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# An Assessment of Pedestrian Waiting Time at Unsignalized Crosswalks: A Case Study of Jamal and Bagbazar Crosswalks in Kathmandu

**By**

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**A THESIS**

**SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING**

**IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE**

**DEGREE OF MASTER OF SCIENCE IN TRANSPORTATION**

**ENGINEERING**

**DEPARTMENT OF CIVIL ENGINEERING**

**LALITPUR, NEPAL**

**DECEMBER, 2023**

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The undersigned certify that they have read and recommended to Institute of Engineering for acceptance, a thesis entitled **"An Assessment of Pedestrian Waiting Time at Unsignalized Crosswalks: A Case Study of Jamal and Bagbazar Crosswalks in Kathmandu"** submitted by **Sudeep Thapaliya** in partial fulfillment of the requirement for degree of Master of Science in Transportation Engineering.

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# ABSTRACT

The acceptance of pedestrian signals hinges significantly on the waiting tolerance of the pedestrian in the region. Therefore, due consideration should be given to pedestrian waiting tolerance when designing pedestrian signal timing. This study focuses on the assessment of factors that influence pedestrian waiting time, a metric indicative of pedestrian waiting tolerance at unsignalized crosswalks in Kathmandu. An investigation of pedestrian behavior at the unsignalized crosswalks of Jamal and Bagbazar in Kathmandu was undertaken, identifying potential factors affecting pedestrian waiting time. The discrete choice model is applied due to its effectiveness in handling individual choice behavior. Based on the level of service, pedestrian waiting time is categorized into no waiting time, short waiting time, and long waiting time. Multinomial logistic regression with pedestrian waiting time as dependent variable and width of road, gap between the vehicles, speed of accepted vehicles, pedestrian size, gender, crossing pattern and carrying object as independent variables is carried using Statistical software SPSS to analyze factors that significantly influence pedestrian waiting time. The probability of waiting at both the short and long level increases than the probability of being not waiting if the gap between the vehicles at crossing reduces. The probability of a pedestrians to not wait any seconds drastically increases if they intent to start the crossing other than the designated starting point of crosswalk. Also, the probability of waiting greatly decreases when pedestrians are single rather than in group. As the width of the road increases, pedestrian select longer waiting time before crossing the road. This indicate that, the pedestrian takes more processing time in their brain when the length of crosswalk is more. Numerical tests carried out at the case study crosswalks showed width of road, gap at crossing in the nearer lane, gender, pedestrian size, crossing pattern, and carrying object significantly affect the pedestrian waiting time. The findings could be utilized by the planners to align the design of pedestrian crossing facilities with the pedestrian behavior patterns at the unsignalized crosswalk.

**Keywords:** Waiting Time, Multinomial Logistic Regression, Unsignalized Crosswalk, Pedestrian

# ACKNOWLEDGMENT

I would like to express my deepest gratitude to my supervisor Asst. Professor Dr. Rojee Pradhananga for giving me constant encouragement, support, and guidance throughout my phase of preparation, study and writing this report. I would also like to expand my gratitude to all our course instructors of MSTrE for giving me positive feedback and support as well.

I would also like to thank my classmates for their support and suggestions during this study phase. I also would like to humbly appreciate my childhood friend and my senior of MSTrE class Er. Sudip Luitel for encouraging me and providing me with ideas, and emotional support and enlightening me about possible obstructions that could arise during this study.

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| SPSS | Statistical Package for Social Sciences |
| PWT | Pedestrian’s Waiting Time |
| PWT_5.000 | Pedestrian’s Waiting Time category |
| NWT | No Waiting Time |
| SWT | Short Waiting Time |
| LWT | Long Waiting Time |
| DC | Designated Crossing |
| DS, PE | Designated Start, Peripheral Exit |
| PS, DE | Peripheral Start, Designated Exit |
| PS, PE | Peripheral Start, Peripheral Exit |
| MNL | Multinomial Logistic |
| MNP | Multinomial Probit |
| LRT | Likelihood Ratio Test |
| LOS | Level of Service |

# CHAPTER 1: INTRODUCTION

## 1.1 Background

Pedestrians frequently use the crosswalks, pedestrian paths, sidewalks, etc. as a means of transportation while walking. Walking encompasses two fundamental types of movements: walking along the road and crossing the road. While pedestrians engage in walking along the road to reach their desired destinations, road crossing becomes an integral and unavoidable aspect of walk trips. During road crossing, they rely solely on their senses and judgment to navigate the traffic and ensure their safety. Therefore, pedestrians are considered unsafe in the realm of road safety literature due to their increased susceptibility to harm or injury in traffic crashes. Compared to other road users, pedestrians are approximately four times more prone to injury in traffic crashes (Elvik, 2009). Furthermore, due to their lack of protection and exposure during traffic crashes, pedestrians are 23 times more likely to suffer fatal injuries compared to occupants of vehicles (Miranda-Moreno et al., 2011).

In Kathmandu Valley, approximately 40% of all journeys are undertaken on foot. (JICA, 2012). According to a study conducted by the Global Road Safety Facility, the ratio of male to female fatalities is 3:1, with the 15-to-49-year age group being the most vulnerable to fatalities (GRSF, 2018). Pedestrians are often given low priority in developing country metropolitan areas, particularly as the number of motorized vehicles on the road increases, leading to an increased risk of crashes involving pedestrians. As a result, they are considered vulnerable users of the traffic system (Tiwari et al., 2007). Numerous studies have been conducted on pedestrian behavior across a range of fields, such as urban planning, architecture, land use, and marketing, focusing on perceptual, attitudinal, psychological, and motivational factors.

According to the Metropolitan Traffic Police Division, there are 107 zebra crossings in the Capital. A Kathmandu Walkability Study-2018, conducted in 35 different sections of the metropolis, shows that 60 percent of the zebra crossings in the capital have already faded away, and 80 percent of the roads do not even have zebra crossings. In the modern world, planners are giving greater importance to pedestrian facilities due to the deep-rooted advantages of walking trips. The safety of pedestrians is a top priority in urban transportation planning. In developing countries like Nepal, pedestrians face a variety of challenges due to inadequate infrastructure and ineffective traffic management. Many of the pedestrian crossing in Kathmandu are being signalized. However, due to long red timing, violations are prevalent that raises the safety issues. Acceptance of pedestrian signalization largely depends on pedestrian tolerance of waiting and pedestrian risk-taking behavior. Therefore, a behavior study of pedestrian tolerance of waiting can significantly help in the design of pedestrian signal timings that are well acceptable to pedestrians and therefore help in successful implementation of the signalized crossings. Hence, a study of pedestrian waiting tolerance and factors that affect it is very important and is the focus of this study

The results from this study will give assistance to urban planners and policymakers in designing appropriate pedestrian facilities, such as signalized or unsignalized at-grade pedestrian crossings, overhead pedestrian crossings and specially to plan for pedestrian signal timing. Implementing findings from this study into urban planning strategies will ultimately improve pedestrian safety, enhance pedestrian mobility, and reduce the risk of pedestrian crashes and contribute to traffic management practices. In this study, a discrete choice analysis is used to analyze the waiting time of pedestrians accurately and to determine the factors that affect their crossing behavior.

The multinomial logit model provides important insights into the factors that influence pedestrian behavior at crosswalks. The multinomial logistic regression has the ability to handle categorical dependent variables with more than two categories and eases the interpretation of model parameters The multinomial logit model identifies which independent variables are significant predictors of waiting time categories, while the utility equation helps to identify the underlying reasons why pedestrians may choose to wait for different categories of time. These insights can further be used in the development of strategies to improve different predictor factors which greatly affect the pedestrian waiting time.

## 1.2 Problem Statement

Designing pedestrian crossings that align with pedestrian behavior patterns is essential to ensure their effectiveness. By investigating and understanding the factors that significantly influence pedestrian waiting time at unsignalized crosswalks, the findings can serve as crucial inputs for urban planners, traffic engineers, and policymakers. By gaining insights into how pedestrians make decisions regarding when and how to cross the street, this study can contribute to the optimal design of pedestrian crossings, crosswalk signal design, etc. making them more pedestrian-friendly and safe. Therefore, research is required to pinpoint the variables that affect pedestrian waiting time and offer insights into pedestrian behavior.

## 1.3 Objective of the Study

The main objective of the study is to analyze the waiting time of pedestrians before crossing at unsignalized crosswalks in Kathmandu. The specific objectives are

i. To study the pedestrian waiting time behavior and identify the factors that influence it at unsignalized crosswalks.
ii. To model relationship between the pedestrian waiting time with different identified factors.

## 1.4 Scope of Study

The study's intended scope is as follows:

i. Extraction of various statistics such as and traffic related and pedestrian behavioral characteristics from the video recording.
ii. Better understand the reasons behind waiting behavior and to identify areas where interventions may be needed to improve pedestrian safety
iii. Study of the pedestrian gap acceptance while crossing/risk taking behavior.

## 1.5 Limitation of Study

The limitation of this study is:

i. The questionnaire survey is not considered in the study; limiting the variables such as reason for waiting longer time before the cross.
ii. The study focused on peak hours of pedestrian flow, an analysis during non-peak hours could not be analyzed for waiting behavior.
iii. The choice of only two locations for study due to time limitation might bring bias.
iv. Carrying of heavy or light object is not taken separately reducing the detailed impact of luggage types on pedestrian waiting time.
v. Types of pedestrians like walking, running, etc. is not being considered in the study.

## 1.6 Organization of Report

The report consists of total five chapters, which are listed as follows:

**Chapter 1: Introduction**

It briefly explains the pedestrians' waiting time behavior along with the study's aims, scope, and constraints.

**Chapter 2: Literature Review**

It discusses the relevant literature of pedestrian and traffic behavior.

**Chapter 3: Research Methodology**

It outlines a sequential theoretical plan, spanning from the collection of data to analysis of data, and introduce the structure of study.

**Chapter 4: Results and Discussions**

It encompasses the interpretation of results obtained from modeling the extracted data and includes the model validation.

**Chapter 5: Conclusion and Recommendation**

It provides a concise summary of the findings from the obtained results and discusses its implications and scope in the context of design practice in engineering.

# CHAPTER 2: LITERATURE REVIEW

## 2.1 Pedestrian Behavior Studies

Numerous studies have shed important light on how demographic factors like age and gender, which affect pedestrian behavior when crossing the street. The vulnerability of elderly pedestrians because of their physical and cognitive decline was examined by Oxley et al. (1997). They measured pedestrians' typical kerb delays and gap acceptance on one-way and two-way roads for both young and older pedestrians. The results of the study showed that elderly pedestrian cross one-way roads in a manner similar to that of their younger counterparts, which is safer than how they cross two-way roads. The findings also showed that age-related perceptual deficits significantly increase the risk of accidents.

Evans & Norman (1998) examined how the Theory of Planned Behavior (TPB) can be used to investigate pedestrians' road crossing decisions. The TPB posits that behavior is influenced by attitudes, subjective norms, and perceived behavioral control. The authors collected survey data on these factors, along with demographic characteristics and road crossing behavior, and found that attitudes, subjective norms, and perceived behavioral control were significant predictors of pedestrians' intentions to cross the road at a signalized crossing. The authors also observed that perceived risk associated with road crossing and the number of cars waiting at the crossing impacted pedestrians' road crossing behavior. The study concludes that the TPB can be a valuable framework for understanding and predicting pedestrian road crossing behavior. The authors suggest that interventions designed to promote safe road crossing should focus on influencing attitudes, subjective norms, and perceived behavioral control.

On both divided and undivided roads, Hamed (2001) conducted a study to estimate pedestrian crossing behavior models at mid-block crosswalks. According to the study, the number of attempts necessary to cross the street safely depends on how long pedestrians must wait. On undivided roads, pedestrians also behave differently when crossing the street from one side to the middle and from the middle to the other. Males are 1.35 times more likely than females to wait less time before crossing a divided road to a refuge, and males are 3.105 times more likely than females to wait less time before crossing from a refuge to the other side of the road.

Using a simulated road crossing activity, Oxley et al. (2005) investigated the effects of various variables on pedestrians' judgments regarding time gaps. The study looked at how factors like age, distance from the oncoming vehicle, time gap, vehicle speed, and walking time affected crossing decisions. The findings showed the most crucial factor in influencing pedestrian crossing decisions was the approaching vehicle's distance. Furthermore, choosing the right time gaps was more difficult for older pedestrians, emphasizing the significance of age in time gap choice. It was discovered that older participants' responses were more sensitive to distance and time gap factors.

The behavior and choices of elderly pedestrians were compared to those of a group of urban 40- to 49-year-olds in the analysis by Bernhoft & Carstensen, 2008. According to the findings, older pedestrians find it riskier to cross the street without such facilities and prefer signalized intersections and pedestrian crossings more than younger pedestrians. Instead of being explained by age or gender, these behavioral variations were linked to variations in physical fitness and health. Additionally, it was discovered that elderly pedestrians were more vigilant than younger ones, always deciding to walk up to a zebra crossing if one was available, never crossing at a red light, and never trying to return on a non-signalized crosswalk. They concluded the cautious behavior is more adopted by elderly pedestrians.

Li (2013) developed a model of pedestrians’ intended waiting times for street crossings at signalized intersections. The study found that the intended waiting time of pedestrians depends on several factors such as the number of pedestrians waiting to cross, the pedestrian’s walking speed, the duration of the pedestrian phase, and the distance to the opposite sidewalk. The study concluded pedestrians' waiting time increases with the number of waiting pedestrians and decreases with the pedestrian’s walking speed. Additionally, pedestrians' waiting time is found to be longer when the pedestrian phase is shorter. Overall, the study concludes that the developed model can be used to estimate the intended waiting time of pedestrians and help improve signal timing and pedestrian safety at signalized intersections.

In 2016, Ferenchak conducted a study on the correlation between pedestrian behavior and motor vehicles. It was found that the waiting time increases as the pedestrian gets older. Furthermore, when crossing the street, older pedestrians have fewer collisions with moving vehicles than younger pedestrians. Apart from that, it was learned that males were twice as likely to cause encounters with moving vehicles in comparison to females. Although this relationship was not statistically significant, males had waiting times that were approximately half the waiting times of females and were less likely to use the crossing infrastructure properly.

Fricker & Zhang (2019) compared the one-way and two-way uncontrolled crosswalk. According to the study, drivers are more inclined to slow down or stop for pedestrians in two-way operations than they are in one-way operations. Moreover, in two-way operations, drivers are less likely to consider the presence of a close follower or adjacent vehicle when interacting with a pedestrian. As a result, drivers tend to respond more to the pedestrian in a two-way operation where the effects of vehicle interaction are less than in one-way operations. The study also found that drivers' decisions to slow down in two-way operations are significantly influenced by environmental factors. These findings suggest that two-way uncontrolled crosswalks may be a safer alternative for pedestrians.

Paudel (2014) explained that study of road crossing behavior is probably the most important element on establishing road crossing facilities since interaction of pedestrian with vehicles is found to be one of the major constraints to pedestrians while crossing the road. So, he conducted a study to develop a model to find out the critical gap on mid-block crossing under mixed traffic condition in the Kathmandu Valley. The results showed that minimum gap size value was significantly explained by waiting time, pedestrian speed and gap type and gap acceptance of pedestrians. Therefore, he concluded that pedestrian’s decision-making process can be better explained by gap size, vehicle speed and vehicle type.

Chand & Marsani (2021.) conducted a study on pedestrian gap acceptance such that it is concentrated on the size of the vehicular gaps accepted by the pedestrian for crossing at mid-block section of the ring road. They concluded that safety distance and vehicle speed were the most important independent variables that influence the gap acceptance behavior.

Shah (2022) conducted a study in signalized crosswalks with an aim to assess the red-light violation behavior of Nepalese pedestrians. It was concluded that pedestrians prefer to wait for green (follow the signal) when the remaining red phase duration (until green phase) is below 50 seconds; pedestrians tend to violate almost instantly when they face a remaining red duration of more than 100 seconds.

## 2.2 Multinomial Logistic Regression

Agresti. (2007) explained that Multinomial Logistic Regression (MNL) serves as a statistical method employed to model the relationship between a categorical dependent variable featuring more than two categories and a set of independent variables. So, this method extends binary logistic regression to analyze categorical dependent variables with multiple categories. MNL is a versatile statistical technique used in various fields, including engineering, healthcare and finance, to assess the categorical data and gain insights into complex relationships.

Ghimire (2019.) conducted a study that employed multinomial logistic regression to analyze the influential factors affecting transport mode choices during work trips, which play a crucial role in transport planning decisions. The research aimed to investigate the mode preferences of employed individuals in Kathmandu Valley. The results indicated that these factors had a significant impact on the selection of transport modes for work-related journeys.

## 2.3 Summary of Literature Review

This comprehensive literature review examines various factors influencing pedestrian behavior when crossing streets. Studies investigate the impact of demographic factors such as age and gender on pedestrian vulnerability, with older individuals showing increased risk due to physical and cognitive decline. The Theory of Planned Behavior

(TPB) is explored as a valuable framework for understanding road crossing decisions, emphasizing attitudes, subjective norms, and perceived behavioral control as significant predictors of pedestrians' intentions to use signalized crossings. Findings from different literatures suggest that gender plays a crucial role in time gap choice. Additionally, models are developed to estimate pedestrians' intended waiting times at signalized intersections, considering factors like pedestrian phase duration, walking speed, and the number of waiting pedestrians. Comparisons between one-way and two-way crosswalks indicate that drivers are more responsive to pedestrians in two-way operations. There is a need for comprehensive study to determine the waiting time of pedestrians so that it could be used by planners in the design of pedestrian crosswalk signals.

# CHAPTER 3: METHODOLOGY

## 3.1 Methodological Framework

All the prior studies were meticulously studied to identify the crucial factors required to be considered for the intended analysis. The adopted methodological framework of the study is shown in Figure 3.1.

Research variables were identified considering the study's objectives. Subsequently, the study areas were assessed. The minimum sample size was determined to allow for the collection of the required amount of data for the study. Following that, video graphic survey was conducted at the selected crosswalk locations and the video recording was used to gather the data, and all pertinent characteristics were extracted from the film and filled out on the observational sheets for further analysis and interpretation.

The relationship between pedestrian waiting time and various identified variables were then investigated using Multinomial Logistic (MNL) regression.

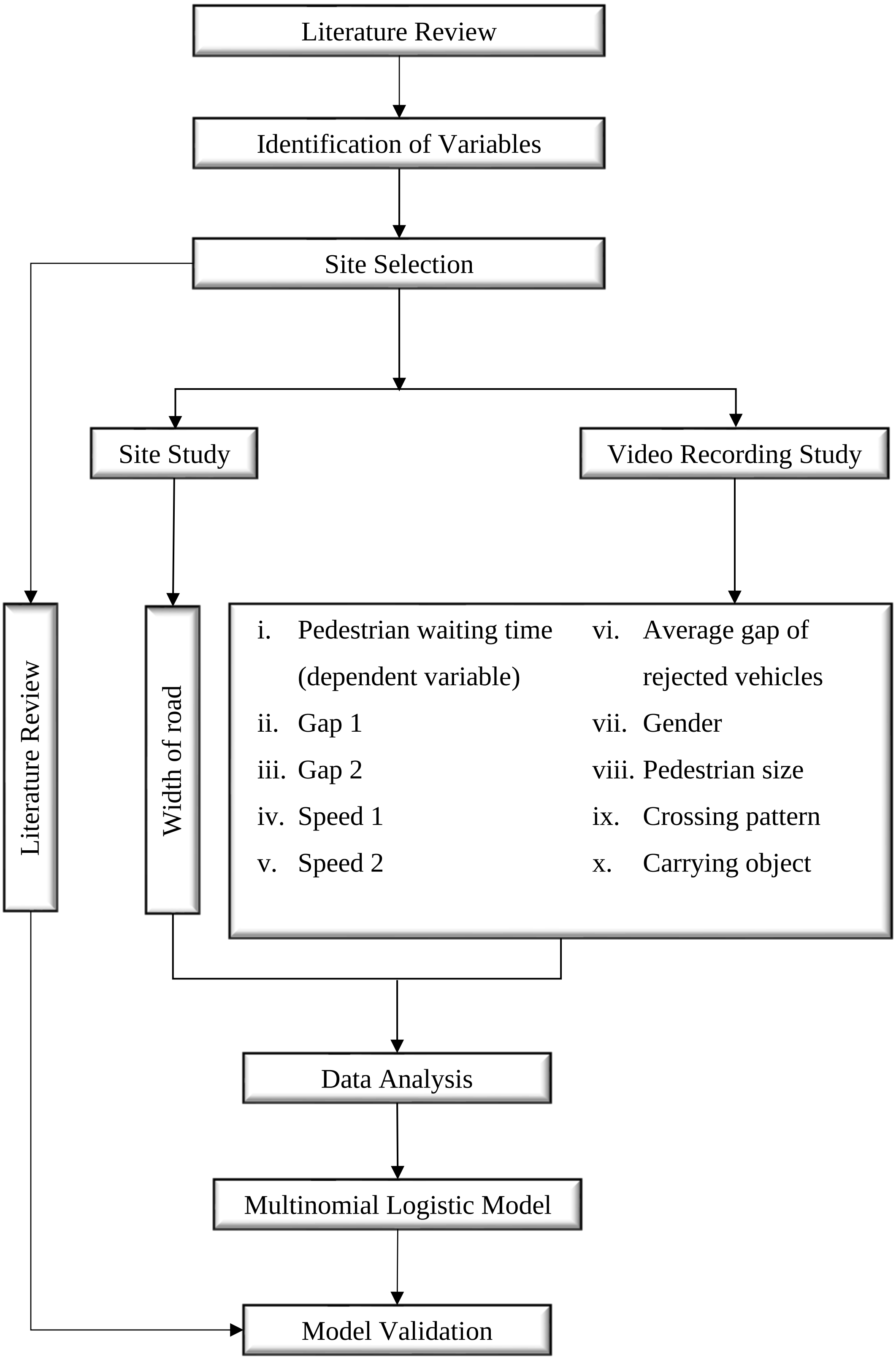

Figure 3.1 Framework of Methodology

## 3.2 Variables Definition

To analyze choice of pedestrian waiting time at the busiest unsignalized crosswalk of Kathmandu, the multinomial logistic regression is the best fit. The relation between the pedestrian waiting time and set of independent variables can be easily evaluated by this method. With multinomial logit model, the effect of different variables on the probability of choosing one of the waiting time categories can be easily explained. The variables included in this study are tabulated and described in Table 3.1. A total of ten independent variables were selected in this study. These variables were selected based on extensive review of literature and preliminary field observations at unsignalized crosswalks in Kathmandu. The outcome (dependent) and predictor (independent) variables are extracted from the video recording whereas the width of the road is measured manually during the early morning time when the traffic movement is very low.

Table 3.1 Description of continuous variables

| Variable | Type of variable | Unit/Code | Description |
|---|---|---|---|
| Pedestrian Waiting Time (dependent) | Categorical | 0- No waiting time<br>1- 0 to 5 secs (Short waiting time)<br>2- >5 secs (Long waiting time) | It is the waiting time of a pedestrian before starting to cross the road. If the pedestrian moves back to curb even after keeping the foot on pavement, it is consider as waiting and is continued to being counted in waiting time. Because, the pedestrian is actual in waiting mode even after trying to cross.<br>It is measured in continuous scale and then categorized accordingly. |
| Gap 1 | Continuous | seconds (s) | It is the time between the last vehicle before (back bumper), and the first vehicle (front bumper) with reference to the crosswalk point at the nearer lane.<br>It is the time gap a pedestrian accept. |
| Gap 2 | Continuous | seconds (s) | It is the time between the last vehicle before (back bumper), and the first vehicle (front bumper) with reference to the crosswalk point at the farther lane. |
| Speed 1 | Continuous | meter/seconds (m/s) | It is the speed of a vehicle that a pedestrian has accepted (approaching vehicle) at the nearer lane. |
| Speed 2 | Continuous | meter/seconds (m/s) | It is the speed of a vehicle that a pedestrian has accepted (approaching vehicle) at the farther lane. |

| Variable | Type of variable | Unit/Code | Description |
|---|---|---|---|
| Average gap of rejected vehicles | Continuous | seconds (s) | It is an average of the rejected gap (in seconds) by the pedestrian for crossing.<br>It is the time between back bumper and front bumper between the rejected vehicles with reference to the crosswalk point at the nearer lane. |

Table 3.2 Description of categorical variables

| Variable | Type of variable | Unit/Code | Description |
|---|---|---|---|
| Gender | Categorical | 0- Female<br>1- Male | Male pedestrians and female pedestrians |
| Pedestrian Size | Categorical | 0- Alone<br>1- Group | Number of pedestrians accumulated at the end of the wait.<br>Single pedestrians and two or more pedestrians |
| Crossing Pattern | Categorical | 0- PS, PE<br>1- DC<br>2- DS, PE<br>3- PS, DE | It is the pattern of path in which a pedestrian crosses the road.<br>PS, PE: Peripheral start and peripheral exit.<br>DC: Designated Crossing.<br>DS, PE: Designated Start and peripheral exit.<br>PS, DE: Peripheral Start and designated exit |
| Carrying Object | Categorical | 0- No<br>1- Yes | Whether pedestrian is carrying any object in hand other than shoulder bag of female and school bag in the back. |
| Width | Continuous | meter (m) | The width of the road that is to be crossed. |

As seen in the Table 3.1, three levels are considered for the waiting time of pedestrians denoted as No Waiting Time (NWT) under which pedestrain chooses not to wait any seconds before crossing, Short Waiting Time (SWT) under which pedestrain choose to wait upto 5 seconds and Long Waiting Time (LWT) under which pedestrain prefers to wait more than 5 seconds. The 5 seconds is taken as the threshold value for the SWT and LWT based on the level of service A of pedestrians waiting time (Nemeth et al. 2014) as highlighted in the Table 3.3.

Table 3.3 Waiting time ranges based on the LOS of PWT (Source: Nemeth, 2014)

| LOS | Descriptions | Waiting time ranges(s) |
|---|---|---|
| **A** | **Usually, no conflicting traffic** | **0-5** |
| B | Occasionally some delay due to conflicting traffic | 5-10 |
| c | Delay noticeable to pedestrians, but not inconveniencing | 10-20 |
| D | Delay noticeable and irritating, | 20-30 |
| E | Delay approaches tolerance level, risk-taking behavior likely | 30-45 |
| F | Delay exceeds tolerance level, high likelihood of pedestrian risk-taking | >=45 |

As shown in Figure 3.2, Gap 1 and Speed 1 are the accepted gap and accepted speed of a vehicle by a pedestrain at nearer lane, respectively. Average gap of rejected vehicles is the another variable considered. To quantify this variable, the rejected gaps by each subject pedestrian were noted and then averaged. For instance, if a pedestrian rejected gaps of 1s, 2s and 0.9s, the average of these rejected gaps 1.3s (1+2+0.9/3=1.3s) would be considered as the average gap of rejected vehicles for that particular pedestrian.

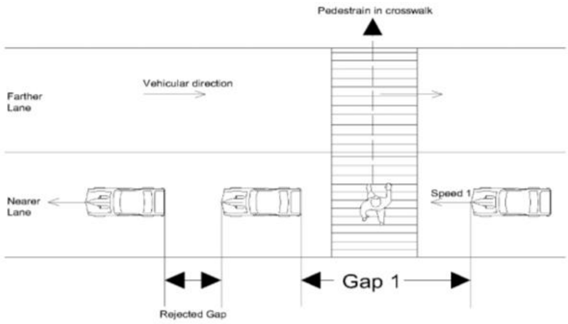

Figure 3.2 Gap 1, Rejected Gap and Speed 1

Similarly in Figure 3.3, Gap 2 and Speed 2 are the accepted gap and accepted speed of vehicle by a pedestrain at farther lane with traffic in opposite direction, respectively.

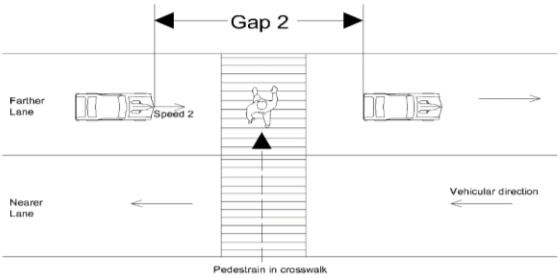

Figure 3.3 Gap 2 and Speed 2

Categories of variable crossing pattern are illustrated in Figure 3.4 to Figure 3.7. The crossing pattern has been categorized as Designated Crossing (DC) when a pedestrian, both, start and exit from the crosswalk point as shown in Figure 3.4. . Figure 3.5.

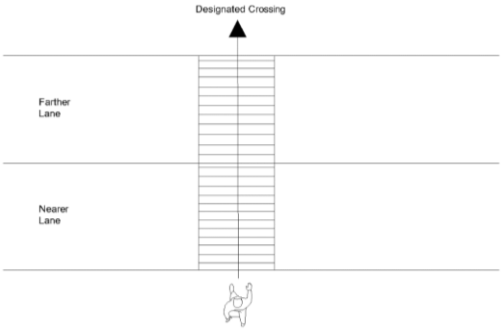

Figure 3.4 DC: Designated Crossing

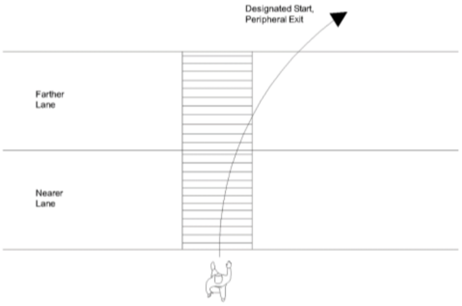

Figure 3.5 DS, PE: Designated Start, Peripheral Exit

Likewise, when a pedestrian chooses to start crossing the road outside of the designated crosswalk point, but exit the crosswalk from the designated exit point, it is called peripheral start and designated exit as in Figure 3.6. When a pedestrian, both, start and exit outside of the crosswalk point, it is considered as PS,PE as shown in Figure 3.7

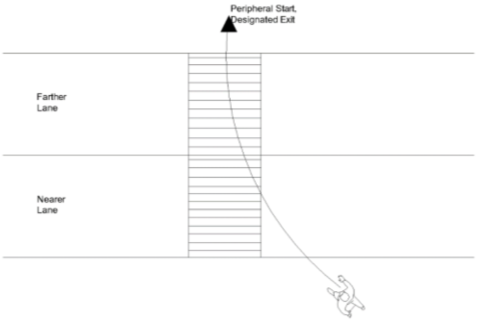

Figure 3.6 PS, DE: Peripheral Start, Designated Exit

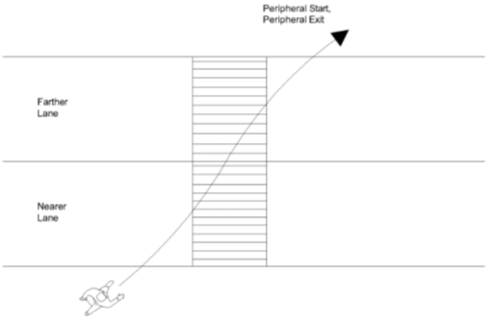

Figure 3.7 PS, PE: Peripheral Start and Exit

### 3.3 Normality Check

The choice of correlation method depends upon the distribution of data. Since, Pearson’s correlation assumes that the data are normally distributed, it is not suitable for non-normal data. Therefore, for non-normal data, non-parametric spearman’s correlation is more accurate and robust. A normal distribution, also known as a

Gaussian distribution, is a symmetrical, bell-shaped distribution that is commonly used as a model for various types of data. While not all data follows a normal distribution, it's crucial to assess whether the data is approximately normally distributed before applying statistical tests. The normal distribution stands as a fundamental and extensively employed probability distribution in statistics. Its distinctive feature is the bell-shaped curve, with the mean (μ) located at the center and symmetrical tails on either side. The standard normal distribution, possessing a mean of 0 and a standard deviation of 1, is a notable variant of this distribution. This distribution's prevalence and versatility make it a valuable tool in various statistical analyses and modeling applications.

The Shapiro-Wilk test and the Kolmogorov-Smirnov test are two statistical tests that can be employed to check the normality assumption of data in order to make appropriate statistical inferences. The Kolmogorov-Smirnov test is used when the sample is more than 2000. Since, the sample for this study is below 2000, Shapiro-Wilk test is used to check normality.

### 3.3.1 Shapiro-Wilk Test

A statistical technique called the Shapiro-Wilk test is used to determine if a sample actually represents a population that is normally distributed. The data has a normal distribution, which is the test's null hypothesis. The null hypothesis is not rejected if the test's p-value is higher than the selected significance threshold, which is typically 0.05. Instead, we infer that the data appear to be normally distributed.

## 3.4 Correlation

A statistical measure that illustrates the connection between two or more variables is correlation. It enables us to comprehend how changes in one variable influence changes in another. A correlation between two variables indicates that there is a statistical tendency for them to move in predictable rhythm. Correlation does not imply causation; it merely indicates that there is a consistent relationship between the variables. In order to run a model with accuracy, it is essential to ensure that the independent variables have minimal or no correlation with each other, thereby avoiding the issue of multi-collinearity. Therefore, in the data analysis stage, the first crucial step is to perform a correlation test among the independent variables. This test enables the evaluation of the degree of association between the independent variables, ensuring that they are not highly interrelated. Strong correlations between independent variables can have detrimental effects on the accuracy and interpretability of the logistic regression model. By identifying and addressing any noteworthy correlations, researchers can uphold the validity and reliability of the model's outcomes. This process enhances the robustness of the logistic regression analysis and helps in making more accurate and meaningful predictions based on the data.

Various correlation coefficients are utilized to assess how variables are related in terms of strength and direction. One widely used type is the Pearson correlation coefficient, which specifically quantifies the linear relationship between two continuous variables. Its value falls within the range of -1 to +1, where -1 signifies a perfect negative linear correlation (meaning when one variable increases, the other decreases), +1 represents a perfect positive linear correlation (indicating when one variable increases, the other also increases), and 0 denotes no linear correlation between the variables.

Another correlation coefficient commonly used is Spearman's correlation. Unlike the Pearson correlation, Spearman's correlation is based on the ranked values of variables rather than their actual numerical values. It measures the degree to which the variables consistently increase or decrease together, regardless of the specific values they take. Spearman's correlation coefficient shares the same range of -1 to +1 as the Pearson correlation coefficient, with similar interpretations. A positive value indicates a monotonic increasing relationship between the variables, while a negative value suggests a monotonic decreasing relationship. A value of 0 indicates no monotonic relationship between the variables.

When the data is not normally distributed, Spearman's correlation is often preferred over Pearson correlation. Pearson correlation assumes that the relationship between the variables is linear and that the data follows a normal distribution. When these assumptions are violated, the accuracy and reliability of Pearson correlation can be affected, leading to misleading results. Additionally, Pearson correlation is sensitive to outliers, which can also impact the correlation coefficient. As a result, Spearman's correlation is more robust when dealing with non-normally distributed data and can handle monotonic relationships better than Pearson correlation. The spearman rho scale and its relationship is as shown in Table 3.4.

Table 3.4 Spearman rho scale

| Spearman rho | Correlation |
|---|---|
| >=0.70 | Very strong relationship |
| 0.40-0.69 | Strong relationship |
| 0.30-0.39 | Moderate relationship |
| 0.20-0.29 | Weak relationship |
| 0.01-0.19 | No or negligible relationship |

(Source: Dancey & Reidy, 2007)

As the Pearson’s correlation and Spearman’s correlation is for examining continuous-continuous variable data, in the case of categorical-categorical data, the Chi-square test and Cramer's V are used to evaluate the association between variables and offer valuable insights into the strength of their relationship. Chi-square test is frequently used to evaluate data presented as contingency tables, which show the joint distribution of the two variables under consideration. Cramer's V is the effect size measurement for Chi-square test. It quantifies the strength of the relationship between two categorical variables presented in a contingency table. The values of Cramer's V range from 0 to 1, where 0 signifies no association between the variables, and 1 indicates a perfect association, implying a strong relationship between the categories of the variables in the table. The range of Cramer’s V scale and it interpretation is shown below in the Table 3.5.

Table 3.5 Cramer’s V scale

| Range | Interpretation |
|---|---|
| 0 | Fields are not associated. |
| $0.1 < R \leq 0.3$ | Fields are weakly associated. |
| $0.3 < R \leq 0.5$ | The fields are moderately associated. |
| $E > 0.5$ | The result is strong. The fields are strongly associated. |

(Source: M.W Kearney, 2017, Shah, 2022)

## 3.5 Modelling Framework

### 3.5.1 Logistic Regression

Understanding the link between independent factors and a categorical or binary dependent variable is an important task in the field of statistical modelling. A popular technique, logistic regression, provides a potent strategy to deal with such circumstances and is especially well suited for modelling probabilities and classification tasks. The logistic model, also known as logistic regression, is designed to model the probability of an event or the likelihood of an observation belonging to a specific category. When dealing with binary outcomes, where the dependent variable can only take one of two potential values, binary logistic regression is very useful. Similarly, the multinomial logistic regression is used when the dependent variable has more than two categories, such as various groups or classes.

### 3.5.2 Multinomial Logistic Regression

As an extension of binary logistic regression, multinomial logistic regression can predict the probability of a nominal dependent variable when one or more independent variables are present. When the dependent variable has more than two unique categories, this sort of regression is used. The Multinomial Logit Model (MNL) is a statistical model used to analyze discrete choice data. In this model, individuals make a single choice from a set of mutually exclusive and exhaustive alternatives. The MNL model assumes that the choice probabilities are related to the utility (or preference) that individuals associate with each alternative. The utility of alternative j for individual i is represented by a linear function of explanatory variables, along with an error term that captures unobserved factors affecting the choice.

In the context of pedestrian waiting time, we can use a multinomial logit model to predict the probability of a pedestrian choosing one of several options over the other for example whether they would choose to cross immediately or wait for some time or wait for longer time before start crossing.

a) **Basic Assumption**

i. The dependent variable must be nominal variable having more than two distinct categories (mutually exclusive and exhaustive categories)
ii. Observation or the sample should be independent.
iii. Independent variables could be either a qualitative or quantitative
iv. No correlation between two or more independent variables.

b) **Model Specification**

The multinomial logit model estimates the values of the coefficients β1 to βn to predict the probability of a pedestrian choosing each alternative, based on the values of the variables $x_1$ to $x_n$. In multinomial logistic regression, it is assumed that the log-odds of each response follow linear model.

$$\eta_{ij} = log(\frac{\pi_{ij}}{\pi_{iJ}}) = \alpha_j + x_i\beta_j \tag{3.1}$$

Where,

$\alpha_j$: Constant term
βj: vector regression coefficients for j= 1 to J-1

Hence, the multinomial logit model can be expressed in term of original probabilities $\pi_{ij}$ instead of log-odds and for j=1 to J, it can be written as,

$$\pi_{ij} = \frac{exp\ (\eta_{ij})}{\sum_{\mathrm{k}=1}^{\mathrm{n}} exp\ (\eta_{ij})} \tag{3.2}$$

Hence, Equation (3.2) yield probabilities that add up to one for each i.

c) **Model Estimation**

The process of determining the coefficients of the model estimating (j-1) regression equations when the model to be estimated has j alternatives, with one alternative serving as the reference. The maximum likelihood method is used to assessed the coefficients and intercept terms of each equation. In this method, the coefficients are evaluated in a way that maximizes the value of the likelihood function, making the observed sample most likely to occur. This approach works by developing the function of likelihood and estimating the values of different variables that yield maximum likelihood function.

### d) **Hypothesis**

In the multinomial logit model, each category of the dependent variable is treated as a binary logistic regression against a reference category. During hypothesis testing, the focus is on the coefficients (β) of the independent variables for each category.

The null hypothesis (H0) for each coefficient states that there is no relationship between the corresponding independent variable and the category of the dependent variable. In contrast, the alternative hypothesis (H1) proposes that there exists a significant relationship between the independent variable and the category of the dependent variable. This testing is used to determine the significance of these relationships and assess the impact of the independent variables on each category of the dependent variable in the multinomial logit model.

In a parameter estimate, let's take the independent variable "gender" as an example. Suppose one dichotomous independent variable like gender (e.g., male and female). After running the multinomial logit model, the odds ratio for the female gender category (compared to the male category) is 1.55, with a 95% confidence interval of (1.10, 2.20). Here, (1.10, 2.20) a range of values within which we are reasonably confident (with a 95% confidence level) that the true population odds ratio for the female gender category lies. Similarly, the 95% confidence level means that if we were to repeat the study many times and calculate 95% confidence intervals for the odds ratio each time, approximately 95% of these intervals would contain the true population odds ratio.

Since the confidence interval includes both values greater than 1 (1.10 and 2.20), it suggests that the odds ratio for the female gender category is statistically significant at the 5% level. In other words, we can say with 95% confidence that the odds of having a certain waiting time category are 1.55 times higher for females compared to males.

### e) Likelihood Ratio Test

The likelihood ratio test involves comparing the likelihood of the fitted model to that of a baseline or null model (typically an intercept-only model). By evaluating the difference in likelihoods between the two models, it determines whether the fitted model offers a significantly better fit to the data than the null model. If the difference in likelihoods, $-2(L(\hat{\beta})-LL(\beta0))$, is statistically significant, it indicates that the fitted model provides a significantly improved representation of the data compared to the null model.

## 3.6 Model Validation

Model validation encompasses both model training and the evaluation of the trained model using a separate testing dataset. It consists of a number of processes and checks used to ensure that the models work as planned. The training set and testing set might both come from the same dataset, or they can come from different datasets. We evaluate the model's accuracy and correctness through validation. It is crucial to do extensive validation and tests on a model before relying exclusively on its predictions. The purpose of validation is to evaluate the performance of our model on data that it has not encountered during the training process, thereby measuring its effectiveness on unseen information.

To evaluate the performance of the proposed classification models, various evaluation metrics such as accuracy, sensitivity, and precision are derived from confusion matrix. The confusion matrix is a square matrix of size n x n where n represents the number of labels or classification classes. This matrix displays the outcomes of actual classifications compared to the predictions made by the model. Sensitivity and specificity are crucial evaluation metrics used to assess a model's capability to correctly identify positive and negative outcomes within a dataset (Trtica-Majnaric et al., 2010). A higher sensitivity means the model accurately identifies data belonging to a particular class (true positives), while a higher specificity signifies the model's ability to correctly recognize data not belonging to that class (true negatives).

Table 3.6 Confusion matrix of 3 x 3 size

| | | Predicted Class | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| Actual Class | 1 | N11 | N12 | N13 |
| | 2 | N21 | N22 | N23 |
| | 3 | N31 | N32 | N33 |

In Table 3.6, the columns and the rows represent the predicted and actual classes respectively. Within this table, nine cases are observed. N11 represent the instances where the classifier correctly predicted class 1 where the samples were indeed from class 1. Additionally, N12 signifies samples from class 1 that were misclassified as class 2, while N13 indicates samples from class 1 that were misclassified as class 3. N12 or N13 represent the total number of samples that were actually class-1 but were misclassified as either class-2 or class-3 respectively. Similarly, N21 or N31 represent the total number of samples that were not class-1 but were misclassified as class-1.

Hence, the false negative (FN1), false positive (FP1), true positive (TP1) and true negative (TN1) for class 1 are as,

FN1 = N12 + N13

FP1= N21+ N31

TP1= N11

TN1= N22 + N23 + N32 + N33

For multiclass classification with n number of classes,

Sensitivity,

$$\mathrm{Sn} = \frac{\sum_{i=1}^{n} Sn_i}{n} \tag{3.3}$$

Sensitivity of ith class,

$$Sn_i = \frac{”TP”_i}{”TP”_i + ”FN”_i} \tag{3.4}$$

Specificity,

$$\mathrm{Sp} = \frac{\sum_{i=1}^{n} Sp_i}{n} \tag{3.5}$$

Specificity of ith class,

$$"Sp"_i = \frac{"TN"_i}{"TN"_i + "FP"_i} \tag{3.6.}$$

Accuracy is a straightforward metric calculated as the ratio of correctly labeled outcomes to the total number of outcomes in the dataset. It is the most intuitive and easily understandable performance measure when compared to other evaluation metrics. Accuracy of each class is obtained from respective predicted classes.

$$A_i = \frac{\mathrm{TPi} + \mathrm{TNi}}{\mathrm{TPi} + \mathrm{FPi} + \mathrm{FNi} + \mathrm{TNi}} \tag{3.7}$$

### 3.7 Site Selection

In order to analyze the waiting time of pedestrian, pilot survey at various crosswalk in the Kathmandu valley was done beforehand where each site was observed for about 15 minutes before shortlisting the final site. This helps in the approximate identification of the peak hours of pedestrian flow and ensure that an adequate and representative sample of pedestrians can be collected. Subsequently, the sites were selected in order to meet the following criteria:

i. Higher pedestrian traffic (i.e., pedestrian volume)
ii. Uninterrupted traffic flow (i.e., vehicular flow).
iii. The width of the road remains constant and consistent throughout the entire length under consideration
iv. Suitable height to position the camera for proper capture of the gap at crossing.

Considering these points, crosswalk at Jamal and Bagbazar were selected for the study of waiting time. Figure Figure 3.8 shows the locations of the selected crosswalk sites.

Figure 3.8 Study area (Jamal and Bagbazar)

### 3.7.1 Crosswalk at Jamal

Jamal is one of the busiest commercial and cultural area, attracting not only shopping enthusiasts but also locals and tourists. The crosswalk at Jamal (shown in Figure 3.9) is a crucial unsignalized crossing situated in the heart of the Kathmandu city. Following are the detail features of the crosswalk:

Length of crosswalk: 18.06 m
Number of lanes: Four
Width of crosswalk: 4 m

Figure 3.9 Pedestrian crosswalk at Jamal

### 3.7.2 Crosswalk at Bagbazar

Bagbazar is one of the central hubs for commercial and educational institutes. The number of pedestrians in this area is very high. Figure 3.10 shows the crosswalk at the Bagbazar, which is selected for this study. Detailed features of the crosswalk include:

Length of crosswalk: 8.74 m
Number of lanes: Two
Width of crosswalk: 3.5 m

Figure 3.10 Pedestrian crosswalk at Bagbazar

### 3.8 Sample Size

The process of estimating the number of participants or data points required to produce valid and insightful results in a research study is known as sample size determination. The size of the sample in research is crucial for the reliability and accuracy of study findings. A carefully chosen sample size ensures an accurate representation of the population, capturing its diversity and characteristics. It impacts statistical power, influencing the likelihood of correctly rejecting a false null hypothesis and reducing the risk of errors. Larger sample sizes contribute to the precision of estimates, confidence intervals, and overall reliability of results. The generalizability of findings to the broader population depends on having an adequate sample size. Practical and ethical considerations, such as budget constraints and participant burdens, must be balanced in determining the sample size. Essentially, an appropriately chosen sample size is integral to conducting methodologically sound and ethically responsible research.

The following are some of the variables that affect the choice of sample size:

i. Population size: In order to attain the appropriate degree of accuracy, a bigger sample size will be required the larger the population.
ii. Confidence interval: The range of values within which the true population parameter is most likely to fall is known as the confidence interval. A higher sample size will be necessary for a wider confidence interval.
iii. Confidence level: The likelihood that the true population parameter falls inside the confidence interval is known as the confidence level. A greater sample size will be necessary for a higher level of confidence.
iv. Standard deviation: Statistical variation in the population is measured by the standard deviation. A bigger sample size will be necessary if the sample standard deviation is high.

According to Peduzzi et al. (1996), in order to use the logistic regression, the minimum number of samples can be determined using Equation (3.8)

$$N = \frac{10k}{p} \tag{3.8}$$

Where,

| | |
|---|---|
| N | Total number of cases to be considered |
| k | Total number of predictor variables considered |
| p | Lowest proportion of positive or negative cases in the population |

Since, 47.23% of the total population account “No waiting time”, whereas, 23.95% of total population account for “Short waiting Time”. That means, 28.82% of total pedestrians fall under the “Long waiting time” category. Therefore, the lowest proportion is 0.2395 is used for the sample size estimation. Since 10 independent variables were used in this study, the required number of samples can be calculated from Equation (3.8) as,

N= (10*10)/0.239 = 417.53 ≈418

The sample needed to build a model is 418. The model is developed using training data (70 percent of total data). This means, Total data to be collected including training and testing data is,

70% of Total data = Training data
Total data = 418/0.7 = 597.14 ≈ 600

A total of 902 data have been used for developing and ensuring the validity of the model which would be helpful for generalizing the waiting behavior of pedestrian.

### 3.9 Data Collection and Extraction

A video graphic survey was carried out at unsignalized crosswalks of Jamal and Bagbazar in normal and clear weather condition during the working days. The video camera was installed on an elevated surface in such a way that traffic and pedestrian behaviors were significantly visible. For both Jamal and Bagbazar crosswalks, data was collected for two hours (9 AM to 11 AM) for two days. A total of 480 min video was collected over the span of four days for the study of pedestrian waiting time. The data was not collected when the crosswalk was controlled by the traffic police.

About 900 data were thoroughly extracted from the video footages in order to carry out the analysis. Sampling was carried out for every third pedestrian in case of Jamal as the pedestrian volume in this crosswalk is relatively higher than that in Bagbazar. Conversely, due to lower pedestrian volume at the crosswalk of Bagbazar, every pedestrian was considered during the data extraction process. However, pedestrians meeting any of the following criteria were not considered for data extraction:

i. Pedestrian crosses the road without touching the crosswalk.

ii. The entry point and exit point of a pedestrian are not visible in the camera frame.
iii. Pedestrian crosses up to the halfway point of the road and starts walking out of the frame along the road.

The data from the video was extracted using the professional video analyzing software used especially in the fast-moving object in the video graphs, Kinovea v0.9.5 software. All the variables were extracted with an accuracy of ≤40 msec (0.040 sec) using a next frame option in the software. The video was totally analyzed in the milliseconds to reduce the error in extracting the time in seconds Data were directly collected in the MS Excel software manually using the video footages as shown in Figure 3.11. An excel sheet form was created to enter the data so that there would not be any confusion and error during the data entry process.

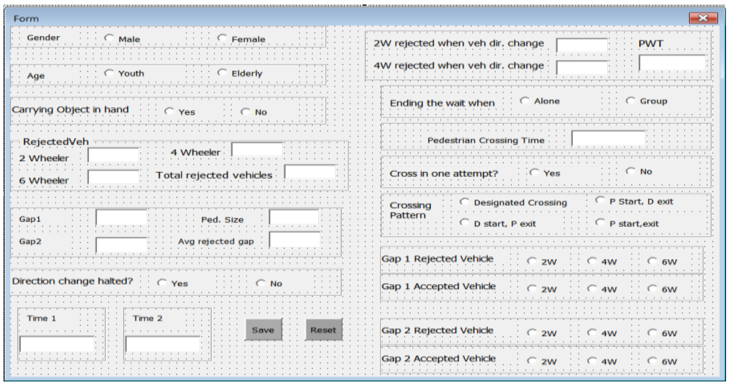

Figure 3.11 Data entry excel form

# CHAPTER 4: RESULTS AND DISCUSSIONS

## 4.1 General

Correlation between different predictor variables was checked before performing the logistics regression analysis. Highly correlated variables were excluded from the sets of independent variables to perform the further analysis. Among different statistical tools, the IBM SPSS v27 software package was used for the calculations and analysis of pedestrian waiting time behavior for the unsignalized crosswalks of Kathmandu.

## 4.2 Overview of data

Statistical measures like minimum, maximum, average and standard deviation values for the parameters Speed 1, Speed 2, Gap 1 and Gap 2 are presented in the Table 4.1. The maximum Gap 1 was 52.988 seconds and minimum Gap 1 was 1.148 seconds. The minimum gap was observed for the condition when the path of rejected and approaching vehicle were not aligned. This was the case mostly when these vehicles were two wheelers. While for the farther lane, 50.988 seconds was the maximum and 1.154 seconds was the minimum gap that a pedestrian had chosen. Similarly, minimum and maximum speed of the vehicle at the nearer lane (Speed 1) accepted by the waited pedestrian was 1.948 m/s (7.0128 km/h) and 13.109 m/s (47.1924 km/h) respectively. The maximum accepted vehicle speed was 15.284 m/s and 0.748 m/s was the minimum accepted speed at the farther lane (Speed 2). The mean width of the road was 13.634m.

Table 4.1 Descriptive Statistics of Continuous Predictor Variables

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Gap 1 | 615 | 1.148s | 52.988s | 7.111s | 5.187 |
| Gap 2 | 615 | 1.154s | 50.988s | 7.265s | 6.843 |
| Speed 1 | 615 | 1.948m/s | 13.109m/s | 6.873m/s | 1.600 |
| Speed 2 | 615 | 0.748m/s | 15.284m/s | 6.792m/s | 2.193 |
| Width | 615 | 8.74m | 18.06m | 13.634m | 4.657 |
| Avg gap of rejected vehicles | 615 | 0.000s | 2.432s | 0.4656s | 0.553 |

The frequency of pedestrian's crossing pattern peripheral start and peripheral exit was observed to low compared to that of other categories. Therefore, the two crossing patterns peripheral start designated exit and peripheral start peripheral exit were merged for analysis as shown in Table 4.2. The distribution of frequency of different categorical predictor variables are tabulated in Table 4.3. Based on 615 training data used in this study, approximately 45.0% were male and 55.0% were female. A total of 55.9% pedestrians were categorized as crossing in group and 44.1% pedestrians were crossing single. Similarly, 41.9% pedestrians followed the pattern of designated crossing, 45.7% followed designated start and peripheral exit pattern, whereas 12.4% pedestrians followed the peripheral start and either designated or peripheral exit. Only 46.3% pedestrians were observed carrying any object in the hand out of 615 pedestrians.

Table 4.2 Merged Crossing Pattern

| Crossing pattern with 4 categories | | Crossing pattern with 3 categories | |
|---|---|---|---|
| Pattern | Nos. | Pattern | Nos. |
| Designated Crossing | 258 | Designated Crossing | 258 |
| Designated Start, Peripheral Exit | 281 | Designated Start, Peripheral Exit | 281 |
| Peripheral Start, Designated Exit | 49 | Peripheral Start and Designated/Peripheral Exit | 76 |
| Peripheral Start and Peripheral Exit | 27 | | |

Table 4.3 Descriptive Statistics of categorical Predictor Variables

| | | N | Marginal Percentage |
|---|---|---|---|
| PWT_5.000 | No Waiting Time | 295 | 48.0% |
| | Shorter Waiting Time | 144 | 23.4% |
| | Longer Waiting Time | 176 | 28.6% |
| Gender | Female | 339 | 55.1% |
| | Male | 276 | 44.9% |
| Pedestrian Size | Alone | 271 | 44.1% |
| | Group | 344 | 55.9% |
| Crossing pattern | Designated Crossing | 258 | 41.9% |
| | Designated Start, Peripheral Exit | 281 | 45.7% |
| | Peripheral Start and Designated/Peripheral Exit | 76 | 12.4% |
| Carrying Object | No | 330 | 53.7% |
| | Yes | 285 | 46.3% |

The number of pedestrians under different categories of dependent variables are given in Table 4.3. The percentage shares are shown in Figure 4.1. The sample data shows that almost half of the pedestrians prefer to walk immediately at the crosswalk without any waiting. However, 34% choose to wait for longer time before they start to cross the road.

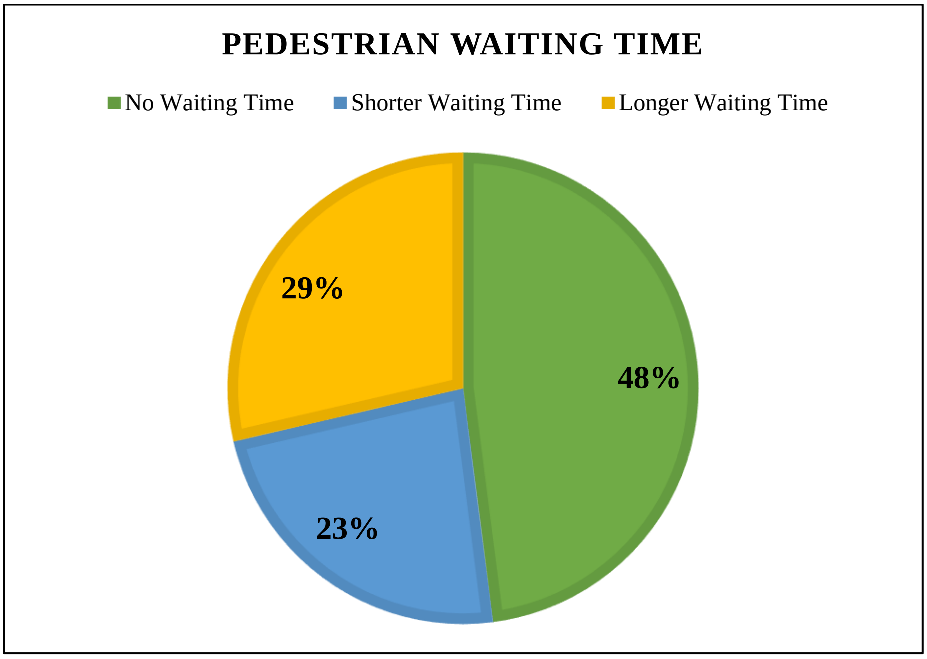

Figure 4.1 Distribution of three category of PWT

### 4.3 Preliminary Data Analysis

From the preliminary analysis of the data, presented in the charts from Figure 4.2 to Figure 4.6, it is evident that the average Gap 1 of no waiting, short waiting and long waiting time categories are 8.452, 6.094 and 5.698 seconds respectively.

Additionally, the mean speed at the nearer and farther lanes is almost indistinguishable, indicating that mean speed of the accepted vehicles at the study sites have minimal fluctuation.

Figure 4.2 clearly shows that pedestrian choose to cross without any waiting when the gap between the vehicles is higher in the nearer lane.

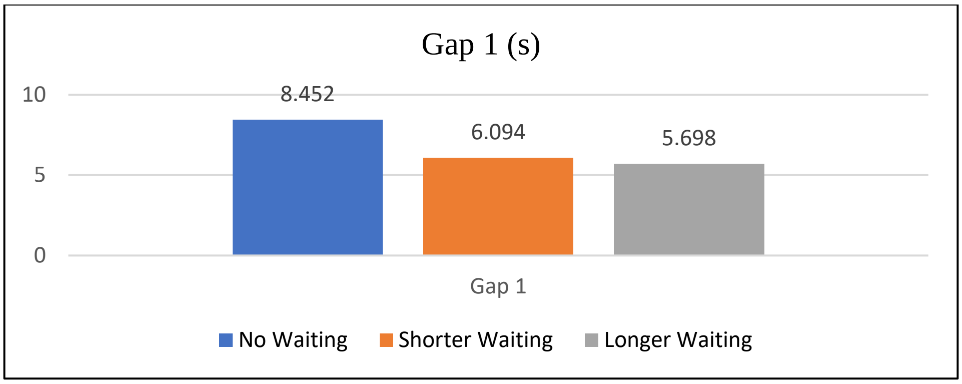

Figure 4.2 Description of Gap 1 with respect to PWT

The mean value of gap 2 are 7.134 s, 7.046 s and 7.665 s for no waiting, short wait and long wait respectively as shown in Figure 4.3.

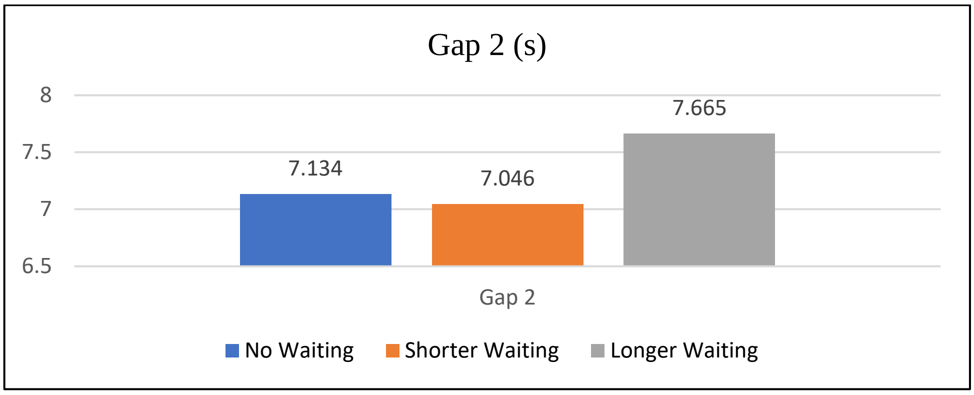

Figure 4.3 Description of Gap 2 with respect to PWT

The mean value of speed 1 are 6.903 m/s, 6.909 m/s and 6.793 m/s for no any waiting, short waiting and long waiting respectively. It can be presented as shown in Figure 4.4. There is no significant difference in the value of speed of accepted vehicle

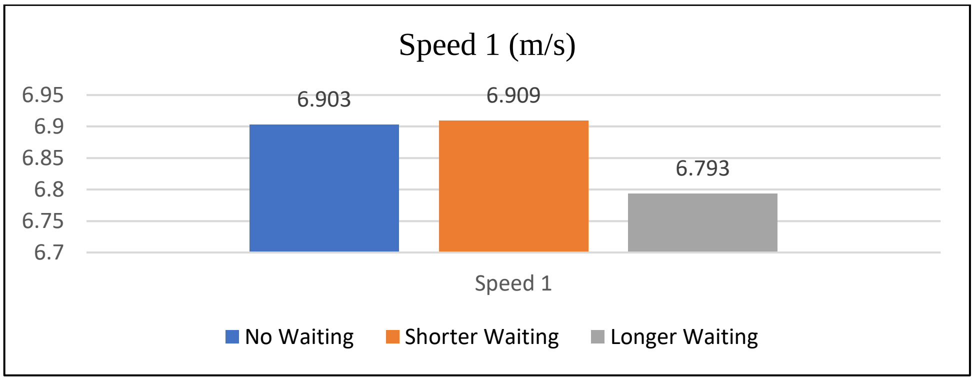

Figure 4.4 Description of Speed 1 with respect to PWT

The mean value of speed 2 are 6.863 m/s, 6.971 m/s and 6.527 m/s for not waiting, short wait and long wait respectively.

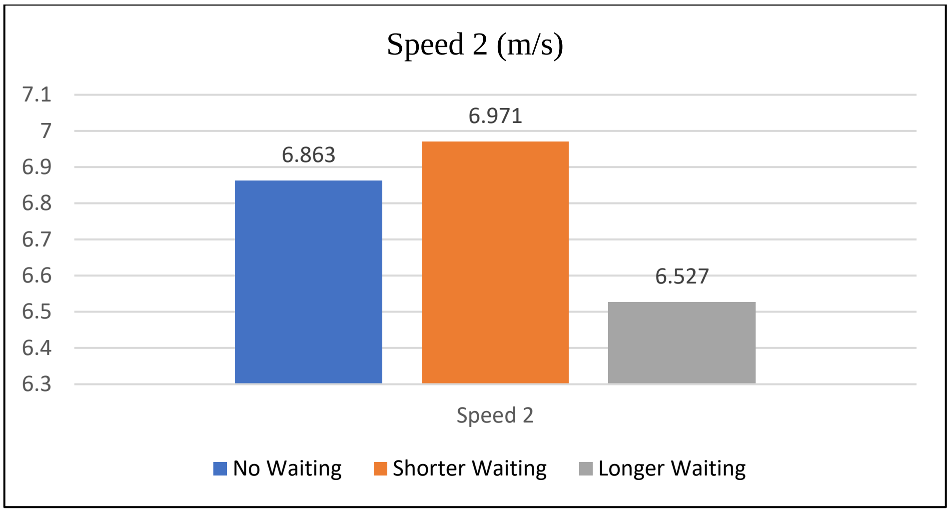

Figure 4.5 Description of Speed 2 with respect to PWT

The mean value of width of road are 13.13 m, 13.46 m and 14.62 m for not waiting, short wait and long wait respectively. The Figure 4.6 clearly explained that as the length of the crosswalk increases, the number of pedestrians prefer to wait for longer time before starting to cross the road.

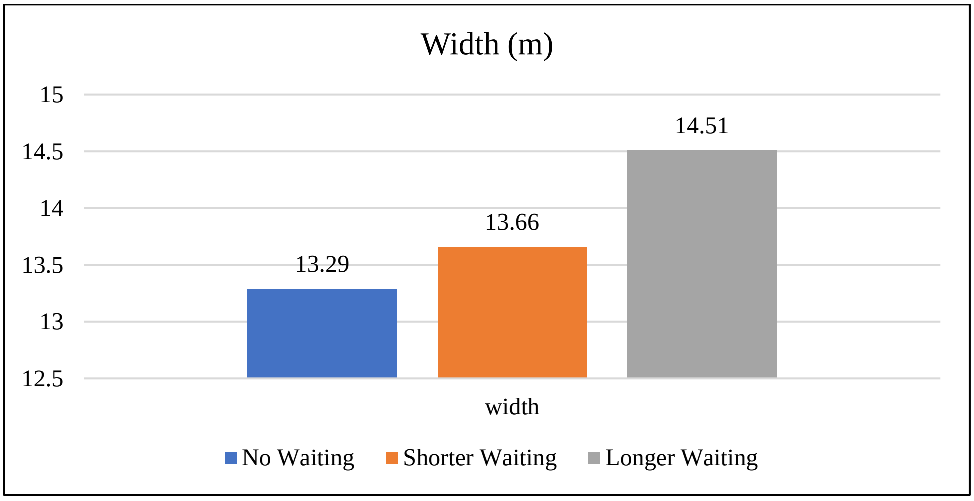

Figure 4.6 Description of road width with respect to PWT

The mean value of average gap of rejected vehicles are 0.650 s and 1.084 s for short wait and long wait respectively. The Figure 4.7 clearly explained that as average rejected gap increases as the waiting time increases.

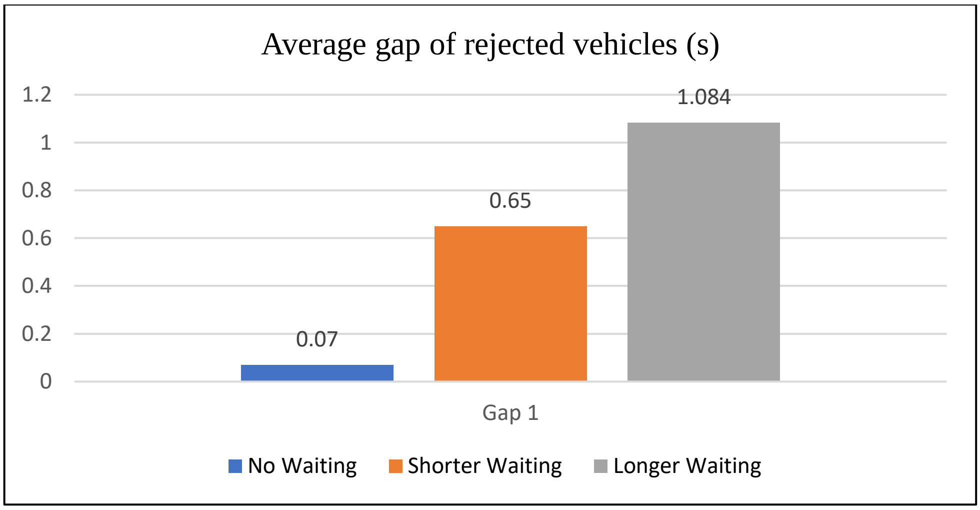

Figure 4.7 Description of avg gap of rejected vehicles with respect to PWT

From Figure 4.8, it can be clearly seen that majority of pedestrians are male who chooses not to wait any seconds and start crossing immediately at the crosswalk. 67.39% of male prefer to not wait for crossing the unsignalized crosswalk and 38.93% of female prefers longer waiting time before crossing the road, whereas, only 15.94% of male choose the longer waiting time and 32.15% of female choose to cross immediately without any waiting

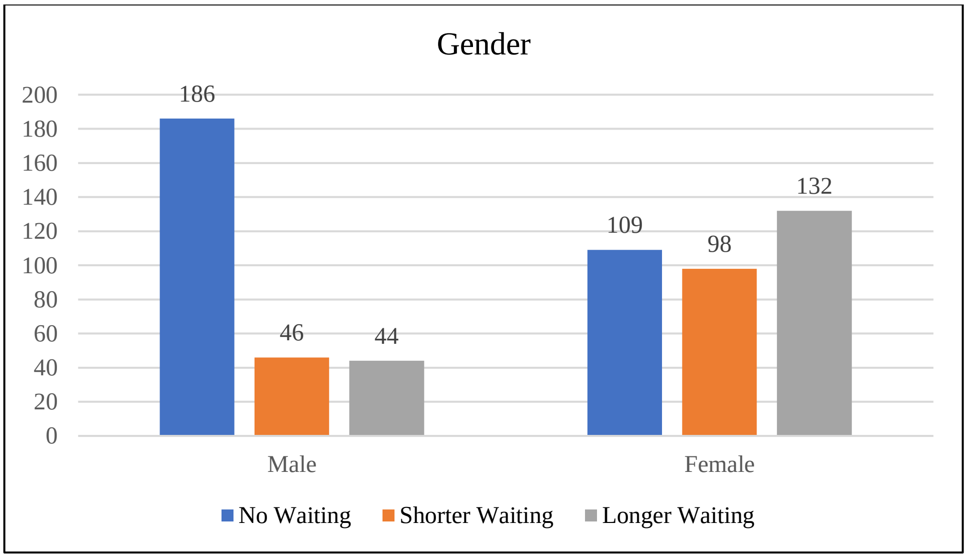

Figure 4.8 Description of Gender with respect to PWT

Among single people, 58.67% prefer to not wait before crossing and 30.23% of people who are in group prefers to wait for shorter or longer time before crossing the road.

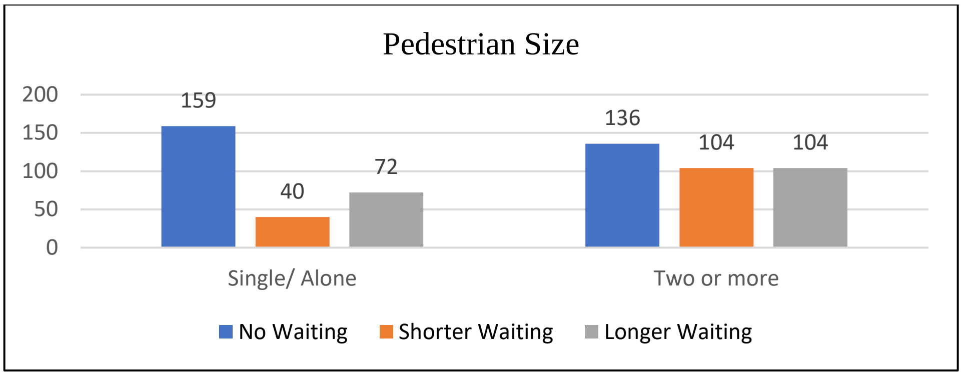

Figure 4.9 Description of Pedestrian Size with respect to PWT

Among various waiting time, 18.21% choose to wait for longer time if they carry any object in hand and 35.60% of people who crosses the road without carrying anything chooses to not wait before start crossing as shown in Figure 4.10

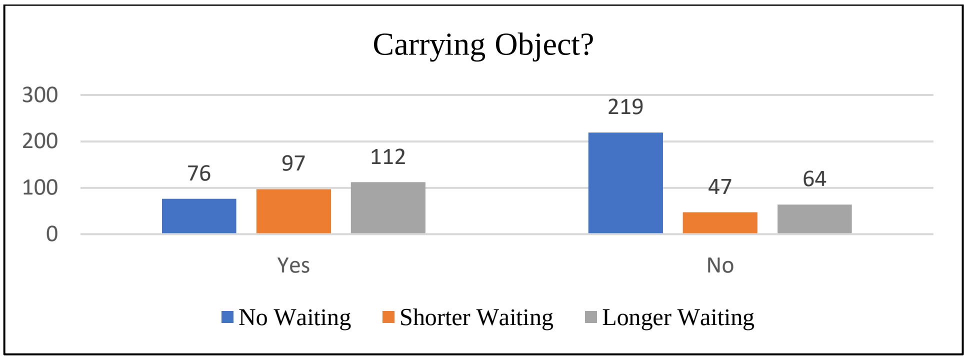

Figure 4.10 Description of Carrying Object with respect to PWT

Among various waiting time, people who follow the designated crossing pattern, only 57.75% prefer to wait before crossing and likewise, 58.36% also chooses waiting time who crosses the road in the DS, PE pattern as shown in Figure 4.11

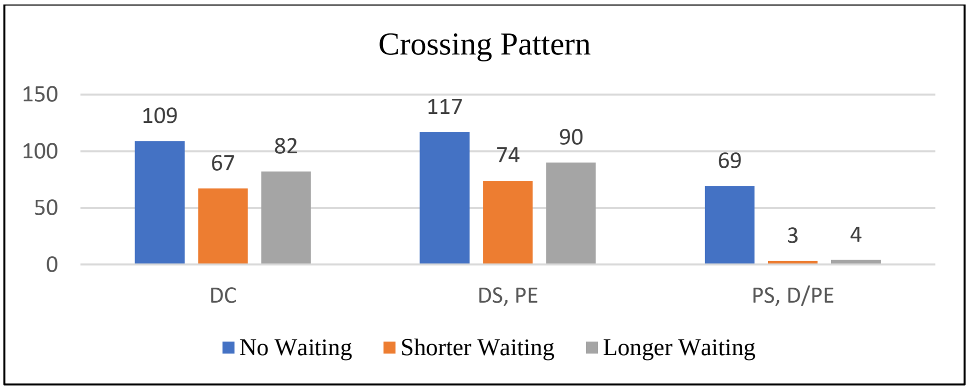

Figure 4.11 Description of Crossing Pattern with respect to PWT

## 4.4 Correlation Analysis

When aiming to explore the association between two variables without relying on normality and preferring a non-parametric approach that is robust to outliers, spearman correlation becomes a suitable choice. For predictor variables (average rejected gap, width of road, gap at crossing, and speed of vehicles), normality assumption is not relevant when using Spearman's correlation, as it is based on ranks and not the actual data values.

Since the sample for study is less than 2000, the p-value from the Shapiro-Wilk test of normality (<0.05) clearly indicated that the independent variables involved in this study are not normally distributed as seen in Table 4.4. Therefore, using Spearman's correlation is a reasonable approach to analyze the relationship between the pedestrian waiting time with other continuous predictor variables.

Table 4.4 Tests of normality of independent variable

| | Shapiro-Wilk | | |
|---|---|---|---|
| | Statistic | df | Sig. |
| Gap 1 | 0.702 | 615 | <0.001 |
| Gap 2 | 0.682 | 615 | <0.001 |
| Avg gap of rejected vehicles | 0.813 | 615 | <0.001 |
| Speed 1 | 0.973 | 615 | <0.001 |
| Speed 2 | 0.991 | 615 | <0.001 |

Table 4.7 shows the results of correlation test of the continuous variables. As seen in the Table 4.5, the variable “Gap 1” and “Average gap of rejected vehicles” have the rho value of -0.501, which is greater than the threshold value of 0.5 for behavioral analysis, that explained a strong negative monotonic relationship between “Gap 1” and “Average gap of rejected vehicles”. Therefore, to avoid any multi-collinearity, the variable “Average gap of rejected vehicles” was removed after meticulous consideration.

The $\chi 2$ test results and the Cramer’s V values for the categorical variables are shown in Table 4.6. It can be seen from the p-value of chi-square test for correlation of Gender and Crossing pattern, Gender and Carrying object, Crossing pattern and Carrying object showed p-value less than 0.05. Hence, these pairs are found to be statistically significant. Cramer's V value for these pairs were checked but found to have a weak relationship between them from Table 3.5. Therefore, all the categorical variables were considered for analysis.

Table 4.5 Spearman`s correlation matrix for the continuous variables

| | | Gap 1 (s) | Gap 2 (s) | Speed 1 (m/s) | Speed 2 (m/s) | Width of road (m) | Average gap of rejected vehicles (s) |
|---|---|---|---|---|---|---|---|
| Spearman's rho | Gap 1 (s) | -- | | | | | |
| | Gap 2 (s) | -0.081 | -- | | | | |
| | Speed 1 (m/s) | 0.144 | 0.102 | -- | | | |
| | Speed 2 (m/s) | 0.042 | 0.111 | 0.100 | -- | | |
| | Width of road (m) | -0.130 | -0.395 | -0.156 | -0.086 | -- | |
| | Average gap of rejected vehicles (s) | **-0.501** | 0.084 | -0.076 | -0.066 | 0.064 | -- |

Table 4.6 Chi-square and Cramer's V values for the categorical variables

| | **Gender** | **Pedestrian's Size** | **Crossing pattern** | **Carrying object** |
|---|---|---|---|---|
| **Gender** | - | Chi square (p-value) 0.204<br>Cramer's V 0.042 | Chi square (p-value) **0.001**<br>Cramer's V 0.210 | Chi square (p-value) **0.001**<br>Cramer's V 0.207 |
| **Pedestrian's Size** | | - | Chi square (p-value) 0.199<br>Cramer's V 0.060 | Chi square (p-value) 0.758<br>Cramer's V 0.010 |
| **Crossing pattern of the pedestrian** | | | - | Chi square (p-value) **0.001**<br>Cramer's V 0.126 |
| **Carrying object** | | | | - |

## 4.5 Pedestrian Waiting Time Model

A Multinomial Logistic Regression (MNL) model for pedestrian waiting time was developed using the IBM Statistical Package for the Social Sciences (SPSS) version 27 software to identify the major factors that affects the pedestrian waiting behavior and to analyze the of various pedestrian categories at unsignalized crosswalk of Kathmandu using the specific category of waiting time (No waiting, short waiting time or long waiting time). The no waiting time was coded as 0, waiting time from 0 to 5 seconds were coded as 1 and the waiting time greater than 5 seconds were coded as 2. The MNL regression was carried out at confidence level of 95%. No waiting time was used as reference category to interpret the short waiting time and long waiting time in the study.

The coefficients, p-value, likelihood ratio tests and the equation of Multinomial Logit Model can be explained as following:

### 4.5.1 Model I: Considering All Variables

About 615 data were used for the formation of the model. The Table displays the case processing summary of Model I which represents those 615 cases were selected without any of the missing cases. This mean none of the data is missing during analysis and minimizing the chances of error due to missing data.

Table 4.7 Case Processing Summary of Model I

| Unweighted Cases | | N | Marginal Percent |
|---|---|---|---|
| Selected Cases | Valid in Analysis | 615 | 100 |
| | Missing Cases | 0 | 0 |
| | Total | 615 | 100.0 |
| Unselected Cases | | 0 | 0.0 |
| Total | | 615 | 100.0 |

In Table 4.8 Model Fitting Information, the 'Final' row indicates whether all the coefficients in the model are zero, determining whether any of the coefficients are statistically significant. The inclusion of predictor variables (gap 1, gap 2, speed 1, speed 2, gender, etc.) in the model is compared to an intercept-only model (with no variables added). The p-value of 0.000, which is less than 0.05, indicates that the full model significantly improves the prediction of the dependent variable (PWT) compared to the model with intercept-only.

Table 4.8 Model Fitting Information

| Model I | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood | Chi-Square | df | Sig. |
| Intercept Only | 1291.963 | | | |
| Final | 1007.193 | 284.770 | 20 | 0.000 |

Similarly, from Table 4.9 the Nagelkerke pseudo-R square is 0.428% which indicates that the model explains approximately 43% of the variance in the pedestrian waiting time (dependent variable). Since, the McFadden pseudo R-square value is 0.230, which is between the 0.2 to 0.4, it can be said that MNL model appears to be a reasonably good fit for the data.

Table 4.9 Pseudo R-Square

| | | |
|---|---|---|
| Model I | Cox and Snell | 0.372 |
| | Nagelkerke | 0.428 |
| | McFadden | 0.230 |

The Likelihood Ratio Test (LRT) is used as shown in Table 4.10 to test the significance of variable in the model. For categorical variables, the LRT is like an overall test of significance of an independent variable. Both width of road, gap 1, gender, pedestrian size, crossing pattern and carrying object have p-value less than 0.05 which is highly significant. Whereas, gap 2, speed 1 and speed 2 have higher p value and considered non-significant predictor variables of pedestrian waiting time.

Table 4.10 Likelihood Ratio Test of Model I

| Effect | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood of Reduced Model | Chi-Square | df | Sig. |
| Intercept | 1007.193a | 0.000 | 0 | |

| Effect | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| | -2 Log Likelihood of Reduced Model | Chi-Square | df | Sig. |
| Width of road | 1018.066 | 10.873 | 2 | 0.004 |
| Gap 1 | 1032.236 | 25.043 | 2 | 0.000 |
| Gap2 | 1012.626 | 5.433 | 2 | 0.066 |
| Speed 1 | 1010.549 | 3.355 | 2 | 0.187 |
| Speed 2 | 1010.916 | 3.723 | 2 | 0.155 |
| Gender | 1051.510 | 44.317 | 2 | 0.000 |
| Pedestrian Size | 1040.219 | 33.026 | 2 | 0.000 |
| Crossing pattern | 1039.781 | 32.588 | 4 | 0.000 |
| Carrying Object | 1077.567 | 70.374 | 2 | 0.000 |
| The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0. | | | | |

From Table 4.11, parameter estimates provide a summary of the impact of each predictor. In the context of this study, the parameter estimate indicates the effect of each predictor on the pedestrians' short waiting time relative to no waiting time. The B value represents the estimated coefficients from the multinomial logistic regression model. Additionally, Exp (B) values serve as odds ratios, comparing various predictor categories to the reference category. The p-value is a crucial metric for hypothesis testing. When the p-value is less than the significance level (in this case, 0.05), we reject the null hypothesis; otherwise, we fail to reject it. Null hypothesis defines there is no significant relation between variables (dependent and predictors). With three categories of pedestrian waiting time, two sets of logistic regression coefficients, often referred to as "2 logits," are formed as shown in Table 4.11.

The first set of coefficients is associated with the short waiting time row, representing the comparison between short waiting time (SWT) and the reference category, no waiting time (NWT). The second set of coefficients corresponds to the long waiting time row, representing the comparison between long waiting time and the reference category, no waiting time. These coefficients allow for the assessment of the impact and significance of predictors on both short and long waiting times relative to no waiting time.

Table 4.11 Parameter Estimates of Model I

| Pedestrian Waiting Time[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|---|
| Shorter Waiting Time | Intercept | -2.062 | 1.030 | 4.010 | 1 | 0.045 | |
| | Width of road (m) | 0.003 | 0.029 | 0.010 | 1 | 0.919 | 1.003 |
| | Gap 1 (s) | -0.118 | 0.033 | 12.919 | 1 | 0.000 | 0.889 |
| | Gap 2 (s) | -0.001 | 0.020 | 0.004 | 1 | 0.949 | 0.999 |
| | Speed 1 (m/s) | 0.127 | 0.076 | 2.783 | 1 | 0.095 | 1.136 |
| | Speed 2 (m/s) | 0.021 | 0.055 | 0.143 | 1 | 0.705 | 1.021 |
| | [Gender=0] Female | 1.172 | 0.249 | 22.085 | 1 | 0.000 | 3.227 |
| | [Gender=1] Male | 0b | | | 0 | | |
| | [Pedestrian Size=0] Alone | -1.421 | 0.259 | 30.207 | 1 | 0.000 | 0.241 |
| | [Pedestrian Size=1] Group | 0b | | | 0 | | |
| | [Crossing pattern=1] DC | 2.226 | 0.649 | 11.771 | 1 | 0.001 | 9.265 |
| | [Crossing pattern=2] DS, PE | 2.300 | 0.649 | 12.547 | 1 | 0.000 | 9.976 |
| | [Crossing pattern=3] PS, D/PE | 0b | | | 0 | | |
| | [Carrying object=0] No | -1.815 | 0.253 | 51.543 | 1 | 0.000 | 0.163 |
| | [Carrying object=1] Yes | 0b | | | 0 | | |
| Longer Waiting Time | Intercept | -2.782 | 0.984 | 7.996 | 1 | 0.005 | |
| | Width of road (m) | 0.080 | 0.028 | 8.096 | 1 | 0.004 | 1.083 |
| | Gap 1 (s) | -0.126 | 0.033 | 14.825 | 1 | 0.000 | 0.882 |
| | Gap 2 (s) | 0.035 | 0.017 | 4.130 | 1 | 0.042 | 1.036 |
| | Speed 1 (m/s) | 0.109 | 0.076 | 2.042 | 1 | 0.153 | 1.115 |
| | Speed 2 (m/s) | -0.076 | 0.054 | 2.000 | 1 | 0.157 | 0.927 |
| | [Gender=0] Female | 1.465 | 0.240 | 37.234 | 1 | 0.000 | 4.326 |
| | [Gender=1] Male | 0b | | | 0 | | |
| | [Pedestrian Size=0] Alone | -0.757 | 0.236 | 10.264 | 1 | 0.001 | 0.469 |
| | [Pedestrian Size=1] Group | 0b | | | 0 | | |

| Pedestrian Waiting Time$^a$ | | B | Std. Error | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|---|
| | [Crossing pattern=1] DC | 2.149 | 0.583 | 13.574 | 1 | 0.000 | 8.575 |
| | [Crossing pattern=2] DS, PE | 2.145 | 0.584 | 13.465 | 1 | 0.000 | 8.540 |
| | [Crossing pattern=3] PS, D/PE | 0b | | | 0 | | |
| | [Carrying object=0] No | -1.598 | 0.241 | 44.160 | 1 | 0.000 | 0.202 |
| | [Carrying object=1] Yes | 0b | | | 0 | | |

a. The reference category is: No Waiting Time.

b. This parameter is set to zero because it is redundant.

### 4.5.2 Model II: Considering Significant Variables

The inclusion of significant predictor variables only in the model is compared to an intercept-only model (with no variables added). The p-value is 0.000, which is less than 0.05, so that the full model significantly improves the prediction of the dependent variable (PWT) compared to the model with intercept-only as shown in Table 4.12.

Table 4.12 Model Fitting Information

| | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| Model II | -2 Log Likelihood | Chi-Square | df | Sig. |
| Intercept Only | 1289.191 | | | |
| Final | 1016.926 | 272.265 | 14 | 0.000 |

Similarly, from Table 4.13 the Nagelkerke pseudo-R square is 0.418, which indicates that the model explains approximately 42% of the variance in the pedestrian waiting time (dependent variable) after the consideration of significant variables only. Also, the McFadden pseudo-R square value is 0.22, which lies between 0.2 to 0.4.

Furthermore, the pseudo R-square value is not notably changed after using the significant variables only. This shows a good fit of the model.

Table 4.13 Pseudo R-Square

| | | |
|---|---|---|
| Model II | Cox and Snell | 0.363 |
| | Nagelkerke | 0.418 |
| | McFadden | 0.220 |

Table 4.14 presents the LRT of the significant variables only. Since, all of the p-value of variables presented are less than 0.05, width of road, gap 1, gender, pedestrian size, crossing pattern and carrying object are found to be the significant variables of pedestrian waiting time.

Table 4.14 Likelihood Ratio Test of Model II

| | Model Fitting Criteria | Likelihood Ratio Tests | | |
|---|---|---|---|---|
| Effect | -2 Log Likelihood of Reduced Model | Chi-Square | df | Sig. |
| Intercept | 1016.926a | 0.000 | 0 | |
| Width of road (m) | 1023.324 | 6.398 | 2 | 0.041 |
| Gap 1 (s) | 1039.170 | 22.244 | 2 | 0.000 |
| Gender | 1060.974 | 44.048 | 2 | 0.000 |
| Pedestrian Size | 1050.222 | 33.296 | 2 | 0.000 |
| Crossing pattern | 1048.152 | 31.226 | 4 | 0.000 |
| Carrying object | 1086.571 | 69.645 | 2 | 0.000 |
| The chi-square statistic is the difference in -2 log-likelihoods between the final model and a reduced model. The reduced model is formed by omitting an effect from the final model. The null hypothesis is that all parameters of that effect are 0. | | | | |
| a. This reduced model is equivalent to the final model because omitting the effect does not increase the degrees of freedom. | | | | |

From Table 4.15, parameter estimates provide a summary of the impact of each significant predictor.

Table 4.15 Parameter Estimates of Model II

| Pedestrian Waiting Time[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|---|
| Shorter Waiting Time | Intercept | -1.055 | 0.786 | 1.802 | 1 | 0.180 | |
| | Width of road (m) | -0.003 | 0.027 | 0.009 | 1 | 0.926 | 0.997 |
| | Gap 1 (s) | -0.104 | 0.032 | 10.664 | 1 | 0.001 | 0.902 |
| | [Gender=0] Female | 1.158 | 0.248 | 21.893 | 1 | 0.000 | 3.185 |
| | [Gender=1] Male | 0b | | | 0 | | |
| | [Pedestrian Size=0] Alone | -1.417 | 0.257 | 30.352 | 1 | 0.000 | 0.243 |
| | [Pedestrian Size=1] Group | 0b | | | 0 | | |
| | [Crossing pattern=1] DC | 2.201 | 0.645 | 11.650 | 1 | 0.001 | 9.033 |
| | [Crossing pattern=2] DS, PE | 2.275 | 0.644 | 12.481 | 1 | 0.000 | 9.728 |
| | [Crossing pattern=3] PS, D/PE | 0b | | | 0 | | |
| | [Carrying object=0] No | -1.797 | 0.251 | 51.217 | 1 | 0.000 | 0.166 |
| | [Carrying object=1] Yes | 0b | | | 0 | | |
| Longer Waiting Time | Intercept | -1.850 | 0.735 | 6.330 | 1 | 0.012 | |
| | Width of road (m) | 0.054 | 0.026 | 4.374 | 1 | 0.036 | 1.056 |
| | Gap 1 (s) | -0.120 | 0.032 | 13.742 | 1 | 0.000 | 0.887 |
| | [Gender=0] Female | 1.450 | 0.238 | 37.177 | 1 | 0.000 | 4.265 |
| | [Gender=1] Male | 0b | | | 0 | | |
| | [Pedestrian Size=0] Alone | -0.771 | 0.234 | 10.860 | 1 | 0.001 | 0.463 |
| | [Pedestrian Size=1] Group | 0b | | | 0 | | |
| | [Crossing pattern=1] DC | 2.014 | 0.574 | 12.310 | 1 | 0.000 | 7.492 |
| | [Crossing pattern=2] DS, PE | 2.038 | 0.573 | 12.636 | 1 | 0.000 | 7.678 |

| Pedestrian Waiting Time[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) |
|---|---|---|---|---|---|---|---|
| | [Crossing pattern=3] PS, D/PE | 0b | | | 0 | | |
| | [Carrying object=0] No | -1.573 | 0.237 | 43.946 | 1 | 0.000 | 0.207 |
| | [Carrying object=1] Yes | 0b | | | 0 | | |

a. The reference category is: No Waiting Time.

b. This parameter is set to zero because it is redundant.

### 4.5.3 Factors Affecting Pedestrians' Choice of Short Waiting Time to No Waiting Time

**Width of road:** The odds of choosing the short waiting time instead of choosing no waiting time almost increases by a times if width of a road increases by 1 meter, assuming all other predictor variables remain constant. The estimated coefficient for the width of road is statistically insignificant (p-value >5%), indicating the width have no significant impact on choice between short waiting time and no waiting time by the pedestrians.

**Gap 1:** The odds of choosing the short waiting time in reference to no waiting time decreases by about 10% if gap 1 increases by 1 second, assuming all other predictor variables remain constant. As gap 1 increases in short waiting time pedestrian chooses no waiting time and gap 1 has significant impact on the selection of waiting time.by pedestrians.

**Gender:** The odds of choosing short waiting time, in reference to no waiting time, increase by 3.185 times when pedestrians are female rather than male, assuming all other predictor variables remain constant. The study reveals that females prefer short waiting time, while males choose no waiting time. Therefore, gender has a significant effect on the selection of the waiting timeframe for pedestrians.

**Pedestrian Size:** The odds of choosing the short waiting time in reference to no waiting time decreases by 75.7% if the pedestrians are alone rather than in group, keeping all other predators variable constant. From this study, it can be known pedestrian in group choose short waiting time whereas single pedestrian chooses no waiting time. Thus, size of pedestrians has significant effect on the selection of waiting timeframe.

**Crossing Pattern:** The odds of choosing the short waiting time in reference to no waiting time increases by 9.033 times if pedestrians aim to cross the road within the marked designated crosswalk rather than peripheral start for crossing, assuming all other predictor variables remain constant. Similarly, odds of choosing the short waiting time in reference to no waiting time increases by 9.728 times if the pedestrians aim to cross the road with designated start but peripheral exit pattern rather than peripheral start pattern for crossing, assuming all other predictor variables remain constant. Thus, short waiting time is more preferred by the pedestrian who crosses the road in designated path or at least start to cross from designated point rather than pedestrians who start crossing from periphery of cross walk.

**Carrying Object:** The odds of choosing short waiting time, in reference to no waiting time, decreases by 83.4% when pedestrians are empty handed rather than carrying object in hand, assuming all other predictor variables remain constant. The pedestrian carrying object in hand chooses to wait for longer time.

### 4.5.4 Factors Affecting Pedestrians' Choice of Long Waiting Time to No Waiting Time

**Width of road:** The odds of choosing the long waiting time increases by 1.056 times if width of a road increases by 1 meter, assuming all other predictor variables remain constant, in reference to no waiting time. This can be explained as width of the road increases, the odds of choosing to wait for longer time also increases.

**Gap 1:** The odds of choosing the long waiting time in reference to no waiting time decreases by 11% if gap 1 increases by 1 second, assuming all other predictor variables remain constant. Pedestrian chooses no waiting time when gap 1 increases in longer waiting time category and thus gap 1 is the significant factor on the selection of waiting time.by pedestrians.

**Gender:** The odds of choosing long waiting time, in reference to no waiting time, increase by 4.265 times when pedestrians are female rather than male, assuming all other predictor variables remain constant. The study reveals that females choose longer waiting time while males prefer not to wait before crossing. Therefore, gender has a significant effect on the selection of the waiting timeframe for pedestrians.

**Pedestrian Size:** The odds of choosing the long waiting time in reference to no waiting time decreases by 53.7% if the pedestrian is alone rather than in group, keeping all other predators variable constant. From this study, pedestrian in group is more inclined to wait longer whereas single pedestrian chooses immediate crossing without any wait. Thus, gender have significant effect on the selection of waiting timeframe.

**Crossing Pattern:** The odds of choosing the longer waiting time in reference to no waiting time increases by 7.492 times if pedestrians aim to cross the road within the marked designated crosswalk rather than peripheral start for crossing. Similarly, odds of choosing the short waiting time in reference to no waiting time increases by 7.678 times if the pedestrians aim to cross the road from designated starting point but with peripheral exit pattern rather than peripheral start patten for crossing, keeping all other predictor variables constant. Thus, short waiting time is more preferred by the pedestrian who crosses the road in designated path or at least start to cross from designated point. Pedestrians who start crossing from periphery of cross walk choose no waiting time.

**Carrying Object:** The odds of choosing long waiting time, in reference to no waiting time, decreases by approximately 80% when pedestrians are empty handed rather than carrying any object, assuming all other predictor variables remain constant. The pedestrian carrying object in hand chooses to wait for longer time.

### 4.6 Model Validation

The validation of the developed model is a very crucial process to assess the model's performance. The accuracy of a model was examined using all the variables from the testing dataset only. This validation process helped to verify that the model's predictions can be trusted and applied to new datasets, enhancing its practical utility and applicability. Out of 902 samples, 285 samples were used for the model validation with respect to the model specifications.

Table 4.16 Validation table

| | | **Predicted** | | | |
|---|---|---|---|---|---|
| | | **Pedestrian Waiting Time** | | | |
| **Observed** | | **No Waiting Time** | **Shorter Waiting Time** | **Longer Waiting Time** | **Percent Correct** |
| **Pedestrian Waiting Time** | **No Waiting Time** | 104 | 20 | 7 | 79.4% |
| | **Shorter Waiting Time** | 31 | 19 | 22 | 26.4% |
| | **Longer Waiting Time** | 9 | 6 | 69 | 82.1% |
| | **Overall Percentage** | 50.2% | 15.7% | 34.1% | **66.9%** |

The prediction ability of the developed multinomial logit model is found to be 66.9% as shown in Table 4.16. It is found that, the pedestrian's no waiting time, short waiting time and longer waiting time have 79.4%, 26.4% and 82.1% of prediction accuracy. The overall accuracy of the model is approximately 67% which represented that 67% of the actual choices and the predicted choices of waiting time of pedestrian matches.

Additionally, the McFadden pseudo-R square value from the testing data is 0.266 which lies between 0.2 to 0.4 as shown in Table 4.17. Therefore, the developed model can be considered an excellent model.

Table 4.17 Pseudo R-Square from Testing Data

| | |
|---|---|
| Cox and Snell | 0.433 |
| Nagelkerke | 0.491 |
| McFadden | 0.266 |

# CHAPTER 5: CONCLUSION AND RECOMMENDATION

## 5.1 Conclusion

Recognizing the importance of understanding crossing behavior of pedestrians from diverse backgrounds when designing appropriate crosswalk signals, a study, investigating pedestrian waiting times in relation to several independent variables, was conducted. A discrete choice model was developed with the help of six significant independent variables for three different hierarchy of waiting time. Following list out some important findings from numerical analysis: Following conclusions are drawn based on the numerical outcomes generated by the models:

- The test of normality shows that the independent variables are not normally distributed as the p-value from the Shapiro-Wilk test of normality was less than 5%.
- Spearman correlation test of continuous variables shows average gap of rejected vehicles are highly correlated with spearman correlation coefficient of time gap at the nearer lane. So, the average gap of rejected vehicles was removed from the study due to its multicollinearity
- The McFadden pseudo $R^2$ value of the final model was found to be 0.220 which is between 0.2 to 0.4. So, the model appeared to be a reasonably good fit for the data.
- Width of the road, gap at crossing in the nearer lane (Gap 1), gender, pedestrian size, crossing pattern and carrying any object are observed to significantly affect pedestrian choice of waiting time.
- Multinomial Logistic Regression (MNL) gap at crossing in the farther lane (Gap 2) and speed of the accepted vehicles at both directions (speed 1 and speed 2) have insignificant relationship with the PWT.
- The odds of choosing the longer waiting time increases as the width of the road increases.
- The odds of choosing the SWT and LWT decreases by 10% and 11% when the gap 1 increases by 1seconds respectively.

- The odds of choosing SWT and LWT increase by 3.185 and 4.265 times respectively when pedestrians are female rather than male.
- The odds of choosing the SWT and LWT decreases by approximately 83% and 80% respectively when the pedestrian is not carrying anything.
- The odds of choosing the SWT and LWT increases by approximately 9 times and 7 times respectively when the pedestrian at least start to cross the road from the designated crosswalk point.
- The odds of choosing SWT and LWT decreases by 75.7% and 53.7% respectively when the pedestrians are alone.

### 5.2 Recommendation

The outcome from the study indicates that not only traffic characteristics but pedestrian behaviors also significantly affect the pedestrian waiting time. This analysis can be used to predict how pedestrian’s waiting time at different crossing changes depending on the traffic and pedestrians’ characteristics of the crosswalk. This can provide insights to planners to plan suitable solution measures. For example, in crosswalks where majority of pedestrians starting to cross the road from periphery rather than the designated starting point of crosswalk result in avoiding the waiting before crossing, often without assessing the traffic situations. This may risk the safety of a human as well. A sidewalk railing with only opening at the ends of crosswalk would greatly encourage pedestrian to adopt safe crossing behavior. These could result improved and uninterrupted vehicles flow as well.

The absence of an ordinal regression model, despite the existence of an ordered outcome (no waiting time to longer waiting time) is one of the limitations in this study. Following are some of the recommendations for future works in this area:

- Since, the waiting time is in the ordered form, ordered logit model and nested logit model can also be used for thorough understanding of the waiting time behavior.
- Additionally, more locations with different traffic nature, geometry, etc. can be included.

- Type of vehicles which the pedestrians reject and accept for crossing the road can be used in further studies.
- Multiple Linear Regression model can be used to calculate the exact waiting time in reference to different parameters.

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# APPENDIX A: EXCEL FORMULAE SYNTAX

## 6.1 Show Form Formula

```
Sub Show_Form()

        UserForm1.Show

End Sub
```

## 6.2 Reset Formula

```
Sub Reset()

    Dim iRow As Long
    Dim sh As Worksheet

    Set sh = ThisWorkbook.Sheets("Database")
    iRow = WorksheetFunction.Count(sh.Range("A:A"))

    With UserForm1
        ' Reset the values of controls
        .optMale.Value = False
        .optFemale.Value = False

        .optCarryingYes.Value = False
        .optCarryingNo.Value = False

        .txtPWT.Value = ""

        .optAlone.Value = False
        .optGroup.Value = False
```

```
        .txtGap1.Value = ""
        .txtGap2.Value = ""

        .optDesignatedCrossing.Value = False
        .optPerStartDesigExit.Value = False
        .optPerStartDesigExit.Value = False
        .optPeriStartExit.Value = False

        .txtFarT.Value = ""
        .txtNearT.Value = ""

        .lstDatabase.ColumnHeads = True

        If iRow > 1 Then
            .lstDatabase.RowSource = "Database!A2:AI" & iRow
        Else
            .lstDatabase.RowSource = "Database!A2:AI2"
        End If

    End With

End Sub
```

### 6.3 Submit Formula

```
Sub Submit()

    Dim sh As Worksheet
    Dim iRow As Long

    Set sh = ThisWorkbook.Sheets("Database")
```

```
    iRow = WorksheetFunction.CountA(sh.Range("A:A")) + 1

    With sh
        ' Store values in worksheet cells
        .Cells(iRow, 1) = iRow - 1

        .Cells(iRow, 2) = IIf(UserForm1.optMale.Value = True, "1", IIf(UserForm1.optFemale.Value = True, "0", ""))

        .Cells(iRow, 3) = UserForm1.txtPWT.Value

        .Cells(iRow, 4) = IIf(UserForm1.optAlone.Value = True, "0", "1")

        .Cells(iRow, 5) = UserForm1.txtGap1.Value

        .Cells(iRow, 6) = UserForm1.txtGap2.Value

        .Cells(iRow, 7) = IIf(UserForm1.optDesignatedCrossing.Value = True, "1", IIf(UserForm1.optDesigStartPeriExit.Value = True, "2", IIf(UserForm1.optPerStartDesigExit.Value = True, "3", "0")))

        .Cells(iRow, 8) = UserForm1.txtNearT.Value

        .Cells(iRow, 9) = UserForm1.txtFarT.Value

    End With

End Sub
```

# APPENDIX B: SAMPLE DATA

| PWT | Width of road (m) | Gender | Carrying Object | Pedestrian Waiting Time (s) | Average Rejected Gap (s) | Gap 1 (s) | Gap 2 (s) | Speed 1 (m/s) | Speed 2 (m/s) | Pedestrian Size | Crossing Behavior |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 18.06 | 1 | 1 | 0.000 | 0.000 | 20.252 | 1.807 | 7.859 | 9.456 | 1 | 3 |
| 2 | 18.06 | 1 | 0 | 7.767 | 0.654 | 1.576 | 6.191 | 5.109 | 6.504 | 0 | 2 |
| 2 | 18.06 | 1 | 0 | 6.075 | 0.769 | 5.037 | 5.345 | 6.838 | 6.116 | 1 | 1 |
| 0 | 18.06 | 0 | 1 | 0.000 | 0.000 | 20.172 | 5.575 | 6.390 | 6.932 | 0 | 1 |
| 1 | 18.06 | 0 | 1 | 3.874 | 0.731 | 5.229 | 8.305 | 6.920 | 6.504 | 1 | 1 |
| 1 | 18.06 | 0 | 1 | 1.038 | 0.346 | 6.572 | 1.154 | 6.932 | 8.000 | 0 | 1 |
| 0 | 18.06 | 0 | 0 | 0.000 | 0.000 | 5.575 | 1.730 | 6.504 | 8.000 | 0 | 2 |
| 2 | 18.06 | 0 | 1 | 22.109 | 1.115 | 3.248 | 4.806 | 5.376 | 6.504 | 0 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 19.564 | 4.191 | 7.326 | 4.162 | 1 | 3 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 16.214 | 2.922 | 6.838 | 6.116 | 0 | 1 |
| 1 | 18.06 | 0 | 0 | 2.115 | 0.423 | 5.948 | 3.422 | 6.838 | 5.533 | 1 | 2 |
| 1 | 18.06 | 0 | 0 | 4.148 | 0.269 | 5.152 | 2.576 | 5.256 | 6.504 | 1 | 2 |
| 0 | 18.06 | 0 | 1 | 0.000 | 0.000 | 5.575 | 3.076 | 6.838 | 4.334 | 1 | 2 |
| 2 | 18.06 | 1 | 0 | 5.768 | 1.307 | 5.076 | 5.306 | 6.920 | 5.533 | 1 | 2 |
| 2 | 18.06 | 0 | 1 | 12.497 | 1.269 | 3.614 | 7.383 | 6.920 | 3.152 | 1 | 2 |
| 2 | 18.06 | 0 | 0 | 7.806 | 0.654 | 4.076 | 5.960 | 6.504 | 4.525 | 0 | 1 |
| 2 | 18.06 | 0 | 1 | 16.572 | 1.346 | 3.268 | 7.767 | 6.838 | 5.780 | 0 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 15.416 | 3.730 | 6.135 | 6.504 | 0 | 3 |
| 2 | 18.06 | 0 | 1 | 9.651 | 1.038 | 4.037 | 9.036 | 6.015 | 5.533 | 1 | 2 |
| 2 | 18.06 | 0 | 1 | 10.959 | 1.154 | 3.843 | 12.074 | 6.504 | 4.525 | 0 | 2 |

| PWT | Width of road (m) | Gender | Carrying Object | Pedestrian Waiting Time (s) | Average Rejected Gap (s) | Gap 1 (s) | Gap 2 (s) | Speed 1 (m/s) | Speed 2 (m/s) | Pedestrian Size | Crossing Behavior |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 18.06 | 0 | 1 | 14.496 | 1.576 | 2.538 | 2.499 | 6.015 | 6.504 | 0 | 1 |
| 2 | 18.06 | 0 | 0 | 7.536 | 0.961 | 4.114 | 4.845 | 6.838 | 5.533 | 0 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 14.884 | 3.960 | 6.390 | 3.587 | 0 | 2 |
| 2 | 18.06 | 1 | 0 | 8.921 | 1.269 | 4.037 | 16.572 | 5.780 | 8.000 | 1 | 1 |
| 1 | 18.06 | 0 | 1 | 2.461 | 0.000 | 5.691 | 5.345 | 6.504 | 7.326 | 0 | 2 |
| 0 | 18.06 | 1 | 1 | 0.000 | 0.000 | 13.273 | 4.499 | 5.533 | 5.533 | 1 | 1 |
| 2 | 18.06 | 0 | 1 | 35.529 | 1.461 | 2.807 | 6.075 | 5.682 | 3.591 | 0 | 1 |
| 1 | 18.06 | 0 | 0 | 2.807 | 1.077 | 5.575 | 10.459 | 7.299 | 6.504 | 1 | 1 |
| 2 | 18.06 | 1 | 1 | 9.536 | 1.230 | 4.076 | 7.344 | 6.838 | 6.116 | 0 | 1 |
| 2 | 18.06 | 1 | 1 | 7.575 | 1.192 | 5.268 | 6.229 | 6.504 | 4.525 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 12.043 | 6.884 | 6.390 | 11.236 | 0 | 2 |
| 1 | 18.06 | 0 | 0 | 3.691 | 0.615 | 5.191 | 7.075 | 6.504 | 4.334 | 1 | 2 |
| 1 | 18.06 | 1 | 0 | 2.192 | 0.538 | 5.867 | 6.268 | 6.192 | 6.504 | 1 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.231 | 11.382 | 4.883 | 6.504 | 5.780 | 0 | 1 |
| 0 | 18.06 | 0 | 0 | 0.000 | 0.000 | 10.959 | 10.420 | 6.192 | 9.456 | 1 | 3 |
| 1 | 18.06 | 1 | 0 | 2.309 | 0.461 | 5.752 | 4.307 | 6.504 | 6.116 | 1 | 1 |
| 0 | 18.06 | 1 | 1 | 0.000 | 0.000 | 10.845 | 5.998 | 6.116 | 6.504 | 0 | 1 |
| 0 | 18.06 | 1 | 1 | 0.000 | 0.269 | 10.806 | 2.422 | 6.192 | 8.000 | 1 | 3 |
| 2 | 18.06 | 1 | 1 | 5.499 | 0.807 | 4.424 | 4.768 | 6.116 | 8.677 | 1 | 1 |
| 1 | 18.06 | 0 | 0 | 3.874 | 1.038 | 5.383 | 3.730 | 6.920 | 6.504 | 0 | 1 |
| 1 | 18.06 | 0 | 0 | 4.460 | 1.192 | 4.845 | 4.230 | 6.504 | 8.000 | 1 | 2 |
| 2 | 18.06 | 0 | 1 | 8.882 | 0.884 | 4.076 | 6.037 | 6.838 | 4.525 | 1 | 2 |
| 0 | 18.06 | 0 | 0 | 0.000 | 0.000 | 10.768 | 8.229 | 7.313 | 9.456 | 1 | 2 |
| 0 | 18.06 | 0 | 0 | 0.000 | 0.000 | 9.836 | 2.307 | 5.682 | 6.116 | 1 | 2 |

| **PWT** | **Width of road (m)** | **Gender** | **Carrying Object** | **Pedestrian Waiting Time (s)** | **Average Rejected Gap (s)** | **Gap 1 (s)** | **Gap 2 (s)** | **Speed 1 (m/s)** | **Speed 2 (m/s)** | **Pedestrian Size** | **Crossing Behavior** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 18.06 | 0 | 1 | 2.038 | 0.423 | 6.191 | 2.153 | 6.838 | 6.504 | 1 | 2 |
| 0 | 18.06 | 0 | 0 | 0.000 | 0.000 | 9.722 | 10.997 | 7.859 | 4.334 | 0 | 1 |
| 0 | 18.06 | 1 | 1 | 0.000 | 0.000 | 9.684 | 8.805 | 5.256 | 6.504 | 1 | 2 |
| 1 | 18.06 | 0 | 1 | 3.538 | 0.615 | 5.494 | 5.499 | 6.504 | 5.533 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 9.646 | 4.576 | 6.504 | 6.504 | 0 | 2 |
| 1 | 18.06 | 0 | 1 | 3.384 | 0.538 | 5.596 | 11.997 | 6.838 | 6.932 | 0 | 1 |
| 2 | 18.06 | 0 | 1 | 8.575 | 1.230 | 4.076 | 4.537 | 6.932 | 3.854 | 0 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 9.570 | 4.345 | 5.472 | 6.504 | 0 | 3 |
| 1 | 18.06 | 1 | 0 | 4.729 | 1.230 | 4.731 | 3.345 | 6.504 | 6.932 | 1 | 2 |
| 2 | 18.06 | 0 | 1 | 12.535 | 0.923 | 3.614 | 5.500 | 6.504 | 7.435 | 1 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 9.418 | 1.884 | 7.435 | 6.932 | 1 | 2 |
| 1 | 18.06 | 0 | 0 | 2.269 | 0.692 | 5.867 | 7.998 | 6.920 | 3.252 | 1 | 2 |
| 2 | 18.06 | 0 | 1 | 14.611 | 1.269 | 3.345 | 2.768 | 6.504 | 6.504 | 0 | 1 |
| 2 | 18.06 | 0 | 0 | 5.152 | 0.615 | 4.576 | 3.366 | 6.504 | 6.015 | 1 | 2 |
| 2 | 18.06 | 0 | 0 | 5.691 | 0.654 | 6.075 | 6.114 | 7.313 | 8.677 | 1 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 9.228 | 4.268 | 6.015 | 4.957 | 1 | 1 |
| 1 | 18.06 | 0 | 0 | 4.109 | 0.577 | 5.152 | 4.037 | 7.859 | 4.334 | 1 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 8.805 | 3.922 | 6.383 | 6.932 | 1 | 1 |
| 1 | 18.06 | 0 | 1 | 3.960 | 0.654 | 5.191 | 3.538 | 6.814 | 9.456 | 1 | 2 |
| 1 | 18.06 | 0 | 0 | 4.114 | 0.500 | 5.152 | 3.601 | 6.920 | 9.456 | 1 | 2 |
| 1 | 18.06 | 0 | 0 | 3.345 | 0.269 | 5.614 | 2.038 | 6.814 | 6.932 | 0 | 1 |
| 0 | 18.06 | 1 | 1 | 0.000 | 0.000 | 8.805 | 2.115 | 7.435 | 6.932 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 8.651 | 2.038 | 6.504 | 6.932 | 0 | 1 |
| 1 | 18.06 | 0 | 0 | 4.806 | 1.192 | 4.692 | 3.345 | 6.920 | 6.932 | 0 | 2 |

| PWT | Width of road (m) | Gender | Carrying Object | Pedestrian Waiting Time (s) | Average Rejected Gap (s) | Gap 1 (s) | Gap 2 (s) | Speed 1 (m/s) | Speed 2 (m/s) | Pedestrian Size | Crossing Behavior |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 18.06 | 0 | 0 | 4.076 | 0.846 | 5.191 | 3.268 | 5.533 | 6.932 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 8.602 | 3.999 | 7.313 | 5.472 | 0 | 1 |
| 2 | 18.06 | 0 | 0 | 5.076 | 0.654 | 4.614 | 9.613 | 6.932 | 7.435 | 1 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 8.602 | 2.115 | 7.299 | 3.152 | 1 | 1 |
| 1 | 18.06 | 0 | 0 | 3.405 | 1.038 | 5.596 | 4.499 | 7.435 | 4.957 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 8.602 | 2.845 | 6.504 | 7.435 | 1 | 2 |
| 0 | 18.06 | 0 | 1 | 0.000 | 0.000 | 8.575 | 4.792 | 6.504 | 5.472 | 1 | 2 |
| 2 | 18.06 | 0 | 1 | 13.073 | 1.346 | 3.422 | 4.268 | 6.015 | 10.390 | 1 | 1 |
| 1 | 18.06 | 1 | 1 | 1.884 | 1.000 | 6.379 | 2.307 | 6.504 | 2.214 | 1 | 1 |
| 1 | 18.06 | 0 | 0 | 4.114 | 0.961 | 5.152 | 2.346 | 6.116 | 6.932 | 0 | 2 |
| 2 | 18.06 | 0 | 1 | 6.575 | 0.761 | 4.187 | 2.115 | 6.015 | 6.116 | 1 | 2 |
| 0 | 18.06 | 1 | 1 | 0.000 | 0.000 | 8.133 | 4.114 | 7.435 | 8.000 | 0 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 5.383 | 6.383 | 5.533 | 8.677 | 0 | 2 |
| 0 | 18.06 | 1 | 1 | 0.000 | 0.000 | 8.113 | 2.692 | 7.859 | 8.000 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.846 | 5.575 | 6.383 | 5.472 | 8.677 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 7.944 | 8.305 | 6.932 | 3.714 | 1 | 2 |
| 1 | 18.06 | 0 | 1 | 3.013 | 0.538 | 5.494 | 6.037 | 6.504 | 8.677 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 5.345 | 3.691 | 6.504 | 7.435 | 1 | 2 |
| 1 | 18.06 | 1 | 1 | 3.422 | 0.385 | 5.596 | 3.576 | 5.376 | 7.435 | 1 | 1 |
| 1 | 18.06 | 0 | 0 | 1.487 | 0.308 | 6.762 | 2.653 | 7.435 | 5.202 | 0 | 1 |
| 1 | 18.06 | 1 | 1 | 3.845 | 0.577 | 5.229 | 5.691 | 7.435 | 6.932 | 1 | 2 |
| 0 | 18.06 | 1 | 1 | 0.000 | 0.000 | 7.844 | 3.653 | 6.932 | 9.456 | 1 | 1 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 7.651 | 4.653 | 6.504 | 6.116 | 0 | 2 |
| 0 | 18.06 | 1 | 0 | 0.000 | 0.000 | 7.651 | 2.961 | 7.299 | 8.677 | 0 | 3 |

| PWT | Width of road (m) | Gender | Carrying Object | Pedestrian Waiting Time (s) | Average Rejected Gap (s) | Gap 1 (s) | Gap 2 (s) | Speed 1 (m/s) | Speed 2 (m/s) | Pedestrian Size | Crossing Behavior |
|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 8.020 | 3.170 | 2.545 | 5.393 | 1 | 1 |
| 2 | 8.74 | 0 | 1 | 5.276 | 1.388 | 10.208 | 6.576 | 7.625 | 6.541 | 1 | 2 |
| 1 | 8.74 | 1 | 1 | 1.909 | 0.000 | 20.508 | 8.707 | 6.108 | 7.642 | 1 | 2 |
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 8.325 | 20.508 | 6.108 | 10.174 | 0 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 4.048 | 1.528 | 6.542 | 5.902 | 0 | 1 |
| 1 | 8.74 | 0 | 0 | 1.680 | 1.680 | 6.148 | 28.336 | 7.991 | 10.802 | 1 | 2 |
| 2 | 8.74 | 0 | 0 | 9.280 | 1.938 | 6.034 | 6.510 | 7.642 | 7.642 | 0 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 5.232 | 5.232 | 5.728 | 7.056 | 0 | 1 |
| 1 | 8.74 | 0 | 0 | 2.444 | 0.570 | 2.330 | 7130.000 | 4.581 | 4.581 | 1 | 1 |
| 1 | 8.74 | 0 | 0 | 2.447 | 0.000 | 5.443 | 6.148 | 6.796 | 6.542 | 1 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 4.926 | 5.614 | 6.542 | 7.642 | 0 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 3.781 | 3.513 | 7.056 | 6.542 | 1 | 3 |
| 2 | 8.74 | 0 | 1 | 6.110 | 1.216 | 9.127 | 10.158 | 6.108 | 5.728 | 1 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 3.190 | 22.417 | 8.333 | 7.642 | 1 | 3 |
| 2 | 8.74 | 0 | 1 | 8.172 | 1.362 | 6.454 | 13.404 | 6.542 | 6.542 | 0 | 3 |
| 1 | 8.74 | 1 | 0 | 1.337 | 1.337 | 4.621 | 6.607 | 5.728 | 9.162 | 1 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 2.330 | 5.843 | 4.821 | 7.642 | 0 | 2 |
| 2 | 8.74 | 0 | 0 | 5.232 | 1.064 | 4.812 | 20.836 | 9.162 | 6.108 | 1 | 1 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 4.926 | 19.056 | 4.821 | 4.167 | 1 | 2 |
| 2 | 8.74 | 0 | 0 | 9.013 | 2.014 | 21.539 | 2.253 | 9.162 | 5.728 | 1 | 2 |
| 1 | 8.74 | 0 | 1 | 3.399 | 1.102 | 11.991 | 25.090 | 9.162 | 9.162 | 1 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 5.308 | 4.621 | 10.802 | 9.162 | 0 | 2 |
| 1 | 8.74 | 0 | 0 | 2.599 | 0.000 | 20.011 | 23.257 | 13.109 | 9.162 | 0 | 3 |
| 1 | 8.74 | 0 | 0 | 1.986 | 1.986 | 3.017 | 14.054 | 7.056 | 3.986 | 1 | 1 |

| **PWT** | **Width of road (m)** | **Gender** | **Carrying Object** | **Pedestrian Waiting Time (s)** | **Average Rejected Gap (s)** | **Gap 1 (s)** | **Gap 2 (s)** | **Speed 1 (m/s)** | **Speed 2 (m/s)** | **Pedestrian Size** | **Crossing Behavior** |
|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|
| 1 | 8.74 | 1 | 1 | 3.513 | 0.784 | 7.485 | 3.093 | 7.056 | 6.542 | 0 | 1 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 8.211 | 1.986 | 6.542 | 7.642 | 1 | 1 |
| 1 | 8.74 | 0 | 1 | 2.139 | 0.000 | 16.198 | 6.320 | 9.162 | 10.174 | 1 | 1 |
| 1 | 8.74 | 0 | 0 | 2.444 | 0.722 | 6.454 | 7.905 | 6.108 | 8.333 | 1 | 1 |
| 1 | 8.74 | 1 | 0 | 1.871 | 0.646 | 9.204 | 11.266 | 9.162 | 13.109 | 1 | 2 |
| 1 | 8.74 | 0 | 0 | 1.909 | 0.000 | 11.571 | 3.246 | 8.333 | 4.821 | 0 | 2 |
| 1 | 8.74 | 0 | 0 | 1.948 | 0.646 | 3.208 | 5.843 | 7.056 | 4.821 | 1 | 1 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 11.839 | 2.711 | 6.542 | 9.162 | 0 | 2 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 5.003 | 5.156 | 8.333 | 7.642 | 0 | 1 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 11.571 | 6.110 | 3.986 | 9.162 | 0 | 1 |
| 1 | 8.74 | 0 | 1 | 1.031 | 0.912 | 19.209 | 2.520 | 8.333 | 9.162 | 0 | 3 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 10.769 | 6.569 | 9.162 | 5.393 | 0 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 3.475 | 7.065 | 7.642 | 6.542 | 0 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 3.513 | 7.180 | 7.056 | 9.162 | 1 | 2 |
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 9.662 | 6.110 | 7.056 | 7.642 | 0 | 3 |
| 2 | 8.74 | 0 | 0 | 9.738 | 1.976 | 3.208 | 4.506 | 9.162 | 3.986 | 1 | 2 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 10.960 | 7.007 | 7.642 | 9.669 | 1 | 3 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 7.982 | 9.127 | 9.162 | 11.438 | 0 | 2 |
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 4.545 | 11.037 | 9.162 | 9.162 | 0 | 1 |
| 1 | 8.74 | 0 | 1 | 3.552 | 1.064 | 3.781 | 3.781 | 5.095 | 9.162 | 1 | 2 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 6.950 | 2.139 | 8.333 | 9.162 | 0 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 12.602 | 5.156 | 2.864 | 9.162 | 0 | 3 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 12.480 | 2.368 | 7.056 | 3.817 | 0 | 1 |
| 1 | 8.74 | 1 | 0 | 2.444 | 0.912 | 12.259 | 8.860 | 5.393 | 3.054 | 1 | 2 |

| **PWT** | **Width of road (m)** | **Gender** | **Carrying Object** | **Pedestrian Waiting Time (s)** | **Average Rejected Gap (s)** | **Gap 1 (s)** | **Gap 2 (s)** | **Speed 1 (m/s)** | **Speed 2 (m/s)** | **Pedestrian Size** | **Crossing Behavior** |
|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|
| 2 | 8.74 | 0 | 0 | 6.454 | 0.874 | 3.017 | 16.345 | 6.108 | 8.333 | 1 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 24.288 | 16.001 | 8.333 | 10.174 | 0 | 1 |
| 2 | 8.74 | 0 | 0 | 5.003 | 0.836 | 7.027 | 15.008 | 3.274 | 11.438 | 0 | 2 |
| 2 | 8.74 | 0 | 0 | 6.187 | 1.216 | 3.857 | 6.874 | 3.986 | 7.056 | 1 | 1 |
| 2 | 8.74 | 1 | 0 | 6.378 | 1.330 | 1.833 | 19.438 | 5.393 | 5.095 | 1 | 3 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 7.561 | 19.438 | 6.542 | 5.117 | 0 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 22.914 | 15.810 | 9.162 | 8.333 | 1 | 1 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 5.423 | 21.462 | 7.056 | 7.642 | 0 | 3 |
| 1 | 8.74 | 0 | 0 | 2.520 | 0.912 | 15.772 | 5.003 | 9.162 | 9.162 | 1 | 1 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 4.888 | 10.540 | 8.333 | 4.581 | 1 | 1 |
| 2 | 8.74 | 0 | 0 | 5.385 | 0.988 | 5.881 | 6.301 | 8.750 | 6.542 | 1 | 1 |
| 2 | 8.74 | 0 | 1 | 8.822 | 2.166 | 5.003 | 14.130 | 5.728 | 4.821 | 1 | 1 |
| 1 | 8.74 | 1 | 0 | 4.812 | 1.026 | 3.704 | 9.967 | 6.542 | 3.054 | 1 | 1 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 2.520 | 11.075 | 2.956 | 9.162 | 1 | 2 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 6.798 | 1.298 | 6.108 | 4.364 | 0 | 1 |
| 1 | 8.74 | 1 | 0 | 1.566 | 0.646 | 2.979 | 7.943 | 6.542 | 6.542 | 1 | 1 |
| 2 | 8.74 | 0 | 0 | 12.717 | 2.090 | 2.826 | 9.013 | 6.542 | 3.525 | 1 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 7.676 | 10.235 | 7.642 | 6.542 | 0 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 13.023 | 52.739 | 7.642 | 3.817 | 1 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 2.711 | 9.356 | 6.542 | 5.095 | 0 | 3 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 7.256 | 2.330 | 6.108 | 6.542 | 0 | 1 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 14.550 | 5.919 | 6.108 | 4.364 | 0 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 2.520 | 5.385 | 7.642 | 4.821 | 1 | 1 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 7.179 | 10.655 | 9.162 | 9.162 | 0 | 1 |

| PWT | Width of road (m) | Gender | Carrying Object | Pedestrian Waiting Time (s) | Average Rejected Gap (s) | Gap 1 (s) | Gap 2 (s) | Speed 1 (m/s) | Speed 2 (m/s) | Pedestrian Size | Crossing Behavior |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 8.74 | 1 | 0 | 3.361 | 0.532 | 2.177 | 2.941 | 5.728 | 4.581 | 0 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 26.236 | 10.311 | 10.174 | 8.333 | 0 | 2 |
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 3.246 | 1.451 | 8.333 | 2.618 | 1 | 1 |
| 2 | 8.74 | 1 | 0 | 8.707 | 1.102 | 2.482 | 2.864 | 6.542 | 4.167 | 0 | 1 |
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 18.980 | 8.554 | 9.162 | 11.438 | 0 | 1 |
| 2 | 8.74 | 0 | 0 | 5.232 | 0.912 | 10.617 | 15.161 | 9.162 | 6.108 | 1 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 12.259 | 17.949 | 13.109 | 7.642 | 0 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 8.287 | 6.110 | 11.438 | 11.438 | 0 | 2 |
| 1 | 8.74 | 1 | 0 | 2.711 | 2.166 | 7.409 | 4.659 | 7.642 | 6.108 | 1 | 1 |
| 1 | 8.74 | 0 | 0 | 2.215 | 0.000 | 11.839 | 1.604 | 5.095 | 8.333 | 1 | 1 |
| 2 | 8.74 | 0 | 1 | 12.412 | 1.406 | 9.089 | 1.948 | 7.056 | 8.333 | 0 | 1 |
| 2 | 8.74 | 1 | 0 | 5.232 | 1.140 | 4.277 | 7.370 | 7.642 | 5.393 | 0 | 2 |
| 2 | 8.74 | 1 | 1 | 6.798 | 0.988 | 4.086 | 10.808 | 10.174 | 8.706 | 1 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 17.262 | 3.972 | 8.333 | 6.108 | 0 | 2 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 15.085 | 4.659 | 7.642 | 7.642 | 0 | 2 |
| 1 | 8.74 | 0 | 1 | 2.482 | 0.684 | 12.641 | 3.322 | 8.333 | 5.393 | 1 | 2 |
| 2 | 8.74 | 0 | 0 | 8.478 | 1.178 | 9.395 | 3.170 | 7.642 | 5.728 | 1 | 1 |
| 2 | 8.74 | 0 | 0 | 7.447 | 1.558 | 9.395 | 3.895 | 8.333 | 4.821 | 1 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 6.187 | 11.800 | 7.642 | 6.542 | 1 | 1 |
| 2 | 8.74 | 1 | 0 | 5.156 | 1.406 | 3.093 | 5.194 | 6.542 | 9.162 | 1 | 3 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 9.776 | 3.017 | 7.056 | 8.333 | 0 | 2 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 11.839 | 7.103 | 3.162 | 13.109 | 0 | 2 |
| 1 | 8.74 | 0 | 0 | 2.330 | 0.532 | 5.423 | 11.762 | 9.162 | 3.162 | 1 | 2 |
| 1 | 8.74 | 0 | 1 | 2.139 | 0.608 | 6.110 | 11.571 | 3.665 | 8.333 | 1 | 1 |

| PWT | Width of road (m) | Gender | Carrying Object | Pedestrian Waiting Time (s) | Average Rejected Gap (s) | Gap 1 (s) | Gap 2 (s) | Speed 1 (m/s) | Speed 2 (m/s) | Pedestrian Size | Crossing Behavior |
|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|---:|
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 6.435 | 11.037 | 3.817 | 9.615 | 1 | 2 |
| 2 | 8.74 | 1 | 0 | 5.008 | 0.912 | 4.167 | 1.912 | 4.821 | 5.385 | 0 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 19.362 | 11.037 | 9.162 | 9.615 | 1 | 2 |
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 5.079 | 3.513 | 9.162 | 7.642 | 0 | 2 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 21.157 | 11.610 | 9.162 | 9.162 | 0 | 3 |
| 1 | 8.74 | 0 | 0 | 2.559 | 0.532 | 1.986 | 35.172 | 8.333 | 7.056 | 1 | 1 |
| 1 | 8.74 | 0 | 1 | 4.468 | 1.064 | 3.055 | 35.172 | 10.174 | 7.056 | 1 | 2 |
| 1 | 8.74 | 1 | 1 | 3.819 | 1.596 | 4.583 | 3.933 | 8.333 | 8.333 | 1 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 11.342 | 3.590 | 3.986 | 9.162 | 1 | 3 |
| 2 | 8.74 | 1 | 0 | 5.156 | 0.836 | 25.271 | 9.967 | 6.542 | 9.162 | 1 | 3 |
| 0 | 8.74 | 0 | 1 | 0.000 | 0.000 | 11.342 | 11.533 | 9.669 | 3.986 | 0 | 2 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 13.252 | 44.949 | 11.438 | 5.393 | 1 | 2 |
| 2 | 8.74 | 0 | 0 | 10.808 | 2.204 | 6.034 | 11.877 | 7.642 | 9.162 | 0 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 10.922 | 11.839 | 7.642 | 3.525 | 0 | 1 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 11.839 | 20.164 | 3.525 | 4.167 | 0 | 2 |
| 2 | 8.74 | 1 | 0 | 7.027 | 2.014 | 2.253 | 8.211 | 4.575 | 5.095 | 1 | 2 |
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 25.052 | 5.569 | 6.542 | 13.109 | 0 | 3 |
| 1 | 8.74 | 1 | 1 | 3.017 | 0.784 | 3.056 | 4.774 | 9.162 | 4.167 | 0 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 8.974 | 9.833 | 6.318 | 8.333 | 1 | 1 |
| 1 | 8.74 | 0 | 0 | 3.361 | 0.000 | 16.421 | 3.170 | 5.393 | 9.162 | 1 | 2 |
| 0 | 8.74 | 1 | 1 | 0.000 | 0.000 | 6.034 | 5.156 | 2.235 | 7.642 | 0 | 2 |
| 0 | 8.74 | 1 | 0 | 0.000 | 0.000 | 6.569 | 5.576 | 6.542 | 8.333 | 0 | 1 |
| 0 | 8.74 | 0 | 0 | 0.000 | 0.000 | 11.648 | 2.444 | 2.477 | 8.333 | 1 | 2 |