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Determination of Lag Acceptance and Effects for Left Turning Movements at Intersections

Foad Shokri, Amiruddin Ismail, Mohammad Hesam Hafezi, Mohammad Ganji, Riza Atiq O.K. Rahmat

Sustainable Urban Transportation Research Centre (SUTRA)/, Department of Civil and Structural Engineering, Faculty of Engineering and Build Environment, University Kebangsaan Malaysia, 43600 UKM Bangi, Selangor Dural Ehsan, Malaysia.

Abstract: Interaction between traffic streams is an important aspect of highway traffic flow. It occurs when a driver changes traffic lane, merges with or crosses a traffic stream. Probably it takes place most frequently when priority control is used to resolve vehicular conflicts at highway intersections. Lag acceptance behavior can be studied by observing driver reactions at a priority intersection where the flow on the minor road exceeds 100 veh/h and where the major road traffic stream or streams exceed 400 veh/h. The determination of lag acceptance for turning movements at priority junctions and comparisons of lag acceptance during day time and hours of darkness is very important in the performance evaluation of priority junctions and in maintaining the safety of vehicular traffic flow. Data collection at site would involve four selected junctions. The determination of the lag acceptance will serve as a minimum local value for drivers to merge into main roads from priority junctions when turning left. The limitations of the study are first, the data base for the research would only involve cars and second, the movement to be taken in consideration is the left turning movement and within Bangi areas only. It is found that an overall of 3.8 seconds of lag acceptance has been obtained for daytime and 4.7 seconds for hours of darkness.

Key words: Lag acceptance, intersection, delay time, turning movement, Delay time.

INTRODUCTION

Today, increased urbanization was due to the population that was increased by the number of urban and suburban trips (Shokri *et al*. 2012; Hafezi and Ismail 2011a). Hence delay time as a part of traveling period has a significant impact on travel time calculation (Shokri *et al*. 2010), in addition delay time calculation is the inconsistency of that in different times (Hafezi and Ismail 2011b).While intersection has the significant role in the urban and highway flow, most available urban arterials and intersections weren't originally designed to accommodate today's heavy traffic and it's one of the causes of the delay time at intersection. By the late 1970s, the individual states in the United States had each adopted a Left Turn on Red (LTOR) policy whereby left-turn movements were permitted after the driver stopped unless specifically prohibited by a sign. Several studies have shown that LTOR increased the frequency of left-turning crashes at signalized intersections, especially crashes involving pedestrians and bicyclists. Speed is one of the important factors that have the significant impact on the merging vehicles, so the designer should pay more attention to this factor in the all approaches (major and minor approaches). Some important factors for describing the lag acceptance phenomenon in freeway merging are the critical lag, percent of ramp vehicles delayed, mean duration of static delay accepting a length of queue, and total waiting time on the ramp (Shokri *et al*. 2009; Hafezi and Ismail 2011c). Critical value defined as the lag accepted by half the divers, it means the acceptable average minimum lag time (Hafezi and Ismail 2012; Ismail *et al*. 2012). Most of the studies usually involve the recording of vehicle speeds in the presence and absence of pedestrians for example, studied the situation in which drivers give way to crossing pedestrians in Iraq. A research in Iraq shows that a reduction in vehicular speed was noticeable at the crosswalk when pedestrians were present (Seifabad *et al*. 2012). The authors also discovered that a greater reduction in speed occurred when the number of pedestrians was greater than one. In contrast, Thompson *et al*. studied driver behavior in Nottingham, England but found no differences in speed when pedestrians were present. At the same time, they studied the position of the vehicle on the road (i.e., the distance from the curb) and found that drivers did not change their paths (i.e., moving further away from the curb) when pedestrians were present. Experiments show that the interaction between drivers and child pedestrians also in Nottingham. He found that most drivers took avoiding actions within less than 20 meters from a child which was about to cross; this distance was less than the safe stopping distance in many instances.

Most investigators have found that headway between successive vehicles decrease at a lessening rate as one progress until through the queue. As speed increase, the times pacing between vehicles decreases until the fifth

Corresponding Author: Foad Shokri is currently Post Doctoral Fellow in Civil and Structural Engineering, Universiti Kebangsaan Malaysia (The National University of Malaysia).
E-mail: foad_shokri@yahoo.com

in line vehicle has entered the intersection. After 50 vehicles, headway tends to level out at approximately 2.0 seconds (Wildermuth, B.R. 1962).The results of study conducted by indicate that the length of the green phase does have a substantial effect on average headway, with a 10 seconds green phase. The average headway was 2.35 seconds and with a 35 to 45 seconds green phase 2 second headways were obtained.

During a journey, the pedestrian needs to perform maneuvers, detect obstacles, and make decisions (Hafezi *et al*. 2012). An error in these skills or physical limitations of the pedestrian may lead to serious injuries or death as the pedestrian interacts with vehicles (Hafezi and Ismail 2011d; Ismail *et al*. 2011). Base on mentioned problem, this study tries to improve the design of the intersection to help the pedestrian to avoid of conflict with drivers if the designers don't have enough attention to these groups especially for left turning vehicles. At signalized intersections, the green phase has to be long enough to permit pedestrians to cross safely. The current engineering standards establish the walking speed of pedestrians at 1.22 m/sec (4 ft/sec) for design purposes (Dewar 1992.). However, many researchers consider this speed to be too fast for design purposes. For example (Fruin, J.J. 1971), researchers examined the speed distribution of pedestrians in free-flow conditions in Port Authority and Penn Station, New York. This author showed that nearly half of pedestrians walk below 1.22 m/sec (Dewar 1992). They found that the walking speed of pedestrians decreased as the number in the group got larger (especially for the people at the back of the group) and they proposed a new method to evaluate the minimum crossing time. These authors suggested a regression equation which takes into account the number of pedestrians in the platoon. Signalized intersections can be provided with separate pedestrian signals (e.g. WALK and DON'T WALK).

The general aim of this research is the development of a relationship between the many variables associated with the interaction of vehicles traversing a ramp such as traffic characteristics (lag availability, lag acceptance Speed and volume) and ramp geometric (length, curvature/Angle of convergence and grades and acceleration lane geometric such as length, Shape, delineation and location of lateral obstructions) and merging into a freeway so as to determine the effects of merging operation and level of service.

The main objective of this research is to determine the critical lag for day time and night time, because it has a significant role in safety of the intersection. To reach to this goal this study tries to find out the critical lag for left turning vehicles during the day, evaluate the critical lag for the same movement during the night and Recommend the acceptable actual value of time which is required by local drivers for left turning movement.

Methodology:

Site Selection and Data Collection:

Four intersections are selected in the Bandar Baru Bangi (BBB) in the near location of the high range of residence and the data are collected in day time (4:00pm to 6:00 pm) and night time (9:00pm to 9:00pm). At the site notes and photographs are taken, specific observations are made (street width, timing patterns) and a redesign is brainstormed. Observations were focused on one class of minor road vehicle making one type of turning movement. For this reason it is proposed that the observation would involve left turning cars.

Using a stopwatch, the time is noted when a car at a minor road arrived at the intersection and also the time when the next conflicting major road vehicle arrived at the intersection. It was also noted whether the minor road driver accepted the lag and drove out into the major road or rejected the lag and remained in the minor road. After the first decision all further actions of the driver were ignored to reduce bias in the observations. A set of sample observations for left-turning passenger are shown in Table 1. The observations were continued until at least 25 observations were obtained in each class. The difference between the two recorded times is the accepted or rejected lag. As observations were taken with a stopwatch it was only possible to record lag acceptance to the nearest 0.5 second and so the observed lag acceptances and rejections are grouped into one-second classes.

The data analysis procedures involve a statistical analysis on the data that was collected at site. The analysis involved tabulation of the data that was collected at site. The analysis involved tabulation of the data in the form shown in Table 1.Column 1 in contains the classes that run between 0 and 100 percent acceptance. Column 2 and column 3 give the numbers of observed lags that were rejected and accepted in each class. Column 4 is obtained by dividing column 3 by the sum of column 2 and column 3. If the percentage acceptance is plotted against lag class mark, it can be seen that the curve is in the form of a cumulative normal distribution. This is to be expected in any action that is dependent on human reaction.

The value of the critical lag would then be determined by two methods. The first involved drawing a line across the lag acceptance distribution curve at 50% volume. The second method is a graphical method involves obtaining the volume at the intersecting point between the accepted lag and the rejected lag to determine the critical lag. The critical lag values would be calculated for each site separately. For each site the critical lag value during the daytime and nighttime would be calculated. Finally, the average critical lag value based on all four sites for daytime and the hours of darkness would be determined.

The standard normal distribution, that is the z distribution, was used as the test statistic. To employ the z distribution, we need either to know the population standard deviation (a) or to have a large sample (at least 30 observations). In any situations, however (σ) is unknown and the number of observations in the sample is less than 30. In these cases, the use of sample standard deviation s as an estimate of σ, but cannot use the z distribution as the test statistic. In this research the appropriate test statistic is Student's t, or just the t distribution. This study tries to find the critical value of lag with two methods. The first involves taking the 50% volume from the lag acceptance distribution curve that was plotted. The second method involves obtaining the volume at the intersecting point between the accepted lag and the rejected lag.

Site One:

Figure one shows the intersection design and table 1 illustrates the detail data of site 1 that the first column contains the classes that run between zero and 100% acceptance. The second and third columns are for the observed lags that were rejected and accepted in each lag class and the next two columns are the acceptance and rejection percent under the first scenario, which was between 4.00 p.m. to 6.00 p.m.

Fig.1: Hentian kajang station.

The observed rejected samples were 52 vehicles where most of them rejected lags below 2 seconds. On the other hand the total observed accepted samples were 146 vehicles and a majority of them accepted the 3 seconds lag to merge into the major roads. Figure 1 show the percentage acceptance plotted against the lag class mark. It can be seen here that the curve is approximately in the form of a normal cumulative graph. This is to be expected in any action that is dependent on human reaction. The observed value of lag acceptance for the first site in the first scenario is taken at 50% value in the acceptance percentage lag graph which yielded the critical lag to be 3.2 second.

Table 1: Rejected and accepted lag for left Turning Vehicles from 16:00 to 18:00.

Lag class	Number of observed rejections	Number of observed acceptance	Percentage of acceptance	Percentage of rejections
0.5-1.5	12	0	0	100
1.6-2.5	14	2	13	87
2.6-3.5	12	8	11	58
423.6-4.5	8	11	58	42
4.6-5.5	3	20	87	13
5.6-6.5	2	21	92	8
6.6-7.5	0	23	100	0
7.6-8.5	0	26	100	0
8.6-9.5	1	27	97	0
9.6-10.5	0	2	100	0
10.6-11.5	0	1	100	0
11.6-12.5	0	0	100	0

The second method determines the critical lag based on a graphical method. By using the graphical method the critical value of lag acceptance was obtained at the intersecting point between the accepted lag and the rejected lag. Figure 4.2 shows the number of acceptance and rejections of vehicles which are plotted against the lag class mark. It can be seen here that the two curves intersect at the 3.2 seconds lag hence obtaining the lag acceptance for the first scenario to be 3.2 seconds.

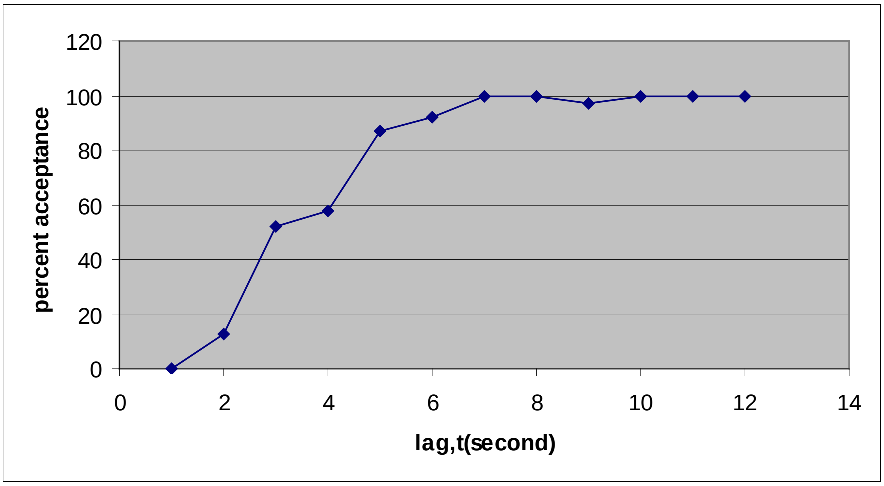

Fig. 2: Lag Acceptance Distribution at Priority intersection site (16:00-18:00).

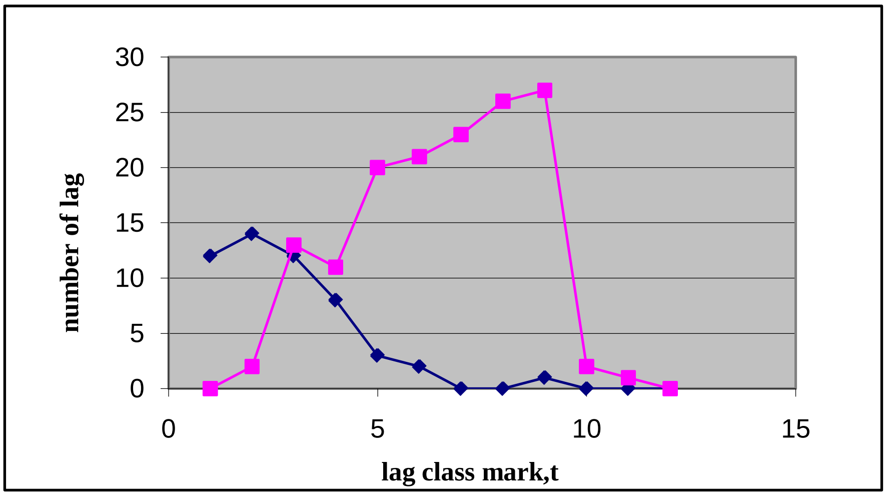

Fig. 3: Graphical Determination of the Critical Lags.

The mentioned approach is followed for calculating the critical lag times of the rest intersections. Table 2 illustrates the critical lag time of site 2 to 4 at day and night time.

Table 2: Critical lag acceptance in day time and night time.

Site	Critical lag value at daytime	Critical lag value at nighttime
Site 1	3.2	4.8
Site 2	4	4.5
Site 3	4	4.8
Site 4	4	4.8
Average	3.8	4.7

Validation:

The standard normal distribution, that is the z distribution, was used as the test statistic. Employing the z distribution needs either to know the population standard deviation (a) or to have a large sample with the level of significant of 0.10(at least 30 observations). In any situations, however o is unknown and the number of observations in the sample is less than 20. In these eases, the use of sample standard deviation s as an estimate of a, but cannot use the z distribution as the test statistic. In this research the appropriate test statistic is Student's t. or just the t distribution.

$$t = \frac{(X_1 - X_2) - 0}{\sqrt{[(S_1^2/n_1) + (S_2^2/n_2)]}}$$

Where:

X= each score.
n= number of values.
S= standard deviation.
Degrees of Freedom,

$$df = n1 + n2 - 2$$
$$=4+4-2$$
$$= 6$$

From Student's t distribution table, which existed at appendix 1, the critical value is 1.440. Because this is a one-tailed test and the rejection region is in the left tail, the critical value is negative. The decision rule is to reject the value of t is less than 1.440

X1 =3.8, n1 =4
X2 =4.7, n2 =4

The standard deviation of the sample can be determined by squaring the deviations from the mean. The formula is given by:

$$s = \sqrt{\left[\frac{\sum(X-\bar{X})^2}{n-1}\right]}$$

Where:
X = Each score.
$\bar{X}$= The mean or average.
n = Number of values.
$\sum$ =Means we sum across the values.

$$S_1 = \frac{\sum[(3.2-3.8)^2 + (4-3.8)^2 + (4-3.8)^2 + (4-3.8)^2]}{3} = 0.16$$

$$S_2 = \frac{\sum[(4.8-4.7)^2 + (4.5-4.7)^2 + (4.8-4.7)^2 + (4.8-4.7)^2]}{3} = 0.023$$

$$\mathrm{t} = \frac{(\mathrm{X}_1-\mathrm{X}_2)-0}{\sqrt{[(\mathrm{S}_1^2/\mathrm{n}_1)+(\mathrm{S}_2^2/\mathrm{n}_2)]}}$$

$$t = \frac{(3.8-4.7)-0}{\sqrt{[(0.16^2/4)+(0.023^2/4)]}} = -11.13$$

The value of t is -11.13 which lie in the region to the left hand side; the full hypothesis is rejected at the 0.1 significant levels.

Discussion:

Analysis results (table 2) illustrate that the overall critical lag value during daytime is 3.8 seconds. The overall critical lag value for hours of darkness is 4.7 seconds. Base on table 2 the critical lag for day time is 0.9 second less than the critical lag in the night. Nights are darker and making it difficult to most of the drivers in sees the junction clearly. In the selected junctions most of the road users are students and most of these young drivers have aggressive driving characteristic which includes accepting lower values lag. In Site 2, the condition of the junction itself may affect the driver reaction at any priority junctions such as in this site, the driver's view at this location is restricted by a huge tree on the right hand side thus making driver require larger lags in the process of merging. The critical lag obtained from this site is 4 seconds for daytime and 4.5 seconds for nighttime due to the poor sight conditions at this junction. Another reason is that the speed limit on the major road is 60 km/h and this gives the drivers adequate time to merge into the major road without any hesitation.

In Site 3, the critical lag for daytime was found to be 4 seconds while for nighttime was 4.8 seconds. During the day time the traffic is smooth and there was no problem but during the night time the drivers face to one main problem, there were no enough lamps installed around the intersection to make the area light, so drivers had problem to see the vehicles which arrive to the intersection from the opposite approach.

In Site 4, the critical lag obtained from the analysis in the daytime is found to be 4 seconds while on the hour of darkness, the lag is much bigger which is 4.8 seconds, this is probably cause by the poor visibility at nighttime from 7.00 p.m. to 9.00 p.m. where road users have to be more cautious before merging into major roads.

In many cases in Malaysia the roads were built regarding to the rules of the western countries especially the United Kingdom. There are many similarities and different between the Malaysia and other countries that has a impact on the acceptance of the lag time by the drivers such as:

- Channelization in the form of a painted island, small raised island or a large raised island is one element often incorporated into the design and in most of the intersections the short lane and islands are available in Malaysia.
- Traffic control may be addressed using right-turn-on-red, dedicated turn lanes with stop control, or dedicated turn lanes with yield control, and in most of the intersection in Malaysia the left turn is allowed on red.
- The signs for the traffic controlling are available in the roads and the directions are obvious for the drivers and this is the important notes because most of the drivers make decision before arriving to the intersections and it reduces the traffic at intersections.
- The lights are available near the intersections in Malaysia like the western countries and they make the intersections bright so the level of the accidents decreases because of that. On the other hand there are some different between the intersections in Malaysia and western countries.
- In most of the intersections the bridges are available for pedestrians and they use that but in Malaysia there is not enough bridge or something like that so there traffic increase in the vicinity of the intersection.
- There are many police officers in the roads in the western countries in comparison of the Malaysia and they control the traffic but in Malaysia the drivers drive without any control so the level of the accident is so higher than the western countries.

Conclusion:

This research tries to find out the critical gap for the left turn vehicles at intersection in day and night time. Safety is one element that has a effects of a wide variety of geometric design, traffic, and control elements of at-grade intersections. Focuses on the safety effectiveness of intersection left- and right-turn lanes, the initial scope of the research was not limited to this topic and could potentially have included the safety evaluation of any type of intersection design improvement.

An overall of 3.7 seconds of critical lag has been obtained for daytime then using the percentage lag acceptance distribution curve. The lag is slightly higher by 0.2 seconds when tabulated using the graphical method. From the four sites selected, the critical lag for daytime determined to be an average of 3.8 seconds by graphical method. The critical lag value for hours of darkness is 4.5 seconds for both methods. There is an increase in lag time of 0.9 seconds in the hour of darkness compared to daytime if using the lag acceptance distribution curve. As graphical method is concerned, the lag increases by 0.7 seconds at nighttime compared to daytime.

Lastly after this research have been done, the result shows that drivers in the Bangi areas need more time at nighttime compare to daytime. This is mainly due to the conditions at nighttime when it is darker and the visibility is low. Comparing the data from before and after study the researchers found that the installation of a separate left-turn phase was associated with a reduction of left-turn accidents by 85% and an increase in rear-end accidents by 33%. Total intersection accidents were reduced by 15 %(Agent, k.R and Deen, R. C. 1977).

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