ISSN: 0189-9546
Faculty of Engineering & Technology University of Ilorin, Ilorin, Nigeria.

GAP ACCEPTANCE AND DRIVER BEHAVIOUR AT INTERSECTIONS IN MINNA, NORTH CENTRAL NIGERIA.

[1]P. N. NDOKE* AND S. S. KOLO
Department of Civil Engineering, Federal University of Technology, Minna, Nigeria.
[1]E-mail: jemeandoke@yahoo.com

ABSTRACT

The headways, spacing distributions and gap acceptance were measured from two main intersections in Minna, Central Nigeria. The average critical gap and spacing for stadium junction are 2.39 seconds and 11.08m respectively, and that of Mustapha hospital junction are 2.28 seconds and 9.56m respectively. The gap size at the intersections ranges between 1 and 57 seconds. Drivers accept gaps ranging from 2.89 to 3.72 seconds with an average of 3.2 seconds at Mustapha hospital junction and the average time of movement is 2.06 seconds. Similarly, drivers accept gaps ranging from 3.60 seconds and 4.5 seconds with an average of 4.05 seconds at Stadium Junction, and the average time of movement is 2.69 seconds. Comparing these values with the respective critical gaps from the Highway Capacity Manual shows that only values from stadium junction get close. This shows that the delays at the intersections are due mostly to driver impatience and intolerance which at times lead to accidents at the intersections. Hence, it can be concluded that traffic accidents at the intersections are due mostly to driver judgment rather than gap availability.

Keywords: Gap acceptance, critical gap, driver, behaviour, intersections

1.0 INTRODUCTION

Unsignalized intersections are the most common intersection types on many roads. Although, their capacities may be lower than other intersection types, they do play an important role in the control of traffic in a network. They give no positive indication or control to the driver, and the driver is not told when to leave the intersection.

The driver alone must decide when it is safe to enter the intersection. He must look for a safe opportunity or gap in the traffic to enter the intersection. This process is called gap acceptance (Troutbeck, 1993; Transportation Research Board, 2000). Gap acceptance is an important factor in safe driving. Ragland and Zabyshny (2003) reported that crossing-path crashes account for 25% of all crashes on U. S. roadways and about 45% of crashes at intersections.

Gaps are measured in time and are equal to headways.

ISSN: 0189-9546
Faculty of Engineering & Technology University of Ilorin, Ilorin, Nigeria.

At unsignalized intersections, a driver must also respect the priority of other drivers. Although gap acceptance is generally well understood in traffic engineering, it is useful to consider the gap acceptance process as one that has two basic elements, namely:

I. The extent drivers find the gaps or opportunities of a particular size useful when attempting to enter the intersection.

II. The manner in which gaps of a particular size are made available to the driver. Consequently, the proportion of gaps of a particular size that are offered to the entering driver and the pattern of the inter-arrival times are important (Troutbeck, 1993).

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. The minimum gap that all drivers in the minor stream are assumed to accept at all similar locations is the critical gap (Gattis and Low, 1999). According to the driver behaviour model usually assumed, no driver will enter the intersection unless the gap between vehicles equal to the critical gap, t_c.

Within gap acceptance theory, it is further assumed that a large number of drivers will be able to enter the intersection from a minor road in very long gaps. Usually, the minor stream vehicles (those yielding right of way) enter in the long gaps at headways often referred to as the "follow-up time", t_f (Abou-Henady *et al.*, 1994).

In the theory used in most guides for unsignalized intersections around the world, it is assumed that drivers are both consistent and homogeneous. A consistent driver is expected to behave the same way every time at all similar situations.He or she is not expected to reject a gap and then subsequently accept a smaller gap. For a homogeneous population, all drivers are expected to behave in exactly the same way.

The assumptions of drivers being consistent and homogeneous for either approach are clearly not realistic. Troutbeck (1993) and Kimber (1989) 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 behavior is assumed (Adebisi and Sama, 1989). Natural variations in traffic cause the gaps available to vary unpredictably from driver to driver and drivers who have long wait times generally accept smaller gaps.

It has been found that the gap acceptance parameters t_c and t_f may be affected by the speed of the major stream traffic (Troutbeck, 1993; Pollatscek et al., 2002).

ISSN: 0189-9546
Faculty of Engineering & Technology University of Ilorin, Ilorin, Nigeria.

It is also expected that drivers can be influenced by the difficulty of the maneuver. The more difficult a maneuver is the longer the critical gap and follow-up time parameters. There has also been a suggestion that drivers require a different critical gap when crossing different streams within the same maneuver. For instance, a turn movement across a number of different critical gaps or periods between vehicles in each stream (Kadyali and Lal, 2008).

However, one of the major problems at most intersections is traffic congestion, but congestion is not a new phenomenon, though, it could increase the delay time, rate of accident, cost of operation and lower the standard of living. Today, in both developed and the developing nation, the problem of congestion is noticed, at least, at morning and evening peak hours.

Traffic congestion occurs when a volume of traffic generates demand for space greater than the available road capacity. There are six root causes of congestion, and can be summarized as: bottlenecks 40%, traffic incidents 25%, bad weather 15%, work zones 10%, poor signal timing 5% and special events/other 5%. (Rodriguez, 2006).

This paper aims at highlighting the behaviour of drivers at intersections in a developing city as regards gap acceptance and usage. It is also aimed at determining whether the critical gaps proposed by the Highway Capacity Manual could be used to model traffic at intersections in Minna, Nigeria.

2.0 METHODOLOGY

2.1 Selection of Intersections

2.1.1 Description of Project Site

The intersections used as case studies for this paper are in Minna (latitude 9°37' North and longitude 63°3' East), in North Central Nigeria. Minna has a population of over 300,000 people and lies in the Guinea Savannah Region of the country (Minna Master Plan, 1979). The town has a standard dual carriageway passing through the heart of the town. There are three overhead bridges for pedestrians and the streetlights in the town are fully utilized. The road network coupled with its good drainage system is one of the best in the country as of today. The major roads in Minna are the western bye-pass, eastern bye-pass and Paiko-Bosso Road.

2.1.2 Assessment of site

The intersections were assessed by site visits and peak hour traffic volumes. They were selected based on geometry and traffic volumes. The main criterion was the flow of 100veh/hour in the minor approach and 400veh/hour in the major approach (Ragland and Zabyshny, 2003). These ensure the availability of sizeable gaps in the major stream and vehicles to accept them in the minor stream (Rodriguez, 2006). The access grades at both intersections are flat with speeds of 40km/hour on the major approaches. Based on these criteria, two intersections, Mustapha Hospital intersection and Stadium road intersection were chosen for this study.

ISSN: 0189-9546
Faculty of Engineering & Technology University of Ilorin, Ilorin, Nigeria.

Mustapha hospital intersection is a four legged intersection and lies along Bosso road with the major approaches having 2 lanes of 3.75m widths and the minor approaches having one lane of 3.65m width each. The same dimensions apply for Stadium road intersection but the fourth approach or leg is not operational, hence it can be rightly considered a three-legged intersection. Sketches are presented in Figs 1 and 2.

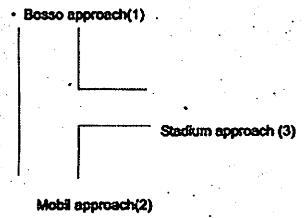

Fig. 1 Sketch of Stadium Intersection

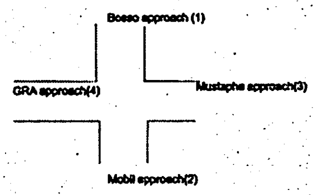

Fig. 2 Sketch of Mustapha Intersection

2.2 Traffic Data Collection and Analysis Techniques

2.2.1 Traffic Data Collection

Observers with synchronized wrist watches were placed at each approach of the intersections. They recorded the number of vehicles that passed them and the time between successive vehicles at the peak hours of the typical working days from Mondays to Fridays. The peak hours had earlier been determined from traffic volumes collected from 7AM to 7PM for a week by manual counting. Regression analysis techniques were then used to obtain valid relationships that were used to draw conclusions.

2.2.2 Data analysis

For each gap t, the number of vehicles, n, that entered the gap was recorded. For each of the gaps that were accepted by only n drivers, the average gap size was then calculated. Linear regression on the average gap size values (as the dependent variable) against the number of vehicles that entered during this average gap size was then carried out. The linear regression equations are presented below.y only n drivers, the average gap size was then calculated. Linear regression on the average gap size values (as the dependent variable) against the number of vehicles that entered during this average gap size was then carried out. The linear regression equations are presented below.

$$S_{XX} = \sum_{i=1}^{n} \left(x_i - \bar{x}\right)^2 \qquad (1)$$

$$S_{XY} = \sum_{i=1}^{n} \left(x_i - \bar{x}\right)\left(y_i - \bar{y}\right) \qquad (2)$$

$$B = \frac{S_{XY}}{S_{XX}} \qquad (3)$$

$$A = \bar{y} - B\bar{x} \qquad (4)$$

Where S_{xx} and S_{xy} are the X sum of squares and cross product respectively, B is the gradient and A is the intercept.

If there is a continuous queue on the minor street, then this technique proposed by Rodriguez (2006) produces acceptable results because the output matches the assumptions used in a critical gap analysis. For this technique, the queue must have at least one vehicle in it over the observation period.

ISSN: 0189-9546
Faculty of Engineering & Technology University of Ilorin, Ilorin, Nigeria.

3.0 RESULTS AND DISCUSSIONS

3.1 Headway and Spacing Distribution

The headway and spacing distribution of the intersections are shown in Figures 4 to 6. The headway distribution range from 1-10 seconds with the mode as 2 seconds for both Mustapha hospital and Stadium Junction intersections. Drivers at the intersections generally accept gaps ranging from 3.2 to 4.5 seconds. This shows that that more gaps are needed compared to the available ones hence, the occurrence of accidents at the minor approaches. Driver impatience can also be seen as a major cause of the accidents. The spacing ranges from 6 23m. The modal spacing of Mustapha hospital intersection and Stadium Junction are 8m and 13m respectively. This shows that there is more congestion on the Mustapha hospital intersection.

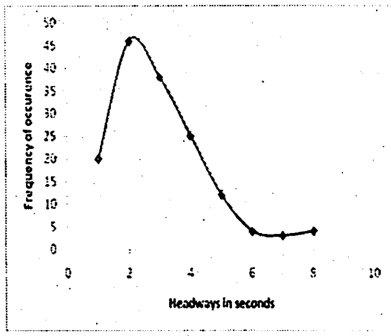

Fig.5: Distribution of gaps at Stadium intersection

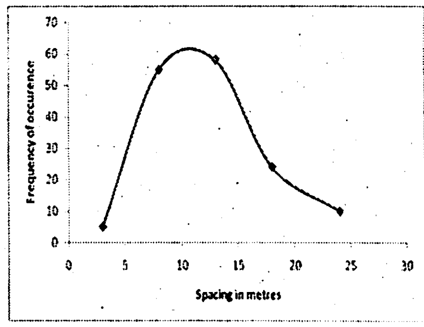

Fig. 6: Distribution of spacing at Stadium Intersection

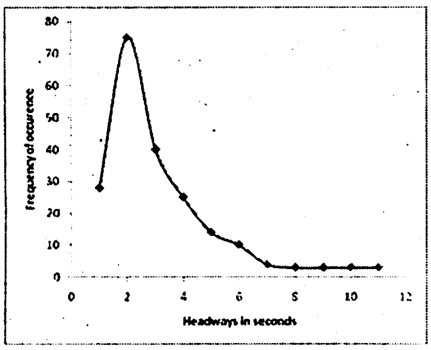

Fig. 3: Distribution of gaps at Mustapha Intersection

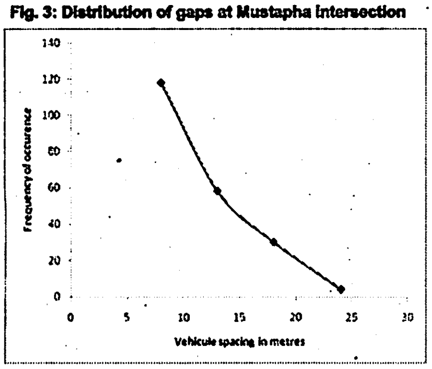

Fig. 4: Distribution of spacings at Mustapha Intersection

A direct relationship exists between spacing and headway at the intersections as shown in Fig. 7. The spacing increases as the headway increases. It was also noticed that for both intersections, the ratio of headway to spacing increases from 1:3 to 1:4.6. Beyond 5 seconds of headway, there is no corresponding spacing because the total road length considered for the analysis for visibility and ease of data collection is overshot and traffic is no longer deterministic.

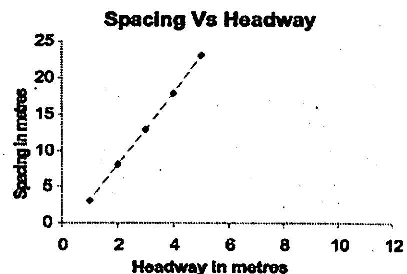

Fig. 7: Relationship between spacing and headways at the intersections

ISSN: 0189-9546
Faculty of Engineering & Technology University of Ilorin, Ilorin, Nigeria.

3.2 Average Spacing and Critical Gap

To estimate the critical gap and average spacing, different gap sizes and the number of vehicles using these gaps were observed. The critical gap for each leg was estimated using regression analysis and equation 5 (Rodriguez, 2006):

$$t_c = t_o + \frac{t_f}{2} \qquad (5)$$

where t_c, t_f and t_o are respectively the critical gap, slope and intercept on the gap size axis.

The average spacing for each leg of the intersection was estimated using the linear equation, Rodriguez (2006);

$$S_a = A + Bt_c \qquad (6)$$

Tables 1and 2 show the average spacing and critical gap for stadium junction and Mustapha hospital intersection respectively. The regression equations are also shown in the Tables.

Leg Number	Average Spacing S_a (m)	FieldCritical Gap t(s)	HCM critical gaps (s)	Regression equations (S)
1	11.21	2.44	4.1	2.412h + 5.328
2	10.93	2.39	4.1	2.707h + 4.457
3	11.09	2.34	7.1	2.295h + 5.718

Table 2: Average Spacing and Critical Gap for Mustapha hospital junction

Leg Number	Average Spacing S_a (m)	FieldCritical Gap t_c(s)	HCM critical gaps (s)	Regression equations (S)
1	8.783	2.540	4.1	1.046h + 6.123
2	7.425	2.580	4.1	1.36h + 5.419
3	11.290	2.34	7.1	1.89h + 6.423
4	10.761	2.500	7.1	2.748h + 3.891

The regression equations could easily be used to obtain values for spacing if time headways are known for the intersections. Driver behaviour can be assumed to be constant and uniform throughout Minna Metropolis, hence the values for Stadium road junction which is a three legged intersection could be used for the analysis of gap availability and acceptance at other 3-legged intersections.

On the other hand, values obtained for the Mustapha hospital intersection could also be applicable to other intersections in the Metropolis.

4.0 CONCLUSIONS

The majority of accidents at intersections today are directly linked to the nature of gap distribution and the driver's judgment in selecting gaps through which to execute their desired movements. The results show that the critical gaps at the intersections are low. However, the traffic operation could be improved by strict adherence to traffic rules by both the traffic wardens and motorists.

The average critical gap for stadium junction and Mustapha hospital intersection are 2.39 seconds and 2.28 seconds respectively. These values are low compared to the standard values in the Highway Capacity manual. This shows that there is a lot of aggressiveness on the part of most of the drivers at the intersections.

Drivers at these intersections react to the inter-vehicle spacing, which they directly perceive, rather than to the traditional front bumper-to-front bumper measure used in traffic engineering analysis. The latter includes the length of the vehicle, which is becoming smaller for passenger cars in a vehicle mix. The average spacing in meters between any pairs of vehicles at stadium junction and Mustapha hospital intersection are 11.08m and 9.56m respectively.

The regression line analysis results show that a straight line correlation exists between the headway and spacing, however, this relationship is dependent on the speed of the vehicle following.

ISSN: 0189-9546
Faculty of Engineering & Technology University of Ilorin, Ilorin, Nigeria.

REFERENCES

AbouHenady, A., Teply, M. S. and Hunt, J. D. (1994). Gap Acceptance investigations in Canada. Proceedings of the Second International Symposium on Highway Capacity. Australian Road Research Board Transportation Research Board, 1:1 20.

Adebisi, O. and Sama, G. N. (1989). Influence of Stopped Delay on Driver Gap Acceptance Behaviour. Journal of Transportation Engineering, ASCE, 115(3): 305 315.

Gattis, J. L. and Low, S. T. (1999). Gap Acceptance at a Typical Stop-controlled intersection. Journal of Transportation Engineering, ASCE, 125 (3): 201 207.

Henry, L. (1999). Traffic Flow Theory: Pp. 1 9, Turner Fairbanks Highway Research Centre.

Kadyali, L. R. and Lal, N. B. (2008). Principles and Practice of Highway Engineering. 5th Edition, Khanna Publishers, New Delhi, pp 684 - 697.

Kimber, N. M. (1989). Gap Acceptance and Empiricism in Capacity Prediction. Transportation Science, 23 (2): 100-111.

Minna Master Plan (1979-2000). The capital city of Niger State. Town planning Division, Ministry of Housing and Environment. Final Report prepared by Max Lock group, Nig Ltd.

Pollatscek, M. A; Polue, A., and Livneh, M. (2002). A Decision Model for Gap Acceptance and Capacity at Intersections". Transportation Research Part B, 36: 649 - 663.

Ragland, D. R. and Zabyshny, A. A. (2003). Intersection Decision Support Project: Taxonomy of Crossing-path Crashes at Intersections using GES 2000 data, U. C. Berkeley. Traffic Safety Centre, paper UCB-TSC-RR-2003-08.

Rodriguez, J. J. R. (2006). Gap Acceptance Studies and Critical Gap times for Two-way stop Controlled Intersections in the Mayaguez area. Unpublished Masters of Engineering Thesis, Department of Civil Engineering and Surveying, University of Puerto Rico, Puerto Rico, pp 14-28.

Transportation Research Board (2000). *Highway Capacity Manual,* Special Report 209. pp.56, Washington, D. C.

Troutbeck, R.J. (1993). Estimating the Critical Gap Acceptance from Traffic Movements. Research Report; 92 5, Wikipedia: The Free Encyclopedia, 10th September, 2008..