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Estimation of Drivers' Critical Gap Acceptance and Follow-up Time at Four – Legged Unsignalized Intersection

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ABSTRACT

Intersections which are meant to facilitate the convenience, ease, and comfort of people traversing them appear to be most hazardous locations on roadway systems. This study aims at determining the driver's critical gap at Shao expressway intersection. The morning and evening peak traffic flow was captured using a video camera for seven days and then analyzed by playing back the video on daily basis. The camera was placed at a suitable height in order to cover all area of the intersection. The traffic count data show the most prevalent operations at the minor indicating frequent peak hour flows along Ilorin - Malete due to location of Kwara State University at Malete. The resulted critical gap which is the minimum gap that all drivers in the minor stream are assumed to accept at all similar location is 2.9sec and this is lower than 6sec recommended by the HCM (1995).This implies that most drivers using Shao intersection are in a hurry to cross the major road, thereby resulting into potential conflicts or serious accident. Thus, there is need to improve the geometrical features of the intersection as well as to introduce appropriate control mechanism at the intersection.

Keywords: gap acceptance, critical gap, unsignalized intersection, follow up time.

INTRODUCTION

Background

The gap acceptance theory commonly used in the analysis of unsignalized intersections is based on the concept of defining the extent drivers will be able to utilize a gap of particular size or duration. Gap acceptance is critical to motorists in making decisions such as stop, slow down, turn enter a traffic stream from a drive way or public road, or merge into traffic. Adequate gap acceptance allows motorists the time they need to avoid crashes and conflicts and thus helps to keep roadways operating safely and smoothly. A main factor that affect gap acceptance is the traffic flow rate at main road

(Adebisi 1982, Abu Sheikh 1997, Guo & Lin 2011, Rene & Manoj 2012, Abdul Kareem 2001).

In the theory used in most guides for unsignalized intersections around the world, it is assumed that drivers are both consistent and homogeneous. The assumptions of drivers being both consistent and homogeneous for either approach are clearly not realistic. Catchpole and Plank (1986), Plank and Catchpole (1984), Troutbeck (1988), and Wegmann (1991) have indicated that if drivers were heterogeneous, then the entry capacity would be decreased. However, if drivers are inconsistent then the capacity would be increased. If drivers are assumed to be consistent and homogeneous, rather than more realistically inconsistent and heterogeneous, then the difference in the predictions is only a few percent. That is, the overall effect of assuming that drivers are consistent and homogeneous is minimal and, for simplicity, consistent and homogeneous driver behaviour is assumed. It has been found that the gap acceptance parameters *t* and *t c f* may be affected by the speed of the major stream traffic (Harders 1976 and Troutbeck 1988). It also expected that drivers are influenced by the difficulty of the manoeuvre. The more difficult a manoeuvre is, the longer are the critical gap and follow-up time distribution.
Highway Capacity Manual (HCM) 2000, compared the minimum critical gap and the minimum follow up time as shown in Table 1.

Table 1: Critical gap t_g and follow-up time t_f for TWSC intersection (TRB, 2000)

	Critical gap		
Vehicle maneuver	Two lane Major road	Four lane Major road	Follow up time t_f (sec)
Left turn major road	5.0	5.5	2. 1
Right turn, minor street	5.5	5.5	2.6
Through traffic, minor street	6.0	6.5	3.3
Left turn , minor street	6.5	7.0	3.4

DEFINITION

A gap can be defined as the time interval between the passages of two successive vehicles on the major road at a priority intersection (Abdul Kareem 2001, Abu Sheikh 1997, Dissanayake, LU, Ping 2001). Gattis & Sonny (1998) defined the gap as the time interval between passage of one vehicle and the arrival of the next vehicle. In strict technicality, the gap is measured from the back bumper of the front vehicle to the front bumper of the next vehicle.

Other studies like Kearney et.al (2006) and Patil, Patare & Sangole (2011) defined the gap between two vehicles as the interval of time between the moment the rear of the lead vehicle reaches the crossing line to the moment the front of the tail vehicle reaches the crossing line While Hwang & Park (2005) stated that: "Gap" means the time and space that a subject vehicle needs to merge adequately safely between two vehicles. HCM (2000) defined the gap as "the time in seconds for the front bumper of the second of two successive vehicles to reach the starting point of the front bumper of the first".

Critical gap is the time interval between two successive vehicles considered to be just adequate for a minor road vehicle' enter or cross the main road (Abdul Kareem 2001, Abu Sheikh 1997). Critical gap is the threshold by which drivers in the minor stream judge whether to accept a gap. If the gap is larger than critical gap, drivers accept it and enter the intersection; otherwise, drivers reject the gap and wait for the next gap.

Drew (in Nabaee, Moore & Hurwitz, 2011) defined the critical gap as the size of the gap for which half of all traffic will reject larger gaps while half will accept smaller gaps. While Roess (in Nabaee, Moore & Hurwitz, 2011) assumed that the most commonly accepted definition for critical gap is the minimum usable gap accepted by the minor approach drivers.

The HCM (1985) defined critical gap as the median time headway between two successive vehicles in the major street traffic stream that is accepted by a driver in a subject movement that must cross and/or merge with the major street flow. HCM (1994) defined critical gap as "the minimum time interval between vehicles in a major traffic stream that permits side-street vehicle at a stopped controlled approach to enter the intersection under prevailing traffic and roadway conditions in seconds". HCM (2000), had similar definition which is "the minimum time in seconds, between successive major stream vehicles in which a minor street vehicle can make a maneuver.

Raff (in Patil, Patare & Sangole, 2011) defined the critical gap as the gap for which the number of accepted gaps shorter than it is equal to the number of rejected gaps longer than it.Gap acceptance or rejection is fundamental to the description and understanding of traffic movement at priority or stop sign intersections. Gap acceptance is the decision of a side-street (minor road) driver to use a gap created in major road traffic to merge or maneuver safely with the major road traffic. A gap may be accepted if it is large enough or rejected if it is too small. Thus it is expected that the acceptance of an available gap by a driver depends not only on the size of the gap but also on the drivers' sensitivity to such a gap (Abdul Kareem, 2001).

Nabaee, Moore & Hurwitz (2011) assumed that drivers on minor approaches have shown a tendency to accept a gap when "the benefit from entry is greater than the associated risk". When the waiting time exceeds the drivers' expectation and tolerance limit, they will accept higher levels of risk associated with smaller gaps. Darzentas (in Abu Sheikh, 1997) defined gap acceptance behavior as: The decision making process of whether or not to enter the path of an oncoming vehicle. Golias (in Abu Sheikh, 1997) defined gap acceptance function as: The function that defines the probability of accepting a randomly selected gap by certain driver.

Gattis & Sonny (1998) illustrate the difference between accepting gap & lag as follow.When entering an intersection, all drivers decide whether to accept or reject a lag or gap. A lag is accepted if the side street vehicle crosses or enters the main street before the arrival of the first main street vehicle. A gap is accepted if the side street vehicle crosses or enters between the arrivals of two main street vehicles that form a gap. Wagner (in Gattis & Sonny, 1998) concluded lag and gap acceptance differed at a 0.05 level of significance, while Adebisi (1982) assumed lag and gap acceptance values were similar if drivers come to a complete stop.

Rene & Manoj (2012) described decision of gap acceptance as being guided by two motives:
- To minimize the total travel time when entering the main road.
- To proceed as safely as possible onto the main road.

As the opposing flow rate on the main road increases, the two motives conflicts with each other, which makes the decision to accept or reject a gap difficult to understand.

Study Location

The study area is located at Shao at an elevation of 269 meter above sea level and its coordinates are 8°34′60″N and 4°34′0″ E. The area is 7 km from Ilorin city, the north central of Nigeria. It consists of four-leg unsignalized intersections connecting traffic from Ilorin (Kwara State Capity City) on West Bound approach to Malete (14 km away) on East Bound approach. The major approach which is 4km from end of Ogbomosho – Ilorin Expressway at Oko-Olowo connects heavy vehicles traffic coming from Lagos to the north.

There are some existing activities at the intersection. Such activities include petrol station and Motor Park, Market and erection of various sign posts/bill boards along the East and West bond of the minor approaches respectively. These activities constitutes distractions, obstructions to sight and lateral clearance for crossing traffic and thereby creating potential conflict for vehicle and pedestrian crossing the major road from the minor approaches. The pictorial view of the study intersection is as shown on Plate 1.

Plate 1: Pictorial View of the Intersection

METHODOLOGY

Data Collection

Data for this study were collected based on the simultaneous use of video camera. Video recording was done from a vantage point to cover all the four legs of the intersection up to the merge area. The camera was placed on the top of a parked vehicle along the major road in such a way that a good view of all the four approaches was obtained to get attributes of the traffic stream. Recording was done for morning and evening peak hour's period from Monday, to Sunday, for 8:00am to 10:00am and 3:00pm to 5:00pm peak period.

Data Analysis

The video CD was played back slowly on a screen to extract gap acceptance and follow-up time data. This process provides accurate information about the exact time vehicles arrived at the intersection, initiated a through movement, and the length of available gaps in major traffic stream. Minor street vehicle waiting times at stop line were extracted from video to determine the gap-acceptance information for each driver decision.

RESULTS AND DISCUSSION

Table 2 below compares the average waiting time for crossing and follow up time with the average gap acceptance. The average follow up time of 2.3sec in this table is less than the follow up time of 3.3 sec in Table 1 for the through traffic (crossing traffic) on Minor Street. Similarly, the minimum gap acceptance which is defined as the critical gap for crossing Major Street from minor street is 2.9sec and it is also less than 6sec recommended in Table 1. This implies that most vehicles on the minor street are always in hurry to cross the major street. This action may result in potential conflict or likely serious accident at the intersection.

Table 2: Estimation of Critical Gap Acceptance

Day	Daily Average (sec)		
	Waiting time	Follow up time	Gap Acceptance
Monday	18.35	2.9	4.6
Tuesday	17.7	1.9	3.1
Wednesday	18.85	2.3	3.6
Thursday	13.8	2.2	3.5
Friday	10.35	2.2	3.6
Saturday	7.3	1.8	2.9
Sunday	24.3	3.0	4.8
Average	15.8	2.3	3.7

The table agrees with HCM (2000), which defines "the minimum time in seconds, between successive major stream vehicles in which a minor street vehicle can make a maneuver.

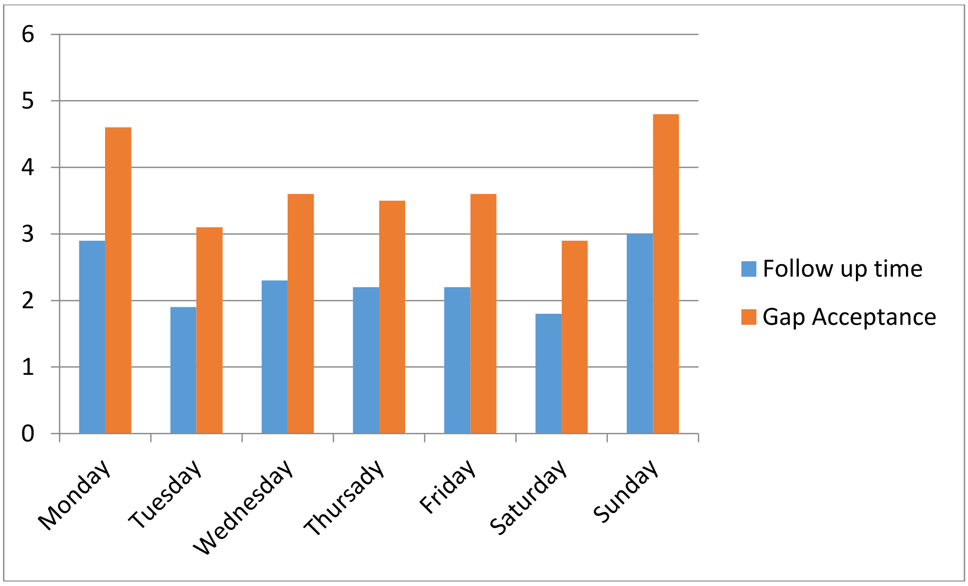

Fig. 1: Distribution of Daily Gap Acceptance and Follow up time

Figure 1 illustrates the distribution of daily gap acceptance and follow up time by drivers using the intersection. This result agrees with the assumption of Panchavati (in Gattis & Sonny, 1998) that there is a fixed dependency of follow-up time and gap time with the relationship that Follow- up time = 0.6 Gap time. Thus, Critical gap is the threshold by which drivers in the minor stream judge whether to accept a gap. If the gap is larger than critical gap, drivers accept it and enter the intersection; otherwise, drivers reject the gap and wait for the next gap.

CONCLUSION

This study has been able to estimate the critical gap acceptance and the follow up time for drivers using the four legged unsignalized intersection located at Shao. It has been found that critical gap of 2.9sec and follow up time of 2.3sec is possible at the intersection. These figures are less than the recommended values in HCM (2000). it can then be recommended that gap acceptance can be improved at the intersection by redesigning the intersection with flared entry lanes, channelized left turning bays and ensuring that the sight distance is adequate. This improvement will increase the capacity and overall efficiency of the intersections.

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