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Factors Affecting the Waiting Time of Pedestrians at Unsignalized Crosswalks of Kathmandu: A Case Study of Bagbazar and Jamal Crosswalks

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Abstract

Unsignalized crosswalks are the most common pedestrian crossing facilities on the city roads of Kathmandu. This sharing of the road between pedestrians and vehicles can be very unsafe for walking. To demur such conflict, analyzing the waiting behavior of pedestrians and designing pedestrian signal considering different factors is the most efficient way. The degree to which pedestrians adhere to signals depends largely on their patience while waiting. Thus, it is crucial to account for pedestrian waiting tolerance when planning pedestrian signal timing. A study at unsignalized crosswalks of Bagbazar and Jamal were taken into consideration for this study. This research delves into analyzing the factors that impact the waiting time, a key indicator of pedestrian patience at unsignalized crosswalks in Kathmandu. Using SPSS, binary logistic regression is conducted with the waiting time of a pedestrian before crossing as the dependent variable and road width, the gap between vehicles, speed of accepted vehicles, pedestrian size, gender, crossing pattern, and the presence of a carried object as predictor variables. The article encountered that gender, crossing pattern, carrying any object, size of pedestrians, road width and time gap between the vehicles at the nearer lane of a pedestrian are the significant factors to affect the waiting time. The results could be employed by planners to coordinate the design of pedestrian crossing facilities with the behavioral patterns of pedestrians at unsignalized crosswalks.

Keywords: Unsignalized Crosswalk, Waiting Time, Pedestrian Behavior, SPSS, Binary Logistic Regression

1. Introduction

1.1. Background

Crosswalks hold significant importance in urban settings as they serve as essential facilities frequently employed to mitigate conflicts between pedestrians and vehicles. Their primary purpose is to contribute to the reduction of potential pedestrian fatalities by creating designated areas for pedestrians to safely cross roads. The utilization of crosswalks is a key strategy aimed at enhancing pedestrian safety, ensuring a structured and organized flow of both pedestrian and vehicular traffic. The pedestrian crossing process is influenced by different types of crosswalks, each having its own impact on how pedestrians navigate streets. These variations are shaped by factors such as the intervals between passing vehicles and the specific behaviors exhibited by both pedestrians and drivers within these designated crossing areas. (Kadali et al, 2016). Unlike crossings with traffic signals that help in the management of flow, it's tricky to keep pedestrians and vehicles organized when there is no signal controlling traffic. When people walk across the street without traffic signals, their paths might mix with where vehicles are going. This sharing of space can be very risky for pedestrians because there's a competition for the right of way, making it dangerous. (Ishiyama et al., 2018). So, conflicts between vehicles and pedestrians at unsignalized crosswalks are one of the leading causes of reduced roadway capacity (Yue et al., 2020). Since, pedestrian crossing markings might give pedestrians a misleading feeling of safety. In such situations, it's important to study how Pedestrians behave and how much pedestrians can wait in unsignalized crossings to alleviate the contributing factors so that the pedestrian

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can have a safe environment for crossing in aid of pedestrian signal and also improve the efficiency of traffic operation. However, longer waiting time triggers the traffic violation. Hence, this study pinpoint factors that affect the waiting time, pedestrian tolerance and risk-taking behavior, and help in the signal timing design of pedestrians.

1.2. Objectives of the Study

- To study different factors that affect the waiting time of pedestrians at unsignalized crosswalks of Kathmandu.
- To develop a model that can be used to predict the waiting time based on the identified factors.

2. Literature Review

Hamed, (2001) did a study to understand how people cross roads in the middle of the block, whether the road is divided or not. The study found that the number of times people try to cross safely depends on how long they have to wait. On roads without a divider, people act differently when crossing from one side to the middle and from the middle to the other side. The study found that men are 1.3 times more likely to cross a divided road to a safe spot faster and 3.1 times more likely to cross from a safe spot to the other side of the road faster than women.

Oxley et al., (2005) examined the impact of different variables on pedestrians' judgments of time gaps through a simulated road crossing task. The research explored the influence of factors such as age, proximity to the approaching vehicle, time gap, vehicle speed, and walking time on individuals' decisions to cross. The results indicated that the most significant factor affecting pedestrian crossing decisions was the distance of the approaching vehicle.

Li, (2013) developed a model for pedestrians' anticipated waiting times at signalized intersections. The study identified factors affecting waiting times, including the number of pedestrians waiting, walking speed, pedestrian phase duration, and distance to the opposite sidewalk. Results showed that waiting times increase with more waiting pedestrians, decrease with faster walking speeds, and are longer with shorter pedestrian phases. The study suggests that this model can estimate pedestrians' intended waiting times, offering potential improvements for signal timing and pedestrian safety at signalized intersections.

Paudel, (2014) emphasized the significance of understanding road crossing behavior, deeming it a crucial aspect in the establishment of road crossing facilities. Recognizing the interaction between pedestrians and vehicles as a major hindrance to safe road crossings, he conducted a study aimed at developing a model to identify the critical gap in mid-block crossings under mixed traffic conditions in the Kathmandu Valley. The findings highlighted that waiting time, pedestrian speed, and gap type were significant factors explaining the minimum gap size value and the acceptance of gaps by pedestrians. Consequently, study concluded that the decision-making process of pedestrians could be more effectively elucidated by considering gap size, vehicle speed, and vehicle type.

Chand, (2021) explored pedestrian gap acceptance specifically focusing on the dimensions of vehicular gaps accepted by individuals when crossing at mid-block sections of the ring road. Their findings indicated that the primary independent variables influencing gap acceptance behavior were safety distance and vehicle speed.

In the investigation carried out by (Shah, 2022), the focus was on evaluating the red-light violation tendencies of Nepalese pedestrians at signalized crosswalks. The findings indicated that pedestrians exhibit a preference for adhering to the signal, waiting for the green phase, especially when the remaining duration of the red phase (until the green phase) is less than 50 seconds. However, there is a noticeable trend of pedestrians violating the signal promptly losing the waiting tolerance when confronted with a remaining red duration exceeding 100 seconds.

3. Methodology

3.1. Framework and Variables Involved

The framework adopted in this study is as shown in Figure 1. The literature review was done thoroughly throughout the study for better understanding the behavior of pedestrians.

Figure 1. Study Framework

Different variables for the study were pinpointed focusing on the objectives of study. Since, the purpose of the study is to determine the factors that affect the waiting behavior of pedestrian at the most occupied unsignalized crosswalks of Kathmandu. The variables involved are waiting time (s), near gap (s), near speed (m/s), far gap (s), far speed (m/s), crosswalk length (m), gender, pedestrian size, crossing pattern and carrying anything. Near gap can be defined as the time gap between the last rejected vehicles and the accepted vehicles at the near lane of a pedestrian and the speed of this accepted vehicles is near speed. Far gap and far speed are respective definitions at the opposite lane of pedestrian. The crossing pattern is divided into whether the pedestrian ends the waiting time from the designated starting point of a crosswalk or from outside the marking as shown in Figure 2Figure 2. Additionally, the outcome variable waiting time is divided into dichotomous categories of waiting or not waiting before crossing the road for binary logistic regression modeling.

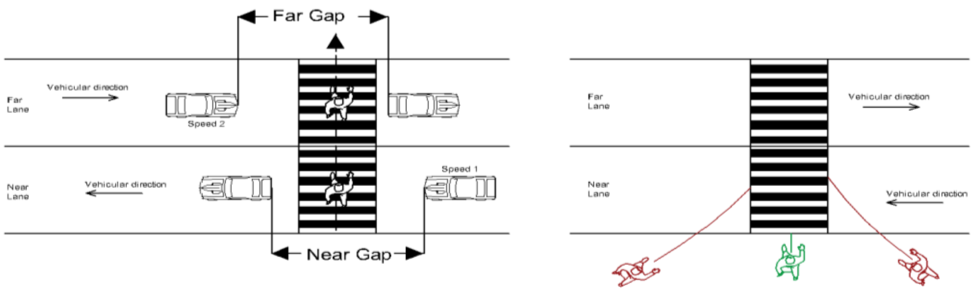

Figure 2. Variable Description

3.2. Study Sites

For identifying the factors that affect the waiting time, recce was done at different unsignalized crosswalks of Kathmandu. Based on pedestrian flow, vehicular flow, position for the camera, and availability of enough variables, bagbazar and jamal crosswalks were finalized for study. Bagbazar road was 8.74 m two-way two lanes road and jamal road was 18.06m two way four lanes. Correspondingly, the width of bagbazar and jamal crosswalks were 3.5m and 4m respectively. Parking was not allowed on either side of the street.

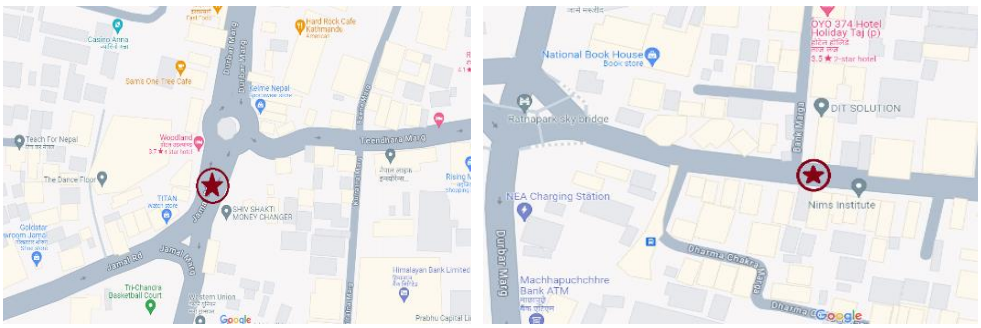

Figure 3. Study Site (Jamal and Bagbazar respectively)

3.3. Binary Logit Model

Logistic regression can be employed in a confirmatory approach to examine the association between an explanatory variable and a binary outcome, providing insights into the factors influencing the outcome. In this context, a logit refers to the natural logarithm of the odds of an event occurring.

$$Odd\ Ratio\ or\ Exp(B) = \frac{Probability\ of\ an\ event\ occuring}{Probability\ of\ an\ event\ not\ occuring} \quad \text{(Equation 1)}$$

(Equation 1 reveals that an odd ratio of 1 signifies a neutral relationship between the predictor and the event. A value above 1 implies a "positive" association, where the event's probability grows alongside the predictor. Conversely, an odd ratio below 1 suggests a "negative" association, meaning the event becomes less likely as the predictor increases. Importantly, the odd ratio goes beyond simply indicating the direction of the relationship. It also quantifies the "strength" of each variable's contribution to predicting the event's occurrence. A larger deviation from 1 in either direction signifies a stronger influence on the probability. As shown in (Equation 2, the probability of waiting based on the linear combination function is given as

$$Probability\ of\ waiting\ (P) = \frac{e^Y}{1 + e^Y} \quad \text{(Equation 2)}$$

where,

$Y = \beta_0 + \beta_i * X_i$: Dependent variable (the log of odds of waiting)

β0: Intercept

βi: Coefficient of regression for i= 1, 2, 3, …n

Xi: Independent variables

3.4 Sample Size and Data Collection

The reliability and accuracy of study findings are contingent upon the critical consideration of sample size in research. A thoughtfully selected sample size guarantees a precise portrayal of the population, encompassing its diversity and characteristics. Utilizing empirical formulas presented by Levy and Lemeshow (2008), the sample size was determined under the assumption of a normally distributed population.

$$N_\infty = \frac{Z^2 * p * q}{e^2} \quad \text{(Equation 3)}$$

Since, Z is a parameter having a value of 1.96 for a 95% confidence interval, e is a desired error margin having the value of 5% and p represents the hypothesized true proportion for the population, chosen as 0.5 to accommodate the worst-case scenario. Therefore, the minimum sample size derived from Equation 3 for the finite population is

$$N_f = \frac{N_\infty}{1 + \frac{N_\infty - 1}{N}} \quad \text{(Equation 4)}$$

where,

N_∞: Size for the infinite population.

N_f: Size for the finite population.

N: Population Size

Hence, the minimum sample size required from (Equation 4 is found to be 385. A total of 902 data is collected and 615 samples are used as model training data. The data was collected by observing pedestrians' crossing behavior at the crosswalk over a 4-hour peak period on a standard workday for each site in the month of June, 2024.

4. Result and Discussion

4.1. Preliminary Analysis

Table 1 displays the mean values for pedestrian waiting time, road width, accepted gaps at both vehicular directions and speed of those accepted vehicles. In Table 1, the maximum waiting time is noted to reach values as high as 36.365 seconds; the crosswalk and traffic conditions appear to contribute to prolonged waiting times for pedestrians. Additionally, the speed of accepted vehicles at both vehicular direction is diminutively close indicating that the mean speed of the accepted vehicles at the study sites exhibits minimal variation. Similarly, Table 2 shows the description of different categorical variables observed during the study.

Table 1. Statistics of Continuous Variables

Variables	Minimum	Maximum	Mean
Pedestrian Waiting Time (s)	0.000	36.365	3.38305
Width of road (m)	8.74	18.06	13.6349
Near Gap (s)	1.148	52.988	7.11150
Far Gap (s)	1.154	50.824	7.26551
Near Speed (m/s)	1.948	13.109	6.87319
Far Speed (m/s)	0.748	15.284	6.79214

Table 2. Statistics of Categorical Variables

Pedestrian Size		Gender		Carrying any object		Crossing path	
Alone	Group	Female	Male	No	Yes	Designated Start	Periphery Start
271	344	339	276	330	285	539	76
44.1%	55.9%	55.1%	44.9%	53.7%	46.3%	87.6%	12.4%

Table 3 provides a data analysis of the relationship between certain characteristics of pedestrians and their corresponding waiting time. When examining waiting categorizations, the data indicates that, at waiting time category, the highest percentage is attributed to females who were in the group. Similarly, the frequency of pedestrians who at least start to cross the road while waiting is higher than any other category.

Table 3. Categorical variables description with respect to waiting category

Waiting Category	Pedestrian Size		Gender		Carrying any object		Crossing path	
	Alone	Group	Female	Male	No	Yes	Designated Start	Periphery Start
No waiting	159	136	109	186	219	76	226	69
Waiting	112	208	230	90	111	209	313	7

Table 4 presents the averages for gaps and speed of accepted vehicles at two different waiting time categories. It can be seen that pedestrians choose to cross without any waiting when the gap between the vehicles is higher in the nearer lane. It also indicates that the average gap at nearer lane during waiting time is lower compared to both categories of waiting at a farther gap of vehicles.

Table 4. Continuous variables description with respect to waiting category

Waiting Category	Near Gap (s)	Far Gap (s)	Near Speed (m/s)	Far Speed (m/s)
No waiting	8.452	7.134	6.903	6.863
Waiting	5.876	7.387	6.846	6.727

4.2. Waiting Time Model

The Nagelkerke R2 for this study was 0.465, indicating that 46.5% of variations in waiting time could be accounted for by the observed data within the specified parameters as shown in Table 5.

Table 5. Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	588.190[a]	0.348	0.465

An analysis is conducted to assess the likelihood of a pedestrian's waiting tolerance based on various specified factors using the waiting model. Table 6 clearly shows that the odds of waiting increase with the increment in the width of road, however, the waiting probability decreases with the increase in time gap between the vehicles at the nearer lane. Similarly, with respect to males, the maximum likelihood of waiting by the females is approximately 4 times more. This may be due to the reason that men typically tend to make riskier crossing choices than women and are willing to accept shorter gaps, as indicated by Moyano Díaz (2002) and Holland and Hill (2007). In reference to a single pedestrian, the odds of waiting by the pedestrians in a group increase by almost 3 times. Likewise, the odds of choosing to wait by the pedestrian increases by whooping 9 times when, at least, start to cross from the designated crosswalk point in comparison to those who start walking from the periphery of the designated crosswalk. Also, when the pedestrian carries an object, the maximum likelihood of waiting increases by 5 times apropos of pedestrian crossing with an empty hand.

$$Y = -4.52 + 0.045\,(Y1) + 1.33\,(Y2) + 1.70\,(Y3) - 0.122\,(Y4) + 1.048\,(Y5) + 2.210\,(Y6) \qquad \text{(Equation 5)}$$

Table 6. Waiting Model Coefficient

	B	S.E.	Wald	df	Sig.	Exp(B)
Width of road (m) (Y1)	0.045	0.025	3.335	1	0.048	1.046
Gender (Female) (Y2)	1.333	0.208	41.037	1	0.000	3.792
Carrying any object (Yes) (Y3)	1.699	0.213	63.483	1	0.000	5.468
Near Gap (s) (Y4)	-0.122	0.027	20.234	1	0.000	0.885
Far Gap (s)	0.020	0.016	1.595	1	0.207	1.020
Near Speed (m/s)	0.117	0.065	3.247	1	0.072	1.124
Far Speed (m/s)	-0.029	0.046	0.394	1	0.530	0.971
Pedestrian Size (Group) (Y5)	1.048	0.211	24.708	1	0.000	2.853
Crossing path (Designated Start) (Y6)	2.210	0.459	23.160	1	0.000	9.113
Constant	-4.522	0.854	28.013	1	0.000	0.011

The results from Table 6 consecutively indicate that the time gap between the vehicles at farther lane and speed of accepted vehicles at both vehicular directions have a p-value greater than 5%. These variables are, thus, considered insignificant variables in the study; these variables have no significant impact on the choice between waiting and no waiting time by pedestrians. Hence, the equation consisting of coefficients is given by Equation 5.

4.3. Model Validation

Validating the developed model is a vital step in evaluating its performance. The model's accuracy was assessed exclusively using variables from the testing dataset. This validation process ensures the reliability of the model's predictions, allowing it to be applied to new datasets and enhancing its practical utility.

Specifically, 287 out of 902 samples were used for model validation, adhering to the model specifications. The binary logit model developed demonstrates a predictive accuracy of 76.3%, as indicated in Table 7. Specifically, the model achieves prediction accuracies of 69.5%, and 82.1% for pedestrian scenarios of no waiting time and waiting time, respectively. Overall, the model signifies a matching rate of 76.3% between the actual and predicted choices regarding pedestrian waiting times.

Table 7. Validation Table

Observed Waiting Time	Predicted Waiting Time		
	No Waiting Time	Waiting Time	Percentage Correct
No Waiting Time	91	40	69.5
Waiting Time	28	128	82.1
Overall Percentage			76.3

Moreover, the Nagelkerke R square value for the testing data is 0.401 as shown in Table 8 which does not significantly deviate from the training data showing the similarity between the training and testing data and, therefore, illustrates the developed model can be regarded as a good model.

Table 8. Validation R Square Value

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	293.434[a]	0.300	0.401

5. Conclusion and Recommendation

Acknowledging the significance of comprehending the crossing behavior of pedestrians from diverse backgrounds in the design of suitable crosswalk signals, a study was undertaken to examine the factors that affect the waiting time of pedestrians in the crosswalk. This research investigated the waiting time at two unsignalized crosswalks in Kathmandu City. The final model's R2 value was determined to be 0.465. This suggests that the model is reasonably well-suited to the data. Notably, factors such as road width, gap at crossing in the nearer lane (Gap near), gender, pedestrian size, crossing pattern, and the act of carrying an object significantly influence pedestrians' choices of waiting time. On the other hand, Binary Logistic Regression (BLM) revealed that the gap at a crossing in the farther lane (Gap far) and the speed of accepted vehicles in both vehicular directions (speed near and speed far) exhibit an insignificant relationship with pedestrians waiting. Moreover, the higher the gap between the vehicles, the lower the probability of a pedestrian waiting before crossing the road. The probability of waiting is less for males compared to females. Also, the probability of waiting is more when a pedestrian is not empty-handed. In comparison to a pedestrian who is alone, the likelihood of waiting in a group is higher. And, the probability of waiting is diminishingly less when the pedestrian is looking to cross the road outside of the designated starting point of crosswalk. And, waiting increases with the increase in the length of unsignalized crosswalk.

The findings suggest that pedestrian waiting time is influenced not just by traffic characteristics but also by pedestrian behaviors. This analysis enables the prediction of how waiting time at crossings may vary based on the traffic and pedestrians' attributes at the crosswalk. Such insights can aid planners in devising appropriate measures to address these issues. Therefore, this framework may serve as a valuable reference for forthcoming pedestrian models, aiming to enhance future safety. These enhancements could lead to improved and uninterrupted flow of vehicles as well. Moreover, the waiting time can be divided into more categories in the ordered form, and thus, the ordered logit model and nested logit model can be used for a thorough understanding of the waiting time behavior. Likewise, Multiple Linear Regression model can also be used to calculate the exact waiting time in reference to different parameters.

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