J. Basic. Appl. Sci. Res., 2(9)9649-9657, 2012

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Comparison of Delays between Twilight Time and Day Time

MohammadAli Sahraei, Assoc. Prof. Dr. Othman Che Puan, Nima Jahandar

Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM), Skudai: 81310, Johor, Malaysia

ABSTRACT

Traffic delay is an important measure of quality of a journey. The longer delay has the lower quality of a journey. Delay at a priority junction is expected not only to be influenced by traffic volumes on the major road but also by the surrounds environments. This article was carried out to appraise the delay at the priority junctions during twilight time and day time. Therefore, theoretical delay during these two parts of a day was determined. Then, delay base on Highway Capacity Manual 2000 (HCM2000) was compared with observe delays. The results of the analysis indicate that delay during twilight time is less than other times in a day. Similarly, the comparison between the observed delay and the HCM method show that both values are similar.

Keywords—Observe delay, priority junction, twilight time, theoretical delay.

INTRODUCTION

Intersection is defined as an area where two or more roadways join or cross. Each roadway extending from the intersection is referred to as a leg. The intersection of two roadways has four legs. When one roadway ends at the intersection with another roadway, a three-leg intersection, or T intersection, is formed [1].

Two types of unsignalised intersections have been the main focus in modeling uncontrolled intersection flow which are include two-way stop-controlled intersection (TWSC) and all-way stop-controlled intersection (AWSC) [1]. Unsignalized intersections can be either uncontrolled, yield-sign controlled, stop-sign controlled [2]. Performance measurements for TWSC have included capacity (the maximum number of vehicles that can pass through an intersection from a given road), queue length, gap-acceptance and delay [3].

The unsignalized intersections work on the basis of relative priority of traffic movements. The right-turning movement from the minor street has the lowest priority at an unsignalized intersection. The performance of an unsignalized intersection is described by the delay experienced by low priority movements [4]. Service delay is defined as the delay experienced by a vehicle at stop line while waiting for an opportunity to enter the intersection. It is an important component of the total delay experienced at intersections controlled by stop signs. Service delay mainly depends upon the conflicting traffic volume, its composition and the priority of the movement [5]. Generally, there are two type of loss time (delay) which will occur in priority junctions includes stop delay and total delay. Stop delay is loss time for vehicles at the minor road when those drivers reach back of the stop line until vehicles departs into the major roads. Total delay is loss time for total vehicles at the minor road when those drivers reach back of the queue length until turns into the major roads.

Most of traffic control traffic studies focus on the estimation of delays and queue lengths that result from the adoption of a traffic control strategy at individual intersections, as well as on a sequence of intersections. Traffic delays and queues are principal performance measures that enter into the determination of the evaluation of the adequacy of lanes, and in the estimation of fuel consumption and emissions [6]. Drivers in intersections can change their direction of travel either to the left or right. The capability of intersections for drivers through the major road and changing from minor road to major road and vice versa depends on the junction and traffic volume. Due to increase safety factor, many of drivers wait for a large gap for emerging to junctions. Therefore, it causes to produce different delay at the priority junctions.

Traffic control in unsignalized junctions will relate with geometry of junction such as number of lane, flared, grading, and so on. A problem in these junctions is accident in term of movement either to the left turn or right turn from minor road to the major road with other vehicles that are traveling through the junctions. Due to avoid of accident will produce many delays at these intersections. On the other hand, delay will produce queue length because of delay at the minor road. Some important factors for determination of delay are traffic flow rate for each direction, critical gap for movement, conflicting flow rate, weather condition, driver's characterization and so on. But, the most factors for delay at the junctions are level of gap acceptance that is very different between drivers during twilight time and day time.

There are two methods for calculation of delay at the priority junctions:

- Calculation of delay with queue length at the minor road which will determine base on the length of gap at the major road.
- Calculation of delay base on the length of gap at the major movement which probabilities of acceptance by minor road drivers knew as gap acceptance.

*Corresponding Author: Mohammad Ali Sahraei, Faculty of Civil Engineering, Universiti Teknologi Malaysia, Skudai: 81310, Johor, Malaysia. Tel: +60-111-2770897 E-mail: alisahraiee2007@yahoo.com

Driver at the minor movement can reject different gap and acceptance one or more of those gaps. Gap is the distance between two successive vehicles which will pass from the major road. This distance will calculate between in front or back of the bumper of those successive vehicles which passing of a specific point.

Whenever a gap at the major road is equal to or greater than a value that a driver on minor road believes large enough for him/her to enter or cross the major road, the driver accepts this gap. This gap is an acceptable gap for that particular driver. Otherwise, the driver rejects the gap and waits for a larger gap [7].

METHODOLOGY

This article was carried out to concentrate to determine level of delay at the priority T-junction during twilight time and day time for a day. The data was collected at two junctions by using video recorder.

Because of different traffic volume for junctions for a day, data was collected base on following time for each 15 min, and then delay was calculated. These times were chosen for collecting data:

- Twilight time between 6:00 am until 7:00 am,
- Day time between 7:00 am until 7:00 pm.

In this research, two unsignalized junctions in Malaysia with three arms (T-junctions) were chosen. In this case, some factors were important for determination level of delay such as, number of lane in each direction, flared, shared lane and so on. These items were evaluated before data collection. The location of Junction for Jalan Kebudayaan/Jalan Kebudayaan3 and junction for Jalan Titiwangsa 3/Titiwangsa4 with some partial map is shown:

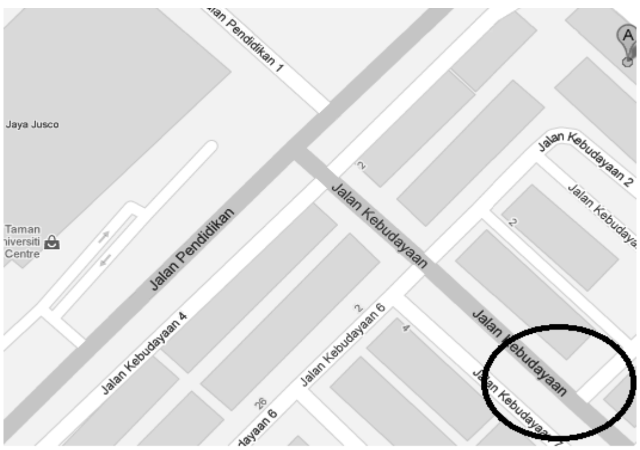


Fig. 1 Jalan Kebudayaan and Jalan Kebudayaan 3

Fig. 2 Jalan Titiwangsa 3 and Titiwangsa

According to the description of gap acceptance for T-junctions at the previous section, it expected to determine three conflicts in every junction. Therefore, the most delay was occurred in these three movements.

- Right turn from minor road to major road,
- Right turn from major road to minor road,
- Through vehicles at the major road.

Base on these conflict points at the junctions, data collection were occurred for determination traffic flow with counting vehicles which passed from minor road to the major road and vice versa. Then, finding optimum time for critical gap acceptance, headway and then calculates of delay with Highway Capacity Manual 2000 (HCM2000) was done.

The equation of hcm2000 for calculation of delay is shown:

$$D=\frac{3600}{Cm,x}+900T\left[\frac{Vx}{Cm,x}-1+\sqrt{\left[\frac{Vx}{Cm,x}-1\right]^2+\frac{\left[\frac{3600}{Cm,x}\right]\left[\frac{Vx}{Cm,x}\right]}{450\,T}}\right]+5 \qquad (1)$$

Where

d = control delay (sec/veh),

v_x = flow rate for movement x (veh/h),

$c_{m,x}$ = capacity of movement x (veh/h),

T = analysis time period (h) (T = 0.25 for a 15-min period).

Other important factor for data collection in these junctions is weather condition which should sunny condition and avoid of data collection during rainy condition (heavy or slow rainy).

After analysis data base on previous equation, comparison between theoretical with actual delay via Chi-Square's method (χ^2) at the same time period was done. The maximum value for (χ^2) is approximately 3.84 with 95% interval of confident. The equation of Chi-Square is:

$$\frac{(O-E)^{\wedge}2}{E} \leq 3.84 \qquad (2)$$

Where,
O=Observed Delays,
E= Theoretical Delays.

DATA COLLECTION

Data collection were done for each junction includes Jalan Kebudayaan/Jalan Kebudayaan 3 and junctions for Jalan Titiwangsa 3/Titiwangsa from 6:00 am until 7:00 pm. Base on this procedure, traffic flow for each 15 min interval was determined. Table (I) and table (II), traffic flow (veh/15 min) for twilight time (6:00 am to 7:00 am) and one hour for day time (8:00 am until 9:00 am) for junction Titiwangsa 3/Titiwangsa 4 are shown:

Table 1. Traffic flow for Jalan Titiwangsa 3/Titiwangsa 4 (Twilight time)

Time	East-West	East-South	West-East	West-South	South-East	South-West
6:00-6:15	91	4	11	7	0	13
6:15-6:30	86	5	13	1	1	25
6:30-6:45	127	7	12	11	4	32
6:45-7:00	150	9	18	34	4	28

Table 2. Traffic flow for junction Jalan Titiwangsa 3/Titiwangsa 4(day time)

Time	East-West	East-South	West-East	West-South	South-East	South-West
8:00-8:15	180	24	37	37	7	69
8:15-8:30	197	38	48	46	16	68
8:30-8:45	140	34	34	39	9	73
8:45-9:00	101	22	49	61	7	82

These data collections were continuing until end of the day time (7:00 pm) for both priority junctions. In figure (3) until figure (5) traffic flow for each 15 min interval for junction Jalan Titiwangsa3/Titiwangsa4 were determined.

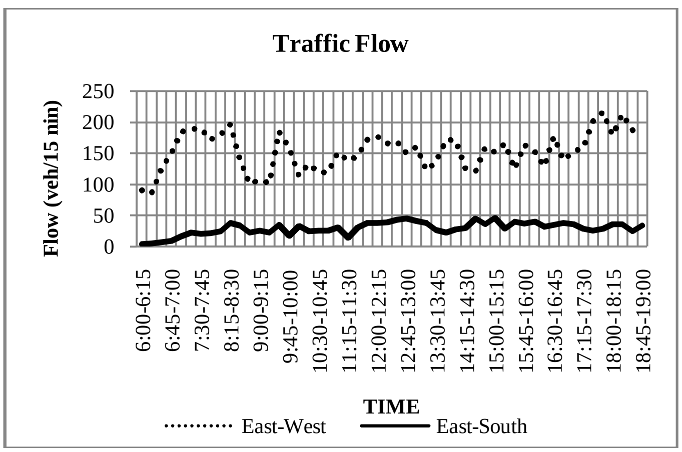


Fig. 3 Traffic Flow from East Direction

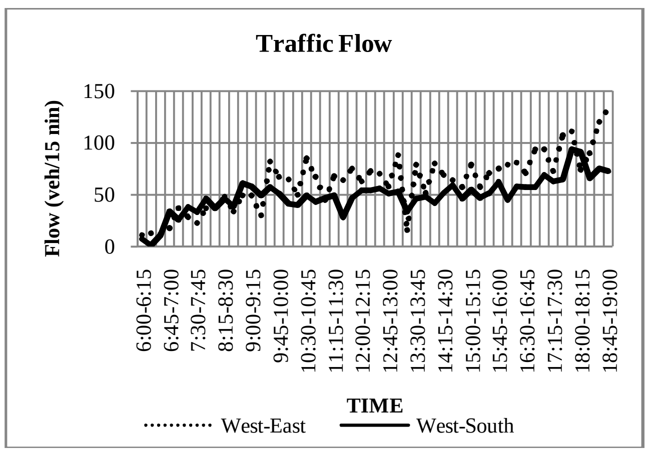


Fig. 4 Traffic Flow from West Direction

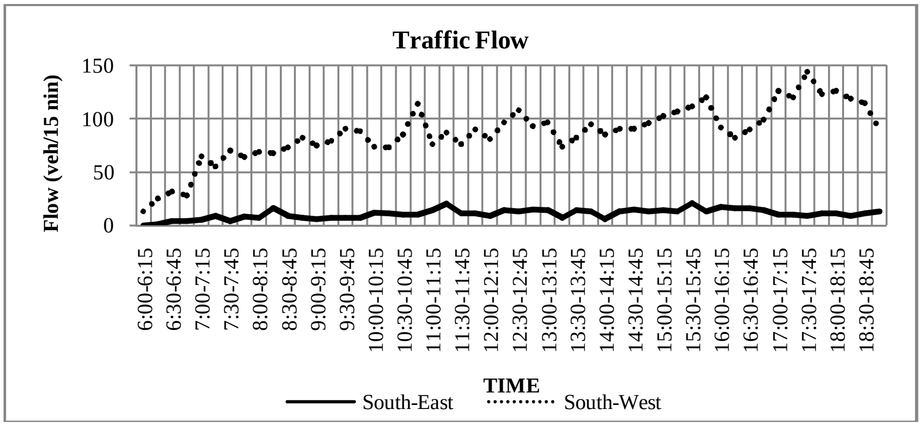


Fig. 5 Traffic Flow from South Direction

Data collections for second junction (Jalan Kebudayaan /Jalan Kebudayaan3) from 6:00 am until 7:00 pm were continuing. Similar to previous junction, flow rates were estimated for vehicles which emerged from minor to major road and vice versa for each 15 min interval.

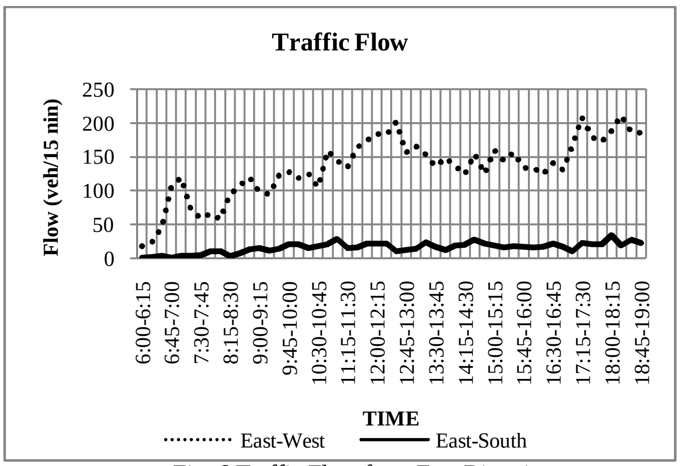


Fig. 6 Traffic Flow from East Direction

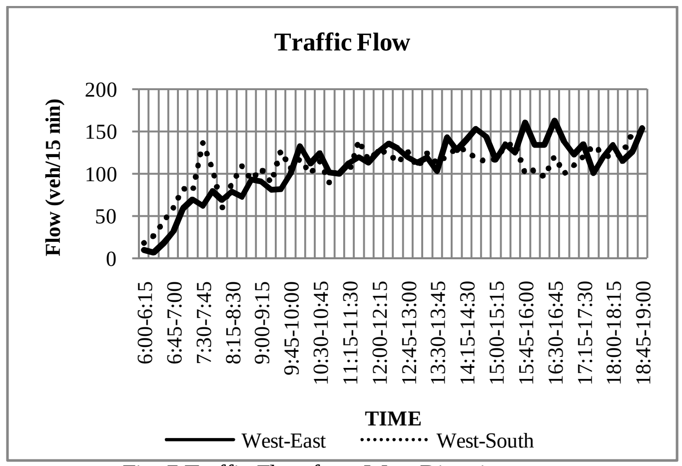


Fig. 7 Traffic Flow from West Direction

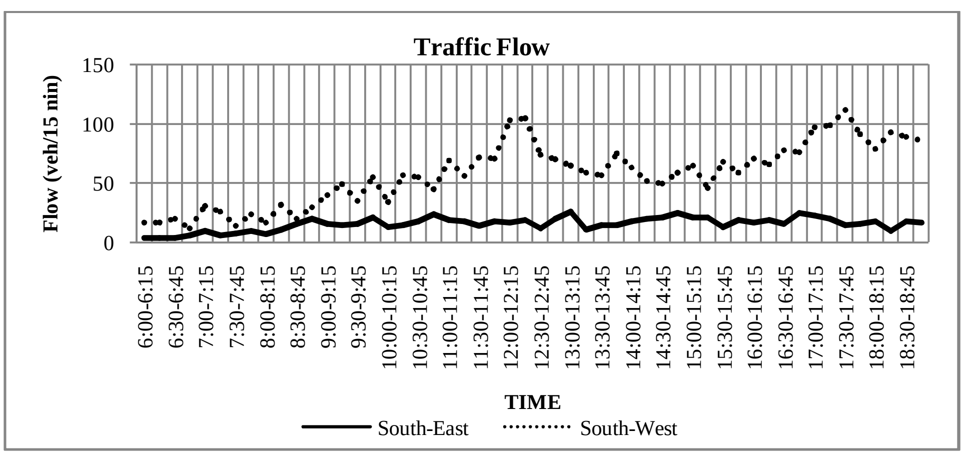


Fig. 8 Traffic Flow from South Direction

THEORETICAL DELAY

Due to calculate of theoretical delay base on HCM2000, equation (1) was used. According to this method, level of delay was calculated during twilight time between 6:00 am until 7:00 am and other day time between 7:00 am to 7:00 pm. In this method, firs, critical gap for movement x (tc,x), follow-up time for minor movement x (tf,x), and potential capacity of minor movement x (cp,x) was determined, next, delay was calculated for right turn and left turn separately. An example of calculation of theoretical delay for junction Titiwangsa 3/Titiwangsa 4 between 18:45 pm to 19:00 pm is shown:

T= 0.25 Vx=52 (veh/hr) Vc,x= 796 (veh/15 min) PHV= 0.15
$T_{f,HV}$=0.9 (sec) $T_{f,base}$= 3.5 (sec) $T_{C,base}$= 7.1 (sec)

$t_{c,x} = t_{c,base} + t_{c,HV} P_{HV} + t_{c,G} G - t_{c,T} - t_{3,LT}$
$t_{c,x}$ =7.1+(1*0.15)+0-0-0 ➔ $t_{c,x}$ =7.25
$t_{f,x} = t_{f,base} + t_{f,HV} P_{HV}$
$t_{f,x}$ =3.5+(0.9*0.15) ➔ $t_{f,x}$=3.64 sec

$$Cp,x = Vc,x * \frac{e^{-Vc,x/3600}}{1-e^{-(Vc,x*tf,x/3600)}}$$

$$Cp,x = 796 * \frac{e^{(-\frac{796}{3600})}}{1-e^{((-796*3.64)/3600)}}$$ ➔ $C_{p,x}$= 289.64 veh/hr

$$P_{0,x} = 1 - \frac{Vx}{Cp,x}$$

$P_{0,x}$ =1-(52/796) ➔ $P_{0,x}$=0.82
$C_{m,x}$= $P_{0,x} * C_{p,x}$
$C_{m,x}$=0.82 * 289.64 ➔ $C_{m,x}$= 237.64 veh/hr

$$D=\frac{3600}{Cm,x}+900T\left[\frac{Vx}{Cm,x}-1+\sqrt{\left[\frac{Vx}{Cm,x}-1\right]^2+\frac{\left[\frac{3600}{Cm,x}\right]\left[\frac{Vx}{Cm,x}\right]}{450\,T}}\right]+5$$

$$D=\frac{3600}{237.64}+(900*0.25\left[\frac{52}{237.64}-1+\sqrt{\left[\frac{52}{237.64}-1\right]^2+\frac{\left[\frac{3600}{237.64}\right]\left[\frac{Vx}{237.64}\right]}{450*0.25}}\right]+5$$ ➔ D=24.34 sec

Similarly, delays were calculated for two junctions during twilight time and day time. Linier graph and scatter graph were designed for comparison of delay between twilight time and day time. Delays during twilight time for right turn and left turn for both junctions were calculated as followed:

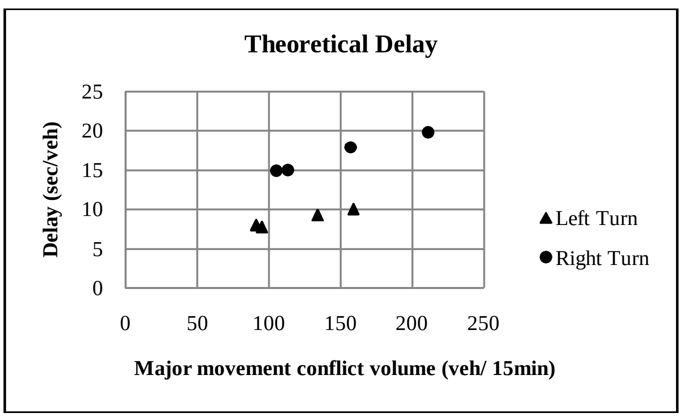


Fig. 9 Delay for Jalan Titiwangsa 3/Titiwangsa 4

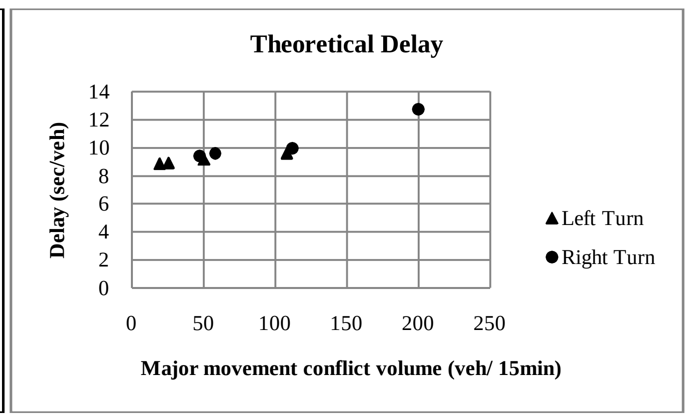


Fig. 10 Delay for Jalan Kebudayaan/Jalan Kebudayaan3

Figure 9 and 10 indicate theoretical delays during twilight time corresponding to major movement conflict volume for left turn and right turn separately. Based on these graphs, delays for right turn movement are more than left turn. For instance, for junction Jalan Titiwangsa 3/Titiwangsa 4, with approximately 160 (veh/15 min) conflict volumes, delay is more than 16 sec/veh for right turn and less than 10 sec/veh for left turn. For this junction, the maximum level of delay for right turn and left turn are about 20 sec/veh, and 10 sec/veh respectively. Similarly, for junction Kebudayaan/Jalan Kebudayaan3, if conflict volume become more than 100 (veh/15 min), delay is approximately 10 sec/veh for right turn and less than 10 sec/veh for left turn respectively. For this junction, the lowest level of delay for right turn and left turn are about 9 sec/veh, and more than 8 sec/veh respectively.

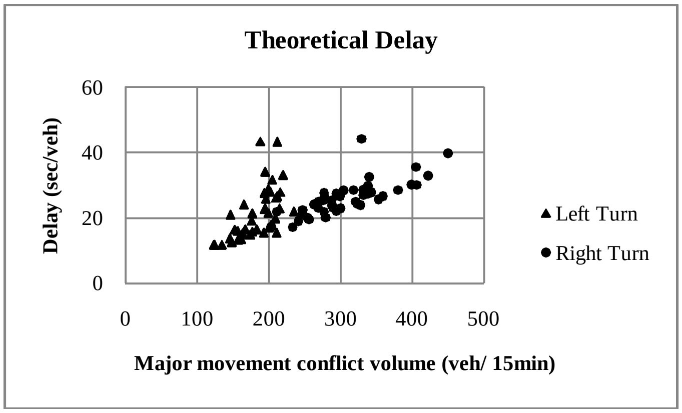


Fig. 11 Delay for Jalan Titiwangsa 3/Titiwangsa 4

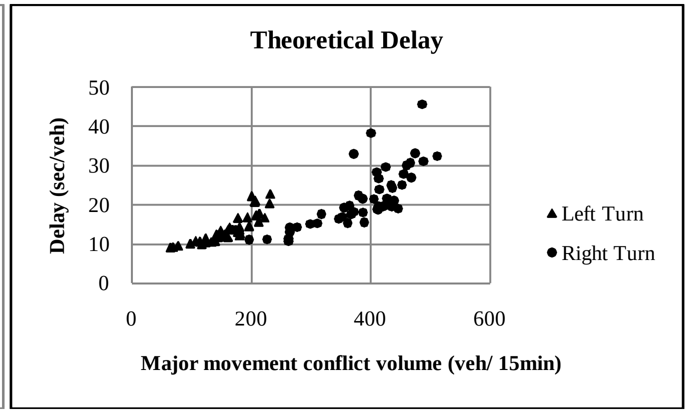


Fig. 12 Delay for Jalan Kebudayaan /Jalan Kebudayaan3

Figure 11 and 12 shows total calculations of theoretical delays during day time. As a results, for junction Titiwangsa 3/Titiwangsa 4, delay for right turn is more than left turn. During to movement from minor road to major road, most of the delays are more than 20 sec/veh for right turn and similarly, for left turn, delays are between 10 sec/veh until about 35 sec/veh. Delays for junction Kebudayaan/Jalan Kebudayaan3 have more diversity. For left turn, the dispersion of delay is between 10 sec/ veh until more than 20 sec/ veh when conflict volumes are about 50 veh/ 15min until more than 200 veh/ 15min. But, range of delay for right turn is between 10 sec/veh until 40 sec/veh with dispersion of conflict volumes which was between 200 veh/ 15min until more than 500 veh/ 15min.

COMPARISON BETWEEN THEORETICAL AND ACTUAL DELAY

In this article, the data was collected at two junctions by using video recorder and level of observe delay was obtained. Conflict volumes at the major road had significant effect for observe delay. If major road traffic volume increased, delay at minor road increased. Similarly, if major road conflict volumes decreased, delay at minor road decreased. Therefore, the major road conflict volumes influenced delay value at the minor road.

Figure 13 and 14 indicates to compare of theoretical and actual delays corresponding to major movement conflict volume during twilight time. Based on these graph, observe delays for left turn and right turn for junction Titiwangsa3/Titiwangsa4 are less than theoretical delay. Except a period of 15 minutes for left turn which level of observe delay was more than 20 sec/veh and it was more than level of theoretical delay.

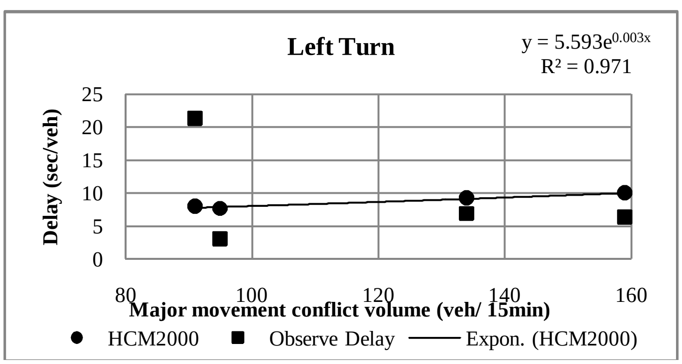


Fig. 13 Junction for Jalan Titiwangsa 3/Titiwangsa 4

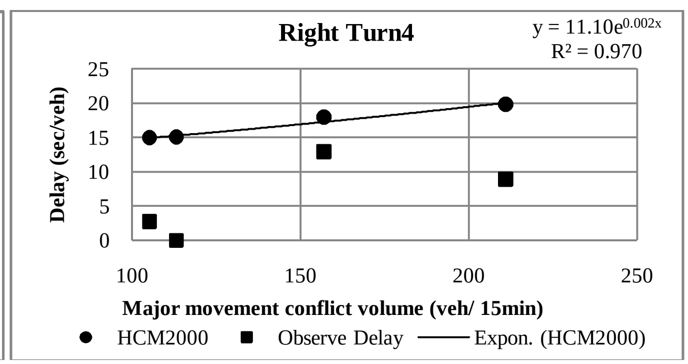
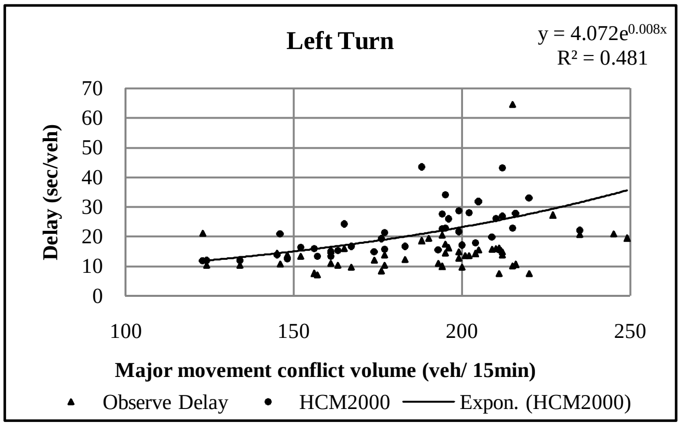


Fig. 14 Junction for Jalan Titiwangsa 3/Titiwangsa 4

The comparison between theoretical and actual delay during day time show that observe delay is less than theoretical delay for vehicles those emerges from minor rod to the left turn. But for right turn, observe delay had more dispersal from less than 10 sec/veh until mor than 60 sec/veh. In contrast, the dispersion of theoretical delays was approximately 20 sec/veh until a little bit more than 35 sec/ veh.



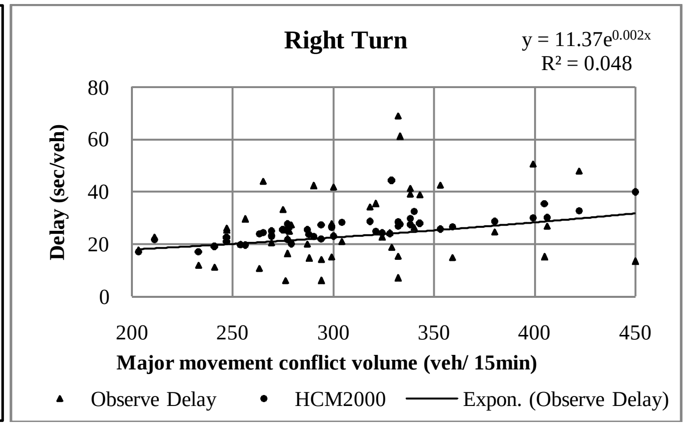
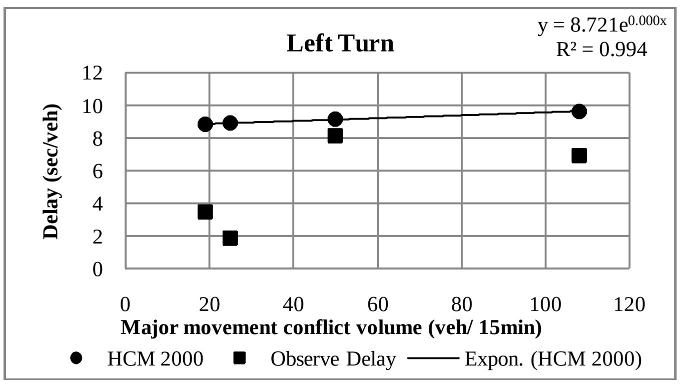


Fig. 15 Junction for Jalan Titiwangsa 3/Titiwangsa 4

Fig. 16 Junction for Jalan Titiwangsa 3/Titiwangsa 4

For Jalan Kebudayaan/Jalan Kebudayaan3, the lowest level of observe delay for left turn is approximately 2 sec/ veh and the highest delay is about 8 sec/ veh. Similarly, for right turn, actual delay is between 4 sec/ veh until 8 sec/veh where as, major movement conflict volume is between 50 veh/15 until 200 veh/15. Therefore, these graphs indicates that level of observe delays are less than theoretical delays for vehicles which were emerged from minor road to the major road.



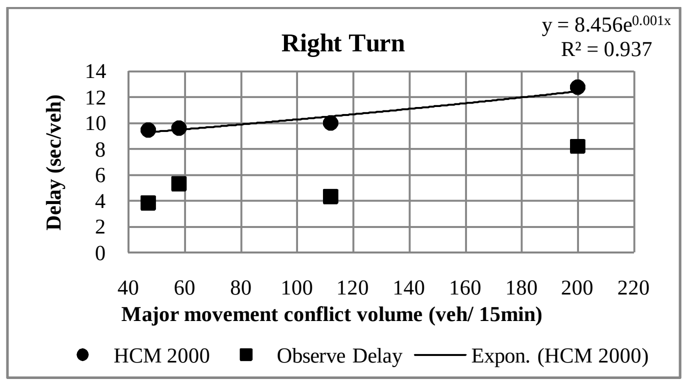
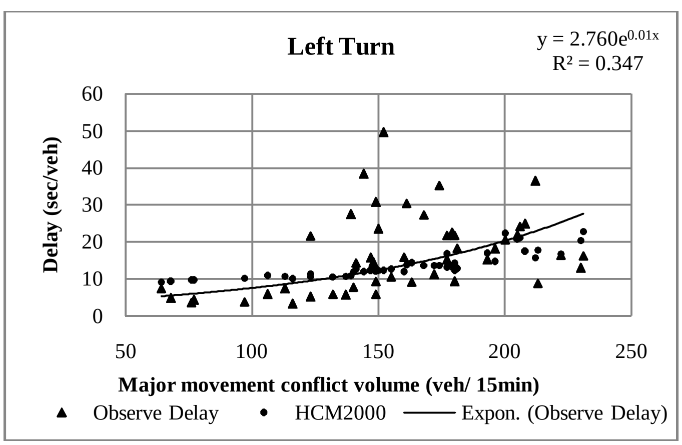


Fig. 17 Junction for Jalan Kebudayaan/Jalan Kebudayaan3

Fig. 18 Junction for Jalan Kebudayaan/Jalan Kebudayaan3



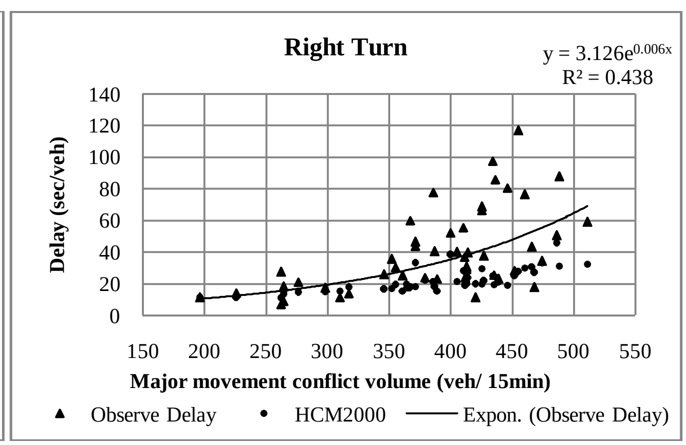


Fig. 19 Junction for Jalan Kebudayaan/Jalan Kebudayaan3

Fig. 20 Junction for Jalan Kebudayaan/Jalan Kebudayaan3

Figure 19 and 20shows that the comparison between theoretical and actual delays for junction Jalan Kebudayaan/Jalan Kebudayaan3 during 7:00 am until 7:00 pm. Base on this comparison, actual delays for left turn have a dispersal up to the 40 sec/veh, but actual delay for right turn is less than 120 sec/veh which are more than theoretical delay. These delays showed clearly that delays for right turn are more than left turn for junction Jalan Kebudayaan/Jalan Kebudayaan3.

Due to approve of these comparisons, Chi-Square's method (χ^2) were used. One of these approvals between actual and theoretical delays is shown for jalan Kebudayaan/Jalan Kebudayaan3 for vehicles which movement to the right turn as followed:

$\frac{(O-E)^2}{E} \leq 3.84$ ➔ $\frac{(18.07-14.22)^2}{14.22} \leq 3.84$

This is an example for approval of comparison between theoretical and actual delay and it was confirmed. This calculation should be continued for both junctions from 6:00 am until 7:00 pm. There are three classification in this table includes accept, reject and, disregard.

Table3. Final comparison between actual and theoretical delay

Direction	TW/Day Light	Classification	Left Turn	Right Turn
Jalan Titiwangsa 3/Titiwangsa 4	Twilight Time	Accept	3	2
		disregard	0	0
		reject	1	2
	Day Light	Accept	28	24
		disregard	2	8
		reject	22	20
Jalan Kebudayaan /Jalan Kebudayaan3	Twilight Time	Accept	3	4
		disregard	1	0
		reject	0	0
	Day Light	Accept	33	21
		disregard	5	7
		reject	10	20

Table III summarizes the evaluation of HCM2000 theoretical delay and actual delays for junction Jalan Titiwangsa3/Titiwangsa4 and junction Jalan Kebudayaan/Jalan Kebudayaan3 during twilight time and day time. Base on this table the numbers of accepted results for both junctions were more than other items during twilight time. Therefore, both junctions were classified as accepted. This table also shows that delay during day time for right turn was accepted, because it was 24 and 21 accepted items for junction Jalan Titiwangsa3/Titiwangsa4 and junction Jalan Kebudayaan/Jalan Kebudayaan3 respectively. Therefore, the observation delay for right turn agreed by suggested HCM2000 theoretical delay. Similarly, left turn was accepted for both junctions, because number of accepted was more than other factors. Therefore, the observation delay for left turn agreed by suggested HCM2000 theoretical delay.

DISCUSSION

This article was conducted to evaluate the delay at the priority junctions during twilight time and day time. Thus, theoretical delay during these two parts of a day was determined. According to this model, theoretical delays were calculated for left turn and right turn for Jalan Kebudayaan/Jalan Kebudayaan3 and Jalan Titiwangsa3/Titiwangsa4. In this case, one important factor was traffic volume at the major road. If major road traffic volume increased, delay in minor road traffic increased. Similarly, if major road traffic volume decreased, delay in minor road traffic decreased.

For junction Jalan Titiwangsa3/Titiwangsa4, during twilight time, delays for left turn were about 7 sec/veh until 10 sec/veh. Similarly, delays for right turns were approximately 14 sec/veh to 19 sec/veh. On the other hand, theoretical delays were calculated during day time for right turn and left turn. Delay for junction Jalan Titiwangsa 3/Titiwangsa 4 was about 11 sec/veh until about 39.00 sec for left turn and around 17 sec/veh until 45 sec/veh for right turn.

For junction Jalan Kebudayaan/Jalan Kebudayaan3, during twilight time, delays for left turn were about 8 sec/veh until around 10 sec/veh. Whereas, delays for right turns were approximately 10 sec/veh to 15 sec/veh. On the other side, delays were calculated during day time for right turn and left turn. It was about 9 sec/veh until 22.75 sec/veh for left turn and 13 sec/veh until 46 sec/veh for right turn.

After calculation of theoretical delay, observed delays were determined during twilight time and day time. Then, comparison between theoretical with actual delay via Chi-Square's method (χ^2) was done at the same time period. For comparison, there are three classifications which were accepted, reject, and disregard. All comparison between HCM2000 theoretical and actual delay for junction Jalan Titiwangsa 3/Titiwangsa 4 and junction Jalan Kebudayaan/Jalan Kebudayaan3 during twilight time and day time was accepted, because the numbers of accepted items were more than other items. Therefore, the observation delay for right turn and left turn for both junctions accepted by proposed HCM method.

CONCLUSION

In this article, delay was analyzed for TWSC intersection. Although, theoretical delay base on HCM method indicate level of delays for these junctions, but we determined observe delay for confirmation of our calculation. Base on previous discussion, due to analyze of delay in these junctions, delays were calculated into two parts includes twilight time and day time. Then, comparison between theoretical delays (HCM) and actual delays were done during these two parts of a day. These comparisons indicated that all theoretical delays were accepted with actual delay during twilight time. Similarly, during day times theoretical delays for left turn and right turn for both junctions was agreed with the actual delays. The comparison between observed delay and theoretical method (HCM) show that both values are similar. In addition, delay for vehicles those wanted emerges from minor road to the major road has direct relevance with major movement conflict volume. Base on previous literature, level of conflict volume during twilight time was less than other day time. Therefore, delay during twilight time (6:00 am to 7:00 am) was less than day times which occurred between 7:00 am to 7:00 pm.

REFERENCES

[1] Wachs, M., John M. S., Robert E., 2000. Highway Capacity Manual. Transportation Research Board (TRB). USA. pp: 522-574.

[2] Tapio Luttinen, R., 2004. Capacity and Level of Service at Finnish Unsignalized Intersections. Helsinki. pp: 22-34.

[3] Ruskin, H. J., R. Wang, 2002. Modeling Traffic Flow at an Urban Unsignalized Intersection. Springer-Verlag Berlin Heidelberg. School of Computer Applications, pp. 381−390.

[4] Chandra, S., Abhishek A., Ashalatha R., 2009. Microscopic Analysis of Service Delay at Uncontrolled Intersections in Mixed Traffic Conditions. Journal of Transportation Engineering., 135(6): 323-330.

[5] Ashalatha, R., Satish C., 2010. Service Delay Analysis at TWSC Intersections through Simulation. Journal of Civil Engineering., 15(2): 413-425.

[6] Yusria D., Mohamed R. K., Jamilah M., Sulaiman A., 2005. Control Delay Variability At Signalized Intersection Based On Hcm Method. Proceedings of the Eastern Asia Society for Transportation Studies., 5: 945 - 958.

[7] D. Sunanda, Jian J. L., Ping Y., 2007. Driver Age Differences In Day And Night Gap Acceptance Capabilities. International association of traffic and safety science., 26(1): 71-79.