

CONFERENCE PAPER

NZAAR-UDCP-17-24 UDCP 2017

Mid-Block Crossing Behavior: A Study of Pedestrians and Vehicles Interaction Along Urban Streets in Malaysia

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PUBLISHED IN

The Third NZAAR International Event Series on Natural and Built Environment, Cities, Sustainability and Advanced Engineering International Conference on Urban Design and Cities Planning (UDCP 2017)

Pages	49-59 of the volume
Held	15 July 2017, GTower Hotel, Kuala Lumpur, Malaysia
ISSN	2463-5979 (online) 2463-5960 (print)
Publisher	New Zealand Academy of Applied Research Ltd, Auckland

ABSTRACT

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HOW TO CITE

Walid A Al Bargi, Basil David Daniel and Mohamed M Muftah (2017). Mid-Block Crossing Behavior: A Study of Pedestrians and Vehicles Interaction Along Urban Streets in Malaysia. In *The Third NZAAR International Event Series on Natural and Built Environment, Cities, Sustainability and Advanced Engineering*, Kuala Lumpur, Malaysia, 15 July 2017 (pp. 49-59). Auckland: New Zealand Academy of Applied Research. ISSN 2463-5979 (online), 2463-5960 (print).

MID-BLOCK CROSSING BEHAVIOR: A STUDY OF PEDESTRIANS AND VEHICLES INTERACTION ALONG URBAN STREETS IN MALAYSIA

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Abstract

Gap acceptance behavior of pedestrian is significant to Safety and crash of pedestrian. The issue of gap acceptance by pedestrians is relevant for road safety. It is novel to analyze the gap acceptance behavior and the effects of selected factors based on observation survey. Many studies examined the mid-block crossing behavior of pedestrians in the developed country. In contrast, this study is one of the first to analyze and model the crossing choice behaviors of pedestrians within an entire Malaysia. However, the main aim of this paper is to investigate and model non-compliant pedestrians' traffic gap acceptance at unsignalised pedestrian mid-block crossings in Malaysia. For this purpose, a field survey was carried out using videotaped data. Gaps size accepted, number and size of the rejected gaps are examined against pedestrians' and traffic attributes, using statistical analysis (SPSS.22) and modeling approach (Multiple linear Regression and Binary logit regression). In addition, Critical gap were determined using Raff's method. The results revealed that seven factors that influence the pedestrian crossing behaviour in terms of accepted gap size in seconds. Results showed traffic speed, pedestrian waiting time, vehicle size, pedestrian gender, crossing distance, age group, and pedestrian number are the significant factors for accepted gap size of pedestrian in Batu Pahat. Pedestrian waiting time was found to have negative impact on gap size acceptance while the remaining factors showed positive influence on the gap size acceptance. In the development of crossing choice model in Batu Pahat, traffic speed, driver yield, pedestrian number and pedestrian age group are the significant influencer for pedestrian choice. Raff's method result shows the critical gap size value is approximately 12.5 seconds, which is quite similar to reported in previous studies. These outcomes would be recommended to use in the evaluation of unprotected mid-block crosswalks and designing of new crosswalk facility in Malaysia..

Keywords: Pedestrian, Gap Acceptance, Multiple linear Regression, Binary logit regression, Critical Gap Raff's method, mid-block, unprotected

1. Introduction

Road accidents, including pedestrian accidents have become a main safety issue all over the world [1] Safety studies on pedestrians crossing has been widely conducted in many countries due to huge number of pedestrian casualties in traffic accidents [2]. The pedestrian behavioral researches are covered as one of the scopes related to pedestrian safety. This is because the pedestrians crossing behavior, particularly for the time of the performance of road crossing is a significant factor in pedestrian safety related matter [3], [4].

In the developing country pedestrians facing difficulty when they are attempting to cross the street due to the driver behavior

towards to them. Pedestrians usually waiting for a long time until finding a volunteer who stops for them to allow them cross safely otherwise they wait until there are no more vehicles This phenomenon, perhaps due to lack of awareness on the rule of the right of way in such situation [5].

The traffic on Malaysian urban streets is considered as heterogeneous. Amongst of the numerous pedestrian crossing facilities, unsignalized midblock crossing locations are critical because barely hard any vehicle slow down to pedestrians there, even though in the presence of signs that shows gives priority to pedestrians over vehicles at unsignalized midblock locations. Therefore, pedestrians must wait until a

proper gap is accessible in the conflicting mix traffic stream. At crossing locations on multi-lane streets, pedestrians usually cross in stages, taking decisions for each conflicting vehicle. Decision to reject or accept gap size is influenced by several variables. All the above discussion underlines the need to understand crossing behavior of pedestrian, gap acceptance at uncontrolled mid-block crossings locations in the presence of mix traffic condition. More analysis and explanations of different aspects of heterogeneous traffic by [6]–[9]

Several researches investigated the pedestrian's gap acceptance behavior in developed countries. They discovered an effect of some factors such as gender, pedestrian waiting time, frequency of attempt, group crossing and type and speed of vehicle, etc. On the other hand, very rare study has been carried out for developing countries. In this paper, binary logit and Multiple linear regression models were developed to predict the probability of reject or accept a given gap size for pedestrian from traffic at mid-block location considering a number of potential influence variables.

2. Literature Review

Past literature discussed several forms of pedestrian's gap acceptance are presented in this context a study by Papadimitriou, E et al. [10] investigated binary logistic “discrete choice models” to analyze pedestrian's crossing decision while crossing a street section [11], [12] employed a lognormal regression model to evaluate the influence of various factors on pedestrian gap acceptance. Based on results showed by Sun, D et al. [13] and Chu, X. [14] making crossing decision pedestrians to cross the street depends on the distance between pedestrian and the coming vehicle. [15] and [16] found that the distance between the pedestrian and the vehicle is significant predictor variable of crossing decisions. Brewer, M et al. [17] Concluded that pedestrians speed is a

factor influencing gap acceptance for pedestrian. A study by [18] to understand pedestrian waiting time while crossing, its influences on pedestrian behavior. Zegeer, C. V et al. [19] carried out a study on safety effects of unmarked and marked mid-block crosswalks locations. The research done by C. M. Dipietro et al. [20] notice that pedestrians crossing in segregated accept longer gaps size than that pedestrians in group. A thorough appraisal of pedestrian gap acceptance have need of an understanding with the different types of gaps that are come across. However, There are gaps defined by site characteristics such as critical gaps and adequate gaps) and it is important to mention that gaps dependent on the situation present when the time pedestrians intending to cross road stream [17].

The critical gap defined by Highway Capacity Manual as the duration below which pedestrians won't try to start crossing a road [21], [22] defined the duration in seconds headway between vehicle and another vehicle in one direction as the pedestrian's gap acceptance to cross the street. Another definition given by Raff Critical gap is the lowest value gap size in second that is acceptable to a pedestrian, wants to cross a conflicting road stream. Critical gap considered as the most significant factor in gap acceptance behavior.

The main objective of this research is to investigate mid-block crossing of pedestrians' traffic gap acceptance at urban street in Batu Pahat under mix traffic condition. The influence of traffic, situational and some important variables were studied to model their effects on pedestrian's gap acceptance. Variables that were not considered in other previous studies in Malaysia but were considered in this study in order to make a better understanding about crossing behavior of pedestrians along urban streets in Malaysia.

3. Research Methods

To achieve desired objectives for this research, video camera were installed to collect and observe the pedestrians behavior characteristics and attitude toward traffic movement while crossing road stream at uncontrolled mid-block location. A total of 380 data samples were collected randomly. at Jalan Rughaya during a fixed period of time. All observations lasted 2 hours and took place either during the morning (10:00–12:00 p.m.) or the afternoon (4:00–6:30 p.m.) over a 3-weeks period excludes weekends. This period of times were chosen because they are the duration during which most pedestrians outdoor. All observations were taken in a good weather conditions. 14 variables were involved in the study of mid-block crossing patterns at Batu Pahat area as described in Table 1. From the table, gap size and gap acceptance are the dependent variables while the remaining 12 variables are independent variables. In addition, gap size is a scale dependent variable to gauge the time gap between two incoming vehicles at the crossing spot in the unit of second; while gap acceptance is a dichotomous variable that measures whether pedestrian crossed (code = 1) or did not cross (code = 0) the road. For independent variables, traffic speed measures the speed of vehicle at the crosswalk (km/h), pedestrian waiting time measures the time used to wait at the crossing area (seconds), frequency of attempt measures the number of attempt made to cross the road (frequency), driver yield measures whether vehicle driver slowed down for pedestrian (0: no, 1: yes), crossing distance measures the crossing distance of road (meter), vehicle size measures the size of vehicle (0: small, 1: big), illegal parking measures presence of illegally parked vehicle along the road side (0: no, 1: yes), gender measures the pedestrian gender (0: female, 1: male), gap type measures the distance between pedestrian and the gap (0: near, 1: far), pedestrian number measure the number of pedestrian waiting to cross the road,

pedestrian baggage measures whether pedestrian carrying baggage to cross the road and lastly, age group measures the pedestrian age (1: young, 2: middle, 3: elder).

Table 1: List of variables

Variable	Type	Unit	Description
Gap Size.	Continuous	sec	Gap between two incoming car at the crossing spot
Gap Acceptance.	Discrete	0: Reject 1: Accept	Whether pedestrian is crossing the road
Traffic Speed.	Continuous	km/h	Speed of vehicle at the crosswalk area
Pedestrian waiting time.	Continuous	sec	Time spent waiting at the crossing area for suitable gap
Frequency of attempt.	Continuous	Count	Number of attempts made by pedestrian before accept the vehicular gap
Driver Yield.	Discrete	0: No 1: Yes	Driver reduces speed when pedestrian is trying to cross
Crossing Distance.	Continuous	m	The crosswalk width that pedestrian need to cross
Vehicle size.	Discrete	0: Small 1: Big	Size of vehicle
Illegal Parking.	Discrete	0: No 1: Yes	Presence of illegally parked car
Pedestrian Gender.	Discrete	0: Male 1: Female	Gender of pedestrian
Pedestrian Number.	Continuous	Count	Number of pedestrian in the group
Gap Type.	Discrete	0: Near 1: Far	Distance between pedestrian and the gap
Age.	Discrete	1: Young 2: Middle 3: Elders	Visual appearance of pedestrian
Pedestrian Baggage.	Discrete	0: No 1: Yes	Pedestrian carrying baggage or not

4. Results & Discussion

4.1 Descriptive Analysis Of Variables

To study the mid-block crossing behavior in Batu Pahat, Descriptive analysis was

conducted on the data using mean, standard deviation, minimum, maximum, frequency and percentage, in which the results are as presented in Table 2 and Table 3 both discrete data and continuous data respectively. Analysing the table of discrete variable, study discovered that 70.3% out of 380 samples crossed the road at Batu Pahat by accepting the gap size. As for the vehicle driver driving behaviour, data showed that 66.1% of the driver actually slowed down their speed to accommodate the pedestrian driving. Data also showed that there were about 29.5% of the road crossing happened in Batu Pahat accompanied by illegal parking along the road side. Further, study found out that majority of the samples were male, accounted for 60.5% of total respondents. As far as gap type is concerned, 53.4% of road crossing attempt happened when gap were near to the pedestrian, while 46.6% happened when gap were far from the pedestrian. Results showed that the age groups of pedestrian distributed almost equally, in which young group accounted for 30.3%, middle group made up 37.6% of total samples and elder group consisted of 32.1% of total samples. In Batu Pahat, majority of road crossing accompanied by small vehicle (80.5%) while large vehicle only accounted for 19.5% of total samples. In addition, it was also found that only minority of respondents carry baggage with about 9.2% of them. As for the continuous variable, gap size showed mean time value of 24.51 secs with range of 4 to 55 secs, while traffic speed showed mean value of 42.29 km/h with range of 28 to 60 km/h. Then, the mean of pedestrian waiting time is 24.98 secs with range of 6 to 59 secs, the mean frequency of attempt was 0.18 with range 0 to 1 times; while the pedestrian number showed mean value of 1.29 with range 1 to 5 person.

Table 2: Descriptive statistic for discrete variables

Variables	Frequency	Percent
Gap Acceptance		
Reject	113	29.7

Accept	267	70.3
Driver Yield		
No	129	33.9
Yes	251	66.1
Illegal Parking		
No	268	70.5
Yes	112	29.5
Pedestrian Gender		
Male	230	60.5
Female	150	39.5
Gap Type		
Near	203	53.4
Far	177	46.6
Age Group		
Young	115	30.3
Middle	143	37.6
Elder	122	32.1
Vehicle size		
Small vehicle	306	80.5
Large Vehicle	74	19.5
Pedestrian Baggage		
No	345	90.8
Yes	35	9.2

Table 3: Descriptive statistic for continuous variables

Variable	Mean	S.D.	Minimum	Maximum
log_gap	1.09	0.236	0.6	1.74
Gap Size	14.51	9.545	4	55
Traffic Speed	42.29	8.938	28	60
Pedestrian waiting time	24.98	11.588	6	59
Frequency of attempt	0.18	0.384	0	1
Crossing Distance	9.26	0.438	9	10
Pedestrian Number	1.29	0.528	1	5

4.2. Pedestrian Behavioural Model

To study the pedestrian road crossing behaviour, study employs multiple linear regression (MLR) model to explain the influence of some factors on the pedestrian accepted gap size (log_gap). It is important to understand that study filtered out those rejected the gap size, i.e. those who do not cross at the recorded road section. Furthermore, study utilised stepwise

method for model estimation to remain only significant factors/ predictors and the results were shown in Table 4. The stepwise regression computation resulted in a significant 7 predictors or factors model ($F_{7, 259} = 166.271$, $p \approx 0.000$) where were able to explain 81.8% of the changes in the log gap size that were accepted by pedestrian at Jalan Rughaya. To assess the multicollinearity of regression model, study examine the VIF values and noticed that there was no multicollinearity potential since all VIF values were lower than 10. Based on the model, it seems that traffic speed, pedestrian waiting time, vehicle size, pedestrian gender, pedestrian number, age group and crossing distance were the significant factors for log gap size at 0.05 significance level. Traffic speed was found to have positive influent on gap size with B value of 0.011, meaning that if the vehicle was found to approaching the crossing zone at higher speed, the pedestrian will more likely to accept wider gap size which is much safer for them to cross. A unit increase in traffic speed (km/h) will increase the accepted log gap size by 0.011 seconds or gap size by 1.025 seconds. Pedestrian waiting time is the only factor that was found to have significant impact on the accepted log gap size with B value of -0.006, suggesting that the longer the pedestrian waiting time, the more likely they will get impatient and accept narrower gap size. A unit increase in pedestrian waiting time (sec) will decrease the log gap size by 0.006 seconds or gap size by 1.014 seconds. For vehicle size (0: small, 1: big), it was found to have significant positive effect on accepted log gap size with B value of 0.095, indicating that pedestrian tends to accept wider gap size when they are facing larger vehicle. In general, when facing large vehicle, pedestrian accept 0.095 seconds wider log gap size or 1.244 seconds wider gap size as compared to facing small vehicle. Pedestrian gender (0: male, 1: female) showed positive B value of 0.058, suggesting that female pedestrian will likely to cross the road with longer gap size

compared to male pedestrian. In general, female accept 0.058 seconds for log gap size or 1.143 seconds for gap size longer than that of male pedestrian in Batu Pahat. As far as pedestrian number crossing the road in group is concerned, positive B value of 0.049 indicated that if the pedestrian were to cross the road at larger group, they tend to accept wider gap size. A person increase in pedestrian number (group crossing), will increase the log gap size by 0.049 seconds or 1.119 seconds. For age groups, results revealed a positive impact on gap size acceptance with B value of 0.041, suggesting that the older the pedestrian, the wider the gap size acceptance. As for the crossing distance, study discovered that it has positive impact on the accepted gap size of pedestrian in Batu Pahat with B value of 0.054, indicated that the wider the crossing gap, the wider the accepted gap size. With that, a unit increase in crossing gap (meter), will increase the log gap size by 0.054 seconds or gap size by 1.132 seconds. To study the relative strength of each factors, the BETA values were assessed, in which high absolute value of BETA indicates greater influence toward the gap size acceptance. Based on the results, clearly traffic speed and pedestrian waiting time have the relatively highest impact to gap size acceptance compared to other factors, both with absolute BETA value of 0.294 and 0.297. In addition, vehicle size was found to have relatively strong influence towards gap size acceptance compared to other remaining factors with absolute BETA value of 0.176. Lastly, pedestrian gender, number, age group and crossing distance were deemed to have competitive strength of influence and were relatively weaker as compared to traffic speed, pedestrian waiting time and vehicle size.

$$\begin{aligned} \text{Log gap_size} = & 0.243 + 0.011 \text{ TS} - 0.006 \text{ PWT} \\ & + 0.095 \text{ VS} + 0.058 \text{ PG} + 0.049 \text{ PN} + 0.041 \text{ AG} \\ & + 0.054 \text{ CD} \end{aligned} \quad (1)$$

Table 4: Regression weight statistics

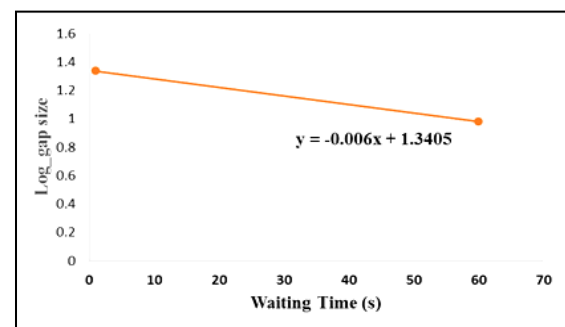
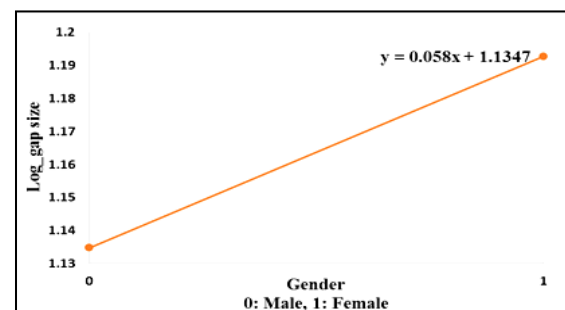
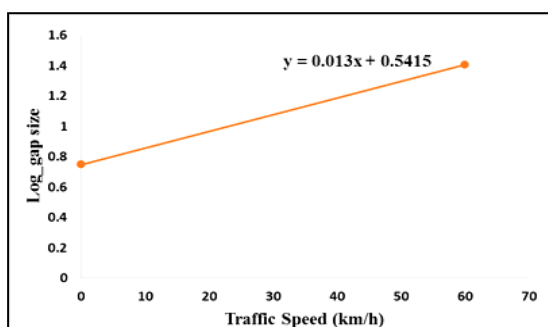
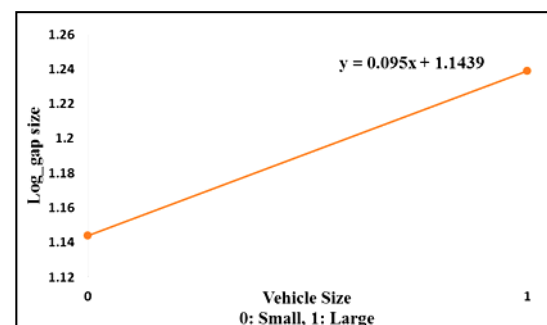
Variable	B	Beta	t	P-value	Tolerance	VIF
(Constant)	0.243		1.665	0.097		
Traffic Speed*	0.011	0.294	7.992	0.000	0.518	1.929
Pedestrian waiting time*	-0.006	-0.297	-9.696	0.000	0.749	1.335
Vehicle size	0.095	0.176	5.13	0.000	0.596	1.678
Pedestrian Gender	0.058	0.136	4.061	0.000	0.625	1.6
Pedestrian Number*	0.049	0.125	3.462	0.001	0.54	1.85
Age Group	0.041	0.113	3.498	0.001	0.675	1.481
Crossing Distance*	0.054	0.121	3.353	0.001	0.542	1.845

DV: Log_gap, $R^2 = 0.818$, $F(7,259) = 166.271$, p value ≈ 0.000 , *continuous variable

Equation 1 was used to plot the relationship graph as in Figure 1 to Figure 7 using the constant mean values as in Table 5. From the graph, factors that showed inclining line suggest positive impact while factors that showed declining line showed negative impact on the accepted log gap size.

Table 5: Mean statistic for variables

Variables	Mean
Traffic Speed	37.74
Pedestrian waiting time	29.75
Vehicle size	0.19
Pedestrian Gender	0.47
Age Group	1.3
Pedestrian Number	1.62
Crossing Distance	9.34

**Figure 2: Relationship between waiting time and log gap size****Figure 3: Relationship between gender and log gap size****Figure 1: Relationship between traffic speed and log gap size****Figure 4: Relationship between vehicle size and low gap size**

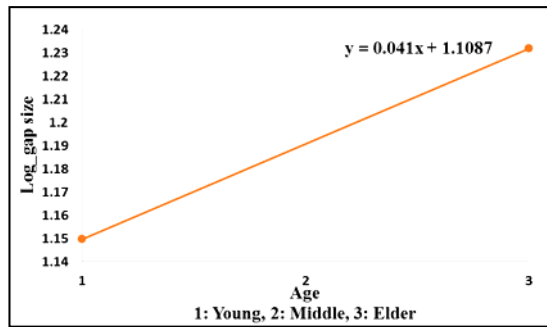


Figure 5: Relationship between age and log gap acceptance

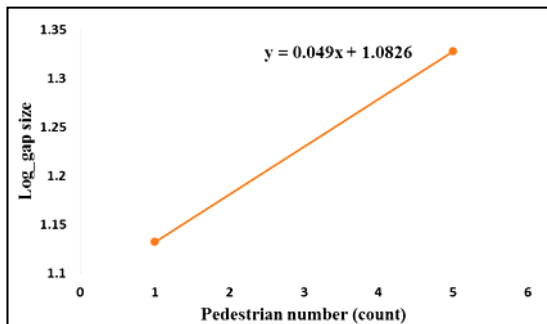


Figure 6: Relationship between pedestrian number and log gap size

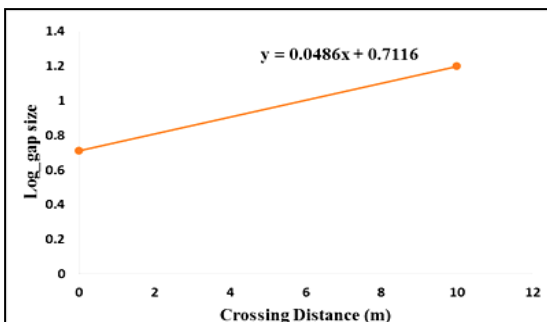


Figure 7: Relationship between crossing distance and log gap size

4.3 Choice Behaviour Model

Binary logit model was employed to analyse the choice opportunities for pedestrian road crossing behaviour at uncontrolled mid-block location in Batu Pahat. For this section, data were randomly divided into calibration set ($n=304$, 80%) and validation set ($n=76$, 20%). Calibration set of data will be used to calibrate the logit model for gap acceptance while the validation set of data will be used to calculate the predictive power of the model.

Based on the result in Table 6, the final binary logit model can be written as:

$$U_i = 34.602 - 0.549 TS + 4.811 DY + 4.772 PN - 7.204 AG \quad (2)$$

From the binary logistic regression, study found out that there were four significant factors namely, traffic speed, driver yield, pedestrian number and age groups for the gap acceptance (0: reject, 1: accept) among the pedestrian at Batu Pahat. From the results, traffic speed showed negative B value of 0.549 meaning that if the vehicle approaching at higher speed, the likelihood for pedestrian to reject the gap will be higher. The $\exp(B)$ value of 0.577 suggests that each unit decrease in traffic speed (km/h), the probability of pedestrian accepting the gap will increase by a factor of 1.73. As for the driver yield, B value of 4.811 indicates that if vehicle driver slowed down their speed near the crossing zone, pedestrian are more likely to accept the gap size. In addition, $\exp(B)$ value of 122.798 indicates that if vehicle driver were to slow down their vehicle, the probability of pedestrian crossing the road would increase by about 122 times. Next, B value of 4.772 for the pedestrian number clearly showed that pedestrian are prone to accept the gap if they were to cross with larger group. Looking at the $\exp(B)$ value of 118.136, it tells us that each unit increase in the pedestrian number in the crossing road, the likelihood of them accepting the gap will increase by 118 times. Moreover, age groups showed negative B value of 7.204 showing that older pedestrian has lower probability of accepting the gap compared to younger pedestrian. Each unit decrease in age group (i.e. from older to middle, from middle to younger) will increase the chances of pedestrian accepting the gap size by 1000 times.

With the calibrated model, study validate the model by calculating the probability of crossing as follows:

$$p(i) = \frac{e^{34.602 - 0.549 TS + 4.811 DY + 4.722 PN - 7.204 AG}}{e^{34.602 - 0.549 TS + 4.811 DY + 4.722 PN - 7.204 AG}} \quad (11)$$

Study used the threshold value of 0.5, meaning that if the calculated probability of crossing (accept the gap) were greater than 0.5, study then predict the sample chose to cross the road in Batu Pahat. From Table 7, the calibrated model showed overall accuracy of 99.3% and the model validation showed accuracy of 97.4%, suggesting that the binary logit model has good predictive power using 4 predictors, namely traffic speed, driver yield, pedestrian number and age groups.

To better explain the impact of traffic speed, driver yield, pedestrian number, and age groups on pedestrian crossing choice model, study plot the probability versus predictor graph as in Figure 8 to Figure 11. The predictor were plotted one at a time, with the remaining predictors held constant at value of 35 km/h for traffic speed, 0 for driver yield, 1 for pedestrian number, and 3 for pedestrian age group. Based on the graphs, clearly traffic speed and age group have reverse impact on the crossing probability while driver yield and pedestrian number have direct impact towards the pedestrian crossing probability.

Table 6: Regression weight for binary logistic regression

Variable	B	S.E.	Wald	df	P-value	Exp(B)
Traffic Speed	-0.549	0.184	8.875	1	0.003	0.577
Driver Yield	4.811	1.787	7.244	1	0.007	122.798
Pedestrian Number	4.772	1.853	6.633	1	0.010	118.136
Age Groups	-7.204	2.935	6.026	1	0.014	0.001
Constant	34.602	12.075	8.212	1	0.004	1.1E+15

Cox & Snell R Square = 0.692, Nagelkerke R Square = 0.979

Table 7: Model accuracy statistic

Gap Acceptance (p)	Correct %

		Reject	Accept	Partial	Total
Gap Acceptance (o)	Calibrated	Reject	91	1	98.9
		Accept	1	211	99.5
	Validated	Reject	20	1	95.2
		Accept	1	54	98.2

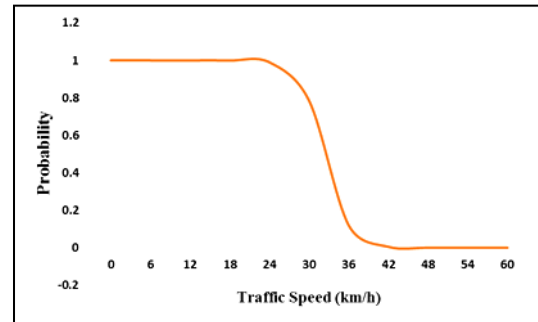


Figure 8: Traffic speed and crossing probability

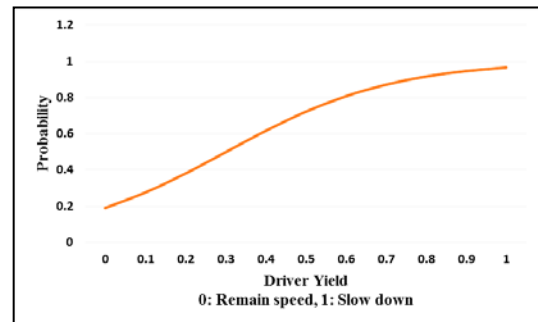


Figure 9: Driver yield and crossing probability

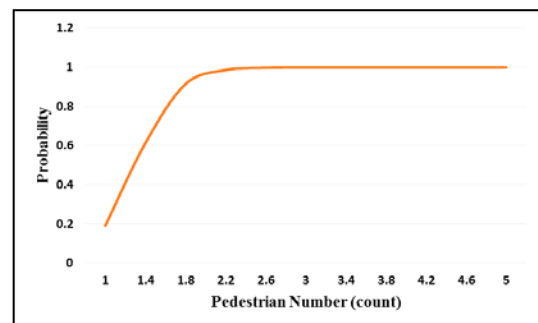


Figure 10: pedestrian number and crossing probability

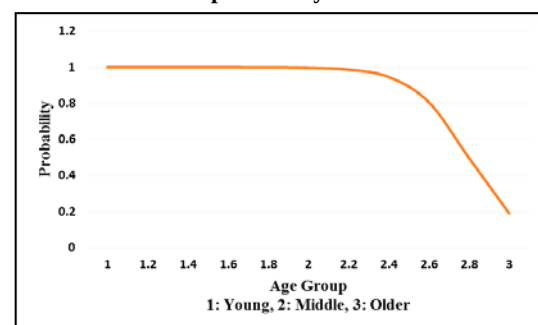


Figure 11: Age group and crossing probability

4.4 Critical Gap Size

Study employed Raff model to determine the critical gap for pedestrian crossing at Batu Pahat. Raff defined the critical gap value as the value at which the cumulative distribution functions (CDFs) of the accepted gaps intersects with the cumulative distribution of the rejected gaps. At this interception, the probability of a pedestrian rejecting a gap becomes less than that of accepting a gap, thus it is the critical gap value. Based on the CDF graph plotted (Figure 12), the critical gap size is approximately 12.5 seconds.

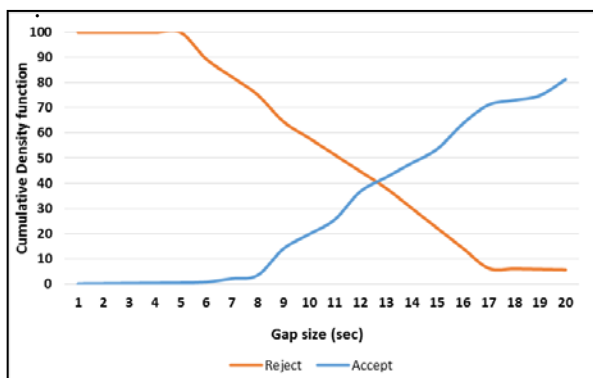


Figure 12: CDF of gap size rejection and acceptance

5. CONCLUSION

In Cyberjaya mid-block crossing data, study found seven factors that influence the pedestrian behaviour in terms of accepted gap size in seconds. Results showed traffic speed, pedestrian waiting time, vehicle size, pedestrian gender, crossing distance, age group, and pedestrian number are the significant factors for accepted gap size of pedestrian in Batu Pahat. Pedestrian waiting time was found to have negative impact on gap size acceptance while the remaining factors showed positive influence on the gap size acceptance. In order words, a pedestrian that facing higher traffic speed, lesser waiting time, bigger coming vehicle, being a female, crossing longer distance, older age, and crossing in larger group will more likely to accept longer gap size. In the development of crossing choice model in

Batu Pahat, traffic speed, driver yield, pedestrian number and pedestrian age group are the significant influencer for pedestrian choice. Results showed that slower traffic speed, driver reduce vehicle speed, pedestrian crossing with lager group, younger age group tends to promote higher probability of crossing the road compared to situation where the traffic speed is faster, no vehicle slow down, crossing with lesser group and older pedestrian.

ACKNOWLEDGMENT

The authors would like to acknowledge Universiti Tun Hussein Onn Malaysia (UTHM) for providing financial support to this research under the Fundamental Research Grant Scheme (Reference No. GPPS U440). This paper was partly sponsored by the Centre for Graduate Studies UTHM

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