VOL. 11, NO. 20, OCTOBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

CAPACITY ANALYSIS OF DIFFERENT GEOMETRIC DESIGN OF UNSIGNALIZED IINTERSECTIONS BASED ON OCCUPATION TIME

Joewono Prasetijo[1], Ning Wu[2], Wan Zahidah Musa[1], Kamarudin Ambak[1], Munzilah Md Rohani[1] and Noorliyana Haji Omar[1]
[1]Smart Driving Research Centre, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, Malaysia
[2]Lehrstuhl für Verkehrswesen, Ruhr-Universiät Bochum, Universitätsstrasse, Bochum, Germany
E-Mail: joewono@uthm.edu.my

ABSTRACT

Traffic flow at low volume is mainly regulated by implementation of unsignalized intersections system. The common approach called as gap-acceptance method is used to assess the performance of the intersection in most developed countries. However, among the drawbacks of the gap-acceptance method are the non-compliance to the right of way, design of intersections and the heterogeneous traffic condition as in developing countries. The conflict method is developed to overcome these shortcomings. The occupation time of vehicle is used to calculate the capacity of vehicular movements for each conflict group. The control delay and level of service of the vehicular streams are evaluated according to the procedures in HCM 2000. Result comparison is made between different designs of intersections. It can be concluded that conflict method are found to be comparable with the HCM 2000 using field data.

Keywords: Conflict method, additive conflict flow, discharging service time, conflict group, gap-acceptance.

INTRODUCTION

Traffic conflicts between vehicular movements are existed when two or more roads crossed each other. Such conflicts may cause delay and congestion with the possibility of road accidents and fatalities. Thus, each intersection requires traffic control. It is mainly regulated with stop signs, traffic lights, and roundabout. The common type of intersection is the unsignalized intersection, which is used to regulate low volume of traffic flow between the major and minor streets. The two-way stop-controlled (TWSC) and all-way stop-controlled (AWSC) are among the types of operation for unsignalized intersections. It is stated [8] that unsignalized intersection operates without positive indication or control to the driver. It depends on the driver's decision to take the right opportunity to enter the major street. This behaviour is defined as gap acceptance while the driver in the minor street will wait for an adequate gap before entering the major street. On the other hand, small gaps are typically rejected.

The current approach of conflict method is developed to overcome the problems in the gap-acceptance method. This method is also known as the additive conflict flow (ACF) method. Wu (2000) stated that it is easier to consider the distribution of traffic flow rates, the number of lanes and pedestrian on different approaches, and flared approaches. The key parameter for the conflict method is the occupation time, $t_{B,q}$. It is the time spent by a vehicle for occupying the conflict area. [1] used the term $t_{B,q,m}$ and $t_{B,q,i}$ alternatively to describe the occupancy time of vehicles at the conflict area. Another parameter to be considered in the conflict method is the blocking time of conflict area due to approaching vehicle, $t_{B,a}$. Thus, the objectives of the following study are to determine the occupation time $t_{B,q}$ of vehicle, and to evaluate the performance of the unsignalized intersection based on the occupation time values.

METHODOLOGY

Two T-intersections in Malaysia has been selected for this study. One intersection was in area of Perak intersection is labelled as Intersection A, while Jalan Sekolah intersection shall be Intersection B. Both intersections have a typical layout geometric design with the combination of shared lane and flared approach. Surveillance equipment is used during field observation. In general, the capacity of a minor stream is expressed by Equation (1). On the other hand, the proportion of time spent by discharging vehicle in the conflict area is calculated using Equation (2). The conflict area can be blocked by the approaching vehicles of higher priority. The proportion of time the approaching vehicle is blocking the conflict area is defined by Equation (3).

$$C_m = C_{max,m} \cdot p_0 \tag{1}$$

Where:

C_m = Capacity of movement m [veh/h]

$C_{max,m}$ = Maximum possible capacity of movement m [veh/h] $= \left(\dfrac{3600}{t_{B,q,m}}\right)$

$t_{B,q,m}$ = Occupation time of movement m [s]

p_0 = Pr(no blockage) [-]

$$B_{q,m} = \frac{Q_m \bullet t_{B,q,m}}{3600} \tag{2}$$

VOL. 11, NO. 20, OCTOBER 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Where:

Q_m	= Traffic demand of movement m	[veh/h
$t_{B,q,m}$	= Occupation time of movement m	[s]
$B_{q,m}$	= Proportion of occupancy by discharging vehicle m	[-]

with the restriction of $Q_m \cdot t_{B,q,m} \leq 3600$

$$B_{a,m} = \frac{Q_m \bullet t_{B,a,m}}{3600} \quad (3)$$

Where:

$t_{B,a,m}$	= Approaching time of movement m	[s]
$B_{a,m}$	= Proportion of period the conflict area is blocked by approaching vehicle m	[-]

The probability p_0 can also be computed as the product of the probability whereby the conflict area is not occupied by standing or discharging major vehicles, and the probability that the approaching major vehicles are not occupying the conflict area. It is computed using Equation (4).

The capacity of each movement is computed with Equation (5) until Equation (10).

$$p_0 = p_{0,q} \cdot p_{0,a} \quad (4)$$

Where:

p_0	= Pr(no blockage)	[-]
$p_{0,q}$	= Pr(no discharging of major stream vehicles	[-]
$p_{0,a}$	= Pr(no approaching major vehicles)	[-]

$$C_2 = C_{max,2} \quad (5)$$

$$C_3 = C_{max,3} \cdot (1-B_{q,5}) \cdot (1-B_{q,4}) \cdot \exp[-(B_{a,5}+B_{a,4})] \quad (6)$$

$$C_4 = C_{max,4} \quad (7)$$

$$C_5 = C_{max,5} \quad (8)$$

$$C_7 = C_{max,7} \cdot (1-B_{q,5}) \cdot \exp[-(B_{a,5})] \quad (9)$$

$$C_9 = C_{max,9} \cdot [1-(B_{q,5}+B_{q,3})] \cdot (1-B_{q,2}) \cdot \exp[-(B_{a,5}+B_{a,3}+B_{q,2})] \quad (10)$$

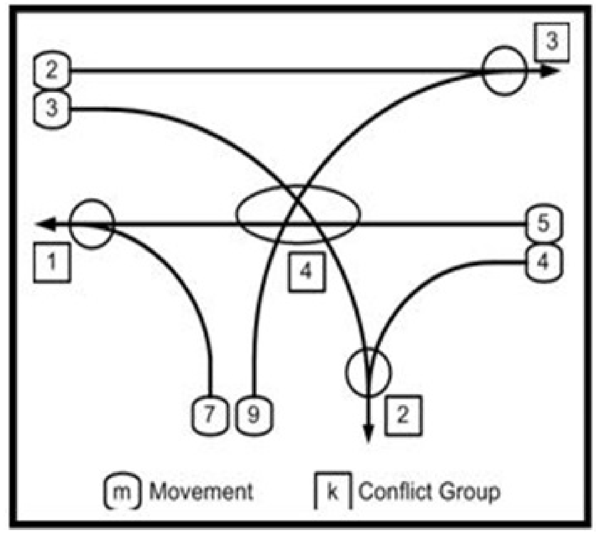

Figure-1. Conflict groups at a T-intersection.

After the actual capacity is determined, the effective occupation time is calculated using Equation (11). A comparison of capacity results can be seen between the capacity values measured using the conflict method and the HCM. In HCM 2000, the performance of unsignalized intersection is indicated by the control delay, which is also applicable for the conflict method [2].

$$t_{B,q,m}{}^{*} = \frac{3600}{C_m} \quad (11)$$

Where:

$t_{B,q,m}{}^{*}$	= Effective occupation time of movement m	[s]
C_m	= Capacity of movement m	[veh/h]

RESULTS AND DISCUSSION

Control delay and level of service (LOS) intersection A

In this study, every movement of Intersection A is analyzed separately. Table-1 shows the control delay and level of service of all vehicular movements at Intersection A. Based on the results obtained, the performance of each movement is satisfactory with LOS A. However, the south right turn stream has achieved LOS B. It is due to the amount of major movements that are blocking its pathway. This factor has caused the increase in control delay. There is no significant variation of control delay between other movements. The difference of control delay between the turning movement and the major streams could be apparent if the intersection is channelized.

Table-1. Level of service of vehicular movements at intersection A.

Vehicular Movement	Control Delay (s/veh)	LOS
South Left Turn	7.58	A
South Right Turn	11.73	B
West Right Turn	7.67	A
West Through (Bottom)	7.15	A
West Through (Top)	7.02	A
East Through	7.35	A
East Left Turn	6.78	A

Intersection B

Based on Table-2, the channelized Intersection B has mixed results. Obviously, the turning movements have higher control delay than the major streams. The south left turn stream and the west right-turning movement have higher control delay than their counterpart in Intersection A. On the other hand, the south right turn movement has lower control delay than similar stream of Intersection A. The channelization of vehicular movements has reduced the control delay of all major through streams.

Table-2. Level of service of vehicular movements at Intersection B.

Vehicular Movement	Control Delay (s/veh)	LOS
South Left Turn	8.05	A
South Right Turn	9.97	A
West Right Turn	8.26	A
West Through (Bottom)	6.37	A
West Through (Top)	6.55	A
East Through	6.44	A
East Left Turn	7.11	A

CONCLUSIONS

Different methods have been developed to analyze the unsignalized intersection. The gap-acceptance method is the dominant approach currently used. It is implemented by many countries in their capacity manuals. The gap-acceptance method has a simple concept which depends on the driver's decision to accept or reject a gap before committing the vehicular manoeuvre.

However, there are drawbacks to this approach, such as non-compliance to the priority rules. Some efforts have been made to improve the reliability of the unsignalized intersection analysis. Conflict method is proposed to assist the current methods available. It is based on the interaction between vehicular movements that created conflict areas in the intersection. Therefore, the following conclusions can be made:

- The occupation time is inversely proportional with the capacity of the vehicular movement. Small occupation time indicates that more vehicles are able to cross the conflict area in a given time period, and vice-versa. It can also provide the estimation of the vehicular speed when crossing the intersection.
- Long duration of occupation time is achieved due to slow-moving vehicles, large intersection area, and multiple blocking major streams. It increases the delay of the vehicular movement, thus degrades its LOS.

Based on the results obtained from the analysis of the intersections, their performance can be concluded as follows:

- The intersections are under saturated, which conform to the field observation.
- The exclusive lane for turning movement is capable to reduce the delay of vehicular stream. However, it still depends on the vehicular speed, and the traffic volume. On the other hand, the shared lane does not always impede the movement of turning streams, provided that the traffic volume is low.
- Results are compared with the HCM 2000 by using field data has shown promising outcome. The conflict method is verified as capable to assist the gap-acceptance approach. With data calibration, better results can be expected.

ACKNOWLEDGEMENTS

The authors would like to express their sincere appreciation to the Ministry of Education of Malaysia through the ERGS grant Vot. E 037 and Faculty of Civil and Environmental Engineering (FKAAS), Universiti Tun Hussein Onn Malaysia (UTHM) for facilitating and supporting this research to be presented and published.

REFERENCES

[1] Brilon, W. and Wu, N. 2002. "Unsignalized Intersections - A Third Method for Analysis". In: Taylor, M. A. P., ed. Transportation and Traffic Theory in the 21st Century - Proceedings of the 15th International Symposium on Transportation and Traffic Theory, 16-18 July 2002 Adelaide. Oxford: Elsevier Science Ltd., 1-19.

[2] Brilon, W. and Miltner, T. 2005. "Capacity at Intersections Without Traffic Signals". Transportation Research Record: Journal of the Transportation Research Board, 1920**,** 32-40.

[3] Gattis, J. L. and Low, S. T. 1998. "Gap Acceptance at Non-Standard Stop-Controlled Intersections". Arkansas: Mack-Blackwell Rural Transportation Center.

[4] Prasetijo, J. 2007. "Capacity and Traffic Performance of Unsignalized Intersection under Mixed Traffic Conditions". Ph.D Thesis, Ruhr-University Bochum.

[5] Prasetijo J, Wu N., Kamarudin A., Munzilah R and Erwan S. 2014. Capacity Analysis of Priority Intersections with Flare under Mixed Traffic Conditions. Proceeding of 9th International Conference on Traffic and Transportation Studies'. Procedia – Social and Behavioral Sciences. DOI: 10.1016/j.sbspro.2014.07.257. Elsevier.

[6] Prasetijo J., Halimshah A. 2012. Paper no.: 12-3050. Effectiveness of Capacity Estimation under Mixed Traffic Conditions. Compendium of 91st Transportation Research Board Annual Meeting (TRB), Washington, D.C., U.S.A., January 22nd to 26th, 2012.

[7] Transportation Research Board, 2000. Highway Capacity Manual. Chapter 17 – Unsignalized Intersection. Washington, D.C.: TRB.

[8] Troutbeck, R. J. and Brilon, W. 1992. "Unsignalized Intersection Theory". Virginia: Turner-Fairbank Highway Research Center.

[9] Wu, N. 2000. Capacity at All-Way Stop-Controlled and First-In-First-Out Intersections. Transportation Research Circular E-C018: Fourth International Symposium on Highway Capacity Proceedings. TRB, National Research Council, Washington, D.C., pp. 369-387