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TECHNICAL PAPER

Assessment of pedestrian's road crossing behaviors and developing a model to predict road crossing speed on zebra-marked crossings

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Abstract
Zebra marked crosswalk is the most common types of road crossings on urban and rural streets. According to previous studies, accidents are frequently occurred on and around marked crosswalk. Assessment on crosswalk utilization, pedestrian crossing speed and modeling the crossing speed were the main goals of this study. The road crosser data were collected by video recording for the sake of its convenience. Road-crosser behaviors were extracted manually. Three road segments of 15 m length with zebra marked crosswalks were selected as a representative location for this study. The video was recorded in three different working days and two times per day, that represented high and low pedestrian movements. The duration for recording and observation was 15 min per segment. There were 494 pedestrians (37%) observed while crossing illegally from 1350 road crosser pedestrians. The extracted data were analyzed to determine the influence of human factors on crosswalk utilization and crossing speed on 323 pedestrians. The results showed that human factors did not influence the crosswalk utilization preference of pedestrians. However, human factors such as gender, number of elders, crossing group, activities and baggage had significant influence on the road crossing speed. A predictive model was developed using multiple linear regression for crossing speed.

Keywords Pedestrians' behavior · Crossing speed · Road segment · Crosswalk utilization · Predictive model

Introduction

Recent increase in the population of Addis Ababa has led to the significant increase in movement of the people. This is due to urbanization and better job opportunity attracts the people toward the city. As the number of road users increases, better facilities and transportation services are needed. Since most of the people are low-income workers, they use walking to do certain activities and to move from place to place. When they are walking on the side of a road way and crossing the road section its common seeing people who use the road illegally. The intervention between drivers and pedestrians is a basic phenomenon, (especially in urban areas) since the number of vehicles and pedestrian increases comparing to rural section. The pedestrian's safety is the main concern and the interaction between drivers and road users' needs emphasis. There are many pedestrians observed when crossing the road illegally. The reason is either design factor, human factor, behavioral, environmental factors or a combination of them [1, 2].

Walking is one means of trip and highly recommended for being healthy [3]. Also walking has many advantages in large cities. Because it can reduce the use of vehicles and then reduces traffic congestions and air pollution due to vehicles emission. Walking has well established health and environmental benefits such as increasing physical activity that may lead to reduced cardiovascular and obesity-related diseases, and many countries have begun to implement policies to encourage walking as an important mode of transport [4, 5]. Most of the time pedestrians walk along the roadway and cross the road illegally. The road networks in developing countries, including Ethiopia, are constructed without pedestrian footpaths. The highest number of crashes and injuries in Addis Ababa occurred at mid-block section of the city than any other locations. About 86% of the victims were pedestrians. The main reason associated with these crashes are pedestrian's improper using of the road

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and driver's speed [6, 7]. Illegal crossers are observed not only in zebra marked crosswalks but also on overpasses. There are many illegal crossers on overpasses according to Demiroz et al. [1].

Accidents on pedestrian during road crossing were increasing from time to time, and it was necessary to identify the root problems on the pedestrian's side. However, other factors like drivers, design factors and environmental factors may have their impact for the contribution for accidents. Pedestrian are the main elements as a risk taker and due to this identifying the safe and the unsafe crossing behaviors help pedestrian to minimize the severity and exposure for accident. Although there were many previous works that proved different injury and fatal reports on pedestrians on the road side and during road crossing, there was no direct study on the road crossing behaviors of pedestrian on road sides or mid-blocks for the study area. Hence, crosswalk utilization, assessment of pedestrian's behavior and modeling the crossing speed were the main aims of the study.

Literature review

Pedestrian road crossing behavior on and around zebra crossing along with crossing speed were studied by many researchers in different parts of the world. The study by Muley et al. (2017) on pedestrians' behavior while crossing the road, gender, group crossing, and destruction observed significantly affected crossing speed [8]. Furthermore, similar study by Walker et al. (2012) showed cautionary behavior (looking before crossing) for male pedestrians with or without personal music devices (PMDs) and found that male pedestrians with PMDs had more looking behavior than not listening PMDs. However, there were no effect on female pedestrians and concluded PMDs do not decrease cautionary behaviors [9]. According to Chen et al. (2018) Activities are one of the main human factors that influence the crossing speed significantly. Internet browsing, texting and emailing while crossing affect pedestrians' speed. Also, cell phone usage, taking, reading text can influence the crossing speed and reduce attentions of pedestrians while crossing [10]. The study by Bungum et al. (2005) on the relationship between distracted and cautionary behaviors of pedestrians while crossing a busy street found that 5.7% of the road crossers observed wearing headphones and 15.1% were eating, drinking, or smoking while crossing the road [11]. Currently most of the pedestrians own smart phones. The survey study shows many of the respondents were extremely dependent on smart phones. These smart phones are the main reasons for pedestrian distraction [12]. The study by Pawar et al. (2016) on analyzing and quantifying the dilemma zone for of 1107 crossing pedestrians at high-speed uncontrolled midblock crossings and find out the distribution of dilemma zone can vary with different categories of approaching vehicle, time of the day (day/night) and number of lanes [13]. Previous study by Pawar and Patil (2016) explore pedestrian temporal and spatial gap acceptance at uncontrolled mid-block street crossings, where vehicles do not yield to pedestrians and pedestrians have to choose safe gap on their own and then proved speed of the conflicting vehicle has significant effect on the spatial gap acceptance [14].

Pedestrian crossing speed affected by many human factors and traffic conditions. The crossing speed of pedestrians are affected by gender, age category, baggage and traffic conditions as studied by Jian et al. and Goh et al. [15, 16]. Additionally, the study by Yannis et al. (2013) revealed that gender and traffic condition can influence the gap acceptance [17]. Crossing speed of pedestrians can be assessed, analyzed and modeled. Multiple linear regression (MLR) and binary logistic regressions (BLR) are used to model pedestrians' behavior like pedestrian speed and gap acceptance by previous works [18–20].

The crash history in Ethiopia and the capital, Addis Ababa, are studied and the possible causes, the crash locations, crash injury severities and road usage are presented by previous works. Tulu et al. (2013) studied the Characteristics of Police-reported Road Traffic Crashes in Ethiopia over a Six Year Period. The study was from July 2005–June 2011 consisting of 12,140 fatal and 29,454 injury crashes on the country's road network. The 12,140 fatal crashes involved 1,070 drivers, 5,702 passengers, and 7,770 pedestrians, totaling 14,542 fatalities, an average of 1.2 road user fatalities per crash are reported. From this report, more than half of the fatalities in Ethiopia involve pedestrians. During the six years, pedestrian collisions comprised an average of 48.55% of fatalities, while rollovers accounted for 17.34%. According to the study failing to observe the priority of pedestrians, speeding and abundance of old vehicles were the major causes for crashes that were attributed by the police [21, 22].

Accidents are increasing from year to year and so different day by day. Saturday is the day of the week with most of the accidents occurred according to Tulu et al. (2013). From the five working days (Monday to Friday) Friday has most accidents. The locations of accidents are identified based injury data and organized by AATA. The injury type and severity also identified and presented in Table 1 for each location and year as shown from Fig. 1, the accident and damages are rising year to year. Most of the accidents and injuries located on the segmental road (no junction). For the study period year 2011 to 2015, the no-junction road location accounts highest injuries of property damages, serious injuries and minor damages [21].

Table 1 Description of variables and coding

Variables	Description	Coding	Symbol	Types of variables
Gender	Male or female	0 = female 1 = male	Gn	Discrete
Age	Child (< 18 years) Adult (18 to 50 years Elder (> 50 years)	0 = child 1 = adult 2 = elder	Age	Discrete
Crosswalk utilization	Pedestrian cross on zebra or not	0 = yes 1 = no	Utz	Discrete
Activity	Activities of pedestrians while crossing	0 = none 1 = talking 2 = talking mobile 3 = reading or texting	Act	Discrete
Crosser's pattern	No pedestrians crossing together or alone	0 = alone 1 = group	CRsize	Discrete
Bagging	Caring or bagging	0 = yes 1 = no	Bagg	Discrete
Crossing speed	Pedestrians crossing speed (m/s)	Numeric	CRspeed	Continuous
Waiting on side	Waiting for a clear space on side of road (sec.)	Numeric	WaitS	Continuous
Waiting on mid-block	Waiting for a clear space on mid-block of road (sec.)	Numeric	WaitM	Continuous

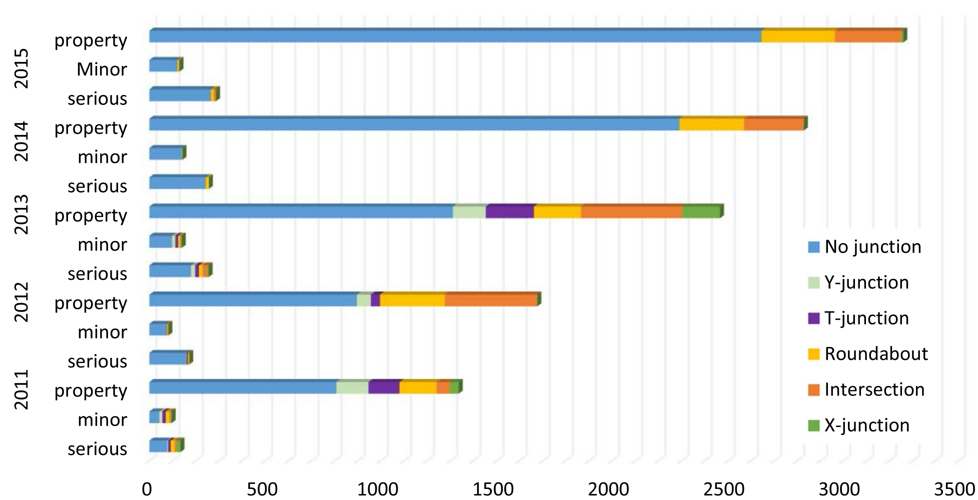

Fig. 1 Distribution of road traffic accident by location

Research methodology

Study design

During road crossing pedestrian may or may not use the zebra marked cross-walk. Also, pedestrians may do different activities that increase exposure of accidents and may affect the traffic flow when they are crossing such as talking with mobile phones, hugging, talking, eating and others that take their concentration on the crossing time or approaching car. From this research the effect of demographic characters (age and gender), pedestrian volume, activities of pedestrian (mobile usage), and crossing pattern (alone/group crossing) on crossing speed and crosswalk utilization are studied. The major steps followed in this study are: (1) Selection of suitable site for field survey (2) Selection of observation time (3) Field data collection (4) Data extraction (5) analysis of pedestrian data (6) Model development for pedestrian road crossing behavior (7) Discussion on results. The data were analyzed and interpreted using both descriptive and analytical methods approach as shown in Fig. 2.

Video recording

Video recording is the most reliable and carful method because data can be viewed by slowdown and replayed when necessary. This data collection method has high significance

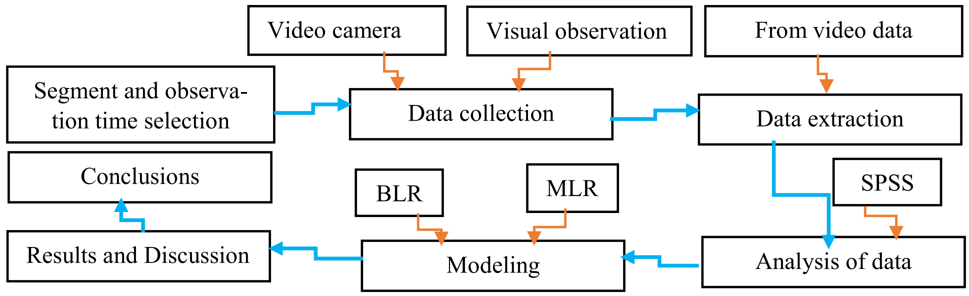

Fig. 2 Research design

of avoiding errors of counting pedestrian when they cross the road. The video cameras are fixed at convenient locations to record the pedestrian and vehicles data clearly. Pedestrians who use and do not use zebra walk are recorded. Waiting and crossing pedestrian are recorded with video.

Visual observation

This type of data collection technique is also carried out by directly observing the conditions on the selected road segments. In this case, different conditions are observed, i.e., number of lanes, crossing distance, fencing condition of pedestrian and choice of crossing section. Factors affecting pedestrian crossing behaviors and pedestrian-vehicle interaction are identified. Crossing length of the road segment was measured in the field.

Types of collected data

The data type that are collected in this study are pedestrian with safe and unsafe crossing, pedestrian who crosses on zebra, waiting pedestrian and vehicles. The data obtained from the camera recording and observations are divided in to two main categories, general and individual. General characteristics that include pedestrian behavior (alone/group crossing), pedestrian volume and pedestrian platoon. Individual characteristics include gender, age of pedestrian, pedestrian crossing path, pedestrian crossing speed and time, crossing condition (talking cellphone, stopping, stepping back, changing speed and path), crossing location/cross-walk utilization and pedestrian-vehicle interaction.

Observational locations selection

In this study purposive sampling method was used. The observation was taken by considering well-marked crosswalk(zebra) with unfenced segments, the selected areas were convenient for video recording and enhance clear observation of group and individual characteristics of the road crossers. Also, they represent different number of lanes as well as traffic volume. The possibility of illegal crossings also different. In order to clearly identify the face and behavior of pedestrian, 15 m length of road segment was selected for analysis from three road segments selected for data collection. The selected sites have different road characteristics and pedestrian conditions. The convenient place for camera fixing and description of the sites are stated. (1) Near to Wabi-Shebele Hotel (M-2): This site has six lanes (3 in each direction) and pedestrian island at the middle. It has fenced segment in one direction and unfenced segment with median in the other direction. (2) In front of Mexico Square(M-1): The location has six lanes (3 in each direction) and zebra marked cross walk with wider median (1 m). The video camera was fixed at ground and high pedestrian volume was observed. There was a flat terrain without fenced median. (3) Near to Bunana shay building (M-3): This location has high number of pedestrians to cross the road. The road has two lanes in each direction and a narrow median of 0.5 m width. There is possibility of illegal movement in both direction of the crosswalk.

Observation time

There were two different stages of data collection time for each site. This was to represent the high pedestrian movement and the low pedestrian movement. This was also to examine the pedestrian behaviors on different scenarios and when the speeds of vehicles were high and low. For both cases the observation duration was fifteen minutes. The data were collected under normal weather condition (sunny, no rain). Pedestrian volume and behavior obtained during this time was used for analysis. Based on previous studies on the area the majority of road crash accidents occurred in the two working days of the week (Monday and Friday). So, these two days were preferred for data collection.

Crosswalk utilization

Pedestrian has the choice to either use or the zebra marked crosswalk. Pedestrians have many reasons to use or not use the crosswalk. This may be human factor or design factors. Based on their utilization there are two types of pedestrians.

The first type of pedestrians is legal who utilized the crosswalk and the second type are illegal pedestrians who didn't utilize the zebra marked crosswalk.

Demographic characteristics

Demographic characters basically include gender and age groups. Gender includes men and female. The crossing speed was determined for male and female pedestrian. Age is grouped in to three categories. Children aged less than 18, adults from 18 to 60 and elders who were older than 60 years. Their age was estimated from their facial expression, physical appearance and walking structure. Facial texture and physical appearance were used to estimate the age category of pedestrian. Observers were close enough to the crossings to note these surface and configuration characteristics and make an age estimation based on observation of the pedestrians.

Pedestrian crossing speed

The crossing speed is determined by dividing the crossing distance by crossing time. The crossing time is the time taken by the pedestrian to complete the crossing path without stopping. The crossing distance is the length of the path used by the pedestrian to cross. The crossing speed is calculated from the video recordings. The crossing distance is taken as the inner two lanes for each case. The time taken by individual and group crossers, males and females, adults, children's and elders, and with different crossing activities is recorded. Pedestrians who changed crossing path, stop, changed direction and changed crossing condition are not included in crossing speed. During pedestrian crossing time determination, the pedestrian who cross on or parallel to zebra marked crosswalk with clear visibility to the entrance and leaving of the lanes are considered.

Pedestrian crossing condition

Pedestrians can cross the road alone or in group when two or more pedestrians cross the road together is considered as group crossing. A single crosser is taken as alone crosser.

Pedestrian crossing activities and bagging

During road crossing pedestrians may involve in different activities. Activities observed are talking mobile phone, texting or reading, bagging or caring, etc. These activities of pedestrians may affect the crossing speed, cross walk utilization preference and vehicle–pedestrian interact.

Waiting time

Before entering the crosswalk or at the mid-block pedestrians wait for the coming vehicle. This time depends on the approaching vehicle speed and the traffic volume. The waiting time is recorded using stopwatch for individual pedestrians and the average time is recoded.

Age estimation process

From the video age is estimated by looking facial observation and physical appearance of pedestrian. Because ages can be predicted to a particularly high degree of accuracy within the age range of 20–60, this method was justified by past research. Angulu et al. [23] surveyed the main issues to consider in age estimation via faces are image representation and estimation techniques. An average age estimation of an unknown person based on facial characteristics were made and therefore warranted by this past research. For the case of this study age group is classified in to three age intervals (i.e., < 18 years-children, 18–50 years-middle age (adult) and > 50 years-elders). This age grouping may have high accuracy than the literatures observed because the interval range is higher hence had less degree of errors.

Sample size determination

To represent the total population who crosses the road segment a sample size was calculated from online sample size calculator for a confidence interval of ± 5. Based on this sample size calculator from 1350 population a minimum of 299 road crossers represented the total population. Hence, for this study, there were 323 road crossers behaviors have been analyzed. However, the samples analyzed were based on purposive sampling technique.

Variables and coding

The dependent and independent variables were coded to use in SPSS software. Gender, age, crossers size, activities during road crossing and bagging or carrying are discrete variables. Crossing speed and waiting time are continuous variables. Categorical predictor variables cannot be entered directly into a regression model and therefore for meaningful interpretation, other method of dealing with information of this type must be developed. In general, a categorical variable with n levels is transformed into n-1 variables each with two levels. For example, age has three levels, hence it has two dichotomous variables that contain the same information as the single categorical variable. Similarly, activity has four levels hence it has three dichotomous variables. Dichotomous variables have the advantage that they can be directly entered into the regression model. The process of creating dichotomous variables from categorical variables is called dummy coding. These variables have the advantage of simplicity of interpretation and are preferred to correlated predictor variables [24, 25]. The codes of the variables are as shown in Table 1.

Data analysis

The qualitative and quantitative data (material) that were obtained from data collection process be analyzed by statistically or descriptive analysis method. For the quantitative analysis, a logistic regression was conducted to model the relationships between dependent variables and several independent variables covering the characteristics of drivers, pedestrian, and the environment. IBM SPSS 25 software and Microsoft excel 2016 were used for statistical and mathematical modeling. The analyzed data then modeled by multiple linear regression model and binary logit model.

Multiple linear regression (MLR)

A multiple regression model is a regression model that contains more than one regressor variable. The MLR model is useful for finding out the crossing speed of pedestrians [26, 27]. To include a categorical variable with more than two level in a multiple regression prediction model, additional steps are needed to ensure that the results are interpretable. These steps include recoding the categorical variable into a number of separate, dichotomous variables. To develop the crossing speed model, a log normal regression was selected by considering that pedestrian human factors which followed a normal distribution. The general model framework is given below:

$$\text{Crossing speed} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \cdots + \beta_n X_n$$

where; $X_{i\text{-}n}$ = explanatory variables; $B_{i\text{-}n}$ = are estimated parameters from the model; β_0 = constant; n = number of independent variables.

Binary logistic regression (BLR)

Further analysis was performed by developing a logistic regression model to describe the effect between two groups [28, 29]. In this study, the probability of pedestrians to utilize zebra marked crosswalk or not utilize was checked by a binary logit model (BLM). The probability of selecting alternatives can be expressed by a utility function given by equation: -

$$U_i = a_i + B_{i1} X_1 + B_{i2} X_2 + B_{i3} X_3 + \cdots . + B_{in} X_n$$

Where: U_i = utilization of alternative I; i = the alternative (utilize / not utilize); X = the independent variable; a = constant; B = coefficients; n = number of independent variables.

Results and discussions

Crosswalk utilization

Pedestrians have two alternatives to cross the road. These alternatives are either using zebra marked crosswalk or without using the crosswalk (Illegally). The human factors (demographic factors, group size, activities and bagging or carrying) that affect the choosing of the alternatives are studied in this research. The probability of utilization of the crosswalk has determined.

From Table 2, it's observed that about one-third of the pedestrians were engaged in illegal crossing (not utilize zebra). There were 494 pedestrians observed while crossing illegally from 1350 road crosser pedestrians. These constitute 37% of the total road crosser within 15 m road segment.

The human factors that contribute to the illegal movement are analyzed by binary regression analysis. From analysis of binary logistic regression for alternatives to utilize or not utilize the crosswalk is obtained as presented in Table 3. Then from the analysis the independent variables with Pearson significant (p value) less than 0.05 are taken as significantly influence the utilization and greater than 0.05 are not significant values. All human factors such as gender, age, number of crossers, activities and baggage of pedestrians can't influence the preference of crosswalk utilization. So, the studied behaviors or human factors doesn't affect the crosswalk utilization. This means whether the pedestrian is male or female, child, adult or elder, alone or group crosser,

Table 2 Crossing preference of pedestrian at high pedestrian movement

Site	Type of crossing	Total number of road crossers	
		High	Low
M-1	Illegal	87	62
	On zebra	274	102
M-2	Illegal	55	33
	On zebra	114	60
M-3	Illegal	179	78
	On zebra	208	98

Table 3 Binary logistic regression (BLR) analysis result for crosswalk utilization

Variables in the equation							
		B	S.E	Wald	Df	Sig	Exp(B)
Step 1[a]	Gn	−.088	.278	.100	1	.751	.916
	CRspeed	.333	1.318	.064	1	.801	1.395
	CRsize	−.264	.320	.683	1	.408	.768
	Bagg	−.002	.272	.000	1	.993	.998
	Child	.150	.464	.105	1	.746	1.162
	Adult	−.252	.350	.518	1	.472	.777
	None	.622	.584	1.137	1	.286	1.864
	Talking	.236	.623	.144	1	.705	1.266
	talking mobile	.717	.615	1.359	1	.244	2.049
	WaitS	−.017	.073	.058	1	.810	.983
	WaitM	−.151	.068	4.912	1	.027	.860
	Constant	−.573	1.656	.120	1	.729	.564

[a]Variable(s) entered on step 1: Gn, CRspeed, CRsize, Bagg, child, adult, none, talking, talking mobile, WaitS, WaitM

involved in activities or not or has baggage or without baggage, the utilization and preference of the crosswalk is not influenced by human factors. Therefore, the crosswalk preference is independent of human factors.

Yannis et al. (2013) proved that the pedestrians' decisions to cross the street depends on the traffic gap, the waiting time, the type the incoming vehicle and the presence of illegally parked vehicles [17]. According to Akash Jain et al. (2014) majority of pedestrian are not inclined to take risks since the safety margins and time gaps were not very high but some pedestrians are there who take very high risks while crossing the roads [15].

Factors affecting crossing speed

Crossing speed was one of the main factors that affect the design and management of the crosswalk. The crossing speed is extracted and categorized by age group, gender, crossing group, activities during crossing and bagging or carrying objects.

Crossing speed at each segment

The video recording is done for three road segments representing different conditions. The total number of pedestrians observed in 15-m road segment (including the crosswalk) for 15 min are presented with the number of pedestrians used for analysis. Pedestrians chosen for analysis are not randomly but in purposive way. Pedestrians must follow straight path and normal walking (not running or changing path) are selected for analysis. Pedestrians hidden from view by vehicles were also excluded from analysis. The number of pedestrians taken for analysis is greater than 20% of the total observed pedestrians for all independent variables and road segments.

The analysis result from MLR is presented with Pearson significant coefficient and p value. The effect of independent variables on the crossing speed (dependent variable) is determined for each road segment.

The MLR analysis of segment M-1 at high pedestrian's volume, as presented in Table 4, shows human factors such as gender, age(elder) and crossers size of pedestrians has significantly influenced the crossing speed having p value of less than 0.05. Utilization, number of children, waiting, activities and baggage have no significant influence on crossing speed on this segment. Significant values closer to 0.05 are more sensitively affect the crossing speed.

For segment M-1 at low pedestrian movement, as shown in Table 5, the analysis result of MLR for human factors such as gender, crossing size, adult and child, reading or texting has a significant influence ($P < 0.05$) on the crossing speed. Human factors such as baggage, talking, talking mobile, waiting time and crosswalk utilization have no significant influence on crossing speed ($P > 0.05$).

From this analysis, age, gender and activities(none) has a significant influence ($p < 0.05$) on the crossing speed for M-2 high pedestrians. However, crossing size, baggage, talking mobile, waiting time and utilization of crosswalk of pedestrians did not significantly influence the crossing speed of the pedestrians ($p > 0.05$) (see Table 6).

From Table 7, human factors like age, activity, crossers size, baggage Waiting times, and crosswalk utilization have no significant influence on crossing speed for M-2 low pedestrians ($p > 0.05$). However, gender have significant influence on the crossing speed ($p < 0.05$). The positive sign of the Pearson correlation coefficient indicates

Table 4 Multiple linear regression analysis result with SPSS 25 at M-1 high pedestrians

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig
		B	Std. Error	Beta		
1	(Constant)	1.379	.063		22.027	.000
	Gn	.107	.024	.385	4.472	.000
	Utz	.014	.025	.050	.563	.575
	Csize	−.102	.030	−.371	−3.391	.001
	Bagg	.044	.027	.146	1.623	.109
	Child	−.017	.038	−.059	−.462	.645
	Elder	−.119	.043	−.352	−2.745	.008
	None	.022	.034	.077	.654	.516
	talking mobile	−.040	.046	−.090	−.886	.379
	reading or texsting	−.114	.084	−.132	−1.360	.179
	Waitsd	−.005	.006	−.072	−.839	.405
	WaitMB	.005	.008	.058	.673	.503

[a]Dependent Variable: CRsp

Table 5 Multiple linear regression analysis result with SPSS 25 at M-1 low pedestrians

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig
		B	Std. Error	Beta		
1	(Constant)	1.305	.082		15.837	.000
	Gn	.101	.047	.313	2.141	.041
	Utz	.023	.037	.074	.625	.537
	Crsize	−.122	.049	−.411	−2.470	.020
	Bagg	.044	.045	.145	.979	.336
	Child	.153	.062	.371	2.475	.020
	Adult	.154	.055	.464	2.795	.009
	Talking	−.041	.057	−.128	−.725	.475
	talking mobile	−.094	.049	−.227	−1.905	.067
	reading or texsting	−.141	.060	−.286	−2.357	.026
	WaitS	.006	.010	.064	.553	.584
	WaitM	−.019	.012	−.189	−1.622	.116

[a]Dependent Variable: Crspeed

direct relationship and a negative sign indicates indirect relationship with the crossing speed.

Waiting times, talking each other, talking mobile and crosswalk utilization have no significant influence on crossing speed for M-3 high pedestrians. However, other human factors like age, gender, activity (reading or texting), crossers size and baggage have significant influence on the crossing speed. Significant values closer to 0.05 are more sensitively affect the crossing speed. The positive sign of the Pearson correlation coefficient indicates direct relationship and a negative sign indicates indirect relationship with the crossing speed (see Table 8).

From Table 9, number of children, talking, talking mobile, waiting times and crosswalk utilization have no significant influence on crossing speed for M-3 low pedestrians. However, other human factors like number of elder pedestrians, gender, reading or texting activity,

Table 6 Multiple linear regression analysis result with SPSS 25 at M-2 high pedestrians

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig
		B	Std. Error	Beta		
1	(Constant)	1.200	.061		19.828	.000
	Gn	.101	.029	.395	3.481	.001
	Utz	− .024	.026	− .093	− .908	.371
	Crsize	− .066	.035	− .258	− 1.909	.065
	Bagg	.039	.025	.154	1.555	.130
	Child	.155	.045	.455	3.413	.002
	Adult	.148	.034	.576	4.295	.000
	None	.088	.032	.336	2.759	.010
	talking mobile	− .011	.039	− .037	− .280	.781
	WaitS	− .002	.009	− .027	− .233	.818
	WaitM	.005	.007	.079	.753	.457

[a]Dependent Variable: Crspeed

Table 7 Multiple linear regression analysis result with SPSS 25 at M-2 low pedestrians

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig
		B	Std. Error	Beta		
1	(Constant)	1.365	.081		16.775	.000
	Gn	.100	.042	.293	2.365	.034
	Utz	.049	.041	.130	1.176	.261
	CRsize	− .130	.130	− .384	− 1.003	.334
	Bagg	.055	.058	.162	.938	.365
	Child	.061	.054	.118	1.127	.280
	Elder	− .130	.088	− .250	− 1.479	.163
	Talking	− .076	.146	− .224	− .517	.614
	talking mobile	− .124	.072	− .238	− 1.713	.110
	reading or texting	− .237	.139	− .276	− 1.709	.111
	WaitS	.009	.014	.079	.671	.514
	WaitM	.011	.011	.110	.988	.341

[a]Dependent Variable: Crspeed

crossers size and baggage have significant influence on the crossing speed ($p < 0.05$).

Crossing speed for all segments

The overall crossing speed is the combined effect of variables of all the selected segments. This combined speed analysis gives the governing factors that can affect the speeds of pedestrian during road crossing. The significant of the variables are checked by p value (which is less than 0.05) at 95% confidence level. For the dependent variable that are significant, a model is developed using multiple linear regression.

The result showed that gender has significant influence on the crossing speed of pedestrians. Number of elder pedestrians also has significant effect on crossing speed. Crossing group size and baggage has influence the crossing speed of pedestrians. Pedestrian activities such as, group talking, talking mobile and reading or texting also have a significant influence on the overall crossing speed ($p < 0.05$).

Crosswalk utilization, number of children and waiting time have non-significant influence on the crossing speed. From Multiple linear regression analysis results presented in Table 10. The dependent variable was crossing speed and model is developed for variables that have significant effect.

$$\begin{aligned} \text{CRspeed} =& 1.413 + 0.088\text{Gn} - 0.116\text{El} - 0.11\text{Csize} - 0.039\text{talk} \\ & - 0.072\text{talkmob} - 0.133\text{redtex} + 0.054\text{Bagg} \end{aligned}$$

Table 8 Multiple linear regression analysis result with SPSS 25 at M-3 high pedestrians

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig
		B	Std. Error	Beta		
1	(Constant)	1.343	.033		40.236	.000
	Gn	.055	.023	.207	2.361	.021
	Utz	− .003	.022	− .012	− .141	.888
	CRsize	− .118	.026	− .445	− 4.625	.000
	Bagg	.056	.024	.207	2.295	.024
	Child	.143	.045	.321	3.172	.002
	Adult	.076	.029	.258	2.583	.012
	Talking	− .026	.030	− .082	− .859	.393
	talking mobile	− .038	.030	− .106	− 1.253	.214
	reading or texting	− .110	.049	− .188	− 2.233	.028
	WaitS	− .010	.013	− .067	− .810	.420
	WaitM	− .001	.011	− .009	− .103	.918

[a]Dependent Variable: CRspeed

Table 9 Multiple linear regression analysis result with SPSS 25 at M-3 low pedestrians

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig
		B	Std. Error	Beta		
1	(Constant)	1.409	.034		41.381	.000
	Gn	.074	.035	.258	2.106	.043
	Utz	.017	.024	.061	.715	.480
	CRsize	− .086	.041	− .296	− 2.115	.042
	Bagg	.097	.042	.325	2.288	.029
	Child	.003	.036	.008	.079	.937
	Elder	− .127	.037	− .303	− 3.399	.002
	Talking	− .055	.049	− .176	− 1.138	.263
	talking mobile	− .020	.044	− .044	− .457	.651
	reading or texting	− .108	.052	− .216	− 2.101	.043
	WaitS	− .005	.009	− .049	− .580	.566
	WaitM	− .007	.009	− .072	− .788	.436

[a]Dependent Variable: CRspeed

The significant of this model is to predict the crossing speed using the demographic characters, crossing conditions and age proportion of pedestrians while crossing as a general model for all segments. From the model developed, the proportion of men can increase the crossing speed by 0.088.the number of elder road crossers can reduce the crossing speed by 0.116 times the proportion of elders relative to adults. Talking with others, talking mobile and reading or texting can reduce the crossing speed by 0.039, 0.072 and 0.133, respectively. Crossing the road without baggage or carrying goods can increase the crossing speed by 0.054.

Group crossing can reduce the crossing speed by 0.11 times proportion of group crossers relative to pedestrians crossing alone. Gender has positive Pearson correlation coefficient ($B = 0.088$). This shows the flow of male pedestrian can increase the crossing speed.), hence it indicates the flow elder pedestrians can reduce the crossing speed. The road crossing group size also has a negative correlation coefficient (− 0.11). This shows group crossing can reduce the crossing speed of the pedestrians than a single crosser. Pedestrians involved with activities, i.e., talking, reading or texting and talking mobile while crossing can reduce the crossing speeds of a pedestrian. Pedestrians

Table 10 Multiple linear regression analysis result with SPSS 25 for all locations

Coefficients[a]						
Model		Unstandardized coefficients		Standardized coefficients	T	Sig
		B	Std. Error	Beta		
1	(Constant)	1.413	.015		91.926	.000
	Gn	.088	.011	.310	8.156	.000
	Utz	.003	.010	.009	.251	.802
	CRsize	−.110	.012	−.392	−8.894	.000
	Bagg	.054	.011	.187	4.793	.000
	Child	.027	.015	.064	1.775	.077
	Elder	−.116	.014	−.316	−8.516	.000
	Talking	−.039	.014	−.127	−2.843	.005
	talking mobile	−.072	.015	−.181	−4.873	.000
	reading or texting	−.133	.024	−.207	−5.622	.000
	WaitS	−.001	.003	−.014	−.390	.697
	WaitM	−.001	.003	−.012	−.338	.736

[a]Dependent Variable: CRspeed

without baggage and carrying things has larger speed than with baggage due to a positive correlation coefficient value.

Similar studies on modeling on pedestrian behavior by Kadali and Vedagiri (2013) presented crossing group size, age affect crossing conditions of pedestrians [18]. Socioeconomic characteristics of the individual like age and gender has also influenced the crossing behaviors of pedestrians as studied by Cantillo et al. [19]. Crosswalk type, age, group size and gender significantly contribute to pedestrian speed according to Zafri et al. and Goh et al. [16, 20]. Generally, the crossing speeds of pedestrians has been affected by human factors such as gender, age crossing group size, activities during crossing and crossing with baggage and carrying things and goods. Crosswalk utilization is non-significant which shows whether the pedestrian utilize zebra crosswalk or not cannot affect the crossing speed. Waiting time at the side or median of crosswalk have no significant influence (p value > 0.05) on the crossing speed of pedestrians.

Conclusion

In this study, pedestrian road crossing behavior on selected road segments was assessed and a predicting model for pedestrians crossing speed was developed by considering the variables that have significant influence. Furthermore, human factors that could and couldn't affect the Utilization of zebra marked crosswalk and the road crossing speed of pedestrians were identified. The data were collected by video camera fixed on appropriate positions on the selected segments. Then the video data were extracted and analyzed. Multiple linear regression and binary logistic regression were used for the analysis.

The findings of this study indicate 494 pedestrians observed while crossing illegally from 1350 road crosser pedestrians. These constitute 37% of the total road crosser within 15 m road segment. Human factor such as gender, age, activities, crossers group, baggage and waiting times have no significant influence on pedestrian's preference for utilization of the crosswalk. Hence, pedestrian's utilization of crosswalk is independent of the human factors.

The crossing speed is highly influenced by gender, age (number of elders), activities, crossers group and baggage of the pedestrians. Number of children and waiting times at the side or median has no significant effect on determining the pedestrians crossing speed. Road crossing speed has a direct relationship with the proportion of male pedestrians and crossers without baggage. Also, the crossing speed has indirect relationship with the proportion of elder pedestrians, group crossers and involvement in activities while crossing the road.

This study helps the government and the road client for design and management of cross walk facilities. Road clients and policy makers can use this model to predict the road crossers speed on mid-block segments and crosswalk of uncontrolled cryosection's. Additionally, the study output is used for urban planning and future research works to determine crossing speed and for comparative study.

The study considered only the uncontrolled road cross section for assessing pedestrian behavior, the researchers recommend to expand the study for signalized cross sections for utilization of crosswalk or modeling crossing speed to reduce pedestrian platoon.

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Declarations

Conflict of interest The authors declare that they have no competing interests.

Ethics approval and consent to participate The submitted work is original and has not been published elsewhere in any form or language.

Consent for publication All participants gave their consent for their data to be published in the journal article.

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