major stream traffic flow, the minor stream vehicles are getting more opportunity to cross the intersection with safe manoeuvring, resulting in higher values of critical gap. The sample data was observed to be insufficient for LCV, bus and tractor. For 3w, the critical gap values are higher as compared to 4w. Most of the major stream vehicle combinations have been found to possess almost similar critical gaps. For LCV, tractor and bus, major stream combinations were

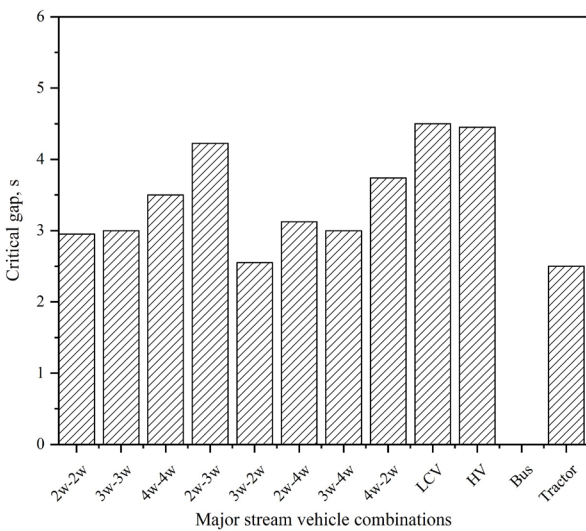


Fig. 12 2w in minor stream for intersection-2

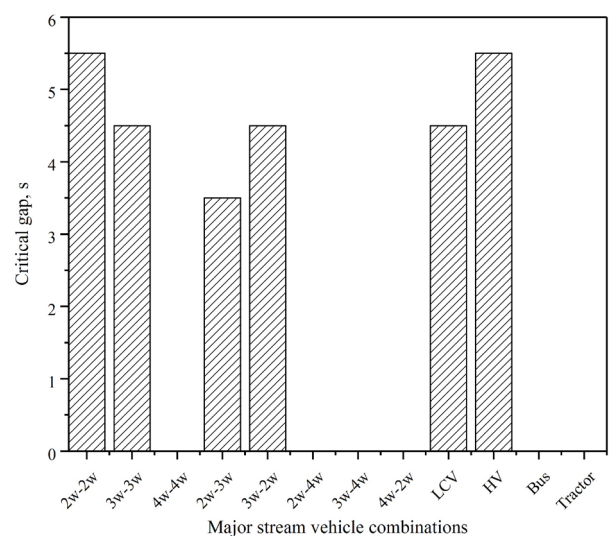


Fig. 13 3w in minor stream for intersection-2

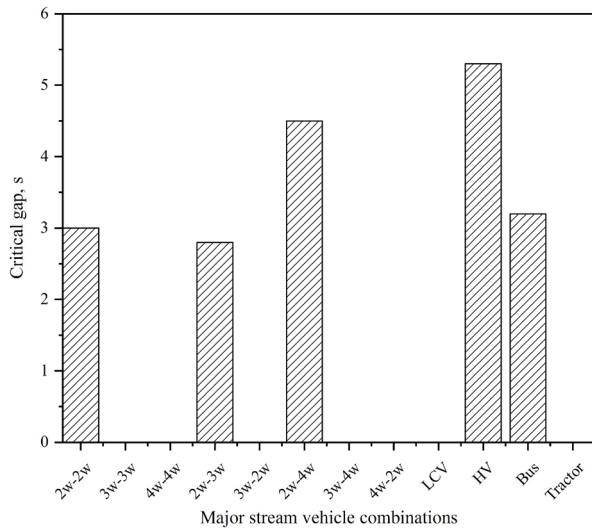


Fig. 14 4w in minor stream for intersection-2

not observed since the sample size is very small. For LCV with 2w-2w and LCV-HV combination, the critical gap was found to be 4.5 s and 3.5 s, respectively. For Tractor with 2w-2w combination, the critical gap was found to be 5 s. Similarly, for Bus with Bus-HV, the critical gap was found to be 4.5 s. It shows that for LCV and HV the critical gap is more, which shows the effect of HV which will lead to reduction in the capacity of major stream traffic flow. The critical gaps for different vehicles taking right turn from minor stream is obtained by using the clearing behavior of vehicles. Comparison of critical gap values is shown in Table 4. The values obtained for 2w and 3w are almost double. For tractors, HV, 4w and LCV resulted in large variation in critical gap for minor to major flow.

From the above comparison, the critical gap value for clearing behavior of vehicle is higher as compared to the normal gap acceptance, as the vehicles with normal gap acceptance normally accepts the gaps in a zig-zag manner. Whereas, in clearing behavior concept, the vehicles

Table 4 Comparison of Critical gaps (in seconds)

Vehicle Type	Intersection-1		Intersection-2	
	Critical gap by clearing behavior	Critical gap by Raff's method	Critical gap by clearing behavior	Critical gap by Raff's method
2w	4.84	2.6	4.03	2.75
3w	7.08	2.27	6.53	4.05
4w	8.59	2.8	7.69	4.8
LVC	9.9	3.4	6.97	3.95
Tractor	11.48	3.85	9.98	4.6
Bus	-	4.2	8.6	4.5

are accepting the gap without any zig-zag movement and without any disturbance to other vehicles.

The capacities of the minor stream vehicles can be obtained from the gap-acceptance models. Tanner (1962; 1967) developed Eq. (1) to determine the capacity of the minor road and also to determine the relationship between different parameters related to the delay occurring at major and minor road intersection. Luttenin (2003) developed a model to determine the minor stream potential capacity as given by Eq. (2).

$$c_p = \frac{q_M (1 - \lambda t_p) e^{-\lambda(t_c - t_p)}}{1 - e^{-\lambda t_f}} \tag{1}$$

$$c_p = \frac{q_M \exp\left(\frac{q_M(t_c - t_p)}{3600 - q_M t_p}\right)}{1 - \exp\left(\frac{-q_M t_f}{3600 - q_M t_p}\right)} \tag{2}$$

where,  $\lambda = q_m/3600$  (veh/s),  $t_p$  = minimum headway in the major traffic stream,  $t_c$  = critical gap,  $q_m$  = number of major stream headways,  $t_f$  = follow-up gap.

The capacities of minor stream flow for both the intersections were calculated and are listed in Table 5.

Capacities obtained from the above methods shows that the values obtained from HCM 2010 method are higher as compared to Luttenin's and Tanner's model. As per HCM, level of service obtained for both the intersections is 'F', resulting in reduction of capacity. The difference observed between the values of gap acceptance models and HCM method is due to the consideration of heavy vehicles which results in higher capacity values. For gap acceptance model, critical gap and follow up time for all the vehicles is taken, resulting in lower capacity. The results of capacity values, delay and level of service obtained through HCM 2010 are shown in Table 6.

Table 5 Capacity of minor stream for both the intersections

Capacity estimation	Intersection-1		Intersection-2	
	NB	SB	NB	SB
Luttenin's model (veh/h)	453	605	526	421
Tanner's model (veh/h)	543	682	530	443
HCM 2010 (veh/h)	804	1076	756	924



**Table 6** Results of HCM 2010 manual method

Parameters	Intersection-1		Intersection-2	
	NB	SB	NB	SB
Capacity(veh/h)	804	1076	756	924
Delay(s)	76.536	64.707	69.317	62.624
LOS	F	F	F	F

## 6 Conclusions

From the critical gap obtained for the right turning vehicles at both the intersections considered in this study, Two-wheeler (2w) are observed to be more aggressive than Three-wheeler (3w) as the critical gap accepted by 2w is less than 3w in most of the combinations. However, for 2w-3w combination at both the intersections, the critical gap accepted by 3w is less than 2w. In a 2w-3w combination, as the following vehicle is a 3w, the 3w approaching the intersection from minor stream is likely to accept lower critical gaps because the 3w driver is likely to have fair idea about the behaviour of a 3w driver approaching the intersection in the major stream.

For 2w as subject vehicle from minor stream with major stream combination 2w-2w, accepts a minimum gap of 2.37 s whereas with 2w-4w combination, accepts a gap of 5.25 s. Whereas, 3w as subject vehicle from minor stream with major stream combination 4w-2w, accepts a minimum gap of 1.75 s and with 3w-Bus combination, accepts

a gap of 3.58 s. For subject vehicle like Light commercial vehicle (LCV), tractor, and bus, most of the combinations were not observed in the field and critical gap values are higher when compared to other vehicle types. When the major stream combinations are heavy vehicle (HV), tractor, and bus, the critical gap values are 30 to 35% higher than 2w-2w combination. This is due to the fact that the critical gap values increase with increase in the size of the vehicles. For intersection-1, it is observed that when the subject vehicle is either 2w, 3w, or 4w from the minor stream with major stream combination of 2w-2w, the critical gap values are 2.37 s, 2.47 s, and 2.60 s, respectively. The critical gaps observed at both the intersections are in the range of 1.3 s to 5.5 s. It is important to note here that the critical gap observed in this study is much lower than the critical gap of 1.6 s reported by Ashalatha and Chandra (2011) for mixed traffic conditions.

The clearing behavior method takes into account several aspects including lack of lane discipline and zigzag movements typically observed under mixed traffic conditions. The critical gap values obtained from the clearing behavior method are higher than that obtained from Raff's method. Also, capacity estimated for minor streams by gap-acceptance models are less than capacity obtained from HCM 2010 method, since the HCM 2010 method considers the percentage of heavy vehicles whereas the critical gap and follow up time is considered for gap acceptance models.

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