EXAMINING PEDESTRIAN GAP ACCEPTANCE BEHAVIOUR AT URBAN MIDBLOCK CROSSWALKS IN INDIA

Vinayaraj V.S.[a], Avinash CHAUDHARI[b], Sumit TOSHNIWAL[c], Shriniwas ARKATKAR[d], Guarang JOSHI[e] Manoranjan PARIDA[f]

[a]*Post Graduate Student, Department of Civil Engineering, SVNIT, Surat, Gujarat - 395007, India*
[a]*E-mail: vinayaraj4u@gmail.com*
[b]*Ph.D Scholar, Department of Civil Engineering, SVNIT, Surat, Gujarat, - 395007, India*
[b]*E-mail: avinashchaudhari17@yahoo.com*
[c]*Under Graduate Student, Department of Civil Engineering, SVNIT, Surat, Gujarat - 395007, India*
[c]*E-mail: sumittoshniwal89@gmail.com*
[d]*Assistant Professor, Department of Civil Engineering, SVNIT, Surat, Gujarat, - 395007, India*
[d]*E-mail: sarkatkar@gmail.com*
[e]*Associate Professor, Department of Civil Engineering, SVNIT, Surat, Gujarat, - 395007, India*
[e]*E-mail: gjsvnit92@gmail.com*
[f]*Professor, Department of Civil Engineering, IIT, Roorkee, UK-247667, India*
[f]*E-mail: mparida@gmail.com*

Abstract: Mid-block crosswalks act as connectors between adjoining activities based on a particular land-use type. At mid-bock, there are higher chances of conflict between a crossing pedestrian and an approaching vehicle. Therefore, uncontrolled midblock pedestrian road crossing is a serious menace particularly under heterogeneous traffic conditions. This paper mainly emphasizes on the pedestrian gap acceptance process at midblock sections. Field surveys were carried out through video-graphic technique, capturing the Pedestrian as well as the behaviour characteristics and traffic characteristics. The present research work is carried out to focus on gap acceptance behaviour and decision making model are to be developed at uncontrolled mid-block crosswalk section for Indian urban road conditions. The study reveals that pedestrian behavioural characteristics like rolling gaps and platoon size plays an important role in pedestrian uncontrolled road crossing. The results may be useful in the designing of pedestrian facilities and suggest appropriate remedial measures to improve pedestrian-safety.

Keywords: *Mid-block, Vehicle speed, Rolling gap, behavior, Gap acceptance.*

1. INTRODUCTION

Walking is considered as the most primary mode of transportation at different stages of a journey and is usually recommended for a healthier lifestyle. It can be considered as a good example of sustainable transportation mode, especially suitable for relatively shorter distance. While walking, people use a sidewalk, crosswalk or Skywalk to reach their destination and these modes are connected to public transit. The crosswalk can be defined as a marked or unmarked path where pedestrians can safely walk across a street or road. It act as connectors between adjoining activities based on a particular land-use type. In general, pedestrians are often allowed to cross the road at the intersection along the zebra marking because these intersections are controlled by signal systems which enhances the safety for pedestrian crossing. Over the last decades, due to exponential increment in the vehicular growth, each category of the urban road faces the heavy traffic volume which can lead into accident risk not only for pedestrians but also for vehicular traffic. Traffic in India, a developing country, is highly heterogeneous in nature. While crossing mid-block section, the pedestrian-vehicle interaction is more, which leads to higher risk of accidents and safety problems. Pedestrians are one of the most vulnerable road users at un-signalized midblock sections. Therefore, pedestrian road crossing is a serious menace to pedestrians at uncontrolled midblock crossing locations under mixed traffic flow conditions in India. The non-exclusive facility for pedestrian crossing is quite common in Indian condition and it often leads to fatal accidents. During the year 2012, the percentage of pedestrians involved in road accidents in major cities were-14.02 % in Kolkata, 38 % in Chennai 20%, Delhi, 64% in Mumbai (MoRTH, 2010) and 13% in Ahmedabad (Ahmedabad and Gandhinagar road accident study, 2012). Among them, 60% of the total pedestrians were involved in fatal accidents. The pedestrian and bicycle fatalities in India is 27.4% (MoRTH, 2010) and most of the pedestrian fatalities (85%) are observed at mid-block locations (Mohan et al, 2009) and 54% pedestrian accidents are related to road crossing (Kumar and Parida, 2011). The ministry of urban Development (MoUD) studies found that 19% of the pedestrians are accused in road accidents (MOUD, 2008). Some studies have found that 8.3% of fatal pedestrian accidents in India occur in road accidents at mid-block crosswalks (NCRB-2013), and global studies show that over the last two decades, the number of pedestrian related road crashes have risen drastically in non-intersection locations where pedestrian trips are more than other modes of transportation (NHSTA-2015). The above records indicate that pedestrians are the most vulnerable component of the transportation system in Indian urban road network. Most of the studies related to pedestrian crosswalk is grounded on the pedestrian crossing speed with the effect of pedestrian demographic as well as gap acceptance criteria, whereas, limited studies are available related to modeling of pedestrian behavioral characteristics such as rolling gap, pedestrian speed change, pedestrian path change, and platoon size. Modelling of pedestrian and vehicular interactions in four lane divided street crossing environment is a complex task because of wide set of action of pedestrian and dynamic behaviour of vehicle movements. Hence, modeling pedestrian crossing behavior at uncontrolled midblock sections in mixed traffic condition will prove to be useful in understanding and improving the pedestrian-safety aspects and help in the designing of pedestrian facilities.

2. LITERATURE REVIEW

The background of the research examined for the comprehensive review of existing literature related to pedestrian crossing behaviour and pedestrian individual characteristics on mid-block crosswalk. Various approaches were adopted for the assessment of the critical gap and its applicability in heterogeneous traffic condition was also scrutinized through various literature. (Hamed et al., 2001) observed that female pedestrian waiting time is more than male pedestrian to cross the street. Oxley et. al. (2005) found in his study that most of the crossing cases involving elderly pedestrians accept more time gap. Kadali et al. (2013) conducted a study on pedestrian speed change while crossing the road. (Rastogi et al., 2011) also carried out studies in pedestrian crossing speed and he mentioned that crossing speed of a male pedestrian is comparable with that of a female pedestrian irrespective of the road type and land use. Most of the male pedestrians have a propensity to show a much riskier road crossing behaviour than female owing to less waiting time (Khan et al., 1999; Tiwari et al., 2007). Pedestrian road crossing behaviour is explained on the basis of gap acceptance theory. Most of the pedestrians choose rolling gap (pedestrian roll over the small vehicular gaps) instead of waiting for larger gaps to cross the street (Brewer et al., 2006; Kadali and Vedagiri, 2013). (Kadali and Vedagiri, 2013) investigated the pedestrian road crossing behaviour at the uncontrolled midblock location under mixed traffic flow conditions. This study concludes that the pedestrian behavioural characteristics like the rolling gap, driver yielding behaviour and frequency of attempts plays an important role in pedestrian uncontrolled road crossing. (Tiwari et al., (2007) collected pedestrian behaviour data at intersections in New Delhi and noticed that a long wait time to cross the road by pedestrian plays an important role in the unsafe behaviour of pedestrians. The pedestrian crossing behaviour can be studied with the help of gap acceptance theory (Dipietro and King, 1970; Himanen, and Kulmala, 1981; Oxley et al., 2005). (Yannis et al., 2013) used a lognormal regression model to develop a binary logistic regression model to examine the effect of traffic gaps and decision to cross the street or not. In his study, he has shown that the strong prediction of pedestrian gap acceptance is possible by approaching vehicle distance rather than the approaching vehicle speed and results also concluded that pedestrian waiting time is an important contributing factor in the decision making process. Chandra et al. (2014) have investigated pedestrian accepted gaps at wide variety of mid-block crosswalk locations under mixed traffic conditions and results concluded that number of lanes, vehicular volume and pedestrian characteristics have great significance on the pedestrian accepted gap values. (Serag 2014) observed that only pedestrian's age and frequency of attempts were found to affect gap acceptance and pedestrian’s individual characteristics were found insignificant in crossing choice.). (Wang et al 2010) used to develop and validate a pedestrian gap acceptance model based on discrete choice approach. Pedestrian walking speed also varies with the prevailing conditions such as environmental, traffic flow (Chandra and Bharti 2013), and also depends on the individual characteristic such as age, gender, direction, luggage condition (Tanaboriboon 1987; Fruin 1981; Laxman et al. 2010; Chandra et al. 2014.

3. STUDY AREA AND DATA COLLECTION METHODOLOGY

For the present study, in order to verify the influence of physical characteristics of the facility, geometry, and cultural diversity of folks, study sites have been selected at two different locations of western part of India, namely Mumbai and Ahmedabad. The reason to choose these locations is the inadequacy of pedestrian-crossing facilities and to analyse the road crossing behaviour of pedestrian at these locations.The survey was carried out in Bandra in Mumbai and Asthodia in Ahmedabad. Locations for data collection were selected on the basis of type of land use, number of lanes (four lane divided), and carriage width of the road as shown in table 1. The study area was located at a distance of 110m and 150m from the intersection at Ahmedabad and Mumbai respectively. Video graphic surveys were carried out from 8:00am to 6:00pm using two high resolution video cameras, mounted on a nearby high rise buildings, which captured the mixed traffic flow as well as pedestrian crossing movement at selected sections simultaneously. Table 2 depicts the 18 variables that are chosen and extracted from the survey data of the above-mentioned sites using Avidemux video editor software. The recorded data were extracted from the video and analyzed. Parameters like pedestrian flow, vehicular characteristics, the demographic composition of pedestrian(age wise), crossing movement, vehicular gap accepted by the pedestrians etc. were obtained. For this gap analysis 8414 gaps were estimated (including accepted and rejected gaps). Analysis based on vehicle composition showed that the mode share of a car was dominant in Bandra whereas in Asthodia, two-wheelers were found to be prevalant. The average vehicular traffic flow at the survey location changed from 2674 to 4612 vehicles per hour at pedestrian flow variation ranging from 610 to1050 Ped/hour and the average speed was ranging from 24 kmph to 27.5 kmph. Hence the present study concentrated on finding the minimum pedestrian gap size to cross the road by Multiple linear regression technique (MLR) and the probability of a pedestrian to cross the street by binary logistic regression (BLR) technique

Table 1. Details of study locations with traffic flow data

Sr. no	Study Location /Classification	Land use Pattern	Classification of the Road	Total Road Width (m)	Pedestrian Volume (Ped /h)	Traffic Volume (PCU/h)	Average Traffic Speed (Kmph)
1	Bandra, Mumbai	Shopping	Four-Lane divided	6.6	1000	2674	24
2	Asthodia, Ahmedabad	Mixed land use	Four-Lane divided	6.7	610	4612	27.5

The time difference between the two points gives the traffic gap accepted by the pedestrian: first one is the point where the pedestrian is just ready to set foot on the road and the second point is the head of the vehicle which has just passed through the vertical virtual line which indicates the crossing path of the pedestrian.

Figure 1a. Snapshot study location in Bandra KFC junction in Mumbai and Asthodia in Ahmedabad

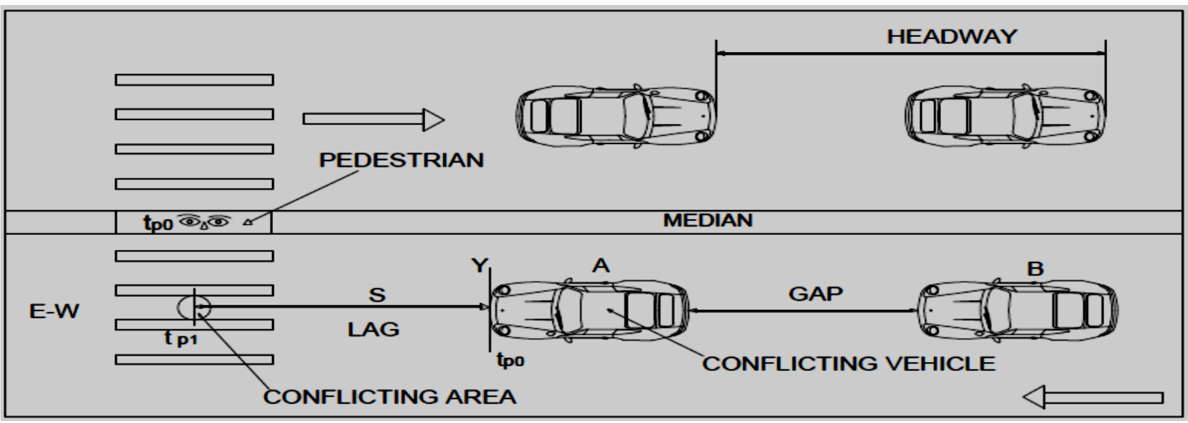

Figure 1b. A schematic diagram of an urban midblock crosswalk section

The extracted data includes decision taking by the pedestrian in terms of accepted gap(sec) rejected gap(sec) which is reported as binary variable,lag (sec), Apporaching vehicle speed (meter/sec) and vehicular gap (sec), pedestrian speed (meter/sec) which is represented in figure1b.

Table 2. List of variables extracted from real time video

Variable (Type of variable)	**Description (unit)**
Gap size (Continuous)	Time gap between two vehicles with Reference to crosswalk point (sec)
Waiting time(Continuous)	Time lost at the curb or median for getting appropriate gap (sec)
Pedestrian speed(Continuous)	The speed with which a pedestrian crosses the road (m/sec)
Frequency of attempt (Continuous)	Number of crossing attempts the pedestrian makes to accept the vehicular gap.
Frequency of disturbance (Continuous)	Number of times the vehicle moving on the paved shoulder (pedestrian standing area) caused disturbance to pedestrian.
Gender (Discrete)	Male or female (0-Female 1-Male)
Age(Discrete)	By visual observation Child <15, Young-aged 16-30, Middle-aged 31-50 and Elders > 50
Pedestrian platoon (Discrete)	pedestrians in the group 1-single, 2-two, 3-three, 4-four
Gap Type(Discrete)	Whether the gap is near to the curb or median. (0: Near1: Far)
Pedestrian speed change(Discrete)	Whether a pedestrian changes speed while crossing the road. (0-No; 1: Yes)
Pedestrian crossing path change(Discrete)	Whether the pedestrian changes crossing path while crossing the road.
Pedestrian rolling gap(Discrete)	Whether pedestrian rolls over the small available gaps. (with stopping and without stopping) (0-No; 1: Yes)
Pedestrian baggage effect(Discrete)	Whether pedestrian is carrying baggage or not (0-No; 1: Yes)
Vehicle category (Discrete)	2-two wheeler, 3-three wheeler, 4-four wheeler, 5-Lcv 6-Bus,7-Truck
Driver behaviour (Discrete)	Whether the driver reduces speed or changes their vehicular path, when pedestrian is already on the carriageway. (0-No; 1: Yes)
Accepted lag or gap(Discrete)	Whether the pedestrian accepts the (first vehicular gap) or successive gaps. (0-Lag; 1: Gap)
Gap acceptance (Discrete)	Whether the pedestrian is accepting gap or rejecting (0-Rejected, 1-Accepted)

4. OUTLINE OF THE MODEL

Pedestrian crossing behaviour, at uncontrolled mid-block sections in Indian cities like Bandra and Asthodia have been modelled by using Multiple Linear Regression technique(MLR) which is the most common form of linear regression analysis. The vehicular gap accepted by the pedestrian is modelled with pedestrian behavioural characteristics and vehicular characteristics chosen as independent variables. The decision-making process of a pedestrian to cross the road can be identified by Binary Logistic Regression (BLR) technique with various socio-economic attributes taken as predictor variables. The output of both MLR and BLR model gives the minimum accepted vehicular gap size to cross the road and the probability of a pedestrian to cross the road with given predictor variables respectively. In this model, the well-designed relationship between input and output variables can be easily represented.

4.1 Multiple Linear Regression model (MLR model)

The crossing behaviour of pedestrians has observed from the field that they may reject more number of available small gap size and they may accept higher gap size. A mathematical model, i.e. a log normal regression was selected (Braduand Mundlak, 1970) by considering that gaps accepted by pedestrians followed a normal distribution. As per probability, log normal distribution is a continuous distribution of a random variable. If the random variable Z is normally distributed, then Y = log Z is a normal distribution. The normal distribution could be successfully fitted to the accepted gap data after taking the logarithm of gaps. The general structure is explained in equation (1)

$$\text{Log-Gap} = \beta 0 + \beta 1\ X1 + \beta 2\ X2 + \beta 3\ X3 + \beta 4\ X4 \ldots\ldots\ldots\ldots + \beta n\ Xn \quad (1)$$

Where

Log-Gap= logarithm of accepted gaps: $X_{i\text{-}n}$= explanatory variables;

$\beta_{1\text{-}n}$= are estimated parameters from the model; β_0= constant

4.2 Binary Logit Model (BL Model)

To estimate the decision of pedestrian whether to cross the street or not; was explained on the basis of binary logistic regression model (Washington, Karlaftis, and Mannering (2003), Sun et al. (2003), Yannis and Papadimitriou, 2010) developed a binary logistic regression model, to examine the effect of traffic gaps and other parameters on pedestrians decisions to cross the street or not. Decision making process of pedestrian based on vehicular gaps (accepted or rejected) is explained using discrete choice theory (Kadali et al., 2015). The probability of selecting an alternative (accept/reject) is based on a linear combination function (utility function) and is expressed as equation (2)

$$Ui = \alpha i + \beta i1\ X1 + \beta i2\ X2 + \beta i3\ X3 + \beta i4\ X4 + \beta i5\ X5 \ldots\ldots\ldots\ldots\ldots + \beta in\ Xn \quad (2)$$

Where

Ui=the utility of choosing the alternative i;

i= number of alternatives (for binary logit model it has taken as two (accept/reject))

n= number of independent variables; α= constant; β = coefficients of corresponding variables.

The utility of choosing the 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:

$$P(i) = 1/[1+\exp(U_i)] \quad (3)$$

Hence the result obtained from the equations (2) and (3) will give the probability of the pedestrian crossing or not.

5. BEHAVIOUR OF PEDESTRIAN CROSSING MODELS

5.1 Multiple Linear Regression model for pedestrian gap

The minimum accepted vehicular gap size by pedestrian have been modelled by considering the traffic stream characteristics and pedestrian behavioural characteristics. Pedestrian rolling gap, pedestrian platoon size, pedestrian speed, vehicle speed (Vs) and area of vehicle(Av)(physical dimensions for different vehicle categories taken from Chandra and Kumar,2003) were deliberated as the independent variables and the dependent variable was considered as logarithm of accepted gap. The developed model is given as equation (4).

Table 3. Results obtained from MLR Analysis

Variables	Coefficient(β)	Standard error	t-value	p-value
Constant(β_0)	0.509	0.19	26.29	0.000
Vehicle speed(Vs)	0.003	0.000	7.09	0.000
Rolling without stopping (Rwos)	-0.399	0.013	-29.65	0.000
Rolling with stopping (Rws)	-0.232	0.008	-29.62	0.000
Platoon size (Pts)	0.11	0.003	4.113	0.000
Pedestrian speed (Ps)	-0.035	0.012	-2.986	0.003
Area of vehicle (Av)	0.006	0.001	6.499	0.000

(Note: p- values and t-values are significant at 95% confidence interval, R^2=0.58)

$$\boldsymbol{loggap} = 0.509 + (0.003 * Vs) - (0.399 * Rwos) - (0.232 * Rws) + (0.011 * Pts) - (0.035 * Ps) + (0.006 * Av) \quad (\mathbf{4})$$

Where,
Log-gap: logarithm of accepted gaps
Vehicle speed (Vs): speed of the vehicle at crosswalk area
Rwos: Rolling without stopping, Rws: Rolling with stopping while crossing.
Platoon size (Pts): Number of pedestrian in group
Pedestrian speed (Ps): The speed of pedestrian while crossing the road.
Area of vehicle (Av): Area of the vehicle in the particular section (Similar to vehicle category)

Table 4. ANOVA test statistics

Type of variable	F-Statistical	F-critical	p-value
Pedestrian crossing speed	2.514	3.85	0.21
Vehicle speed	0.364	3.84	0.61

Analysis of variance (ANOVA) test was carried out to compare the variance in pedestrian crossing speed and vehicle speed of two selected midblock crosswalk sections at 5% level of significance shown in table 4. This result showed that there is no significance difference in pedestrian crossing speed (2.154 Fs<3.85Fc) and vehicle speed (0.364Fs<3.84Fc) in either location. Moreover, geographical features (carriage way width and four lane divided road) of the two locations were similar. Therefore, the data-set comprises of values of both locations. A correlation matrix has been developed to check the significant difference between independent and dependent variables. After a number of trials with different groups of independent variables, the final model, which has the best statistical results was obtained with a confidence level of 95%. P-value of the given variable was less than 0.05 which means that there is a significant correlation between the independent variable and all the dependent variables, and hence, these variables were selected for developing the models. It was found that the waiting time, gender, age, frequency of attempt, pedestrian speed change, and pedestrian crossing path change condition were insignificant, as the p-values obtained were greater than 0.05. In addition to this delay, type of gap, traffic volume and driver behaviour were also insignificant. Table 3 indicates the variables and their descriptions used for MLR model. The calibrated R^2 value was obtained as 0.58 which is satisfactory. The model calibration was carried out with 70% of the extracted data and the remaining data was used for validation purpose. The predicted values calculated by substituting the values of variables in the obtained model were then compared with the observed values. A graph was plotted between observed and predicted values, with a line passing through origin (zero) and is shown in Figure.2. The results showed that the developed MLR model has good prediction proficiencies for estimating the minimum accepted vehicular gap size due to road crossing behaviour of pedestrian at uncontrolled midblock crosswalk section in Indian metropolitan cities. Mean Absolute Percentage Error (MAPE) is calculated for remaining 30% of the total data. According to Lewis scale of interpretation, estimation of accuracy (Kenneth and Ronald, 1982) for any forecast with a MAPE value of less than 10% can be considered reasonably accurate. 11% to 20% as good, 21% to 50% as reasonable and 51% or more as inaccurate. The obtained value of MAPE is 15.04 % and hence the predicted model is good. Here, rolling gap and vehicle speed are proved as the variable having greatest effects explaining in pedestrian gap acceptance behaviour for the observed range of variables. The log gap follows negative relationship with rolling gaps and pedestrian speed. The negative sign depicts that the pedestrian uses rolling gaps, then they can accept minimum gap. This behaviour was also observed predominantly in young-aged pedestrians. So, with the increase in age group, the accepted gap size also increases.

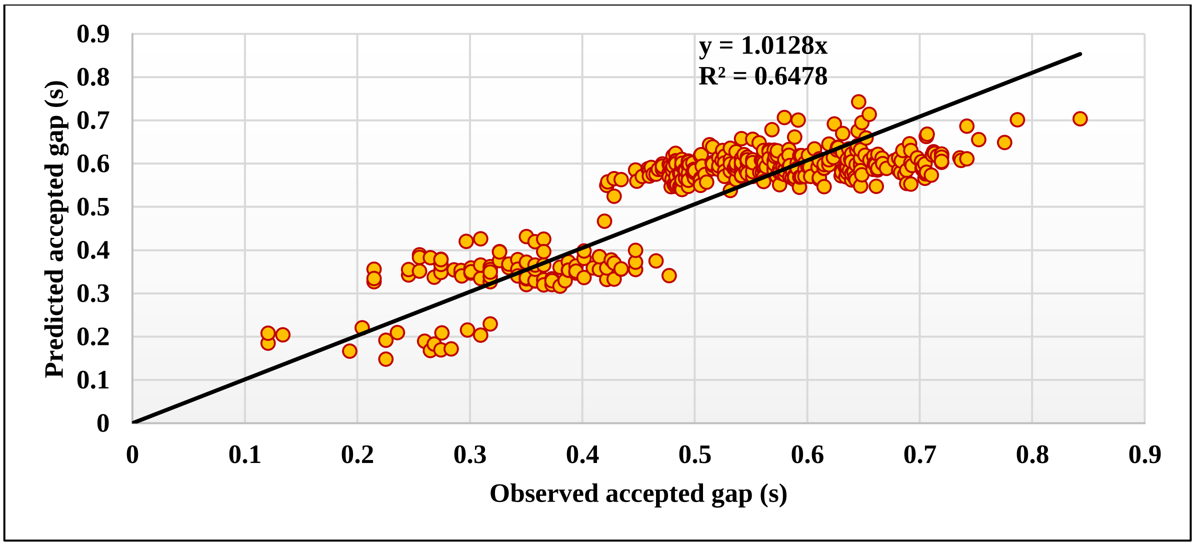

Figure 2. Pedestrian gap acceptance model validation

Further, in order to show clearly to which extent of the independent variables affect the dependent variable, estimation of values of elasticity (e) and the relative effect (er) are carried out, as publicized in Table 5. Moreover, as a normalization of the estimated value of elasticity in relation to the lowest value of elasticity, is calculated in order to compare the magnitude of effects of all independent variables. The point elasticity (ei) was calculated for each individual pedestrian (i) in the sample according to the following equation, whereas the overall values of elasticity (e) is calculated as the average of (ei) in the sample:

$$e_i = (\Delta Y_i / \Delta X_i)(X_i/Y_i) = \beta(X_i/Y_i) \qquad (5)$$

Table 5.Elasticity values in multiple linear regression model (MLR)

Independent variable	Values of Elasticity (e)	Relative elasticity (e_r)
Vehicle speed(Vs)	0.1831	3.66
Rolling without stopping (Rwos)	-0.1706	3.41
Rolling with stopping (Rws)	-0.1521	3.05
Platoon size (Pts)	0.0499	1
Pedestrian speed (Ps)	-0.0884	1.78
Area of vehicle (Av)	0.0596	1.192

Table 5 indicate that vehicle speed has the greatest effect on the gap acceptance process. During the survey, it was observed that those pedestrians who crossed the street when vehicle was close to them had accepted smaller gaps than those who cross the street when vehicle was far away. Here, the former pedestrian takes more risks while crossing. Furthermore, rolling without stopping has the second largest effect on log gap acceptance and followed by rolling with stopping. It is also observed that pedestrian speed follows with the fourth highest elasticity. It appears that pedestrian speed increases when they were facing less vehicular gaps or vehicle was very near. The calculation of the values of elasticity of variables was candid. If the variable platoon size has an elasticity value of one, then the variable vehicle speed has an elasticity value of 3.66. i.e. the variable, vehicle speed, affects the log gap 3.66 times more than the variable platoon size. Similarly, the variables, rolling without stopping and rolling with stopping have values of elasticity as 3.41 and 3.05, respectively but among the different variable vehicle speed and rolling gaps (Rolling with stopping and rolling without stopping) are the most influencing variable on gap acceptance process.

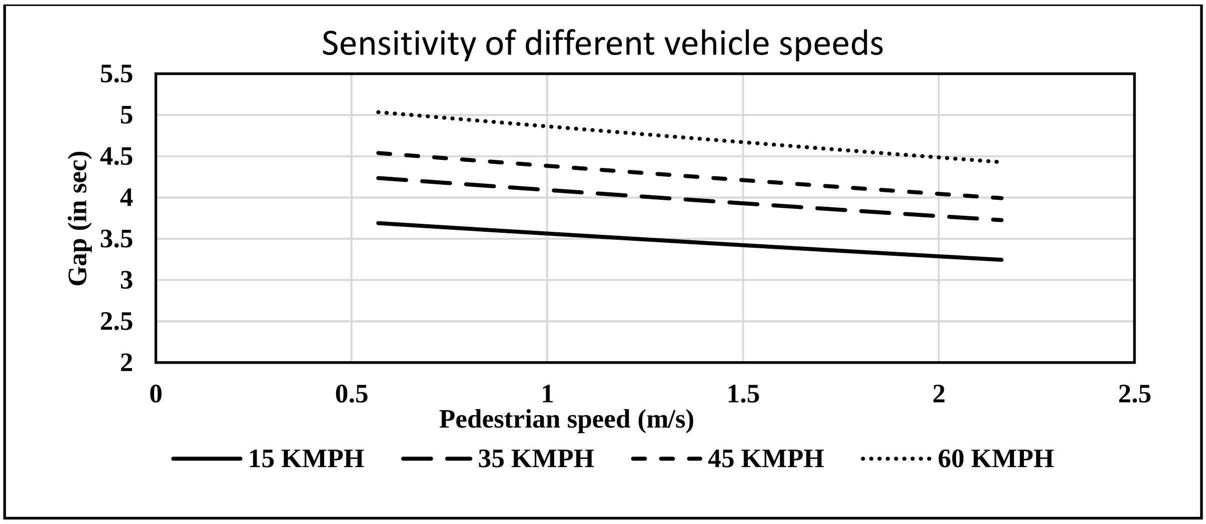

Figure 3. Sensitivity of accepted gap with respect to pedestrian speed –Different vehicle speed

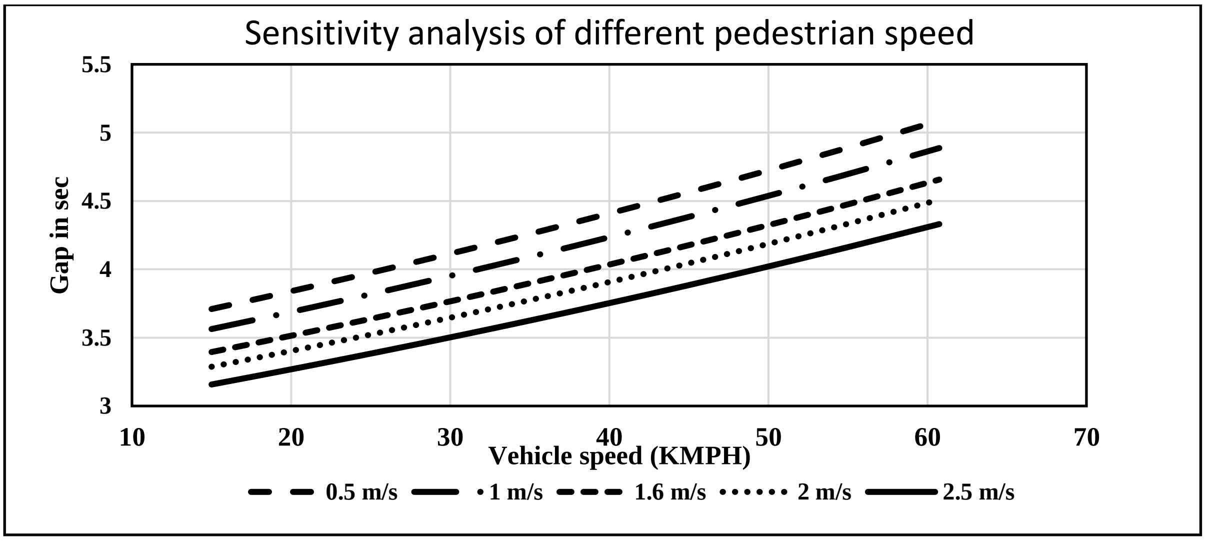

Figure 4. Sensitivity of accepted gap with respect to vehicle speed- Different pedestrian speed

A Sensitivity analysis is a technique used to determine how different values of a predictor variable in the MLR model influencing on a particular set of dependent variable under a given set of assumptions. This analysis gives notion about the impact of those variable on gap acceptance process. In this analysis vehicle speed and pedestrian speed are considered as independent variable. Through Multiple Linear Regression (MLR) analysis, it is found that vehicle speed and pedestrian speed are more influencing factors on pedestrian gap acceptance. Sensitivity of accepted gap with respect to vehicle speed and pedestrian speed are shown in figure 3 and 4. It can been seen that accepted gap is more sensitive to vehicle speed. Here, the speed of the incoming vehicle gradually increases from 15 Kmph to 60 Kmph which results to the increase in pedestrians accepted gap. It is also observed that accepted gap value decreases with increase in pedestrian speed at a particular incoming vehicle speed. The same prevalence can be seen in figure 4. For the incoming vehicle, the speed of the pedestrian increases results to decrease the pedestrian accepted gap. When the incoming vehicle is so far, a particular pedestrian walking at some specified speed (0.5 m/s) can safely cross the road with greater accepted gap. When the speed of the approaching vehicle is very high at specified crossing location at that time pedestrian cannot cross the road safely but any how they have to cross the street by running (2.5m/s) or using some crossing tactics. Here (figure 4) all curves are close to each other which indicates that the pedestrians accept similar vehicular gap. Only accepted gaps were used in this sensitivity model.

5.2 Binary Logit model for mid-block crossing choice:

A binary-logistic regression model was also used in order to capture the choice behaviour (accept/reject) of pedestrian to cross the road. The model is developed with the help of SPSS software platform. The descriptive statistics of binary logit model test are given in Table 6. The utility equation is given for the probability of gap acceptance condition. The significance of the independent variable is considered with the effect of p-values and t-values. Table 7 shows the modelling and validation of binary logit results. The validation is performed against 30% of the total data and the overall correct prediction of the above binary logit model is obtained as 94.3%. Hence, the proposed model is strong and it helps in predicting the gap acceptance behaviour at uncontrolled mid-block crosswalk in Indian metropolitan cities.

Table 6. Binary Logit model test results

Variable	Coefficient (β)	Standard error	t-value	p-value
Constant(α)	-5.166	.362	-14.270	.000
Gap size (Gs)	2.156	.078	27.641	.000
Area of vehicle (Av)	-.166	.022	-7.54	.000
Vehicle Speed (Vs)	-.021	.010	-2.1	.031
Gender (Gr)	.811	.148	5.47	.000
Platoon size of pedestrian (Psp)	-.284	.043	-6.60	.000
Crossing path change(Cpc)	5.707	.570	10.01	.000
Crossing speed change (Csc)	5.898	.536	11.03	.000

(Note: p-value and t-values are represented at 95% confidence interval, Nagelkerke R2=0.80)

Based on the results showed in table, the crossing decision model equation (5) can be written as.

$$U = -5.166 + (2.156 * \mathrm{Gs}) - (0.166 * \mathrm{Av}) - (0.021 * \mathrm{Vs}) + (0.811 * \mathrm{Gr}) - (0.284 * \mathrm{Psp}) + (5.707 * \mathrm{Cpc}) + (5.898 * \mathrm{Csc}) \quad (\mathbf{5})$$

Where
GS: Gap size of the vehicle, Av: Area of vehicle, Vs: Vehicle speed, Gr: Gender
Psp: Platoon size of pedestrian, Cpc: Crossing path change, Csc: Crossing speed change
It is important to outline two issues. The above equation (5), corresponds to a utility function. So the probability that a pedestrian crosses the midblock is given by equation (6)

$$P(i) = \exp(U_i) / [1 + \exp(U_i)] \quad (6)$$

Hence the result obtained from equation (6) will give the probability of the pedestrian crossing the road. In the second case, for this model both accepted as well as rejected gap were used, but in the previous MLR model, only the accepted gap was considered.

5.3 Model results and discussion

Different pedestrian behavioural characteristics were considered for developing pedestrian road crossing behaviour in which a few variables could explain the choice behaviour (accept/reject) of pedestrian to cross the road while the remaining variables have insignificant effect.

Table 7. Binary Logit calibration and validation of test results

Observed		Predicted					
		Calibration part			Validation part		
		PGA		% Correct	PGA		% Correct
		0	1		0	1	
PGA	0	3494	100	97.2	1879	41	97.9
	1	200	1031	83.8	101	453	81.8
Overall Percentage				93.8			94.3

In Binary-Logistic model for mid-block crossing choice, only seven variables; gap size, vehicular speed, area of vehicle, gender, platoon size of pedestrian, path change, and crossing speed change while crossing the road were significant in the model. Pedestrian behavioural tactics (path change and crossing speed change while crossing the road) also come into the picture whereas others variables are insignificant. From this model, it is clear that the probability of gap acceptance increases with the increase in gap size, gender, crossing path change and speed change while crossing the road. Whereas, it reduces with increase in vehicle speed, group size of pedestrian and area of the vehicle. In the present study, frequency of attempt, pedestrian speed, waiting time, rolling gap and age were found to be insignificant in this model. Pedestrian crossing behaviour was exactly predicted by this model by considering all the above mentioned variable. Literature showed that the type or size of vehicle is an important factor for accepting the gaps (Yannis et al., 2010), but in this present study, it is observed that pedestrians are also accepting vehicular gaps with respect to vehicle speed. This observation was strongly sustained by a recent study under mixed traffic conditions in developing countries (Cherry et al., 2012 and Kadali et al., 2015).

Table 8.Elasticity values in Binary logit model

Independent variable	Elasticity (e)	Relative elasticity (e_r)
Gap size (Gs)	7.86	15.17
Area of vehicle (Av)	-0.6346	1.22
Vehicle Speed (Vs)	-0.5504	1.06
Crossing Speed change (Cpc)	1.8338	3.54
Crossing path change (Cpc)	1.489	2.875
Gender (Gr)	0.5179	1
Platoon size of pedestrian (Psp)	-0.776	1.49

Table 8 represents the values of elasticity obtained from Binary logit (BL) model. The traffic gap size is the most influencing parameter on pedestrian decision to cross the road. It was found that the higher the gap available, the pedestrian can easily cross the road. The variable with the second greater effect is the crossing speed change. While crossing the road, if the gap size is less, then pedestrians use some tactics movement which directly affects the crossing speed change. Without considering gender, it is found that individual characteristics tested were found to be insignificant in this model. It is also observed that area of vehicle is also very significant in this model. As the vehicle type changes, the area of vehicle also changes which affect the crossing choice model. Moreover, platoon size of pedestrian has the lowest effect on crossing decision.

A sensitivity analysis for this model is presented in Figures 5 and 6, where the crossing probability is examined in relation to vehicles speed and vehicular gap. From the figure 5, it can be observed that the probability to cross the road increases with the increase in vehicular gap which explicates that if a pedestrian has a larger accepted gap value then the chances of crossing the road is more. It is also observed that increase in vehicle speed results to the increase in vehicular gap at a particular probability. It also put forward the fact that the chances to cross the road increases with increase in accepted gap. Figure 6 depicts that with more vehicular gap value, the chances to cross the street increases but when the speed of approaching vehicle increases at the time of crossing, pedestrian will be more conscious about their safety which leads to decrease the chances to cross the street. It can also be observed that the pedestrian with the higher vehicular gap value is more likely to cross the street as compared to the lower gap value.

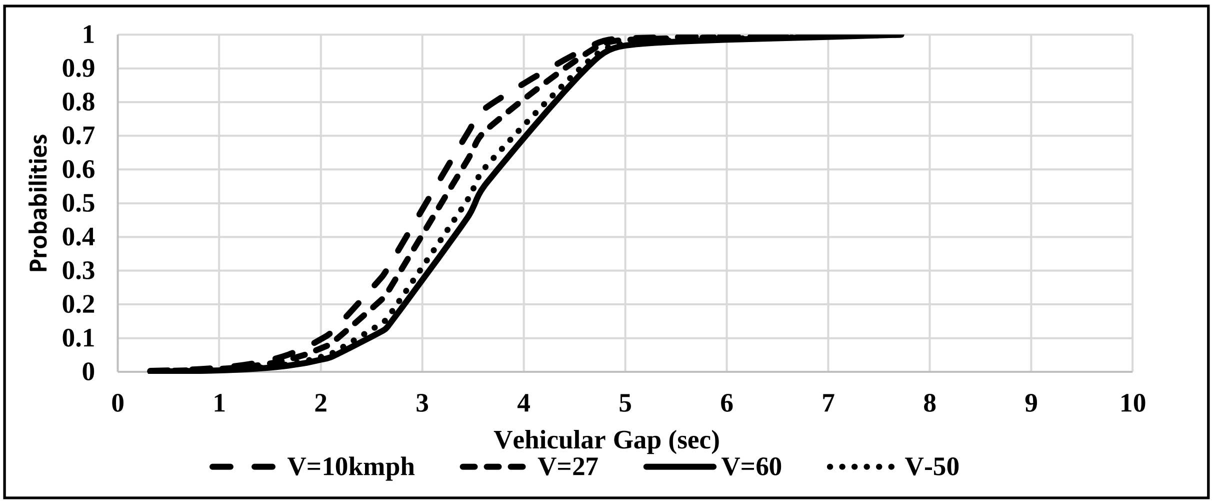

Figure 5. Sensitivity of crossing probability to traffic gaps for different vehicle speed

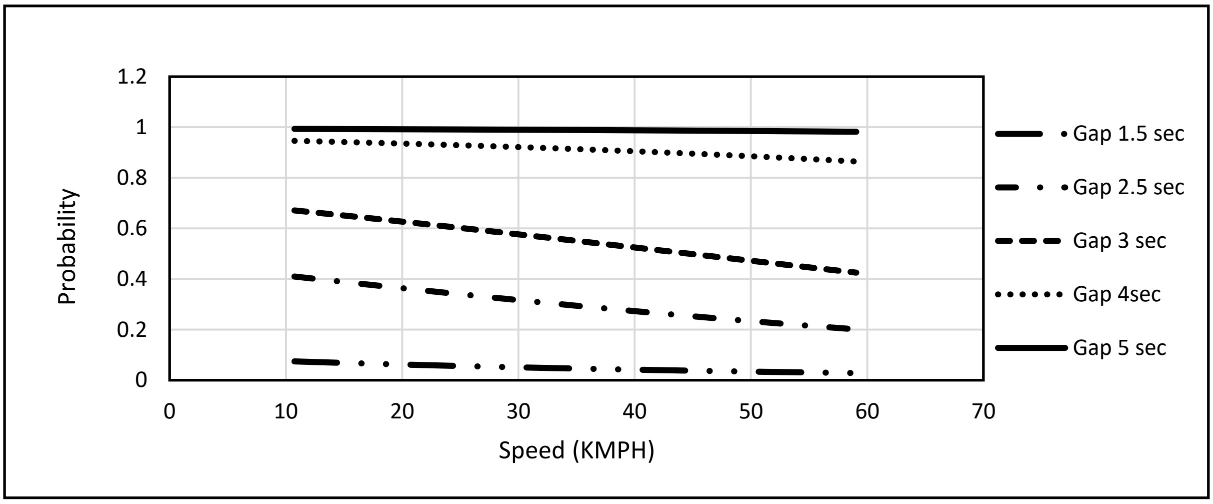

Figure 6. Sensitivity of crossing probability of vehicle speed for a different set of traffic gaps

5.4 The effect of pedestrian group size on pedestrian gap acceptance

Figure 7 depicts the effect of pedestrian group size on gap acceptance process and a decrease in probability of gap acceptance is observed with increase in pedestrian group size. The elasticities of a group of pedestrians was observed as -0.776. It indicate that there will be a decrease in probability of gap acceptance with increase in group size. From this graph, it can be observed that as the number of pedestrian group size increases, the pedestrian become more non aggressive in nature and they may accept larger gaps. When a pedestrian is surrounded by others pedestrians, they may be feel protected by others and they may be looking for safer gap for crossing. But in the case of single pedestrian they may accept lower gap and taking higher risk while crossing the road. These results contradict with earlier findings given by (sun et.al 2003) in which it is shown that as group size increases the probability of accepting gap decreases. One of the possible explanation is that pedestrian is more likely to select minimum gap based on behavioural tactics like rolling gap, crossing speed and path change while crossing.

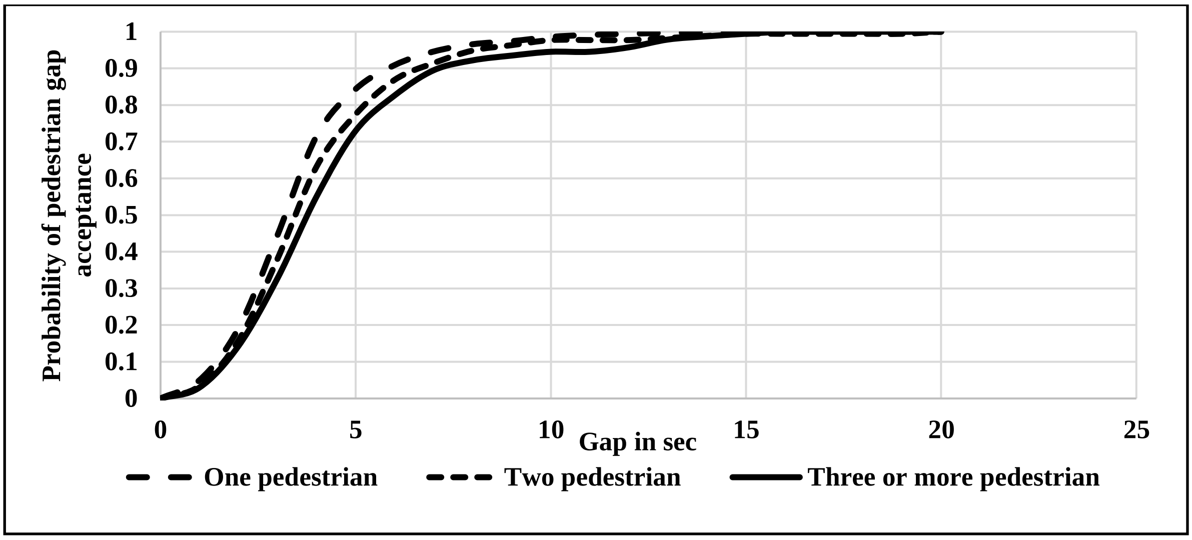

Figure 7. Probability of pedestrian gap acceptance with group size

5.5 The effect of gender on gap acceptance

Present study mainly focus on how the gap acceptance of the pedestrian varies with gender. For this analysis, the data set was divided into two groups: male pedestrian and female pedestrian. It can be seen that gap accepted by the male pedestrian is very less when compared to female pedestrian because of their aggressive nature and tendency to take risks. Female pedestrians are more cautious and they look for more gap while crossing, i.e. they are more concerned about their safety.

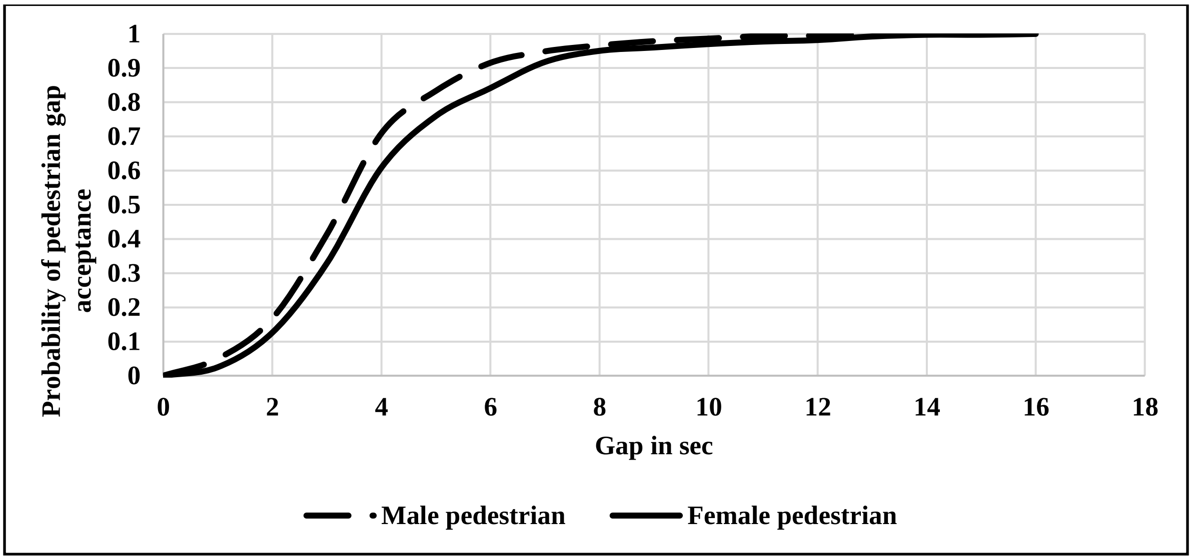

Figure 8. Probability of pedestrian gap acceptance with gender

6. CONCLUSIONS

The present study mainly emphasizes on the behavioural characteristics of individual pedestrians at two locations in the western part of India having different city characteristics and geographical conditions. The survey was carried out at Bandra in Mumbai and Asthodia in Ahmedabad. Multiple Linear Regression (MLR) model and Binary Logistic Regression (BLR) techniques were used in order to analyse the impact of different parameters on the traffic gap accepted by pedestrian and the decision of pedestrian to cross the street or not respectively. It was found that the accepted gap depends on the pedestrian rolling gap, pedestrian platoon size, pedestrian speed, vehicle area and incoming vehicle speed. Here, corresponding to the increase in vehicle speed, pedestrian speed also gets reduced. The results of elasticity analysis showed that vehicle speed and rolling gaps are the most influencing variable in gap acceptance process as they have highest elasticities. The sensitivity of accepted gap is analysed with respect to pedestrian speed and vehicular speed. The results revealed that accepted gap is more sensitive to vehicle speed and accepted gap value decreases with increase in pedestrian speed at a particular incoming vehicle speed.

Binary logistic regression (BLR) technique shows that the decision of the pedestrian whether to cross the street depended on the gap size of vehicle, area of vehicle, vehicle speed, gender, group size of pedestrian, crossing path change and crossing speed change. Furthermore, the increase in the vehicle speed resulted in the decrease in the probability to cross the road (disutility). This might be the effect of their age-related crossing capabilities as well as their higher safety consciousness. Pedestrian's individual characteristics were found to be insignificant and only gender was found to have an impact on gap acceptance. The present study also concluded that the gap acceptance behaviour of the pedestrians was dominantly influenced by the vehicular speed. This observation was strongly substantiated by recent studies under the mixed traffic condition in developing countries (Cherry *et al*., 2012 and Kadali *et al*., 2015). The speed of the vehicle, area of the vehicle and group size played a foremost role in both the models (MLR and BLR). This research revealed that the behaviour of pedestrians at uncontrolled midblock section showed high non-compliance and took high risks while crossing the road. The outcome of the values of elasticity analysis bared that traffic gap size is one of the most influencing parameter on pedestrian decision to cross the road. It was also found that the higher the gap available, the pedestrian can easily cross the road. The sensitivity analysis of this model expounds that the chances to cross the street increases with an increase in vehicular gap value. The results obtain from effect of group size on gap acceptance process revealed that the probability of accepting the gap decreasing with increase in pedestrian group size. Apart from platoon size, the probability to cross the road is also affected by the gender.

The suggestions from the results will be useful in realising the need of having a relook at design parameters for better pedestrian crossing facilities, thereby improving the existing facilities to enhance the pedestrian safety. In this study, pedestrian age was obtained by visual analysis from the video which may contradict the actual age of pedestrians. Moreover, the pedestrian's personal characteristics are not included in this model. Scope of the study is limited to a four lane divided urban road uncontrolled mid-block crosswalk sections in selected Indian cities only. The developed model can be applicable only for other study locations in which the similar geometric and traffic characteristics. We need to generalize the present study, in order to analysis the other same case studies.

Acknowledgment:

This study is a part of the'Development of Indo-HCM' project sponsored by planning commission of India. The authors are very grateful to Central Road Research Institute CRRI-Delhi, for their support and funding to carry out this research.

REFERENCES:

Accidental Deaths and Suicides in India, National Crime Records Bureau Ministry of Home Affairs Government of India, New Delhi (2014) http://ncrb.gov.in/adsi2013/ADSI-2013.pdf, last accessed December 18.

Ashalatha, R., Chandra S., (2011). Critical gap through clearing behavior of drivers at unsignalised intersections. KSCE Journal of Civil Engineering 15, No. 8, 1427-1434.

Asaithambi G., Manu Kuttan (2016), Pedestrian road crossing behavior under mixed traffic conditions: A comparative study of an intersection before and after implementing control measures, TIDE Journal of Civil Engineering 15, No. 8, 16-23.

Chaudhari, A., Shah, J., Joshi, G.J., Arkatkar, S.S., (2017), Evaluation of individual characteristics on walking speed at un-signalized mid-block crossings, Annual Transportation Research Board meeting, Washington D.C. (Accepted for Presentation)

Bradu,D., Mundlak, Y. (1970), Estimation in lognormal linear models. Journal of the American Statistical Association 65, 198-21.

Brewer, Marcus, Fitzpatrick, K, Whitacre, J., Lord, D., (2006) Exploration of pedestrian gap-acceptance behavior at selected locations, Transportation Research Record: Journal of the Transportation Research Board, 132-140.

Werner, B., Koenig, R. Troutbeck, R.J., (1999), Useful estimation procedures for critical gaps, Transportation Research Part A: Policy and Practice 33, No. 3, 161-186.

Chandra, S., Rastogi, R. Das, V.R. (2014), Descriptive and parametric analysis of pedestrian gap acceptance in mixed traffic conditions, KSCE journal of civil engineering 18, no. 1, 284-293.

Cherry, C. and Moore, S.E., (2010), Characterizing illegal midblock pedestrian crossings in China. Jerusalem, Israel, International Conference on Safety and Mobility of Vulnerable Road Users: Pedestrians, Motorcyclists, and Bicyclists.

DiPietro, M., and King, L., (1970), Pedestrian gap-acceptance, Highway Research Record 308, 80–91.

Hamed, M.M., (2001), Analysis of pedestrians' behavior at pedestrian crossings. Safety Science, 38(1), 63-82.

Highway capacity manual,(2010), Washington, DC: Transportation Research Board.

IRC:103:2012 Guidelines for pedestrian facilities, Indian road congress(IRC) New Delhi, India.

Kadali, B. R., Vedagiri, P., (2016) Analysis of critical gap based on pedestrian behaviour during peak traffic hours at unprotected midblock crosswalks, Asian transport studies, 4(1), 261-277.

Kadali, B. R., Vedagiri, P., (2013), Modelling pedestrian road crossing behavior under mixed traffic condition. European transport 55, No. 3, 1-17.

Kadali, B. R., Vedagiri, P., (2012), Pedestrians' Gap Acceptance Behavior at Mid-Block Location. International Journal of Engineering and Technology 4, No., 158.

Kenneth D., Ronald K., (1982), Forecasting performance measurements, tracking signals and randomness tests.

Khan, F. M., Jawaid, M., Chotani, H., Luby, S., (1999), Pedestrian environment and behaviour in Karachi, Pakistan, Accident Analysis and Prevention, 31(4), 335–339.

Kumar, P., Parida, M., (2011), Vulnerable road users in multimodal transport system forDelhi, Journeys, LTA, 6, 38-47.

Mohan, D., Tsimhoni, O., Sivak, M., Flannagan, M. J., (2009), Road Safety in India:Challenges and Opportunities, University of Michigan, USA.

MoRTH. Study on Road Accidents in India 2010, Ministry of Road Transport and Highways (MoRTH), Government of India.

MOUD, (2008), Study on traffic and transportation polies and strategies in urban areas in India Ministry of urban development.

NHTSA (2012), Traffic Safety Facts 2010 Data: Pedestrians, Report Number: DOTHS-811-625, National highway traffic safety administration, Washington DC, USA.

Oxley, J., Fildes, B., Ihsen, E., Charlton, J., Days, R., (2005), Crossing roads safely: An experimental study of age differences in gap selection by pedestrians. Accident Analysis and Prevention 37, 962-971.

Pawar S., Patil, (2015), Pedestrian temporal and spatial gap acceptance at Mid-block Street crossing in developing world, Journal of safety research 52, 39-46.

Serag, M. S., (2014), Modelling pedestrian road crossing at uncontrolled mid-block locations in developing countries, International Journal of Civil and Structural Engineering 4, No. 3, 274.

Sun, D., Ukkusuri, S.V.S.K., Benekohal, R.F., Waller, S.T. (2003), Modeling of Motorist-Pedestrian Interaction at Uncontrolled Mid-block Crosswalks, In the Proceedings of the 82nd TRB Annual Meeting, Transportation Research Board, Washington.

Tiwari, G., Bangdiwala, S., Saraswat, A., Gaurav S., (2007), Survival analysis: Pedestrian risk exposure at signalized intersections. Transportation Research Part F, 10, 77-89.

Troutbeck, R. J., (1992), Estimating the critical acceptance gap from traffic movements, Queensland University of Technology.

Washington, S.P., Karlaftis, M.G., Mannering, F.L., (2003), Statistical and Econometric Methods for Transportation Data Analysis. Chapman and Hall / CRC Press.

Wu,N., (2012), Equilibrium of probabilities for estimating distribution function of critical gaps at unsignalized intersections, Transportation Research Record: Journal of the Transportation Research Board 2286, 49-55.

Yannis, G., Papadimitriou, E., Theofilatos, A., (2013), Pedestrian gap acceptance for mid-block street crossing. Transportation planning and technology 36, No. 5, 450-462.