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# Impact of Social and Technological Distraction on Pedestrian Crossing Behavior at Signalized Crosswalks: A Case Study of Baneshwor Intersection

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**Abstract**
The study of pedestrian mobility is critical while designing pedestrian facilities, especially in urban areas. Although various studies associated with pedestrian crossing behavior have been carried out in the past, the potential impacts of distraction on pedestrian crossing behavior have not been comprehensively studied. Observational field study of 804 pedestrians was conducted at a signalized crosswalk of Baneshwor intersection. Multiple linear regression (MLR) model was developed to analyze the general walking speed of pedestrians. In addition, binary logistic regression model was developed to analyze the probability of distraction among pedestrians. Several demographic and distraction-based variables were found to be significantly associated with the walking speed and odds of distraction among pedestrians. The results obtained could be implemented by planners to incorporate the pedestrians' distraction behavior while designing pedestrian signals at crosswalks.

**Keywords**
distraction, signalized crosswalk, regression

## 1. Introduction

### 1.1 Background

Pedestrians form an integral part of transportation system and the study of their mobility is critical while designing pedestrian facilities, particularly in urban areas. About 40 percent journeys are made on foot in Kathmandu Valley [1]. Walking is regarded as the most efficient and sustainable mode of transport, especially for short trips. It promotes healthier lifestyle and well-being, helps to reduce traffic congestion and adds to social, economic and environmental benefits. Environmental factors that influence walking in urban areas include development patterns, residential density and land use mix [2].

One of the key elements to study the behavioral characteristics of pedestrians is their walking speed. The walking speed of pedestrians is an important parameter to be considered during the design and provision of pedestrian facilities, which is applicable in designing the signal timing for pedestrians. The walking speed generally depends upon age, gender and ability of an individual, as well as purpose and length of the trip. It may also vary according to environmental and geometric conditions. Moreover, the findings from various research papers indicate how the growing use of technology and social influence can affect the walking speed of pedestrians. The number of mobile cellular subscriptions for Nepal was 131.2 per 100 inhabitants [3]. Similarly, the prevalence of pedestrians using cell phones while crossing the road has also increased with the advancement of communication technologies and the popularity of smartphones [4]. Over time, distracted walking has been quite common among the pedestrians which are mainly categorized as technological distraction and social distraction. Distracted behaviour has strong association with the information processing ability of pedestrians, which has significant impact on their walking performance.

Installation of pedestrian countdown signals is a fairly new concept in case of Nepal since majority of the pedestrian crossings were unsignalized in the past. Recently, pedestrian countdown signals are being installed on the major busy intersections of the capital to assist pedestrians in crossing the street. Pedestrian signals are fully functional and operating only on limited crosswalks to date. At some crosswalks, vehicular and pedestrian traffic are controlled by traffic police, even after the installation of signals, which may be due to limited study of signal timing design. Similarly, due to lack of proper coordination and management, pedestrian red time is significantly high in comparison to green time for a cycle length at some locations, which may be due to excessive priority for motorized transportation system over non-motorized transportation system. There is currently a need to investigate how social and technological distraction may affect pedestrian crossing behaviour so that engineers and planners can address this behaviour while designing pedestrian clearance time to provide ample time for the pedestrians to cross the street.

### 1.2 Objectives of Study

The main purpose of the study is to quantify the impact of various forms of distraction on pedestrian crossing behaviour at signalized crosswalks. The specific objectives of the study are enlisted as below:

- To identify the major demographic and behavioral distraction factors that influence pedestrian walking speed at the crosswalks and examine their influence.
- To compare the characteristics of distracted and undistracted pedestrians using walking speed model.
- To analyze distraction behaviour of different groups of pedestrians using distraction model.

## 2. Literature Review

Numerous studies have assessed the effect of distraction on pedestrian crossing behavior at pedestrian crossings. Regression analysis is the most commonly used modelling technique in research studies.

Gates et al. (2006) analyzed the crossing behaviour of 1947 pedestrians at 11 intersections using multi-factor analysis of variance and discovered that pedestrian walking speed was dependent upon age, disability and group size. Elderly pedestrians exhibited slowest walking speeds. Similarly, groups of two or more pedestrians crossed the street 0.12 m/s to 0.18 m/s slower than pedestrians crossing alone. It was concluded that the walking speed of 1.22 m/s was insufficient for the older people, disabled ones or larger groups of pedestrians to cross the road safely [5].

Thompson et al. (2013) performed a study on the crossing behaviour of 1102 pedestrians at 20 signalized intersections using regression analysis and concluded that about one-third of total pedestrians were engaged in distracted behavior while crossing including listening to music, text messaging and using handheld phone. Pedestrians texting on phone took 1.87 extra seconds to cross the street compared to the undistracted pedestrians. However, the pedestrians listening to music walked about 0.54 seconds faster across the intersection [6].

Russo et al. (2018) studied the crossing behaviour of 3038 pedestrians at four signalized intersections and developed an ordinary logistic regression (OLS) model to examine the factors affecting pedestrian walking speed. It was discovered that talking or texting had no discernible effect on the walking speed. However, pedestrians using headphones tended to exhibit faster walking speeds compared to undistracted pedestrians. It was also found that males had slightly greater walking speeds in comparison to females. Age,group size and opposing pedestrians also had significant impact on walking speed of pedestrians [7].

Ropaka et al. (2020) analyzed the crossing behaviour of 2280 pedestrians at three signalized intersections and concluded that about one-fifth of pedestrians performed phone distracting activity while crossing. It was found that at high pedestrian volumes, pedestrians who were found to be texting or web-surfing on their mobile phones exhibited lower walking speeds compared to undistracted pedestrians, irrespective of their age, which resulted in higher crossing times for those groups [8].

Hameed A. Mohammed (2021) conducted a study on 1045 pedestrians from 23 midblock crossings using one-way ANOVA tests and six multiple linear regression models. The study suggested that 80 percent of total pedestrians were distracted by a secondary task. The pedestrians walking with headphones crossed faster (0.28 m/s) than undistracted pedestrians. Other distraction types were associated with lowering the walking speed by 0.09 m/s to 0.25 m/s [9].

There have been very few researches that have specifically examined the effects of both social and technological distraction on pedestrian crossing behaviour at signalized crosswalks. There is a need for comprehensive study to determine the walking speeds of distracted pedestrians in the context of Nepal so that it could be used by planners in the design of pedestrian clearance time.

## 3. Methodology

### 3.1 Study Area

The study area was selected considering high pedestrian flow to ensure large sample size, mixed land use and continuous operation of pedestrian signals. Taking into account the aforementioned criteria, an observational study through video recording was conducted at the signalized crosswalk of Baneshwor intersection using high-definition GoPro camera. Since genuine road user behavior may be recorded and afterwards examined frame by frame during data extraction, this sort of data collection is extremely covert. Similarly, the camera was setup in such a way that the entire crosswalk and pedestrian traffic signals were visible. The video recording was conducted during daylight hours and clear weather conditions. Data were collected via video recording for two hours on a weekday (10:00 -12:00) and a total of 6 hours of video recording was performed over three days for analysis.

**Figure 1:** Baneshwor Intersection

Features of the study area:

- Type of intersection: Four-legged
- Crosswalk selected: On the way to Sankhamul
- Number of lanes: Two
- Length of crosswalk: 9.18 m
- Width of crosswalk: 4 m

### 3.2 Data Description

The summary statistics of pedestrian observations at the study area is presented in Table 1.

**Table 1:** Summary Statistics for Pedestrians

| Variable | Total Observations |
|---|---|
| Pedestrian Walking Speed (m/s) | |
| Speed >0.8-1 | 164 (20.4%) |
| Speed >1-1.2 | 344 (42.78%) |
| Speed >1.2-1.4 | 207 (25.74%) |
| Speed >1.4-1.6 | 89 (11.04%) |
| Distraction | |
| No distraction | 400 (49.75%) |
| Talking on phone | 88 (10.94%) |
| Looking at phone | 40 (4.97%) |
| Wearing headphone | 80 (9.95%) |
| Talking in pair | 104 (12.93%) |
| Talking in group | 32 (3.98%) |
| Carrying heavy baggage | 38 (4.72%) |
| Carrying baby | 22 (2.73%) |
| Pedestrian Gender | |
| Male | 445 (55.34%) |
| Female | 359 (44.65%) |
| Pedestrian Age | |
| Age 16-29 | 459 (57.08%) |
| Age 30-59 | 253 (31.56%) |
| Age 60 or older | 92 (11.44%) |
| Group Size | |
| Single Pedestrian | 216 (26.86%) |
| 2 pedestrians | 233 (28.98%) |
| 3-4 pedestrians | 269 (33.45%) |
| 5 or more pedestrians | 86 (10.69%) |
| Opposing pedestrians | |
| No opposing pedestrian | 512 (63.68%) |
| 1-2 opposing pedestrians | 131 (16.29%) |
| 3 or more opposing pedestrians | 161 (20.02%) |

The demographic and behavioral characteristics of pedestrians were observed through the video analysis. Only those pedestrians who showed completely one form of distraction behavior while crossing the street were taken into account. Following data were extracted from the video recording:

- Pedestrian distraction, recorded as one of eight discrete categories: no distraction, talking on phone (throughout crossing), looking at phone (throughout crossing), wearing headphone (listening to music), talking in pair (engaged in conversation), talking in group (engaged in conversation), carrying heavy baggage (who

were visibly uncomfortable carrying baggage) and carrying baby
- Pedestrian age: 15 or younger (child), 16 to 29 (young), 30 to 59 (middle aged) and 60 or older (old)
- Pedestrian gender: male or female
- Group size at the time of crossing the street
- Number of pedestrians crossing from the opposite direction during crossing
- Pedestrian crossing length and width

The pedestrian data was not recorded if any of the following characteristics were present:

- The pedestrian ran at any moment throughout the crossing.
- The pedestrian started crossing at a point outside of the crosswalk.
- The crosswalk was totally blocked by the passing vehicle.

### 3.3 Sample Size

In order to ensure representativeness, sample size determination entails deciding how many observations to include in a statistical sample.

According to Tabachnick and Fidell (1996), the formula for the determination of sample size for linear regression takes the following form:

$$Sample\ Size > 50 + 8*m \tag{1}$$

where, $m$ = Number of independent variables = 11
∴ $Samplesize$ ¿ 50 + 8*11 ¿ 138

According to Peduzzi et al. (1996), the minimum number of cases to be considered for the study using logistic regression takes the following form:

$$Sample\ Size = \frac{10*k}{p} \tag{2}$$

where, $k$ = Number of independent variables = 3
p = Proportion of undistracted cases from total population= 0.44
∴ $Samplesize = \frac{10*3}{0.44} = 68$

A total of 530 cases were considered for developing both the models, to ensure adequate and representative samples of pedestrians.

### 3.4 Statistical Analysis

Data obtained from the video recording were analyzed using Microsoft Excel and IBM SPSS Statistics (Version 25). Statistical analyses were conducted using two modelling approaches: multiple linear regression and binary logistic regression models. A general pedestrian walking speed model was developed considering both demographic and behavioral characteristics of pedestrian using multiple linear regression. Similarly, a distraction model that predicts probability of an individual being distracted was developed using binary logistic regression.

The basic equation of pedestrian walking speed model takes the following form:

$$S_i = \beta_o + \beta_i X + \varepsilon \tag{3}$$

where $S_i$ is the walking speed (in m/s) for pedestrian i, X is a vector of study site and pedestrian characteristics (age,gender and pedestrian distraction), $\beta$ are vectors of parameters and $\varepsilon$ is the model error or residuals.

The coefficient of determination (R-square) is a statistical measure used to test the accuracy of pedestrian walking speed model. It is used to gauge the extent to which changes in the independent variables may account for variations in crossing speed.

The basic equation of the distraction model takes the following form:

$$Y = \beta_o + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n \tag{4}$$

where $Y$ is the log of odds of distraction, $\beta_o$ is the intercept when all other parameters are zero, $\beta$ is the variable coefficient for i=1,2,3...n and $X_i$ is the independent variable.

The distraction model considers two outcomes: distraction and no distraction. The probability of a pedestrian being distracted is given by the following equation:

$$P = \frac{e^Y}{1+e^Y} \tag{5}$$

## 4. Results and Discussions

### 4.1 Pedestrian Walking Speed Model

Multiple linear regression model was developed using SPSS to determine the walking speed of pedestrians based upon demographic characteristics and forms of distraction. The crossing speed is taken as dependent variable with all other variables being independent. The model includes significant explanatory variables at 95% confidence interval. Table 2 presents the model summary considering significant variables. The R-square value obtained for this model is 0.76 which signifies that 76% of independent variables account for the variation in crossing speed.

**Table 2:** Model Summary

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .875 | 0.766 | 0.759 | 0.088585 |

Table 3 shows the coefficients of the final model considering significant variables, which represents the pedestrian walking speed model. Dummy variables were used to define a comparison group to interpret the coefficients in regression analysis.

**Table 3:** Coefficients of Walking Speed Model

| Model | B | t | Sig. |
|---|---|---|---|
| **(Constant)** | 1.365 | 125.068 | 0.000 |
| **Talk over phone** | -0.226 | -17.762 | 0.000 |
| **Look at phone** | -0.295 | -17.357 | 0.000 |
| **Talking in pair** | -0.188 | -15.241 | 0.000 |
| **Talking in group** | -0.218 | -9.789 | 0.000 |
| **Carrying heavy baggage** | -0.21 | -11.607 | 0.000 |
| **Carrying baby** | -0.279 | -12.314 | 0.000 |
| **Group Size=3-4 pedestrians** | -0.031 | -3.561 | 0.000 |
| **Group Size=5 or more pedestrians** | -0.06 | -4.495 | 0.000 |
| **Age=30-59** | -0.118 | -13.388 | 0.000 |
| **Age=60 or older** | -0.353 | -27.309 | 0.000 |
| **Opposing Pedestrians=No pedestrian** | 0.027 | 2.732 | 0.007 |
| **Opposing Pedestrians=3 or more pedestrians** | -0.069 | -5.363 | 0.000 |
| **Gender=Female** | -0.061 | -7.701 | 0.000 |

From the developed model, it was concluded that the technological distraction in the form of looking at phone and social distraction in the form of carrying baby had the most significant impact on walking speed and caused the reduction of walking speed by 0.29 m/s and 0.28 m/s respectively compared to the undistracted pedestrians. It may be due to the reason that looking at phone is more of a attention demanding task. Carrying baby is another attention-demanding task which could have lowered the walking speed of pedestrians. Other distraction behaviour causing reduction in walking speed were talking over phone, talking in group, carrying heavy baggage and talking in pair which reduced the walking speed by 0.23 m/s, 0.22 m/s and 0.21 m/s and 0.18 m/s respectively. In terms of group size, pedestrians being accompanied by more pedestrians around had significant influence on walking speed. People crossing the street with 5 or more pedestrians in the same direction exhibited slower walking speed compared to when group size was less. People aged 60 or older exhibited slowest walking speeds which was followed by middle-aged adults. Similarly, pedestrians crossed the street faster when they did not encounter pedestrians coming from the opposite direction. With respect to gender, females exhibited slightly lower walking speed in comparison to males.

## 4.2 Distraction Model

Binary logistic regression model was developed using SPSS to determine the probability of being distracted based upon demographic characteristics at 95% confidence interval. Distraction is taken as dependent variable and age, gender and crossing speed were taken as independent variables. Distracted pedestrians were coded as ‘1’ whereas the undistracted pedestrians were coded as ‘0’. Age 30-59 category was taken as reference for interpreting the probability of distraction based on age and female category was considered as reference for interpreting the probability of distraction based on gender.

Table 4 presents the model summary considering significant variables and the Nagelkerke R square is found to be 0.549, which signifies that 54.9% of independent variables account for the variation of distraction behavior.

**Table 4:** Model Summary

| Step | -2 Log likelihood | Cox & Snell R Square | Nagelkerke R Square |
|---|---|---|---|
| **1** | 453.159 | 0.412 | 0.549 |

Table 5 displays the coefficients of the final model considering significant variables, which represents the distraction model. From the developed model, it was found that the probability of a pedestrian being distracted increases with the reduction in walking speed. The odds of youths (aged 16 to 29) being distracted is 7 times more compared to middle-aged people. It may be due to the reason that smartphones are quite popular among youths which significantly increases their probability of using cell phones. It is also possible owing to the fact that youths are more engaged in conversation with others in a pair or group while crossing the street. With respect to gender, the distraction model indicates that male proportion are 1.7 times more likely to be distracted in comparison to females, which is due to the fact that females show more cautious approach at crosswalks compared to males.

**Table 5:** Coefficients of Distraction Model

| Variable | B | S.E. | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|
| **Age** | | | 76.417 | 2 | 0.000 | |
| **Age 16-29** | 1.986 | 0.295 | 45.365 | 1 | 0.000 | 7.286 |
| **Gender (Male)** | 0.557 | 0.245 | 5.173 | 1 | 0.023 | 1.746 |
| **Speed** | | | 90.878 | 3 | 0.000 | |
| **Speed >0.8-1** | 6.531 | 1.057 | 38.164 | 1 | 0.000 | 685.777 |
| **Speed >1-1.2** | 2.188 | 0.294 | 55.382 | 1 | 0.000 | 8.916 |
| **Constant** | -2.747 | 0.362 | 57.729 | 1 | 0.000 | 0.064 |

## 5. Model Validation

### 5.1 Pedestrian Walking Speed Model

From the total data sets, 33% of the data sets (which were not used for developing the MLR model) were considered for validation. Regression analysis between the observed value and predicted value of pedestrian walking speed yielded the following results:

- R Squared Value = 0.785 (i.e. 78.5% of variance of original field data is explained by the variance of field data obtained from MLR equation)
- Regression Equation: Observed Value = 0.16 + 1.13 * Predicted Value

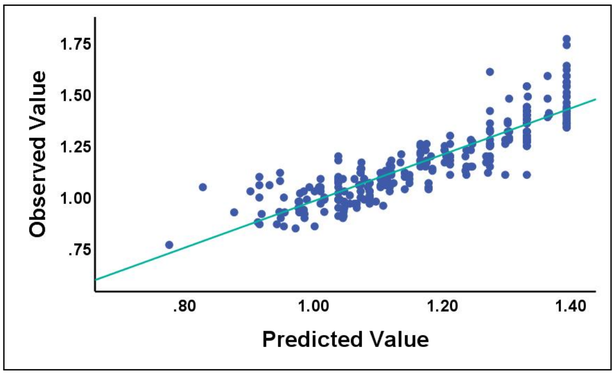


**Figure 2:** Line Fit Plot of Crossing Speed: Validation

### 5.2 Distraction Model

The accuracy of the model was tested using 33% of the total data sets which were not used for developing the actual model. The sensitivity and specificity values were found to be 88.5% and 83.8% respectively. The overall prediction ability of the validated model is 86.2% as shown in Table 6.

**Table 6:** Validation Table

| Observed | Predicted | | |
|---|---|---|---|
| | Undistracted | Distracted | Percentage Correct |
| **Undistracted** | 131 | 17 | 88.5 |
| **Distracted** | 21 | 109 | 83.8 |
| **Overall Percentage** | | | 86.2 |

## 6. Conclusion

Numerical results obtained from the models help to derive the following conclusions:

- Distraction in the form of looking at phone and carrying baby had the most significant impact on the walking speed followed by talking on phone, talking in group, carrying heavy baggage and talking in pair.
- The walking speed of pedestrians reduced significantly when they were accompanied by other pedestrians from both directions while crossing the street.
- Elderly pedestrians exhibited slowest walking speeds followed by middle-aged adults.
- Females exhibited slightly lower walking speed in comparison to males.
- Youths were more likely to be distracted while crossing the street.
- Males had higher odds of being distracted in comparison to females.

## 7. Recommendation

The findings from the study suggest that the distracted pedestrians tend to walk significantly slower compared to undistracted pedestrians. Hence, there is a comprehensive need to incorporate these sorts of behaviour while designing pedestrian facilities. It is recommended to design the pedestrian clearance time on the basis of design walking speed and distraction behavior of pedestrians at signalized crosswalks. The planners need to take into account the behavioral characteristics of pedestrians of all groups so that the design would cater the needs of all pedestrians. Provision of adequate green time for pedestrians would enhance the overall safety and efficiency of transportation system.

The analysis could be performed using alternative modelling techniques for the future purpose. Similarly, the effect of vehicular flow on distracted pedestrians could be considered to analyze the impact of distraction from safety point of view.

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