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Modelling pedestrian choice behavior of crossing facility

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Abstract

Effectiveness of a facility depends highly upon its usage rate. Signalized intersections provided with grade separated pedestrian crossing facilities suffer from under usage of the later by pedestrians. To understand the reason for the same, pedestrian choice of crossing facility need to be studied at disaggregate level. This pedestrian choice behaviour directly influences their walking speeds and crossing behaviour. This study intended to analyse the effect of demographic characteristics of pedestrians on their choice of crossing facility between signalized crossing and a pedestrian footbridge. Video graphic survey was conducted to capture the pedestrians' actual crossing behaviour at two signalized intersections in Mumbai city, India. Overall 1158 pedestrians were observed and their actual choice behaviours were recorded. Binary logit model was used to find the significant variables influencing the decision making process of how to cross. The results showed that pedestrian's age, gender, luggage size and accompaniment majorly affect their choice of crossing facility. It was inferred that increase in pedestrian age reduces the usage of grade separated crossing facility and women find it convenient to cross at-grade. People become more cautious while a minor is around and avoid crossing at-grade. The expected travel time using any facility was modelled using multiple linear regression technique which might help pedestrians to make better choices. The conclusions from this study can be used to improve the efficiency of pedestrian crossing facilities at signalized intersections.

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Keywords: Pedestrian crossing; Detour time; Choice modelling; Signalized crosswalk; Pedestrian behaviour; Footbridge; Behavioral modelling

1. Introduction

Walking is the most unprotected mode of road transport all over the world. Pedestrians belong to more than 20% of the road traffic deaths in the World (Global status report on road safety, 2015). Pedestrian safety is often overlooked. As a result, most of the pedestrian specific facilities remain underused and pedestrians usually interact with motorized

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traffic. Transport planners need to incorporate the safety of the pedestrians before any development of new facility or traffic mobility improvement.

With massive development in transportation a huge number of pedestrian facilities have been built, viz. sidewalk, crosswalk, grade separated crossing (skywalk, foot over bridge and subway), pedestrian traffic signal etc. These facilities give pedestrians the right-of way to move safely without any interaction with other road users. Crossing facilities are also seen as an important component of route planning for walking trip (Hine, 1996). But constructing pedestrian crossing facilities is just not enough to ease the pedestrian flow as certain facilities are unfavorable to the pedestrians. The reason for the same varies for different facility type. Expected traffic conditions and decisions at the tactical level serve as inputs for pedestrian walking and crossing behavior (Hoogendoorn and Bovy, 2004). Pedestrian behavior on crosswalks is complicated which is sometimes exposed to vehicular traffic because of non-compliance of either pedestrian or vehicle or both. Use of pedestrian overpass and underpass is too less compared to at-grade crossing in many places. A possible cause of this might be the design considerations of these facilities which is purely based on the quantitative measures. Pedestrian preference and their attitude are ignored in planning of the facilities, due to which very few people use them for crossing.

It is found that uncontrolled intersections are highly prone to hazardous condition and signalized intersections rank second despite being provided with better protection than other control types (Road Accidents in India, 2016, by MoRTH). Although most of the signalized intersections are provided with grade-separated pedestrian crossing facilities, they remain under-used due to the presence of at-grade signalized crosswalk. Therefore, the attitude and habits of actual and potential users of such facilities need to be understood before designing any pedestrian crossing facility.

This study aims at finding some policy measures in the direction of pedestrian safety at various locations involving such condition. The focus of this paper is to understand the pedestrian behavior of choosing how to cross the road when they are provided with grade separated crossing facility at signalized intersection.

2. Literature review

There exists a rich literature covering the pedestrians' choice of crossing facility. It is observed universally that at-level crossings are preferred over grade-separated crossings (Moore and Older, 1965; Cantillo et al. 2015; Räsänen et al. 2007; Tanaboriboon and YordpholJing 1995; Mfinanga, 2014). Pedestrians choose overpass/underpass instead of level-crossing for safety from conflicting vehicles (Guo et al., 2014). Using a bridge primarily depends on the time saved and secondarily on safety (Räsänen et al., 2007). A study by Moore and Older (1965) found that approximately 95% of pedestrians use an overpass if the walking time using the overpass is the same as crossing at street level. However, if the overpass takes 50% longer than crossing at street level, almost no one will use the overpass. A study reported that in China, pedestrians were less willing to use the grade-separated crossings than signalized crossings, mainly because of the ascending and descending movements required (Tanaboriboon and YordpholJing, 1995). Beijing pedestrians disliked signalized crosswalk mainly because of the long waiting time to cross the street (Tanaboriboon and YordpholJing, 1995). Also, signalized intersections designed with longer pedestrian waiting time results in dangerous pedestrian behaviour (Brosseau et al., 2013). In a study by Rankavat and Tiwari (2016) it was seen that because of longer waiting time to cross the road at the signals (result of high traffic volume), pedestrians found overpass a bit convenient than zebra crossing.

Moore and Older (1965) suggested that usage of pedestrian crossing facility depends on walking distance. Distance of crossing location has a lot to do with the decision of how to cross (Tanaboriboon and YordpholJing, 1995; Sinclair and Zuidgeest, 2016). Sisiopiku and Akin (2003) presented findings from an observational study of pedestrian behaviours in USA in which the crosswalk location relative to the origin and destination of the pedestrian was the most influential decision factor for 90% of the pedestrians deciding to cross at a designated location. Pedestrians choose shortest route to minimize the delay. Bernhoft and Carstensen (2008) reported that pedestrians often cross the road at their present position, irrespective of the nearby presence of a facility for crossing in order to avoid a detour. Older group was found more likely to avoid detour due to inconvenience/difficulty as compared to younger group who usually do so when in hurry. A relationship between crossing location and detour distance was established in China (Guo et al., 2014) and it was observed that nearly 86% of participants were willing to accept a detour distance within 100 meters. Cantillo et al. (2015) concluded from a study in Colombia that longer walking distances diminish the probability of individuals to choose safer alternatives (pedestrian bridges being more affected than signal crossings). A very recent study by Anciaes and Jones (2018) also confirmed that grade separated facilities are favourable only if they are nearer than signalized crossing.

Hine (1996) observed that elderly pedestrians fear of crossing, for which they reschedule crossing activity to avoid rushing across the road during pedestrian precedence period. Young pedestrians were seen choosing light traffic hours and direct routes relative to their destination if in hurry. Old or female pedestrians were found more cautious than the young or male pedestrians in Denmark (Bernhoft and Carstensen, 2008), Israel (Yagil, 2000) and Tanzania (Mfinanga, 2014). Mfinanga (2014) reported that older people prefer safety but younger ones prefer comfort and convenience improvement. Anciaes and Jones (2018) observed women and older people choose surface crossing in general. Few studies in Turkey, China and Cape Town, reported age and gender were insignificant in deciding the crossing facility (Räsänen et al., 2007; Zhang et al., 2009; Sinclair and Zuidgeest, 2016). Expected travel time and trip purpose are also important components of route choice (Hoogendoorn and Bovy, 2004). Rankavat and Tiwari (2016) concluded that the pedestrians evaluate the combined safety benefits along with the extra effort and time in using any facility before making the route choice. The use or non-use of pedestrian facilities is a habit not a coincidental behaviour and pedestrians prefer to cross at-grade irrespective of the traffic volume and the number of lanes (Räsänen et al., 2007). Presence of traffic signal under footbridge reduces the usage rate of bridge (Räsänen et al., 2007). Another study suggested that it is preferable to propose at level signalized crossings along with underpass/overpass, when necessary, in order to avoid pedestrian-vehicular conflicts (Cantillo et al., 2015). Non-level crossing is favourable in higher-class roads than in lower-class roads (Mfinanga, 2014).

The objective of this paper is to model pedestrian choice of crossing facility between at-grade signalized crossing and footbridge. The various individual characteristics contributing for choice of crossing facility will be analysed in this paper. Video graphic technique captures the actual crossing behaviours of pedestrians. Therefore, in this study, field survey was conducted using video camera to record the movements of both signalized crossing users as well as footbridge users. The individual choice is modelled using a binary logit model and the significant factors are obtained. For the selected facility by each pedestrian, the travel time is also modelled.

3. Study area and data collection

Two signalized intersections having pedestrian foot bridges at the intersection, in Mumbai city, India (Shyam Nagar junction and IIT Bombay main gate junction, both located 8km apart along an important arterial road named Jogeshwari-Vikhroli Link Road) were selected for the study. Both the locations experience high pedestrian traffic along with heavy vehicular traffic flow. The conditions of the signalized crosswalk and pedestrian foot bridge at the locations are shown in Fig. 1. The physical dimensions of the existing crossing facilities at each location, land use pattern and type of intersection geometry (zebra marking, number of lanes in both directions, road width and signal cycle time) are presented in Table 1.

A b

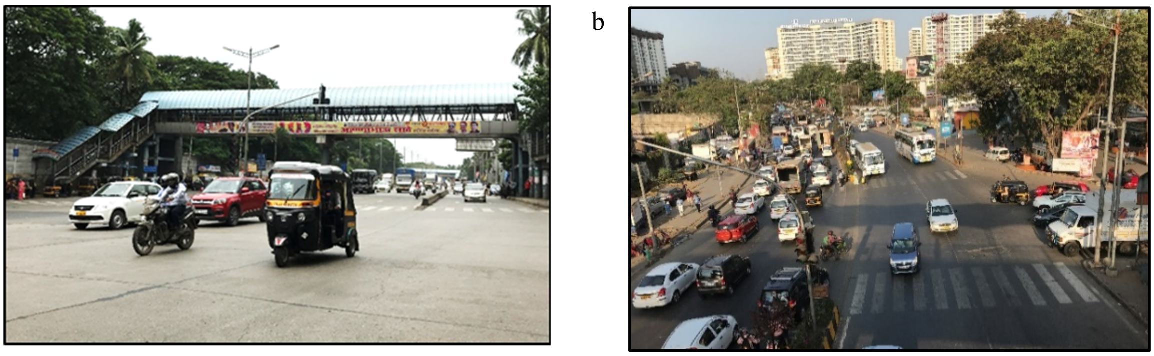

Fig. 1. (a) Pedestrian footbridge; (b) Signalized crosswalk.

Table 1. Location and infrastructure attributes.

Location	Land use	Zebra marking	Crosswalk length	Height of footbridge	Cycle time
1. Shyam Nagar junction	Residential, Bus stop	One side	25 m	6.0 m	109 sec
2. IIT Bombay main gate junction	Residential, Market	One side	40 m	6.7 m	240 sec

Video data was collected capturing the pedestrian movements at the selected locations during 10:00 AM to 12:00 Noon and 4:00 PM to 6:00 PM on weekdays during the month of August, 2017. The videos were taken such that the signal phases were clearly visible. Proper care was taken to set up the cameras at enough height in order to avoid any obstruction to the scenes by heavy vehicles.

The collected data was extracted manually by playing the video clips with the Video snapshot wizard software, at a slow motion. Moderate pedestrian volume was observed and each pedestrian was observed from the arrival time at the intersection till he/she finished crossing successfully. Pedestrians' demographic characteristics such as, age group and gender, presence of any luggage and accompaniment were extracted by visual observation. The waiting time was calculated as the difference between the arrival time of a pedestrian at the intersection and the time he/she steps off the waiting area with the intention of crossing using either signalized crosswalk or the pedestrian foot bridge. If the pedestrian chooses to cross the road at-level, then the crossing time is calculated as the difference between the time when a pedestrian actually leaves the waiting area to cross at-grade by moving forward and the time when he/she reaches the other end. If a pedestrian uses footbridge, then the detour time is calculated as the time it takes for a pedestrian to travel from the nearest end of the footbridge to farthest end (opposite side).

3.1. Sample distribution

A total of 1158 pedestrians were observed from the videos (631 at IIT Bombay main gate junction and 527 at Shyam Nagar junction). 839 pedestrians crossed at-grade and 319 pedestrians used footbridge for crossing. Table 2 shows the distribution of individual characteristics extracted from video data.

Table 2. Summary of extracted sample characteristics from video observation.

Characteristics	Level	Facility: Signalized crossing		Facility: Footbridge		Total	
		Count	% of Total	Count	% of Total	Count	% of Total
Age group	Young (18-30 years)	331	28.6%	190	16.4%	521	45.0%
	Lower middle aged (31-45 years)	426	36.8%	103	8.9%	529	45.7%
	Upper middle aged (46-60 years)	68	5.9%	23	2.0%	91	7.9%
	Elderly (>60 years)	14	1.2%	3	0.3%	17	1.5%
Gender	Female	329	28.4%	75	6.5%	404	34.9%
	Male	510	44.0%	244	21.1%	754	65.1%
Luggage	No/light luggage	457	39.5%	153	13.2%	610	52.7%
	Only one bag	371	32.0%	158	13.6%	529	45.7%
	More than one bags/trolley	11	0.9%	8	0.7%	19	1.6%
Alone		597	51.6%	237	20.5%	834	72.0%
	Crossed alone	328	28.3%				
	Crossed as a platoon	269	23.2%				
Arrived as a group of adults		242	20.9%	82	7.1%	324	28.0%
Group Size	Two	176	15.2%	42	3.6%	218	18.8%
	Three	36	3.1%	15	1.3%	51	4.4%
	Four	3	0.3%	11	0.9%	14	1.2%
Arrived with at least a minor		27	2.3%	14	1.2%	41	3.5%
Mobile phone Users		16	1.4%	8	0.7%	24	2.1%
Crossed against the signal		117	14%				
Total usage of facility		839	72.5%	319	27.5%	1158	100%

65% of the pedestrians were male. Most of the pedestrians were young or middle aged and do not carry more than one bag. 72% of the people were walking alone. 51% pedestrians were not accompanied by anyone who crossed at-grade and half of them crossed the road as a platoon formed with random pedestrians. However, half of them crossed the road alone. The observation shows that 14% at-grade crossing users attempted to cross illegally against the signal, i.e. crossed during the red phase or initiated crossing too early (<15 s before beginning of pedestrian green phase) or initiated too late (during last 15 s of pedestrian green phase). This illegal crossing most often led to two stage crossing thereby causing large waiting time at the median after crossing first half of the road width. Considering the added waiting time at the median, the total crossing time for the pedestrians, who started too late, ranged up to a maximum of 222 s with mean crossing time of 94 s, which is more than double the value for those who crossed during red phase (maximum 110 s with 46 s as the mean crossing time). However, the maximum crossing time of pedestrians who initiated crossing too early was less compared to both the cases. Table 3 presents the descriptive statistics of the illegal crossing of pedestrians.

Table 3. Descriptive statistics of crossing time of pedestrians crossing illegally.

Crossing time (s)	N	Minimum	Maximum	Mean	Std. Deviation
Started during last 15 s of green phase	26	16	222	94.02	40.745
Crossed during red phase	67	16	110	45.70	23.677
Started at <15 s before green phase	24	21	61	39.86	10.917

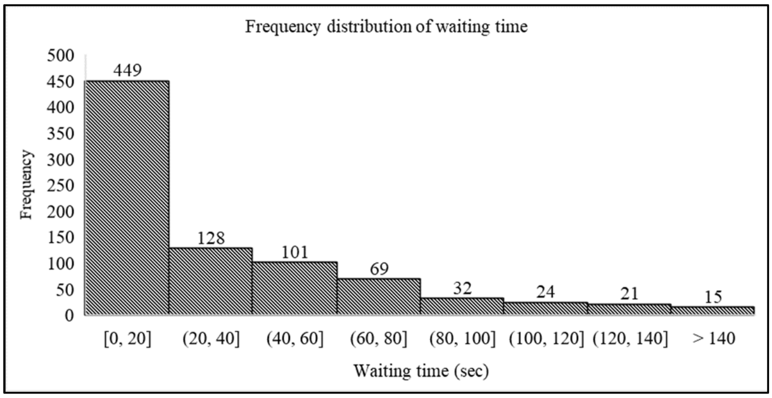

Fig. 2. Frequency distribution of waiting time of pedestrians.

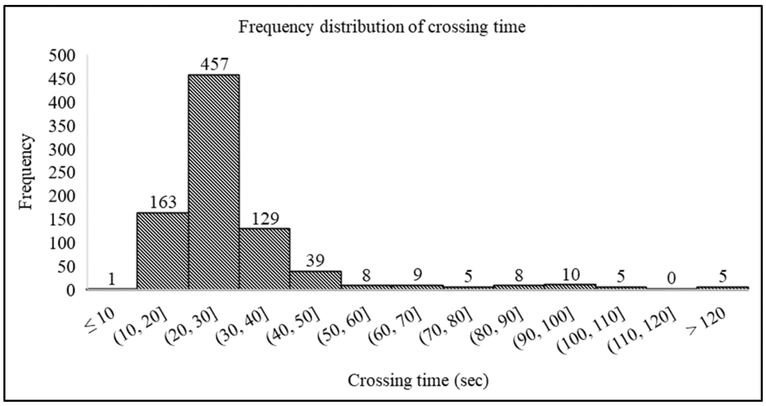

Fig. 3. Frequency distribution of pedestrian crossing time using signalized crossing.

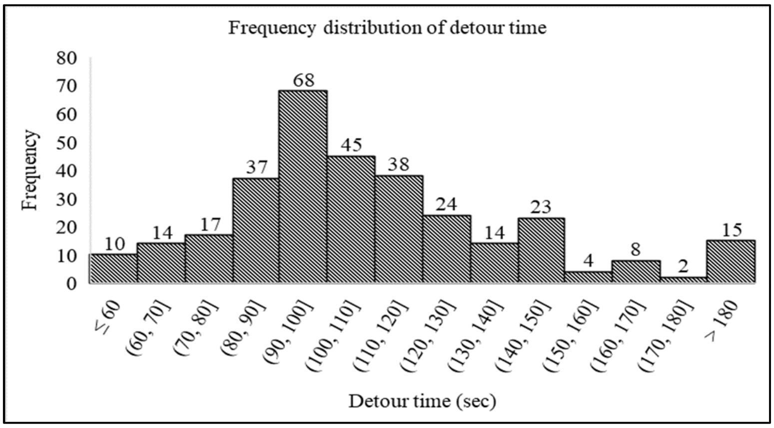

Fig. 4. Frequency distribution of detour time of pedestrian footbridge users.

The frequency distributions of pedestrian waiting time, crossing time and detour time at both the locations are shown in Fig. 2 – 4. Fig. 2 shows that 449 persons (39%) waited for up to 20 s, which is inclusive of 319 footbridge users. It is also observed that 298 persons (26%) waited for 20 s – 80 s which comprises mainly signalized crossing users. A few persons experienced waiting time of more than 140 s. The distribution of crossing time of at-grade crossing users in Fig. 3 shows that 54% people crossed the road within 20 s – 30 s, whereas 42 people (5%) took more than a minute for crossing. The detour time distribution of footbridge users in Fig. 4 shows that maximum number of pedestrians (21%) crossed over the footbridge within 90 s – 100 s. Effectively 80 s to 120 s can be considered as the detour time for majority of pedestrians (nearly 60%).

3.2. Sample characteristics

The dispersion analysis of continuous variables in Table 4 shows that the distribution of crossing time is highly skewed (4.345) and has an excess kurtosis (27.966). The distribution of detour time has also high skewness (1.105) and high kurtosis (2.218). The absolute skewness and kurtosis values in excess of ±1 indicate non-normal distribution or presence of outliers in the sample. Here the values of skewness and kurtosis are positive since the crossing time and detour time can't be negative. The reason for skewness in crossing time might be signal violation which corresponds to two stage pedestrian crossing and further includes excessive waiting times at the median. Using Tukey's (1977) boxplot method of univariate outlier labelling, 79 extreme data points of crossing time and detour time were obtained. The reason for the outliers also might be very low or very high walking speeds of certain pedestrians along the selected facility. The removal of outliers resulted in reduction of skewness and kurtosis values to 0.656 and 0.213 for crossing time and 0.351 and 0.053 for detour time respectively.

Table 4. Dispersion of continuous variables.

	Waiting Time (s)	Crossing Time (s)	Detour Time (s)
N	1158	839	319
Skewness	1.973	4.345	1.105
Std. Error of Skewness	0.72	0.084	0.137
Kurtosis	4.025	27.966	2.128
Std. Error of Kurtosis	0.144	0.169	0.272
Minimum	0.000	9.840	26.440
Maximum	202.096	221.520	241.608

The dispersion of continuous variables in the valid sample is presented in Table 5. The valid 1079 observations are used for modelling purpose. The crossing time of valid sample ranges from 9.84 s to 44.12 s with an average of 25.32 s. The range of detour time is 45 s to 171.52 s and the mean detour time is 105 s.

Table 5. Dispersion of continuous variables after removal of outliers.

	Crossing Time (s)	Detour Time (s)
N	777	302
Mean	25.320	104.754
Std. Deviation	6.529	25.154
Skewness	0.656	0.351
Std. Error of Skewness	0.088	0.140
Kurtosis	0.213	0.053
Std. Error of Kurtosis	0.175	0.280
Minimum	9.840	45.040
Maximum	44.120	171.524

4. Modelling pedestrian choice behaviour of crossing facility

To analyse whether the pedestrian characteristics were correlated to the choice of crossing facility, the model should predict discrete outcomes. A binary model was needed since there were only two choices – signalized crossing or pedestrian footbridge.

4.1. Binary logit model framework

To accommodate the binary model, the response variable "Choice" was created containing one if the selected facility type was signalized crossing and zero otherwise. The utility equation of the discrete choice model is shown in Eq. (1) below.

$$U_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \ldots + \beta_n x_{ni} \quad (1)$$

Where, U_i = utility of individual i for the choice value 1, β_0 = constant, $\beta_1, \beta_2, \ldots\beta_n$ = parameters to be estimated and $x_{1i}, x_{2i}, \ldots x_{ni}$ = characteristics of individual i. Probability of choosing alternative 1 is obtained from the general form of binary logistic regression modelling frame work as shown in Eq. (2).

$$\Pr\left(choice_i = 1 \mid x_i\right) = \frac{e^{U_i}}{1+e^{U_i}} = \frac{1}{1+e^{-U_i}} = \frac{1}{1+e^{-(\beta_0+\beta_1 x_{1i}+\beta_2 x_{2i}+\ldots+\beta_n x_{ni})}} \quad (2)$$

As β becomes larger in a positive sense, P would approach 1, which indicates that the probability of a success (in this case, choice of signalized crossing) increases.

4.2. Pedestrian choice behavior model estimation and results

Dummy variables for lower middle age group, upper middle age group and elderly age group were created with value 1 if yes and 0 if no. Gender was coded as 0 for female and 1 for male. Two dummy variables for group size of 2 or 3 (small group) and group size 4 (big group) were created. Luggage was coded as 1 if one or more luggage present and 0 otherwise. Minor was coded 1 if the person was accompanied by any minor and 0 otherwise.

Table 6. Binary logit model parameter estimates and marginal effects.

Variable (Abbreviation)	Coefficient	Std. Error	t-statistic	Marginal Effect	t-statistic
Constant	1.512	0.234	6.47***	-	-
Lower middle aged (LMA)	1.014	0.187	5.41***	0.1756	5.77
Upper middle aged (UMA)	0.765	0.378	2.02**	0.1167	2.41
Elderly (OLD)	1.725	1.074	1.61	0.2024	2.91
Gender (GEN)	-1.115	0.204	-5.48***	-0.1827	6.22
Luggage (LUGG)	-0.427	0.170	-2.51**	-0.0757	2.51
Small group of 2-3 persons (SG)	0.377	0.212	1.78*	0.0639	1.86
Big group (>3 persons) (BG)	-1.975	0.705	-2.80***	-0.4090	2.99
Minor (MIN)	-0.870	0.492	-1.77*	-0.1713	1.65
Log likelihood at convergence	= -427.571				
Restricted log likelihood	= -474.711				
Chi squared (sig. 0.000)	= 94.279				
Degrees of freedom	= 8				
McFadden Pseudo Rho-squared	= 0.099				
No. of observations (N)	= 810				

***, **, * indicate significance at 1%, 5% and 10% level respectively.

Binary logit model was calibrated with 75% of the sample (810 observations selected randomly) and four explanatory variables. All the predictor variables were entered into the model and the coefficients were estimated in NLOGIT 5 software. The significance of a variable is indicated by t-statistics using a two-tailed t-test. The Hosmer-Lemeshow chi squared value is found to be 8.266 (p-value = 0.408, degree of freedom = 8). Table 6 shows the parameter estimates of the pedestrian crossing facility choice model using binary logit model. The model results show that, the coefficients of three age categories are positive, meaning increase in age contributes towards choice of at-grade crossing facility. The negative coefficients of gender, luggage and minor suggests that female pedestrians prefer to cross at-grade more than males do and people carrying one or more number of luggage and walking with any minor avoid crossing at-grade. The positive intercept value indicates that pedestrians have bias towards signalized crossing facility. The final model is presented in Eq. (3).

$$U = 1.512 + 1.014 * LMA + 0.765 * UMA + 1.725 * OLD - 1.115 * GEN - 0.427 * LUGG + 0.377 * SG - 1.975 * BG - 0.87 * MIN \quad (3)$$

4.3. Marginal effects of the explanatory variables

The marginal effects of the predictors (percentage change in probability of dependent variable with unit change in one predictor, holding all other predictors at their means) and the corresponding t-statistics are shown in Table 7. It is found that the lower middle aged, upper middle aged and elderly pedestrians are 17.56%, 11.67% and 20.24% more likely to select signalized crossing than young pedestrians. This can be supported by the fact that with increase in age, it becomes difficult for people to climb stairs. Similar result was observed in a study by Bernhoft and Carstensen (2008) who found that older people avoided detour than younger group due to inconvenience. Studies by Rankavat and Tiwari (2016) and Anciaes and Jones (2018) also reported that increase in age tend to reduce the attractiveness of pedestrian overpass. The marginal effect of gender shows that male pedestrians are 18.27% less likely to cross at-grade than female pedestrians. That means proportion of more female group contributes more towards surface crossing. A study by Anciaes and Jones (2018) concluded that women cross at-grade in general. Here, the negative marginal effect of luggage shows that people having at least one luggage are 7.57% less likely to use signalized crossing than people with no luggage. Pedestrians having one or more bags might be in hurry so as to not waste time in waiting for the signal, rather detour and cross over safely. Choice behaviour of pedestrians depends on the accompaniment as well as the size of group he will travelling with. It is found that pedestrians walking in a group of 2 or 3 adults (small group) are 6.39% more likely to choose signalized crossing than those walking alone. Whereas pedestrians walking in a bigger group are 40.9% less likely to choose at-grade crossing than the ones walking alone. This is because when pedestrians arrive alone at the junction, most of them try to form platoon with other pedestrians while crossing at-grade. But when pedestrians arrive in pre-defined groups, they find it less difficult to detour. Hine (1996) found that accompaniment boosts confidence while crossing, but nothing was mentioned regarding size of group. Pedestrians walking with any minor are 17.13% less likely to choose signalized crossing than those walking without any minor. This is because people become more cautious while a minor is around and choose safer crossing facilities. A study by Cantillo et al. (2015) reported that pedestrians are more aversive to take risks when crossing with a minor than when alone, which is similar to this study.

4.4. Model validation

Table 7. Prediction success table for binary logit model of pedestrian choice.

	Predicted Choices			
Actual Choices	Signalized Crossing	Footbridge	Row Totals	Actual Share
Signalized Crossing	178	10	188	69.89%
Footbridge	72	9	81	30.11%
Column Totals	250	19	269	
Predicted Share	92.94%	7.06%		
% Correctly Predicted	94.68%	11.11%		
Overall Prediction Success	70%			

The corresponding model was validated using remaining 25% (269 observations) of the sample. The overall correct prediction was found to be 70% as shown in Table 7. It can be observed that 94.68% of the observed signalized crossings were correctly predicted by the model, which is very good. The correct prediction share of footbridge was quite low.

5. Modelling expected travel time using selected crossing facility

Earlier studies have reported that expected travel time using any crossing facility is an important component of decision making process during crossing. Travel time of pedestrian indicates the crossing time using signalized crossing and detour time using footbridge. The response variable travel time is continuous numeric. Multiple linear regression (MLR) is most commonly used method to model this type of data with more than one covariate. The general framework of MLR model is given in Eq. (4).

$$TT_i = \alpha_0 + \alpha_1 x_{1i} + \alpha_2 x_{2i} + \ldots + \alpha_n x_{ni} + \varepsilon_i \tag{4}$$

Where, TT_i is the travel time of individual i (dependent variable), α_0 is the intercept, $\alpha_1, \alpha_2, \ldots \alpha_n$ are the regression coefficients to be estimated, $x_{1i}, x_{2i}, \ldots x_{ni}$ indicate the characteristics of i^{th} individual and ε_i is the random error component associated with i^{th} individual. It reflects the difference between the observed and fitted linear relationship.

5.1. Selection of variables for modelling

One-way Analysis of Variance (ANOVA) test results (unequal sample size) for the variable "Age group" showed violation of homogeneity of variance rule (significance of Levene statistic < 0.05) but proved that there is a difference in means across different groups (F = 6.702, sig. = 0.000). Post Hoc test (Games-Howell test) for multiple comparisons showed that there is significant difference in means of young (mean = 53.007 s and std. deviation = 38.482 s) and lower middle aged (mean = 42.342 s and std. deviation = 36.536 s) pedestrian groups. The variable “group size” also showed significant difference across the groups (F = 12.924, sig. = 0.000). The Post Hoc test identified that the group size 4 has significantly different mean travel time than that of the other three categories. It is found that there is no significant difference between groups of the variable “luggage” (F = 1.987, sig. > 0.05).

The independent-samples t-test indicates that there is a statistically significant difference in mean travel times of male and female (t = -2.819, df = 831.993, sig. = 0.005). Mean travel time of male pedestrians (49.899 s) is slightly higher than that of females (43.183 s). Pedestrians walking with at least one minor have higher mean travel time (66.145 s) than pedestrians walking without any minor (46.911 s). The difference in means between the two groups of variable “minor” is statistically significant (t = -2.097, df = 36.160, sig. = 0.043). The mean travel times in two groups of facility are also significantly different (t = -54.172, df = 316.887, sig. = 0.000). Two dummy variables (yes/no coded) for age group young and age group lower middle aged were created and difference in mean travel time was tested for significance using t-test. The Table 8 and Table 9 present the ANOVA and t-test results of selected variable groups respectively.

Table 8. Results of ANOVA for the variable group size.

Variable	Group category	Mean (s)	Std. Deviation (s)	F-value	Significance
Group size	One	48.181	36.666	12.924	0.000
	Two	32.948	2.284		
	Three	39.885	5.585		
	Four	101.843	13.339		

Table 9. Independent-samples t-test results for variables gender, young age group, lower middle age group, minor and facility type.

Variable	Group	Mean (s)	Std. Deviation (s)	t-value	Significance
Gender	Female	43.183	36.066	-2.819	0.005
	Male	49.899	39.533		
Young age group	Yes	53.007	38.482	4.292	0.000
	No	42.981	37.899		
Lower middle age group	Yes	42.342	36.536	-4.131	0.000
	No	51.920	39.531		
Minor	No	46.911	37.669	-2.097	0.043
	Yes	66.145	54.588		
Facility type	Signalized crossing	25.320	6.529	-54.172	0.000
	Footbridge	104.754	25.154		

5.2. Model formulation and estimation of coefficients for pedestrian travel time

Multiple linear regression model is used to estimate the travel time as the dependent variable. Age group young is coded as 1 for young pedestrians (18-30 years) and 0 for pedestrians above age 30 years. Gender was coded as 0 for female and 1 for male. Group size is ordinal variable with categories 1, 2, 3 and 4. Minor is a binary variable with two levels 0 if the person is accompanied by at least one minor and 1 otherwise. Facility is a binary coded variable, 1 for signalized crossing and 2 for footbridge. The model was estimated using 75% of the observations in IBM SPSS software. The independent variables were added to the model in a step wise manner. Table 10 presents the regression model fit and its adequacy. The F-statistic is obtained as 1035.46 which is highly significant at 5% level. F-test under analysis of variance is termed as the measure of overall significance of estimated regression. The measure of goodness of fit here is the coefficient of determination R^2. It is observed that the selected variables explain 86.6% of the variations in the observed data.

Table 10. MLR model fit and overall significance.

Model	Sum of Squares	d.f.	Mean Square	F	Sig.	R square	Adjusted R square	Std. Error of the Estimate
Regression	879308.036	5	175861.607	1035.460	0.000	0.866	0.865	13.032
Residual	136550.677	804	169.839					
Total	1015858.713	809						

Table 11. Parameter estimates of MLR model.

Variable (Abbreviation)	Coefficient	Std. Error	t-statistic	p-value	Tolerance
Constant	-50.053	1.743	-28.719	0.000	-
Gender (GEN)	-3.052	1.007	-3.032	0.003	0.919
Group size (GS)	3.735	0.716	5.216	0.000	0.920
Minor (MIN)	8.650	2.708	3.194	0.001	0.956
Facility (F)	74.898	1.074	69.761	0.000	0.917
Young (Y)	-4.298	0.967	-4.445	0.000	0.897

The final model comprised of five significant variables and the travel time can be predicted by Eq. (5) as shown below.

$$TT = -50.053 - 3.052 * GEN + 3.735 * GS + 8.65 * MIN + 74.898 * F - 4.298 * Y \quad (5)$$

5.3. Effect of explanatory variables on travel time

Table 11 presents the estimated coefficients and the significance of the predictors is described by t-statistic. From the model it can be predicted that a young male travelling alone without any luggage will take on an average 21.23 s if he selects signalized crossing and 96.128 s if he chooses to detour.

The negative coefficient of gender variable shows that men take shorter time than women to cross a given distance. This is because the size of average step by men is larger than that by women and walking speed of women is lower than that of men. Here it is observed that women take 3.052 s extra than men to cross or detour. The bigger the group size, higher will be the travel time. In general pedestrians involve in conversations while walking in a group. Also, it is a tendency of humans to keep close distance with other group members while walking. Hence their walking speeds decrease as a group thereby increasing the travel time. The parameter for effect of minor shows that travel time tends to increase in presence of any minor than when pedestrians walk alone or with adults only. Since the walking speeds of minor or children are lesser than elders due to smaller average step length of the former, the accompanying adults tend to adjust their walking speed to match with the minor. This results in higher travel time. The mean difference in travel time of a person between two type of facilities is 74.898 s. This is obvious as using footbridge is associated with additional ascending and descending which consumes a greater amount of energy than crossing at level surface. Considering the fact of decrease in walking speed with increase in age of adults, it can be proven that young pedestrians take less time for crossing or detouring than middle aged or elderly group. So, higher the proportion of middle aged or elderly group in the sample, higher will be the average travel time.

The tolerance of a variable is a measure of collinearity. It can be seen in Table 11 than the tolerance of all the predictors are close to 1, meaning no sign of multicollinearity among the variables.

5.4. Model validation

The predicted model was validated with remaining 25% of the sample and the root mean square error (RMSE) was found to be 16.901. The validation of the model was also checked using MLR validation plot (Fig. 5) by plotting observed travel time in x-axis and predicted travel time in y-axis. The coefficient of determination of the model in validation sample was found to be 91.67%. The points are clustered into two groups signifying two types of crossing facilities. Lower travel time values correspond to crossing at-grade and higher travel time values correspond to detour using grade separated crossing facility.

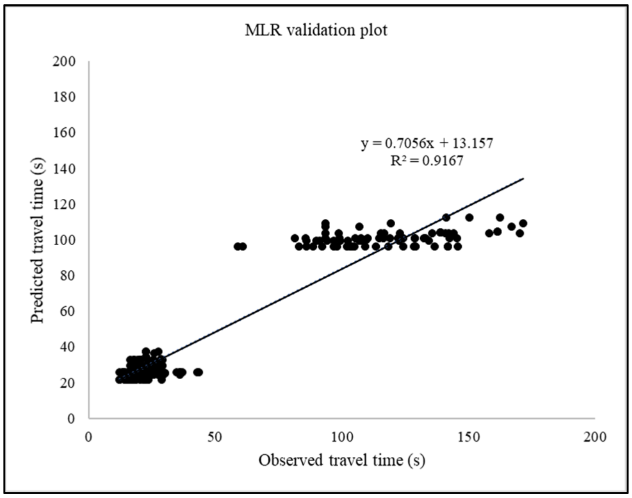

Fig. 5. Model validation plot for MLR.

6. Conclusion

In this study the pedestrian crossing behaviour was observed from video graphic survey. Binary logistic regression model was used to understand the pedestrian choice behaviour of crossing facility. Various factors influencing the choices are obtained. The variables age group, gender, luggage size and accompaniment were found to affect the choice behaviour. It was inferred that increase in pedestrian age reduces the usage of grade separated facility. Similar results were reported by Bernhoft and Carstensen (2008), Rankavat and Tiwari (2016) and Anciaes and Jones (2018). Women find it convenient to cross at-grade. The results showed that pedestrians having one or more bags might be in hurry so as to not waste time in waiting for the signal, rather detour and cross over safely. Choice behaviour of pedestrians depends on the accompaniment as well as the size of group he will travelling with. It is found that pedestrians walking in a group of 2 or 3 adults (small group) are 6.39% more likely to choose signalized crossing than those walking alone. Whereas pedestrians walking in a bigger group are 40.9% less likely to choose at-grade crossing than the ones walking alone. Hine (1996) also found that accompaniment boosts confidence while crossing, but nothing was mentioned regarding size of group. People become more cautious while a minor is around and choose safer crossing facilities. The model was validated using 25% of the sample where it was able to predict 70% of the choices correctly.

The expected travel time using any crossing facility is believed to be an important component of pedestrian choice behaviour. Therefore, the expected travel time was modelled using multiple linear regression technique and results showed that the difference in average travel time using at-grade and grade-separated crossing facility is 75 s for a particular gender, age group, luggage size and accompaniment. A young male travelling alone without any luggage will take on an average 21.23 s if he selects signalized crossing and 96.128 s if he chooses to detour. Men take shorter time than women to cross a given distance. Here it is observed that women take 3.052 s extra than men to cross or detour under similar conditions. The bigger the group size, higher will be the travel time. This study also shows travel time tends to increase in presence of any minor than when pedestrians walk alone or with adults only. Young pedestrians take less time for crossing or detouring than middle aged or elderly group. So, higher the proportion of middle aged or elderly group in the sample, higher will be the average travel time. The results showed that the travel time model could explain 92% of the variation in the validation sample. The MLR validation plot could be improved further by modelling crossing time and detour time separately in order to eliminate cluster formation.

The models presented in this paper can be applied to understand the pedestrian choices of crossing facilities in a better way where signalized intersection is provided with grade-separated crossing facility. Expected travel times can help in decision making of how to cross the road, which might help the pedestrians in making better choices and further reducing the waiting time at the signalized intersections. The ultimate aim of this study is to improve the efficiency of safe pedestrian crossing facilities and ease the pedestrian movement. It can be concluded that the construction of pedestrian crossing facilities should considerably based upon the distributional characteristics of the potential users.

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