Pedestrians' Behavioural Analysis During Road Crossing

B. Raghuram Kadali and Dr.P. Vedagiri

Abstract--- *Pedestrian gap acceptance is one of the most important components in microscopic traffic characteristic in pedestrian road crossing. Pedestrian road crossing needs a mathematical model of pedestrian gap acceptance behaviour, to capture exact behaviour of pedestrian during road crossing. In this paper, a gap acceptance model was developed based on the discrete choice theory. A binary logit model is considered to examine pedestrian behaviour on pedestrian road crossings. To develop this model, survey conducted at mid-block location at Ameerpet in Hyderabad. These real data are used to set up explanatory variables and to estimate the model. The probabilities of crossing the road an each pedestrian, it is the response to an encounter are identified for a variety of pedestrian physical characteristics, vehicular characteristics, pedestrian tactics and traffic conditions. Results shows that the most important explanatory variables included in the model are vehicular gap size, frequently attempting gap, rolling gap and vehicle speed plays main role in pedestrian gap acceptance while crossing the road. It is felt that the model performed well, the behaviour of the pedestrians' is well captured by pedestrians' tactics. It is useful technique for identifying the most hazardous situations and locations within an area, for pedestrian facilities planning relevant safety measures. It should be further studies required to know the heteroscedasticity between the pedestrian physical characteristics and fine tuning the model.*

Keywords--- *Pedestrian, Gap, Logit, Acceptance, Crossing*

I. Introduction

WALKING is an effective and healthy mode of transport. It is environmentally beneficial and most sustainable mode in transportation system. Every person is a pedestrian in their journeys at some point either as a main mode of travel or as part of a multimodal trip. Pedestrians form an integral part of the urban transportation system and it is one of the most important mode of transport in the urban environment for short trips. Short trip lengths within the urban environment would be more appropriate by walking as compared to other modes so long as the facilities are being provided. However, roads can be barriers to pedestrian movement. Marked crosswalks are the infrastructures for pedestrians to walk or cross the streets. Pedestrians need to cross the roads at some locations during the course of travel. The crossing locations should provide safe and comfortable movement. In general, there are two types of crossings i.e., at-grade and grade-separated. They are provided exclusively based on traffic intensity. If crosswalks are too apart from each other, pedestrians have to take longer detours, which will leads to the jaywalking condition. Then pedestrians will be more or less forced to cross motor vehicle lane by violation, causing more interference with vehicles. Road crossing behaviour may be influenced by a number of non-volitional factors, such as judgment of speed of vehicular traffic, vision and road conditions. It is predicted that perceived behavioural control would be the most important predictor of road crossing intentions. A pedestrian conflict situation occurs when a pedestrian crosses in front of a vehicle, thus creating a potential collision situation. The vehicle brakes or swerves, then continues through the intersection. Any such crossing on the near side of the intersection is considered to be a conflict situation. The decision making of the pedestrian whether they walk or not mainly depend on comfort and convenience of walking facilities and alternative modes of transportation along the route.

The gap acceptance mechanism is the modelling process which is directed to an individual behaviour of a pedestrian. Pedestrian selects a gap (or lag) of suitable size in a traffic stream for the safe crossing of a street. There are two aspects that should be followed in pedestrian gap acceptance mechanism. The pedestrian arrival processes, i.e., the distribution of pedestrian inter arrival times and how pedestrians react to gaps in the traffic stream. Sometimes pedestrians continue walking on the sidewalk and wait for the sufficient gap in traffic stream before attempting to seek a suitable gap to cross. An uncontrolled crossing is a crossing that does not have any traffic control measure to provide a dedicated pedestrian right-of-way. Pedestrians must wait for a safe gap sufficient to fully cross the roadway or for vehicles to stop before crossing Wang et al. (2010). Based on the ambiguity caused by movement of pedestrian and vehicle in a time and space resource aspect, the pedestrian-vehicle conflict is defined as the occurrence of collision between pedestrians and vehicles in a given road segment when they approach to a certain degree in the range of time and space without any trend to change their initial movement state. The affected area of the conflict is the whole lane width where vehicles go. When crossing at un-controlled roadway segment, the pedestrians' usually judges the running status of vehicle flow. If the available time gap (Headway) of an approaching vehicle is a less than safe gap, pedestrians' may think it is not safe enough and decide to wait aside instead of going across. But if the time gap of approaching vehicle is more than the safe gap, they will think it is safe to cross the road. This process is

B. Raghuram Kadali, Ph.D Scholar, IIT Bombay. E-mail: raghukadali@gmail.com
Dr.P. Vedagiri, Assistant Professor, IIT Bombay.

usually called as safe gap perception Fang, and Zheng (2009).

II. Literature Review

There are numerous studies available on vehicle gap acceptance; there are very few studies available on pedestrian gap acceptance. Pant et al. (1994) explained the gap acceptance behaviour of vehicles at stop controlled intersections by using neural networks and a binary logit model. Their model deals with vehicle gap acceptance mechanism and they did not consider the pedestrian gap acceptance. Varhelyi (1998) studied the frequency of giving way to pedestrians, speed adaptation problems at the zebra crossing. These results indicate that drivers do not intend to give way to the pedestrian at the zebra crossing. Evans and Norman (1998) examined the pedestrians' road crossing intentions in a three potentially hazardous situations and pedestrian behaviour observed by their attitude, perceived behavioural control and behavioural intention. From the results they concluded that there is a strong relationship between perceived behavioural control and road crossing intention. Hamed (2001) studied pedestrian behaviour at pedestrian crossings, to understand the behaviour of pedestrian when waiting for the crossing and number of crossing attempts at the curb side. The study concluded that pedestrian behave differently with different waiting times. Avineri et al. (2011) studied two specific aspects of crossing behaviour pedestrians' crossing speed and head pitches the proportion of time when pedestrians have their heads down. This study shows that the age difference and fear of falling have significant effects on pedestrian crossing behaviour. Jiangang et al. (2007) studied pedestrian behaviours and traffic characteristics at un-signalized midblock crosswalk. They concluded that the results will not only improve the pedestrian facilities at interrupted facilities, but also help to develop pedestrian safety.

Himanen and Kulmala (1998) developed multinomial logit (MNL) model that describes the behavior of drivers and pedestrians in their encounters on pedestrian crossings. From the results they concluded that the model should enable to evaluate the risks involved in pedestrian crossing situations. Sun et al. (2003) studied pedestrian gap acceptance (PGA) and motorist yield (MOY) behaviour at un-signalized marked mid-block crosswalks. Two different models, probability based model and PGA binary logit model are developed for capturing the PGA behaviour. They concluded that the PGA binary logit model performs very well, for predicting the gap acceptance of pedestrians. Das et al. (2005) examined the behaviour of pedestrians, when crossing a stream of traffic at signalized intersections. From the results they found that men and women in the same age group have similar distributions of critical gaps, but pedestrians appear too different by age in their crossing behaviour.

Brewer et al. (2006) studied pedestrian gap acceptance behaviour at different locations. They evaluated the gap-acceptance behaviour of crossing pedestrians with a two-part analysis viz. behavioural analysis and statistical analysis. Behavioural analysis revealed that pedestrians did not always wait to cross the street and used a "rolling gap" to cross the street. Guangxin, and Keping (2009) studied pedestrian's gap selecting behaviour, it contributes in improving the understanding of pedestrian's psychology and behaviour, which is important to improve pedestrian's safety. From the results they concluded that pedestrian's safety margin time is very useful to analyse the influence factor of their behaviour. Fang, and Zheng (2009) studied safety problem of a pedestrian, while crossing the non-signal controlled multi-lane segment. Wang et al. (2010) studied pedestrians' gap acceptance behaviour when they jaywalk, outside crossing facilities, which is regarded as the most basic and important part to improve current Pedestrian-Vehicle Interaction (PVI) behaviour at mid-block pedestrian crossings. From the results they concluded that near-side traffic gap time, pedestrian's age category and number of pedestrians are most significant factors affected attributes in the pedestrian gap acceptance process.

Yannis and Papadimitriou (2010) studied pedestrian traffic gap acceptance for Mid-block Street crossing in urban areas. A lognormal regression model was developed in order to examine the effect of various parameters on pedestrian gap acceptance. They concluded that pedestrian gap acceptance was better explained by vehicle distance rather than the vehicle speeds. However, most of the above pedestrian gap acceptance studies were carried out in developed countries, where infrastructure of the vehicular and pedestrian correspond to improved levels of service, the outcome of these studies can't be transferred and used in developing countries like India. Due to insufficient facilities the behaviour of pedestrians is particularly non-acquiescent and often risk-taking. In this context, it is very important to study the pedestrian gap acceptance. The aim of this research is to investigate pedestrians' traffic gap acceptance for mid-block Street crossing in urban areas. In particular, the effect of several factors, such as pedestrians waiting time, the vehicular characteristics (speed. size) and finally pedestrians' characteristics (gender, age) affect the traffic gap acceptance of pedestrians and their decision to cross or not.

III. Methodology

To full fill the above objective, a field survey was carried on 21st December 2011 in Hyderabad at Ameerpet uncontrolled mid-block location. Figure 1 shows pedestrian arrival process at curb side, where there is no nearby pedestrian crossing facility. Some pedestrians choose the jaywalking after arrival on the curb side in a mid-block area rather than searching an alternative route with a proper crossing facility. Existing literature suggests that the pedestrian's decision whether to step onto the vehicular lane to start or to cross or to stop or walk along the edge of the vehicular lane to wait for the next available crossing opportunity is related to available gap size in traffic stream and the pedestrian's characteristics. Since the pedestrians have two alternatives: to accept and get ready to star t to cross or to reject, a discrete choice approach is appropriate to model this process.

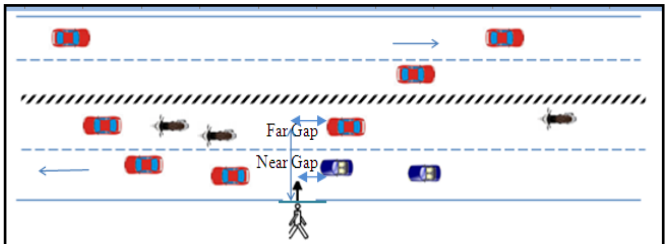


Fig 1. Critical Mid-block unsignalized pedestrian road crossing section

Discrete choice models have gained attention for studying gap acceptance studies. Sun et al. (2003), Yannis and Papadimitriou (2010) studied the pedestrians' gap acceptance behaviour at a zebra crossing using a binary logit model. The logit model is appropriate whenever modeling with two alternatives. However, the gap acceptance behaviour in unsignalized and developing countries, conditions has not been studied as explicitly as those with certain types of pedestrian crossing facilities. In this study, the pedestrian decision making process is described at uncontrolled mid-block location by the binary logit model (an individual choice with two alternative outputs). The following are the factors considered, pedestrian physical characteristics, vehicular characteristics, pedestrian waiting time, pedestrian platoon condition, type of gap, rolling gap, pedestrian speed condition during crossing and pedestrian direction condition to study the pedestrian gap acceptance behaviour. At first, the video was captured and saved as several jpeg file format by a software tool named Video SnapshotWizard to get a serial of pictures. A video of length 1 sec can obtain 30 pictures. From each snapshot, data collected included the size of gaps rejected or accepted by pedestrians, waiting time, number of crossing attempts, each vehicle's speed, type of vehicle, near or far gaps, crossing direction, pedestrians' speed condition, whether they use rolling gap or not, effect of baggage and individual pedestrians' characteristics (gender, age etc.). The probability of choosing an alternative is based on a linear combination function (utility function) expressed as:

$$U_i = \alpha_i + \beta_{i1} * X_1 + \beta_{i2} * X_2 + \beta_{i3} * X_3 + \beta_{i4} * X_4 + \ldots\ldots \beta_{in} * X_n \quad (1)$$

U_i: the utility of choosing the alternative i
i: the number of alternatives (Here two alternatives accept or Reject)
n: the number of independent variables; α: constant; β_1 : 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 with the following function

$$P(i=1)=1/(1+e^{-ui}) \quad (2)$$
$$P_{Ai}=\exp(U_{Ai})/(\exp(U_{Ai})+\exp(U_{Bi}))=1/(1+\exp(-(U_{Ai}-U_{Bi})) \quad (3)$$
$$U_{Ai}-U_{Bi} = \beta(Z^{Ai}-Z^{Bi}) = \beta Z^i$$

Where β = row vector of parameters (coefficient of variables) to be estimated; and Z^{ji}= column vector of attributes of individual *i* and characteristics of mode *j* Sun et al. (2003).

The calibration and validation of the binary logit model encompasses the determining the parameter vector β, which is accomplished by using the data collected from field survey. In this present study fallowing thirteen different variables incorporated to calculate the utility function to captures the pedestrian decision making process (Choice = 0: rejecting a gap, Choice = 1: accepting a gap), including:

- GEN : pedestrian's gender (0: Male, 1: Female);
- AGE: pedestrian's age (0: Elders, 1: Middle: 2: Youngers);
- GAPS: gap size in seconds;
- TGAP : Type of gap near or far-side (relative to pedestrian crossing direction)
- FATM: frequently gap attempting or not (1:yes, 0=no);
- GSIZE: pedestrian platoon size;
- BAGG: baggage effect (1:yes, 0=no);
- WT : pedestrian's waiting time in seconds;
- RGAP: rolling gap (1:yes, 0=no);
- DCS: pedestrian direction of crossing (1:yes, 0=no);
- SC: pedestrian speed change condition during crossing (1:yes, 0=no);
- SV: speed of vehicle in kmph;
- TV: type of vehicle ((0: heavy, 1: car, 2=two wheeler, 3= three wheeler);

Hence, the general form of the binary logit model for pedestrian gap acceptance is

$$U_1 = \alpha + \beta_1 * GEN + \beta_2 * AGE + \beta_3 * GAPS + \beta_4 * TGAP + \beta_5 * FATM + \beta_6 * GSIZE + \beta_7 * BAGG + \beta_8 * WT + \beta_9 * RGAP + \beta_{10} * DCS + \beta_{11} * SC + \beta_{12} * SV + \beta_{13} * TV \quad (4)$$

$$P\,(\text{Accepting Gap}=1) = 1/(1+e^{-U_i}) \quad (5)$$

IV. RESULTS AND ANALYSIS

Pedestrian's gap acceptance behaviour is a sophisticated condition and it is supposed to be influenced by pedestrian's physical characteristics, pedestrian tactics, available gap size and speed of the vehicle. For the analysis 4198 gaps were collected including accepted and rejected gaps, out of these data 212 samples were accepted gaps, with 75% for estimating the coefficient of the utility function and 25% for model validation. For the pedestrian gap acceptance binary logit model NLOGIT 4 software was used. A multivariable binary logit analysis was performed in NLOGIT, which estimates the coefficients of the linear utility function using the maximum likelihood method. Table 1 shows the result of coefficient estimation. The utility equation for the pedestrian gap acceptance from the calibrated data, the estimated binary logit model presented in the equation (6) and the probabilities are calculated by the equation (5). Among the thirteen variables only four variables are identified significant by t-value and to be included into the binary logit model. The pedestrian's physical characteristics (age and gender) are found as insignificant, because it has been found that when the pedestrians' are using rolling gaps then they are accepting small gaps also irrespective of their characteristics. From the Table 1 signs of coefficients show that all included variables are logically significant. The gap size shows positive sign which is indicates that increasing of gap size leads to the increasing of probability of acceptance. If pedestrians' are frequently attempting available gap, then probability of accepting gap also increases and also by rolling gap probability of acceptance increases. The increasing vehicular speed shows that decreasing the probability of acceptance. The validation of the present model is by success and prediction table as shown in Table 2. For the modelling total 3146 data points were considered out of these 2968 rejected gaps and 178 were accepted gaps. For modelling part actual rejected (P=0) values are observed as 2968 and it predicted as 2953 and actual accepted gaps are 178 out these 138 correctly predicted. The overall correctly predicted data as 98.25% in modelling process. For the validation part total data points are 1052 out of these 1018 are rejected and 34 are accepted gaps. Correctly predicted rejected values are 1013 and predicted accepted gaps are 26, overall prediction is 98.7%. So the proposed model is strong enough to predict the gap acceptance behaviour at uncontrolled mid-block location.

$$U_1 = -8.8955 + 2.7858 * GAPS + 0.4893 * FATM + 3.7886 * RGAP - 0.1037 * SV \quad (6)$$

Table 1 Estimated Coefficient

Parameter	β	Standard Error	Wald-Value	Significance
GAPS	2.7858	.174	15.418	0.000
FATM	.4893	.248	1.972	.0830
RGAP	3.7886	.326	10.319	0.000
SV	-.1037	.0236	-4.413	0.000
Constant	-8.8955	.776	-11.030	0.000

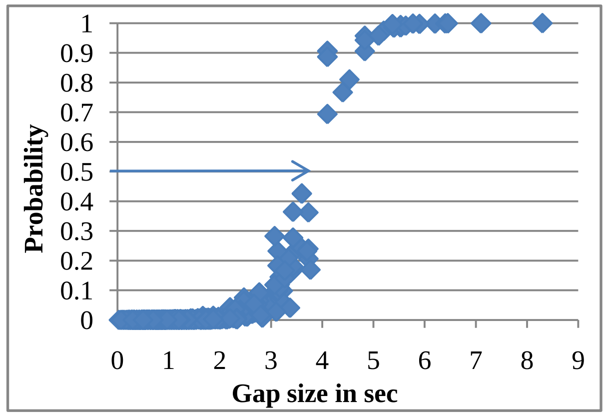
Table 2 Success and prediction Table for Modeling and Validation

Actual Values	Predicted values for Modelling		Total Actual	Predicted values for Validation		Total Actual
	0	1		0	1	
0	2953	15	2968 (94.3 %)	1013	5	1018 (96.7 %)
1	40	138	178 (5.7 %)	8	26	34 (3.2 %)
	2993 (95.1 %)	153 (4.9 %)	**3146**	1021 (97 %)	31 (3 %)	**1052**
	Overall Prediction is 98.25 %			**Overall Prediction is 98.7 %**		

A. Effect of Gap Size on Pedestrian Gap Acceptance with and Without Rolling Gap

The available gap in a traffic stream is a significant influencing factor on the pedestrians' gap acceptance behaviour. Some of the previous studies explained that the male pedestrians accept small gaps when compared to females. Similarly youngsters accept very small gaps than the elders. The present studies found that irrespective of their gender, age and pedestrian platoon they tend to accepting gaps because of rolling gap effect. But it obviously shows that, the gap size increases the probability of the acceptance increases.

Effect of vehicular gap size on pedestrians' probability of gap acceptance with and without rolling gap is shown in Fig. 2. It clearly indicates that in reality pedestrians scarcely pay attention to the far-side incoming vehicles and the actual real gaps available in the traffic stream when they step on the road to cross the road. Fig. 2 states that if the available gap larger than the mean gap also they rejecting, in this case it is very hard to predict the actual behaviour of pedestrians'. In Fig 2(a) pedestrian gap acceptance is considered with rolling gap and then it states that irrespective of available gap size they accepting small gaps also. Fig 2(b) also indicates that, if pedestrians' are not using rolling gap then the minimum gap required for acceptance is more than 3.2 sec. In fact, from the field survey real scenario, it observed that many pedestrians cross the road regardless of the gap size, gap type (Far or Near), baggage effect, even when the near-side gap is too small to be utilized by different criteria's like rolling gap, increasing speeds and direction changes. It results that they accept the minimum gap size, such pedestrians as a potential dangerous situation and it indicates those different types of crossing as very less safety.



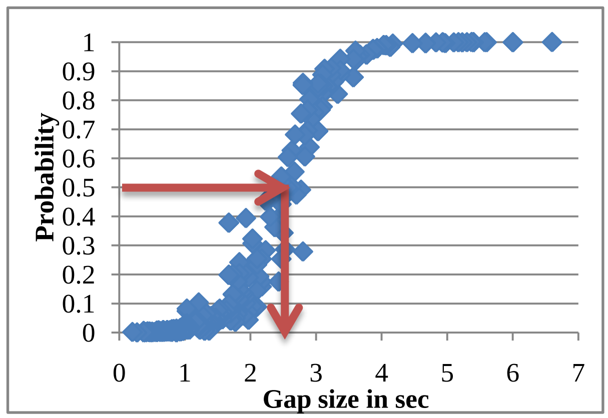


Figure 2(a): Probability of the Pedestrian's Gap Acceptance (Rgap = 1) Figure 2(b):Probability of the Pedestrian's Gap Acceptance (Rgap = 0)

B. Effect of Frequently Attempting Gap on Pedestrian Gap Acceptance

The effect of frequently attempting gap on pedestrians' gap acceptance behaviour is shown in Fig.3. It indicates that, if pedestrians' do not attempt frequently small gaps i.e., FATM=0, then gap acceptance will decreases with available gap sizes and also it suggest that they accept only with larger gaps. Fig 3 (b) indicates that pedestrians' attempting case (FATM=1), if pedestrians' are attempt small gaps then the probability of acceptance with small gaps also very high. One possible explanation is that when a particular pedestrian waiting time increases, then they start to attempt small gaps and also they attempt small gaps by increasing their speeds, changing their direction and rolling gaps then finally they succeed with small gap size.

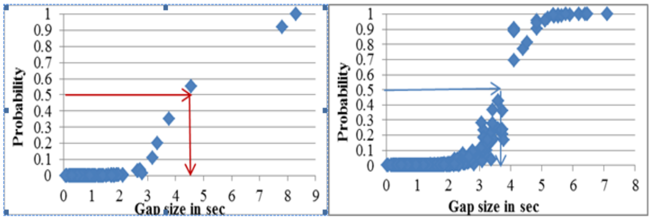


Fig 3(a). Probability of the pedestrian's gap acceptance (FATM = 0) **Fig 3(b).** Probability of the pedestrian's gap acceptance (FATM = 1)

V. Conclusions

This paper studied and explained the pedestrians' gap acceptance behaviour at mid- block location without any pedestrian facilities by using binary logit technique. Thirteen factors are considered in the modelling; out of which four are identified to be significant enough to be included into the binary logit model. The main application of these results indicates those pedestrians are safe at un- marked road crossing with effect of included factors in the model. The result indicates that pedestrians' decision to cross the street depends on the traffic gap, frequency of attempting gap, rolling gap and vehicle speed. It was found that pedestrians crossing decisions are strongly associated with the pedestrian rolling gap condition and available gap size in the traffic stream. It is also found that there is no significant effect of pedestrian physical characteristics on gap acceptance behaviour. On the argumentative, traffic flow conditions were found to be the most vital component of pedestrian crossing behaviour. The frequently attempting gap is significantly contributing on pedestrians' decision making process. In the present study vehicle speed also shows significant contribution on the pedestrian gap acceptance behaviour.

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