Pedestrian Gap Acceptance and Crossing Decision outside Crossing Facilities along Urban Streets in Malaysia: A Case Study of Rughaya Street, Batu Pahat, Johor, Malaysia

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Abstract— **Walking considered as one of the safest modes of travel available, sustainable to human society as well as environmentally beneficial. In this context, the aim of this research is to investigate pedestrians' traffic gap acceptance and crossing decision for Mid-block Street crossing in urban areas in Malaysia. Pedestrian crossing behaviour at Rughaya Street has been examined in terms of the decision to cross or not the street and size of traffic gaps accepted by pedestrian, as well as the related contributing factors. A field study was conducted to collect the data of pedestrians' decisions under real mix traffic Condition using video camera on a typical unsignalized urban street section. JPEG files were obtained from video recording by using Snapshot Wizard software. The data extracted included traffic characteristics such as traffic size, traffic speed, etc. pedestrian individual characteristics such as gender, in addition to individual behavior such as waiting, frequency of attempt, etc.). Furthermore, The extracted data were used to develop and examine a pedestrian gap acceptance model based on A lognormal regression model and binary logistic model by SPSS (22) in order to validate the impact of various parameters on the size of traffic gaps accepted by pedestrians as well as the effect on the decision of pedestrians to cross the street or not. So that the effect of the gap accepted available and of other factors on the decision of pedestrians to cross the street or not is examined. These results indicate that the data set for this particular location has a majority of male pedestrians which were insignificant variables in both models moreover a lognormal regression results shows that accepted gaps size depend on traffic size, crossing distance, speed of approaching vehicle and time spent by pedestrian at the curb waiting for a suitable gap size to start crossing. The BL model performs well for the reason that it captures the pedestrian decision making process with traffic taking the relevant attributes into consideration. According to the coefficients of BL regression analysis equation we noticed that the illegal parking, traffic size, traffic waiting time and gap size are the vital attributes for the Pedestrian gap acceptance model..**

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Index Terms: **Pedestrian crossing, gap acceptance, crossing decision, multiple linear regression, binary logistic regression.**

I. INTRODUCTION

Gap acceptance can be well-defined as the process that happens when a vehicular stream has to either merge with another traffic stream or cross. For instance gap acceptance behavior happen when traffic on a minor approach cross a main street at a two-way stop controlled intersection or when traffic make a left turn through an opposing through movement at a signalized intersection. [1] This paper focuses on crossing gap acceptance behavior for Mid-block crossing in Malaysia.

Gaps along the traffic stream are one of the important elements affecting the tendency of pedestrian to dis-regard the traffic light signals. Individuals have difference smallest acceptable gap (in seconds), depending on the of risk that pedestrian is willing to take and pedestrian's demographic characteristics (such as gender, age) [2]–[4].

Previous researches on gap acceptance were concerned on analyzing capacity and delay as well as analysis in an un-signalized intersection. Gap acceptance, is a significant sub model of the lane changing model, and is an important microscopic vehicular characteristic in the vehicular control system and traffic management. So gap acceptance is more and more significant. Lately vehicular simulation and (Intelligent Transport System) have been used for modeling lane change, but a mathematical model to prove that "gap acceptance" behavior is developing [5]–[7].

[8][9][10][11][12] presented their approaches of using discrete choices theory for modeling pedestrian crossing behavior. These models are based on the gap acceptance model. Very few existing pedestrian crossing models are based on real traffic data and are mostly tested through simulations because they do not generate incidents or interrupt vehicular flow.

II. METHODOLOGY

The study was carried out in Batu Pahat, Johor, Malaysia; a video recording method was used to collect the pedestrian flow data. A camera was fixed in a suitable position, and recording was performed for 4 Hours duration from 10:00 a.m. to 12:00 noon and from 4:00 to 6:00 p.m during 3 days.

The pedestrian crossing analysis process involves the identification of pedestrian crossing locations, establishment of general patterns of crossing, analysis of the elements involved, site studies, and development of pedestrian gap acceptance and crossing decision prediction model using Regression analysis.

III. DATA COLLECTION AND ANALYSIS

Data were collected by using video camera and site observation survey in the center of Batu Pahat city, in Rughaya Street. This street was chosen due to considerable volume of pedestrians and traffic, some of the findings was as shown below in the figures 1. and Figure 2. A total of the 209 pedestrians observed, 179 (86%) were Males and 30 (14%) were females. however, pedestrians crossing behavior recorded in real traffic situations. Factors collected included pedestrian waiting time ,traffic waiting time recorded while some driver stop their vehicles waiting for pedestrian to cross as well as gap size whether rejected or accepted by pedestrians, the related number of crossing attempts, each vehicle's speed. In addition to pedestrian individual characteristics such as gender, it is significant to indicate that illegal parking in Rughaya Street was very frequent and the existence of illegally parked vehicles was videotaped during the data collection vehicle type of vehicles in traffic stream are classified into Malaysian standard car , motorcycle, van/medium vehicle and heavy vehicle .

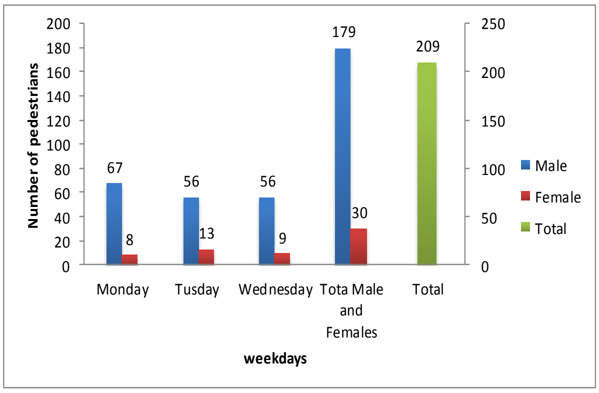

Figure 1. Number of Pedestrian

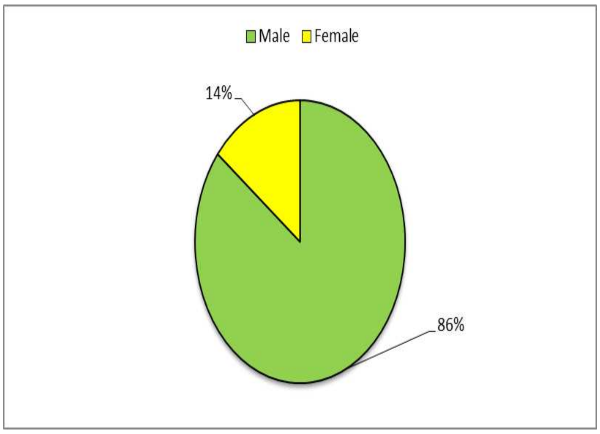

Figure 2. Percentage of Pedestrian

Model Results

Multiple Linear Regression

In this study a multiple linear regression model was constructed to measure the response of accepted gap size towards various predictors. The minimum value of pedestrians' gap acceptance is explained by a regression model. The pedestrian may possibly reject more number of available minimum gap size values and they may possibly accept maximum gap size values. In order to develop the minimum pedestrian's gap acceptance model, a log normal regression [8]has been carefully chosen by considering that pedestrian accepted gaps which followed a normal distribution. The accepted gap sizes are best fitted by a normal distribution by considering logarithm of the gaps. However it is observed that lognormal regression assumes a normal distribution for the logarithm of the dependent variables. The general model framework is given below:

$$\text{Log-Gap} = \beta 0 + \beta 1 \ X1 + \beta 2 \ X2 + \beta 3 \ X3 + \ldots\ldots + \beta n \ Xn \quad (1)$$

Where;

Log-Gap= logarithm of accepted gaps; Xi-n= explanatory variables;

β1-n= are estimated parameters from the model; β0= constant

Table 1 presents the variables that can affect the accepted gap size. A R-squared value of 0.736 indicates that 73.6% of accepted gap size's variation can be predicted in this model. Out of the significant independent variables, traffic speed and crossing distance has negative impact on the on the accepted gap size. This implies that the increase of traffic speed or crossing distance results a lower accepted gap size. On the other hand, the positive coefficient represented by gap acceptance, vehicle size and pedestrian waiting time indicates that the high value of these variables can result a higher accepted gap size.

The final model was as the following:

Log-Gap = 1.066 - 0.002*Traffic Speed + 0.068*Gap Acceptance – 0.032*Crossing Distance + 0.101*Vehicle size + 0.029*Pedestrian Waiting Time

Where,
Traffic Speed: Speed of the vehicle at crosswalk area.
Gap Acceptance: Whether a pedestrian is rejecting or accepting gap.
Crossing Distance: The distance which crossed by pedestrian from curb to curb
Vehicle size: size of vehicle (small / large)
Pedestrian Waiting Time: Time spent by pedestrian at the curb for suitable gap.

Logistic regression

The pedestrian crossing decision making is explained by the binary logit model (BL Model). The probability of choosing an alternative (reject/accept) is based on a linear combination function (utility function) expressed as:

$$U_i = \alpha_i + \beta_{i1} X_1 + \beta_{i2} X_2 + \beta_{i3} X_3 + \beta_{i4} X_4 + \ldots\ldots + \beta_{in} X_n \quad (2)$$

Where;

U_i = the utility of choosing alternative i; i= the alternative (accept/reject)
n = number of independent variables;
α = constant;
β = coefficients

The utility of alternative 'i' has to be transformed into a probability in order to predict whether a particular alternative will be chosen or not. The probability of choosing alternative 'i' is then calculated using the following function:

P(i)=e^u/(e^(u)+1) (3)

In this study a binary logistic regression was built to study the choice behavior (accepted/rejected). As shown in Table 2, the model yields an overall prediction accuracy of 86.4%. Of all the independent variables, only the gap size (G_S), traffic waiting time (T_W_T), vehicle size (v_size), and illegal parking (I_P) are significant in predicting the probabilities of the acceptance (refer to Table 3).

Table 1 .Multiple Regression Result

Variable	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.066	.163		6.543	.000
Traffic Speed	-.002	.001	-.086	-2.096	.038
Gap Acceptance	.068	.030	.095	2.297	.023
Vehicle size	.101	.048	.068	2.090	.038
Crossing Distance	-.032	.014	-.089	-2.195	.030
Pedestrian Waiting Time	.029	.001	.827	19.854	.000

a. Dependent Variable: log_gap R square = 0.736

Table 2. Model Validation

Observed			Predicted		
			Gap Acceptance		Percentage Correct
			ReJect	Accept	
Step 1	Gap Acceptance	Reject	3	21	12.5
		Accept	2	143	98.6
	Overall Percentage				86.4

a. The cut value is .500

Table 3. Logistic Regression Result

Variables		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1[a]	G_S	.174	.059	8.755	1	.003	1.191
	T_W_T	-.177	.083	4.515	1	.034	.838
	v_size(1)	3.007	1.031	8.514	1	.004	20.222
	I_P(1)	-1.237	.551	5.048	1	.025	.290
	Constant	-1.952	1.240	2.478	1	.115	.142

a. Variable(s) entered on step 1: G_S, T_W_T, v_size, I_P.

UI = -1.952 + 0.174*G_S – 0.177*T_W_T + 3.007*v_size – 1.237*I_P (4)

Where;
Gap size (G_S): Time gap between two vehicles with reference to crosswalk point
Traffic waiting time (T_W_T): Time spent by driver at the street to provide a suitable gap for pedestrian to cross.
Vehicle size: size of vehicle (small / large)
Illegal parking (I_P): whether presence of illegal car parking or not

The probability that a pedestrian crosses the street is:

$$P = e^{-1.952 + 0.174*G\_S - 0.177*T\_W\_T + 3.007*v\_size - 1.237*I\_P} / (e^{-1.952 + 0.174*G\_S - 0.177*T\_W\_T + 3.007*v\_size - 1.237*I\_P} + 1) \quad (5)$$

IV. DISCUSSION

A.The Effect Of Traffic Gap Size On Gap Acceptance

Figure 3. measures the impact of gap size towards the probability of gap acceptance. The probability of accept acceptance is lower with a lower gap size. It was found that the pedestrian will accept the gap when at a gap size of approximately more than 41 sec; this means that in reality pedestrians when they are attempting to cross they are paying more attention to size of gap between traffic in order to cross safely. In fact, when we reviewed back to the raw video data, we observed that many pedestrians wait for a long time to find a longer gap size that they can accept, even when the gap is seems safe to be utilized, resulting in the fact that such pedestrians wait for large gap size can be regarded as a potential proper behavior as there are no facilities to protect pedestrian to the on such these locations In general it can be noticed that there is a probability of increasing pedestrian gap acceptance with the increase of the gap size

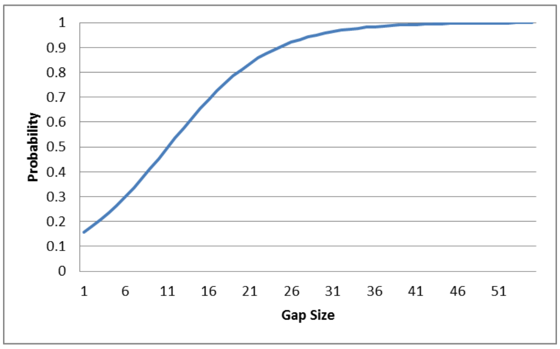

Figure 3. Probability of the Pedestrian's Gap Acceptance

B. The Effect Of Traffic Waiting Time On Gap Acceptance

Figure 4. Measures the impact of gap size towards the probability of gap acceptance by traffic waiting time. The probability of accept acceptance is lower with a higher traffic waiting time.it can be seen that The result shows that increase in traffic waiting time decreases the accepted gap size and it has been found that longer traffic waiting time lead the pedestrian to become not ready to accept available vehicular gaps. This may be attributed to the fact that a crossing a street seems not safer when driver stop his vehicle for pedestrian to cross the road.

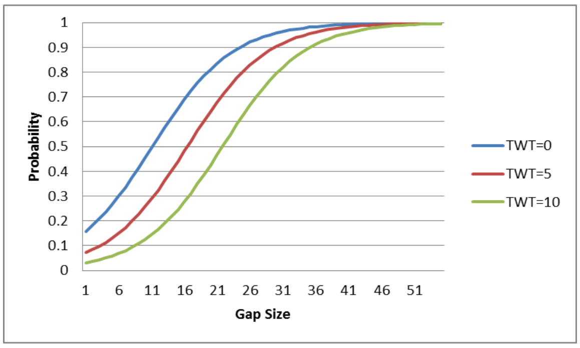

Figure 4. Probability of the Pedestrian's Gap Acceptance

B. The effect of vehicle size on gap acceptance

Figure 5. measures the impact of gap size towards the probability of gap acceptance by vehicle size. The probability of accept acceptance is lower with a smaller vehicle size. Generally, vehicle size is important element for accepting the gaps, but this research has discovered that pedestrians are accepting vehicular gaps in terms of vehicle speed. It can be give a justification by the fact that small vehicles may come with higher speeds. So, the pedestrian may not accept the available gaps with small vehicles in mixed traffic condition at higher speeds and sometimes large vehicle gaps may be accepted due to less speed. So due to this, size of the Traffic plays a significant role in both the models (Binary logit and Multiple Linear Regression).

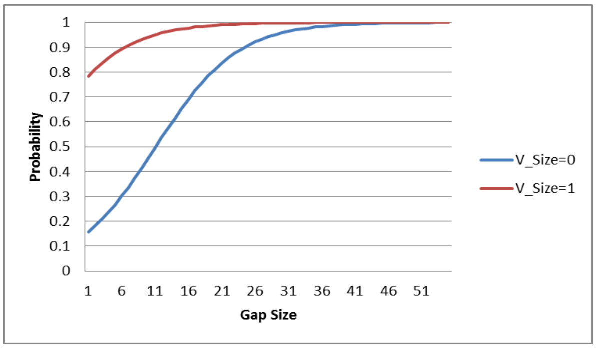

Figure 5. Probability of the Pedestrian's Gap Acceptance

C.The effect of illegal parking on gap acceptance

Figure 6. Measures the impact of gap size towards the probability of gap acceptance by illegal parking. The probability of accept acceptance is lower with the present of illegal parking. The result shows that the presence of illegal parking has the first larger impact on Gap acceptance. Illegal parking made pedestrians more careful and acceptant of larger gaps. Moreover the presence of illegal parking leads pedestrians to pay more cautious to cross the street. This may be attributed to the fact that a crossing seems not safer when part of the crossing distance is taken by parked vehicles. However, the result shows that illegal parking has an effect on pedestrian's gap acceptance and their decisions to cross or not.

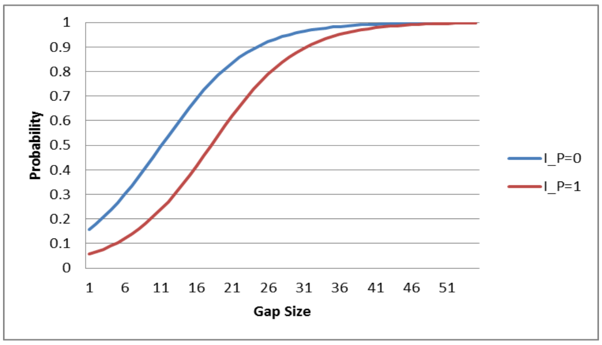

Figure 6. Probability of the Pedestrian's Gap Acceptance

V. CONCLUSION

This research contributes statistical analysis of pedestrian road crossing A field survey and observation was carried out to find effect of several factors on pedestrian crossing which includes observation of pedestrian waiting time at curb, observations gap size between traffic, measuring traffic speed and crossing distance, observation size of traffic, observation duration while crossing, as well as duration traffic waiting time at crossing area and illegal parking, out of several proposed ones these factors are identified to be significant enough to be included into the model in order to investigate pedestrian traffic gap acceptance for uncontrolled Mid-block Street crossing in urban location in Malaysia,

The initial results with the lognormal regression analysis were implemented for modeling pedestrians' traffic gap acceptance. It has been discovered that the accepted gaps in Rughaya Street depend on the speed of traffic, the size of the Traffic, the pedestrian waiting time, the crossing distance. It seems that pedestrian select the highest and the safest gaps, especially when the approaching vehicle is large and when there is a car parked illegally. Generally, pedestrian prefer not to accept a lower gap size as long as traffic speed is very high or crossing distance is long, besides, gap acceptance, vehicle size and pedestrian waiting time referees that the high value of these variables can result a higher accepted gap size.

For the choice analysis (accepted/rejected), a binary Logit model was developed in order to statistically analysis the impact of several factors on the decision of pedestrians to cross or not cross the street. The result was showed that the Pedestrian Gap Acceptance BL model achieves well with 86.4% accuracy in predicting the gap acceptance of pedestrians. It was found that the accepted gaps depend on Traffic waiting time, Vehicle size, Illegal parking and Gap size. Furthermore, None of Pedestrians' characteristics has been found significant in crossing choice in this study; only basic roadway and traffic parameters were found to affect pedestrians crossing decisions. In addition, it has been discovered that vehicular gaps size accepted by pedestrians were with respect to traffic speed rather than traffic size. This might be explained by the fact that small vehicles have higher speed than large vehicles in central area.

The research could not capture exact individual pedestrian age. The pedestrian path change condition is also considered as continues variables in this study, whereas in real situation male or female pedestrian may change crossing path in different directions while crossing. Future work could investigate pedestrian age. Moreover this research can be extended to different urban areas in Malaysia to evaluate the pedestrian gap acceptance behavior. The inferences from the developed models in this study will be useful to evaluate existing pedestrian gap acceptance behavior and develop the current facilities to upgrade pedestrian safety in Malaysia.

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BIOGRAPHIES

Issam Omran m.f alajnaf was born in Gharyan /Libya, on July 22, 1982. He received Bsc degree in civil engineering from Al-Jabal Al Gharbi University of Gharyan, in 2007/2008. He got Msc degree in Civil and Structural Engineering from National University of Malaysia in 2011.