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SCHOOL OF GRADUATE STUDIES

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STUDY ON PEDESTRIAN CROSSING BEHAVIOR AT SIGNALIZED INTERSECTION IN ADDIS ABABA

By:

Yemsrach Geremew Megersa

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the Requirements for the Degree of

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Research Advisor: **Bikila Teklu Wodajo (PhD)**

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DEDICATION

TO my parents (Etaferahu Assefa & Geremew Megersa)

(*For all the unpaid love, support and everything)*

UNDERTAKING

I, the undersigned, certify that this research work titled "***Study on pedestrian crossing behavior at signalized intersection in Addis Ababa***" is my original work performed under the supervision of my research advisor **Dr. BikilaTeklu** and has not been presented elsewhere for assessment and for a degree in any other university. All sources of materials used for this thesis have also been duly acknowledged.

Signature: _____

Undertaker's Full Name: Yemsrach Geremew Megersa,

Place of Undertaking: Addis Ababa, Ethiopia.

Date: May, 2019

ABSTRACT

Pedestrians are vulnerable road users therefore, it is necessary to analyze their behavior in order to define quality measures. Crossing behavior of pedestrians in Addis Ababa City is rarely in compliance with the pedestrian regulation. To study the crossing behavior of pedestrians in Addis Ababa 4 intersections namely Estifanos, Legehar, Banko de roma and post office intersections are selected. The first three intersections were used for the major study and the last one for validation study. Data collection was done using video recording method for the study of pedestrian crossing behavior and 385 respondents were interviewed to get pedestrian perception on the crossing environment. 3783 pedestrian peak hour data is used for statistical analysis. Student t-test and one way ANOVA were used to identify factors affecting pedestrian crossing speed while Mann-Whitney U test and Kruskal-Wallis one way ANOVA test were used to identify determining factors of pedestrian signal and crosswalk compliance. Gender, age group and pedestrian group size were found as a dominant factors affecting pedestrian crossing speed whereas age group and pedestrian group size are found as significant factors affecting pedestrian signal and crosswalk compliance. Multiple linear regression model is developed to study the effect of significant factors on pedestrian crossing speed. Except crossing signal phase, all variables were found statistically significant to predict pedestrian crossing speed. Gender and pedestrian group size are correlated negatively with crossing speed while pedestrian age group is correlated positively. Binary logistic regression models are also developed to study the effect of significant factors on pedestrian signal and crosswalk compliance. Pedestrian age group and group size were found statistically significant to predict pedestrian probability of signal compliance and crosswalk compliance. The external validation study suggests that the regression models are applicable for signalized intersections in Addis Ababa. From the pedestrian attitude survey it is found that the most dominating reasons of pedestrians' noncompliance with crossing locations are drivers' improper usage of roads during red phase and inadequacy of width of cross walk. In addition, reasons for noncompliance with traffic light most likely related to the low level awareness of pedestrians and gap in enforcement and implementation of law.

Key words: pedestrian, crossing behavior, crossing speed, compliance, signalized intersection.

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LIST OF ABBREVIATIONS AND ACRONYMS

H_0– Null hypothesis

H_1 –Alternate hypothesis

Q- Question

Eqn- Equation

OR- Odds ratio

H-L- Hosmer- Lameshow goodness of fit

CBD- Central business district

TH- Through

RT-Right turn

LT-Left turn

G-Green

R-Red

Y-Yellow

CI- Confidence Interval

E- Margin of error

ANOVA- Analysis of variance

Sig. – Significance

C_s – Crossing speed

CR_s– Crossing signal

C_w– Crosswalk

SPSS- Statistical analysis software name

VIF- Variance Inflation Factor

BLR- Binary Logistic Regression

MLR- Multiple Linear Regression

LOS- Level of Service

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CHAPTER ONE: INTRODUCTION

1.1 General Background

In developing countries a vital component of the transportation system is being marginalized the pedestrian, as planners, policy makers, and engineers focus on motor vehicles. Large percentages of the population in developing countries are still dependent on walking; yet do not have safe means to do so. With transportation fatalities predicted to become the 4th leading cause of early mortality globally by 2030, this is an important issue, and especially so in the developing world context. Once, pedestrians behavior in terms of safety when interacting with automobiles and safe utilization of types of signalization & infrastructure treatments is understood, we may then plan and design transportation systems that are safer for all users. ***(Nicholas N and Matin 2017)***

Trying to particularly focus on the capital, commercial and political center of Ethiopia, the above statement holds true for Addis Ababa. The population of the city has nearly doubled every decade since the 1980s. The 2013 population size is estimated at 3.1 million and is estimated to reach 12 million in 2024. ***(Central Statistical Agency 2013)***It has a large concentration of motorized vehicles. In 2017, registered vehicles in the country have reached 831,235. Among these about 65 percent of the total vehicles operate in the city. This number is expected to be growing at a rapid pace with the development of the socio-economic activity of the city and growing purchasing power of its people. ***(EthiopianTranportAuthority 2017)***

One of the major road users of the city are pedestrians with a high volume due to low level of motorization as in other developing countries.***(Tulu 2013)***Pedestrians are expected to follow traffic rules and cross on pedestrian designated facilities particularly in built up areas, and it is worth noting that there are fewer rules for pedestrians than for driver. ***(King, David and Ameneh 2009)***Crossing behavior of pedestrians in Addis Ababa City is rarely in compliance with the pedestrian regulations, though drivers contribute to this as they do not yield at pedestrian crossings.***(Tulu 2013)***

A considerable amount of literature has been published on how traffic operations and pedestrian safety on road ways could be improved. ***(Serge 2001),*** Documented that the complexity of traffic flow system and pedestrian behavior may not allow analytical approaches to provide the desired result. So, models designed to characterize the behavior of the complex traffic flow system have become an essential tool in analysis and experimentation.

This research primarily focuses on assessing the crossing behavior of pedestrians at selected signalized intersections in Addis Ababa by meeting certain objectives that are stated in ***section 1.5***. Statistical analysis and modeling are used to address these objectives.

1.2 Motivation

The pedestrian mode of travel is a vital but neglected component of urban transport and urban activity system. Traffic research on roadways has always been on vehicles. Although pedestrians are vulnerable road users, concerns for the safety, comfort, and convenience of them have often come secondly while designing roadways. One of the major reasons is the complexity involved in modeling pedestrian behavior. At signalized intersections, pedestrian travel is very high in highly populous cities with least amount of safety measures provided to them. Pedestrian crossing behavior is an important and relevant objective when designing roadways and signalized intersection to meet the aims such as safety, comfort and convenience. By studying and describing the real situation of crossing behavior of pedestrians by statistical model and methods will better help in achieving and improving the safety, comfort and convenience of pedestrians.

1.3 Statement of the problem

Traffic accident on pedestrians is increasingly becoming the country's major problem especially for Addis Ababa city. Report obtained from Addis Ababa police commission department of traffic police shows traffic accident on pedestrians is increasing with high rate and level of severity (see ***fig.1.1, fig.1.2 and fig. 1.3***). In addition, congestion is coming to be a vital problem on pedestrian walkways and crossing facilities. However, studies concerned on traffic engineering and safety mainly focus on vehicular traffic flow and pedestrian flow behavior or pedestrian crossing behavior is not studied yet. Thus, the researcher would like

to contribute in filling the observed potential gaps on behavior of pedestrians at signalized intersection.

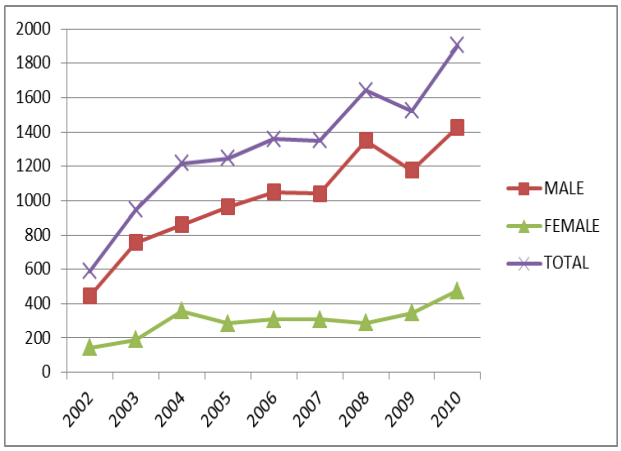


Figure 1.1Slightly injured pedestrian crash data from 2002 up to 2010

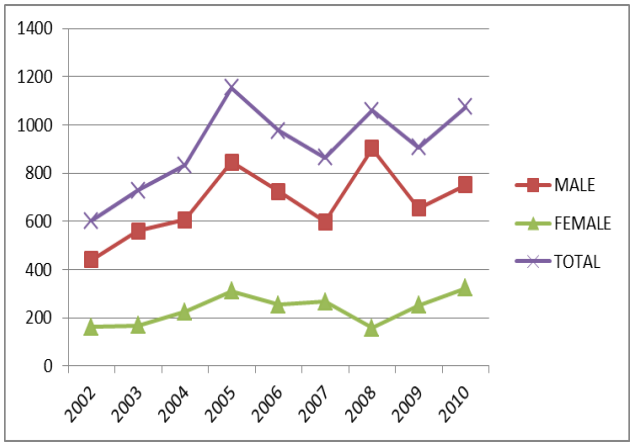


Figure 1.2 seriously injured pedestrian crash data from 2002 up to 2010

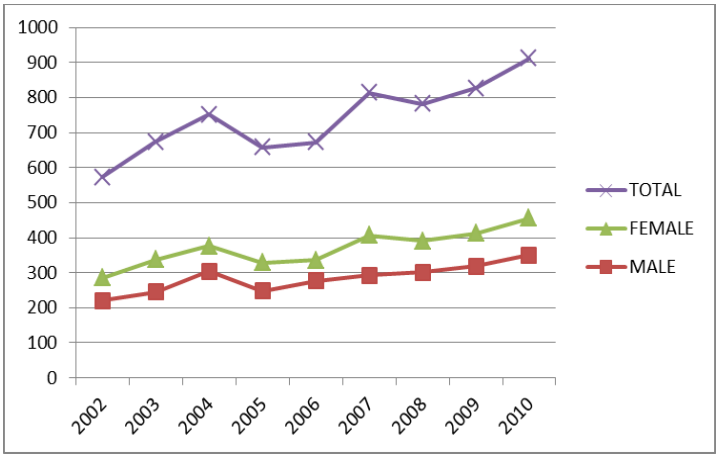


Figure 1.3 Fatal pedestrian crash data from 2002 up to 2010
SOURCE: Addis Ababa Police Commission: Department of Traffic police

1.4 Research challenges

- During data collection stage, due to the instability and insecurity condition the country had been through, getting permission from authorities to film a video was the major challenge.

- In the task to address the overall stretch with simultaneous video recording at 4 intersections each having 4 legs, with total of 16 locations the management was tedious.

- Lack of compatible software that extracts the recorded video data and changes to numerical data forced the researcher to spend too much time on extraction of data as it was carried out manually and only by the researcher in assuring the data quality.

- Lack of organized data and information in different offices was also a remarkable challenge.

1.5 Objectives of the study

1.5.1 General Objectives

The main objective of this paper is to study the crossing behavior of pedestrian at signalized intersection.

1.5.2 Specific Objectives

- To identify the factors that dominantly affect pedestrian crossing speed in the cross walk at signalized intersections

- To determine most significant factors affecting signal and crosswalk compliance & identify the reasons for pedestrian noncompliance of signal timing and crosswalk location.

- To examine the effects of pedestrian characteristics and traffic characteristics on pedestrian crossing behavior.

1.6 Research Hypothesis and Question

The hypotheses that will be tested and research questions the study calls into are presented as follows in ***table 1.1*** with corresponding objectives aimed to be addressed.

Table 1.1: Hypotheses and questions

Objectives	Hypotheses/question
Identify the factors that dominantly affect pedestrian crossing speed in the cross walk at signalized intersection	**Ho**: no significant difference in crossing speed exists between men and women **H1**: significant difference in crossing speed exists between men and women **Ho:** no significant difference in crossing speed exists among age groups **H1**: significant difference in crossing speed exists among age groups **Ho**: no significant difference in crossing speed exists among pedestrian group groups **H1**: significant difference in crossing speed exists among pedestrian group groups **Ho**: no significant difference in crossing speed exists between pedestrian crossing on red phase and pedestrian crossing on non-red phase **H1:** significant difference in crossing speed exists between pedestrian crossing on red phase and pedestrian crossing on non-red phase
Determine the most significant factors affecting pedestrian signal compliance & crosswalk compliance and identify the reasons for non-compliance of signal timing and crosswalk location	**Ho**: no significant difference in signal compliance exists between men and women **H1**: significant difference in signal compliance exists between men and women **Ho**: no significant difference in signal compliance exists among age groups **H1**: significant difference in signal compliance exists among age groups **Ho**: no significant difference in signal compliance exists among pedestrian group groups **H1**:significant difference in signal compliance exists among pedestrian group groups **Ho**: no significant difference in crosswalk compliance exists between men and women **H1**: significant difference in crosswalk compliance exists between men and women **Ho**: no significant difference in crosswalk compliance exists among age groups **H1**: significant difference in crosswalk compliance exists among age groups **Ho**: no significant difference in crosswalk compliance exists among pedestrian group groups **H1**:significant difference in crosswalk compliance exists among pedestrian group groups **Q**: what is the reason for pedestrian non-compliance of signal timing?
Examining the effects of pedestrian characteristic and traffic characteristic on pedestrian crossing behavior	**Q**: what is the effect of pedestrian characteristic [(a)] and traffic characteristic [(b)] on pedestrian crossing behavior [(c)]?

(a) Pedestrian characteristic refers to gender, age group and pedestrian group size

(b) Traffic characteristic refers to departure signal phase and crosswalk location

((c) Pedestrian crossing behavior refers to crossing speed, signal compliance and crosswalk compliance

Ho: null hypothesis H1: alternative hypothesis Q: question

1.7 Scope and Limitation of the Research

1.7.1 Scope of the Study

This work determines crossing behaviors of pedestrian at signalized intersection crosswalks in Addis Ababa and investigates the reason of signal and crosswalk noncompliance of pedestrians.

1.7.2 Limitation of the Research

The study does not included disabled pedestrians as study subjects; taking into account that crossing behavior for disabled pedestrians has to be studied as one major study since there shall be many different factors and characteristics to be considered.

1.8 Focus on Pedestrians Crossing Behavior at Intersections and its effect in Addis Ababa

Pedestrians crossing at intersections are contributing their role to the current inconvenient traffic flow system which in turn leads to congestion. It is well known that congestion in Addis Ababa streets and intersections is highly affecting road users' life and decreasing the convenience and quality of the city. As a result behavior of crossing pedestrians at intersections has got the attention of academicians, practitioners and traffic management offices in making enormous efforts to alleviate the problem. Thus this research aims to share academicians' role in understanding the scope of the problem and solving it.

Since behavior and effect of crossing pedestrians remain to be unstudied and it is believed by the researcher that these contributing factors are determining variables in studying and modeling pedestrian crossing behavior. It is essential to focus on studying the crossing behavior of pedestrians in Addis Ababa.

1.9 Thesis Organization

This study is organized in five chapters. Chapter one gives a brief overview of the general background of the study, motivation to study, statement of the problem, challenges encountered during the study, the general and specific objectives of the study, hypothesis and research question, scope and limitation of the research and the need to focus on pedestrian crossing behavior. Chapter two deals with review of relevant literatures. Chapter three describes research methods, materials and procedures including description of the study area, data collection, extraction and analysis methodology, sample size determination and study design. Detailed data analysis and discussion of results is presented in chapter four. Conclusion and recommendation are drawn in the last chapter.

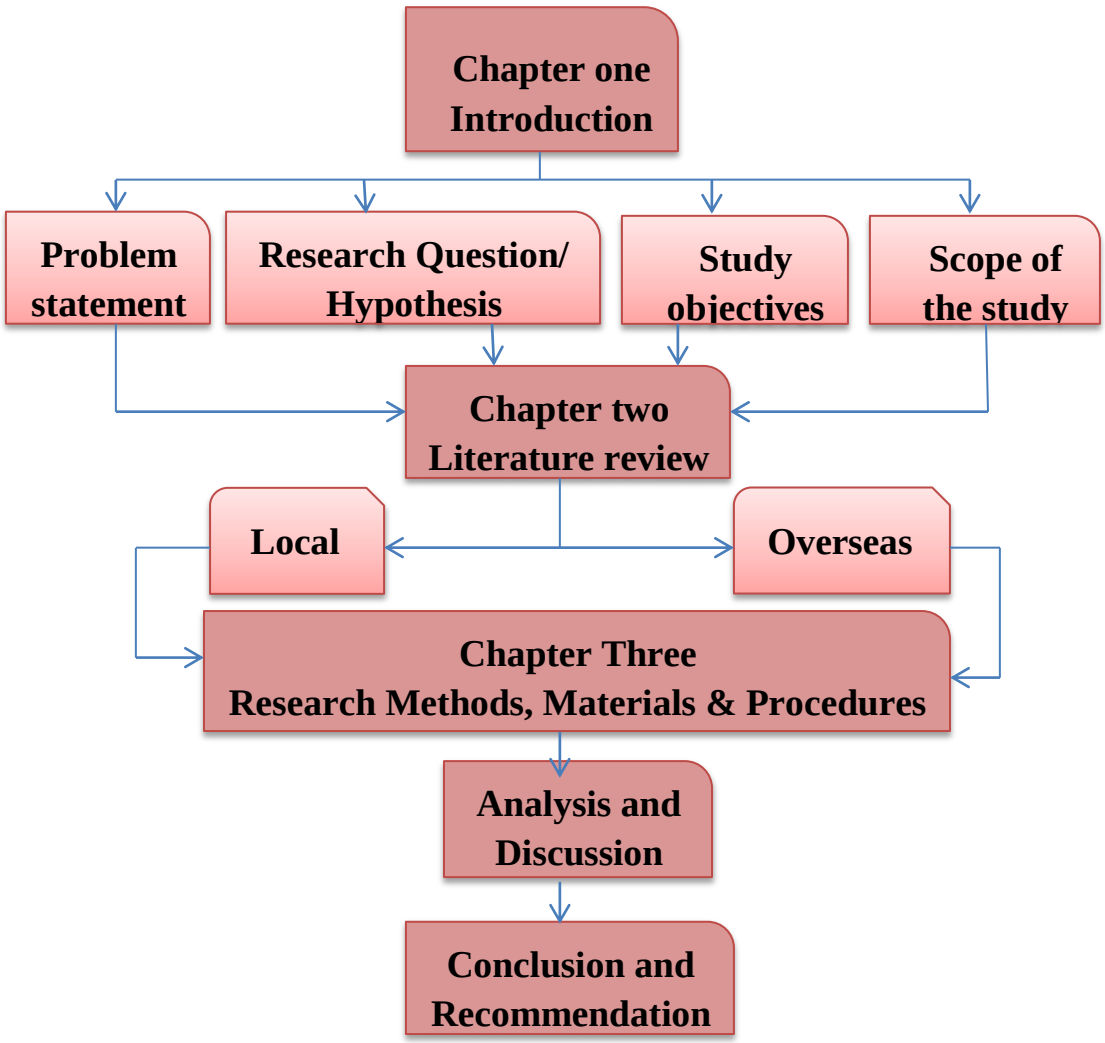


Figure 1.4 Research Organization Chart

CHAPTER TWO: LITRATURE REVIEW

2.1 Introduction

This chapter intends to look on several literatures written in the areas that the scope of this research is concerned about. ***Section 2.2*** will be discussing about importance of pedestrian crossing behavior. Pedestrian crossing characteristic and pedestrian crossing behavior are discussed in ***section 2.3*** and ***section 2.4*** respectively. Moving on factors affecting pedestrian behavior will be discussed in ***section 2.5***.Parametric and nonparametric statistical test are discussed in ***section 2.6*** and ***section 2.7*** respectively. ***Section 2.8*** deals with multiple linear regression model while ***section 2.9*** presents concepts about binary logistic regression model. In the last section of this chapter, ***section 2.10*** model validation technique is discussed,

2.2 Importance of pedestrian crossing behavior

Traffic accidents involving pedestrians have become a major safety problem all over the world, particularly in developing countries, because of high population densities, rapid urbanization, and a lack of adherence to traffic regulations by both drivers and pedestrians. Statistics indicate that one-third of traffic accidents around the world involve pedestrians. ***(Zhang 2005)***. ***(Koh 2014)*** showed that 22% of pedestrian fatal accidents in Singapore occurred at signalized pedestrian crossings. Crashes involving pedestrians are most likely to occur when pedestrians are crossing roads, especially crossing at signalized intersections.***(Zhu, et al. 2013)***In the case of Ethiopia, pedestrians account for 55% of fatal crashes per annum.***(Tulu, 2013) (WHO 2009)*** Crashes involving pedestrians most likely occur when pedestrians are crossing roads, especially at signalized intersections. ***(Gang, et al. 2011)***In addition, pedestrians at signalized intersections are more likely than pedestrians on sidewalks to be run over by right-turning or left-turning vehicles. ***(Sun 2004)***It is important to understand pedestrian street-crossing behavior because it is not only crucial for improving pedestrian safety but also helps to optimize vehicle flow. ***(Nesic, Lipovac and Rosic 2014)***In light of this disappointing state of pedestrian safety, the study described in this paper evaluates causalities among pedestrians using crosswalk at signalized intersections in Addis Ababa.

2.3 Pedestrian crossing characteristics

In some studies, researchers obtained pedestrian movements with cameras and by conducting surveys so that they could collect data on the perceptions of pedestrians about the crossing environment. ***(Gang, et al. 2011)***Very few studies have analyzed pedestrian flow characteristics at signalized intersections for the development of pedestrian models for evaluating walking facilities. ***(Krysto, et al. 2013)***Few researchers studied pedestrian noncompliance behavior at signalized intersections for the purpose of pedestrian speed flow relationship development ***(Zhu, et al. 2013)***and delay model development ***(Marisamynathan 2014)***. Pedestrian crossing behaviors were examined and factors affecting pedestrian crossing behaviors were identified for the improvement of pedestrian safety at signalized intersections ***(Gang, et al. 2011)***. In developing countries vehicles usually do not give right of way to pedestrian leaving them with the only choice to wait until an accepted gap is available. Therefore, pedestrians loose the reason for crossing at designed locations pushing them to cross at arbitrary locations increasing their safety risk***(Deepty, et al. 2017)***.

2.4 Pedestrian crossing behavior

Pedestrian are vulnerable road users & because of that it is necessary to analyze their behavior in order to define quality measures to influence their behavior. Many different researches indicate those pedestrian crossings while there is green light on the traffic light are very common. In a recent study the pedestrian sudden behavioral changes while crossing at signalized crosswalk were analyzed and found that the pedestrian change their crossing behavior in terms of speed and direction due to some of factors (long crossing distance, change in signal indication etc.) without paying attention to the surrounding conditions ***(Alhajyaseen and Iryo 2017)***.Pedestrians violating behavior could be influenced by personal characteristic (in hurry or not crowd behavior) situational characteristic(vehicle volume, pedestrian volume environment conditions like crossing length, pedestrian crossing facilities, count down timers& waiting duration ***(Koh 2014)***.Many researches have been done on pedestrian crossing behavior. Studies on pedestrian behavior analysis have great implications for transportation and urban planning policies and design practices .Many of the existing studies have examined only the pedestrian characteristics in sidewalks and walkways and

analyzed pedestrian flow characteristics in pedestrian walkways under mixed traffic conditions in India. Few studies analyzed pedestrian characteristics at signalized intersections for the development of pedestrian models for evaluating walking facilities and examined pedestrians crossing behavior variation by providing count down display signal. ***(Maristamynathan and Vendagri 2015)*** Crossing behaviors that have been mentioned in these researches are crossing speed, crossing signal compliance and crosswalk compliance.

2.4.1 Crossing speed

Different researches have shown that crossing speed alters with different factors. The average crossing speeds at different study locations are varied with respect to various pedestrian characteristics like gender and age category ***(Akash, Gupta and Rastogi 2014)***.Pedestrian age, gender and departure signal had the most significant effect on crossing speed ***(Marisamynathan 2014)***. The average pedestrian crossing speed is estimated to be 1.36m/s for perpendicular conditions and 1.98m/s for oblique movement conditions. Among various categories of pedestrians children are found to cross at higher speed than others. Males have higher crossing speed than females ***(Akash, Gupta and Rastogi 2014)(Jiang , et al. 2015) (Srinivas, Hani and Machmehl 1994)***. A comparative study done in china and Germany showed that the crossing speed of elderly pedestrians in both countries is found to be lower than the average speed of all samples ***(Jiang , et al. 2015)***. A study done in India to model crossing behavior of pedestrian by studying the situation before and after installation of signal at intersections showed that female pedestrians were found to cross the road at a slower rate than males in both scenarios due to their safety concern***(Asaithambi, Manu and Chandra 2016)***.Older pedestrians crossed the street with lower walking speed than pedestrians aged between 20-50 or under 20 years old and men crossed the street faster than women ***(Athnatios and Nicholas 2012)***.

2.4.2 Pedestrian signal compliance

Illegal pedestrian behavior is common and is reported as factor in many pedestrian crashes. Signalized intersections should be the safest one because conflict flows of traffic (pedestrian and traffic flow) are always separated. However, disrespect of traffic signals may lead to traffic accident. ***(Wall 2000)***Found that over 60% of serious and fatal pedestrian causalities

at crossings were associated with lack of compliance by pedestrians. Many researches have studied pedestrian signal compliance and found that signalized intersections have higher compliance ***(Srinivas, Hani and Machmehl 1994)***. Pedestrians are in noncompliance with traffic signal for various reasons and one of the major reasons is to reduce waiting time delay at signalized intersections. Gender and pedestrian group size have significant effect on pedestrian compliance behavior ***(Marisamynathan 2014)***. Women are more prone to obey traffic signal especially those with the countdown display ***(Krysto, et al. 2013)***.Several studies have examined differences in pedestrian behavior by gender and age. Male pedestrians tend to violate traffic rules more frequently than females and are more likely to cross in risky situations. Young adults and adolescent pedestrians are generally more likely than older pedestrians to commit violations, whereas older road users express greater appreciation for the traffic signals at controlled pedestrian crossings and signalized intersections than younger pedestrians. Pedestrians compliance and arrival pattern were studied without statistical evidence for the purpose of developing pedestrian delay model at signalized intersections. Pedestrian noncompliance with traffic signal, rather than by vehicles, is one of the main causes of traffic accidents on an at-grade intersection. Compliance studies were performed to understand pedestrian behavior in crosswalks of signalized intersections and promote a better pedestrian crossing environment. Many of the earlier studies provided theoretical support on setting pedestrian crossing parameters without considering any statistical support. Initially pedestrian noncompliance was considered during flashing green time only and delay models were developed but, many pedestrians started to noncomplying with signal during red phases also. ***(Gang, et al. 2011)***

2.4.3 Pedestrian cross walk compliance

At signalized intersections pedestrians are more likely to cross within the crosswalk ***(Srinivas, Hani and Machmehl 1994)***. The pedestrian crosswalk marking utilization had significant effect on pedestrian compliance behavior. It was observed that if crosswalk marking is present most of the arriving pedestrians comply with traffic signal. ***(Nesic, Lipovac and Rosic 2014) ,***Observed behavior of 400 adult pedestrians during and after their crossings at two pedestrian crossings with traffic lights and two crossings without them. The results showed that the temporal crossing compliance rate was lower among male

pedestrians, but spatial crossing compliance did not differ between genders. They also showed that there were differences in behavior between men and women before and during crossing; specifically, women were more often focused on other pedestrians, whereas men paid more attention to vehicles. For women, this kind of behavior varied at different crossings but did not for men.

2.5 Factors affecting pedestrian crossing behavior

Different researches have proven that in order to identify unsafe junctions where priority should be shifted to pedestrians it is necessary to understand the behavior of pedestrians as the effect of age, gender or some other circumstances like crossing alone or in group. Many researches have shown that male pedestrians have tendency to commit more violations than women ***(Rosenbloom 2009)***, ***(Krysto, et al. 2013), (Nesic, Lipovac and Rosic 2014)*** and young teenagers tend to violate at traffic light more. It is important to understand pedestrian street crossing behavior because it is not only crucial for improving pedestrian safety but also helps to optimize vehicle flow. ***(Nesic, Lipovac and Rosic 2014)***.

2.6 Parametric statistical tests

(Scott 2015)Stated that parametric statistics are generally used when values in an interval or ratio level variables are normally distributed i.e. the entire group of values has a bell shaped curve when plotted by frequency. These statistics are used because we can define parameters of the data such as the center and width of the normally distributed curve.

2.7 Non parametric statistical tests

In contrast to parametric statistical tests, interval level and ratio level variables with values that are not normally distributed, as well as nominal level and ordinal level variables are generally analyzed using non parametric statistics ***(Scott 2015).***

2.8 Multiple linear regression model

MLR model is designed to study the relationship between one variable and several of other variables that appear in the data set. The model is written in the form of:

$$Y= \beta_0+\beta_1x_1+\beta_2x_{2+\ldots+}\beta_nx_n \ldots\ldots\ldots\ldots\ldots\ldots \textit{ Eqn 2.1}$$

Where:

Y- Response variable

$x_1, x_2 \ldots x_n$ – Predictors

$\beta_0, \beta_1, \beta_2 \ldots \beta_n$ – population estimating parameters***(Montogomery and Runger 2010)***

MLR model requires no assumptions regarding the measurement of independent variables. Independent variables can be dichotomous, nominal, ordinal or continuous. In contrast the MLR requires some essential assumptions to be met. According to ***(Washington, Mattew and Fred 2010)*** the following six assumptions are required to use MLR model.

- *Continuity of dependent variable*: - The response variable should be continuous.
- *Linearity*: - A linear in parameters relationship between the response and predictors variables.
- *Multicollinearity*: - There shall not exist inter correlation between variables.
- *Homoscedasticity (constancy of disturbance)*:- The disturbance of variance term in regression model is assumed to be constant.
- *Normal distribution of residuals*: -The disturbance has to be approximately normally distributed.
- *No significant outliers*: - It is recommended that outlying influential observations be systematically checked to make sure they are legitimate observations.

2.9 Binary logistic regression model

(***Allen T Mense 2010***) stated that binary logistic regression is used for dichotomous response variable.***(Maristamynathan and Vendagri 2015)*** Recommended binary logistic regression to predict binary response variable based on the predictor variables. The mathematical concept of regression is to express the relationship between outcome variable and predictor variables in terms of logit: the natural logarithm of odds. The simplest form of logistic regression model can be written as:

$$\text{Logit}(Y) = \ln\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_{2+\ldots+} \beta_n x_n \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Eqn 2.2}$$

$$P(Y_n) = \frac{e^x}{1+e^x} \quad \text{.....eqn 2.3}$$

Where:

$P(Y_n)$ – Probability that characteristics of pedestrian n have effect on crossing characteristics

x- Pedestrian characteristic that determine the probability of discrete outcome for n

β_0 – Constant

β_1, β_2 …β_n– Estimating parameters (estimated by maximum likelihood estimation technique in SPSS) and

$\frac{p}{1-p}$ –The odds of success ***(Tasnima , et al. 2016)***

The value of regression coefficients,β_1, β_2 …$\beta_i$ndicates the relationship between the predictors and logit of the response variable.

- Coefficient value > 0 indicates an increase in logit of response variable with an increase in predictor variable
- Coefficient value < 0 indicates a decrease in logit of response variable with an increase in predictor variable and,
- When coefficient value = 0 there is no relationship between logit of response variable and predictor variables.

For the ease of interpretation ***(Tasnima , et al. 2016)*** suggest to use the odds ratio along with regression coefficients.

Where; Odds ratio (OR) =e^{β}

- Odds ratio > 1 indicates predictors associated with increased risk of outcome.
- Odds ratio=1 indicates no association predictor and the outcome.
- Odds ratio < 1 indicates predictors associated with decreased risk of outcome.

Hosmer -Lameshow goodness of fit test

Assessing the goodness of fit model is also very important as discussed in ***(Tasnima , et al. 2016).*** Hosmer-Lameshow (H-L) test is commonly used to measure the goodness of fit where the null hypothesis of the test is: H_0-model fit the data well. It is expected to obtain higher P value than the significance level in order to get best representing model.

2.10 Model validation

Application of modeling techniques without subsequent performance analysis of the obtained models can result in poorly fitting results that inaccurately predict outcomes on new subjects ***(Arboretti and Salmaso 2003)***.According to ***(Sohel, Habshah and Sarkar 2015)*** model validation refers to the stability and reasonableness of regression coefficients, the plausibility and usability of fitted regression function and the ability to generalize inferences drawn from the analysis. On the process of model validation ***(Hosmer and Lemeshow 2000)*** suggest using independent data when a researcher is interested in demonstrating the generalizability of the model in order to use it to predict outcomes for future subjects. The authors also state that external validation technique is the most stringent and unbiased test especially for logistic regression model.

2.10.1Model validation of multiple linear regression model

(Consonni, Ballabio and Todeschini 2010) Stated that the model predictive ability measure is sensitive to the selection of training data and models which are developed over a highly homogeneous data are to be under estimated by Q^2 even if the predictions of the model are close enough to the observed values. The authors introduced three methods or equations to calculate the predictive squared correlation coefficient Q^2 from external test data set.

$$Q_{F1}^2 = 1 - \frac{\sum_{i=1}^{n_{EXT}} (\hat{y}_i - y_i)^2}{\sum_{i=1}^{n_{EXT}} (y_i - \bar{y}_{TR})^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ 2.4$$

$$Q_{F2}^2 = 1 - \frac{\sum_{i=1}^{n_{EXT}} (\hat{y}_i - y_i)^2}{\sum_{i=1}^{n_{EXT}} (y_i - \bar{y}_{EXT})^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eqn\ 2.5$$

and

$$Q_{F3}^2 = 1 - \frac{\sum_{i=1}^{n_{EXT}} (\hat{y}_i - y_i)^2 / n_{EXT}}{\sum_{i=1}^{n_{TR}} (y_i - \bar{y}_{TR})^2 / n_{TR}} \dots\dots\dots\dots\dots\dots\dots eqn - 2.6$$

Where

$\hat{y}_i$ is Predicted value

Y_i Observed values

$\bar{y}_{TR}$ is Response mean of training set

$\bar{y}_{EXT}$ is Response mean of external set

n_{ext} is sample size of external set

n_{tr} is sample size of training set

The predictive ability of the first two functions is highly dependent on the sample size of external data set. The third function is less sensitive to sample size, the average Q^2 is always close to the true value. As the number of observation for test data increases the predictive squared correlation coefficient from the first two equations approaches the true value. Q^2_{F1} and Q^2_{F2} are highly influenced by the distribution of the test data set. For test data set which is not uniformly distributed over the range the training data, the first two functions are disadvantageous. However the third function performs well regardless of the distribution of the test data ***(Consonni, Ballabio and Todeschini 2010)***.

2.10.2 Model validation of Binary logistic regression model

- ✓ *Hosmer-Lameshow goodness of fit test*

There are many statistical tools for model validation but, the primary tool for most modeling applications is summary measures of goodness of fit analysis. ***(Sohel, Habshah and Sarkar 2015)(Stombergsson 2009)***Recommended that, the data reported on the result of logistic

regression analysis should include an assessment of the predicted probabilities. The predictive accuracy of the model can be presented in a classification table, where the predicted outcome is compared to the actual outcome. According to ***(Garson n.d.),*** however, Hosmer- Lameshow chi^2 test of goodness of fit is often preferred over classification tables. ***(Sohel, Habshah and Sarkar 2015)*** stated that, assuming each expected response sufficiently large for each term, H-L goodness of fit test statistic 'C' to be distributed as χ^2 (chi-square) and the null hypothesis H_0: the model is correct, the H-L goodness of fit test for validation sample is given as:-

$$C_v=\sum_{j=1}^{g}\frac{(O_j-E_j)^2}{n_j\bar{\pi}_j(1-\bar{\pi}_j)} \quad \textbf{.....eqn 2.7}$$

Where:-

C_v–Hosmer-Lameshow goodness of fit test statistic for validation sample

O_j -Observed response

E_j –Expected response

n_j –Total observation

$\bar{\pi}_j=\sum\frac{m_j\hat{\pi}_j}{n_j}$

m_j- Number of subjects

$\hat{\pi}_j$–Logistic probability for the covariate pattern

CHAPTER 3: RESEARCH METHODS, MATERIALS AND PROCEDURES

3.1 Introduction

In this chapter the research methods, materials and procedure are presented. In doing so, the major study area description is presented in ***section 3.2*** while the research procedure and study design is summarized in ***section 3.3*** and ***section 3.4*** respectively. Sample size concepts are discussed in ***section 3.5***. Moving on the research methods is discussed in ***section 3.6***. The final part of this chapter, ***section 3.7*** deals with research materials.

3.2 Description of the study area

In order to conduct this study, the researcher selected 4 intersections in Addis Ababa namely, Estifanos intersection, Legehar intersection, Banko de roma intersection and Post office intersection. Among these the first 3 are used for the major study and the last one for validation.

3.2.1 Location

To describe the location of the intersections:-

- *Estifanos intersection*-located around Estifanos church
- *Legehar intersection*- located around Legehar bus station
- *Banko de roma intersection*- located on Churchill avenue
- *Post office intersection*- located around post office on the way to Piazza from Biherawi

3.2.2 Description of intersections

Detailed description of intersections is presented as follows in ***table 3.1***.

Table 3.1 Intersection detail

Item no.	Approach name	No. of lane	Signal cycle(s) Total	G	Y	R	Crosswalk Width(m)	Length(m)
Name of Intersection- Estifanos								
1.	*Mexico-Estifanos*	6	188	60TH, 30LT	3	125TH, 155LT	3	10.6
2.	*Bole-Estifanos*	4	188	50	3	135	3.6	13.65
3.	*Arat kilo-Estifanos*	3	188	35	3	150	3.3	13
4.	*Hayahulet-Estifanos*	3	188	61TH, 31LT	3	124TH 154LT	3	12
Name of Intersection-Legehar								
1.	*Stadium-Legehar*	4	206	94TH, 44LT	3	109TH, 154LT	3	9.8
2.	*Mexico-Legehar*	3	206	51	3	152	3	13.9
3.	*Biherawi-Legehar*	3	206	25	3	178	3	16
4.	*Legehar bus station- Legehar*	5	206	20	3	183	3	10.5
Name of Intersection-Banko de Roma								
1	*Piazza-Biherawi*	4	152	40	3	109	4	11
2.	*Biherawi- Piazza*	4	152	40	3	109	4	11
3.	*Churchill avenue-Arat kilo*	2	152	20	3	129	4	6.5
4.	*Churchill avenue-Merkato*	2	152	20	3	129	4	6.5
Name of Intersection-Post office								
1.	*Ambassador-Post office*	2	152	40	3	109	4	10.9
2.	*Piazza-Post office*	3	152	40	3	109	4	10.6
3.	*Immigration-Post office*	2	152	40	3	109	4	7.3
4.	*Biherawi-Post office*	3	152	40	3	109	4	11.5

3.3 Research procedure

The research is carried out dividing the overall procedure into three major steps. Detailed research procedure is presented in ***figure 3.1*** below.

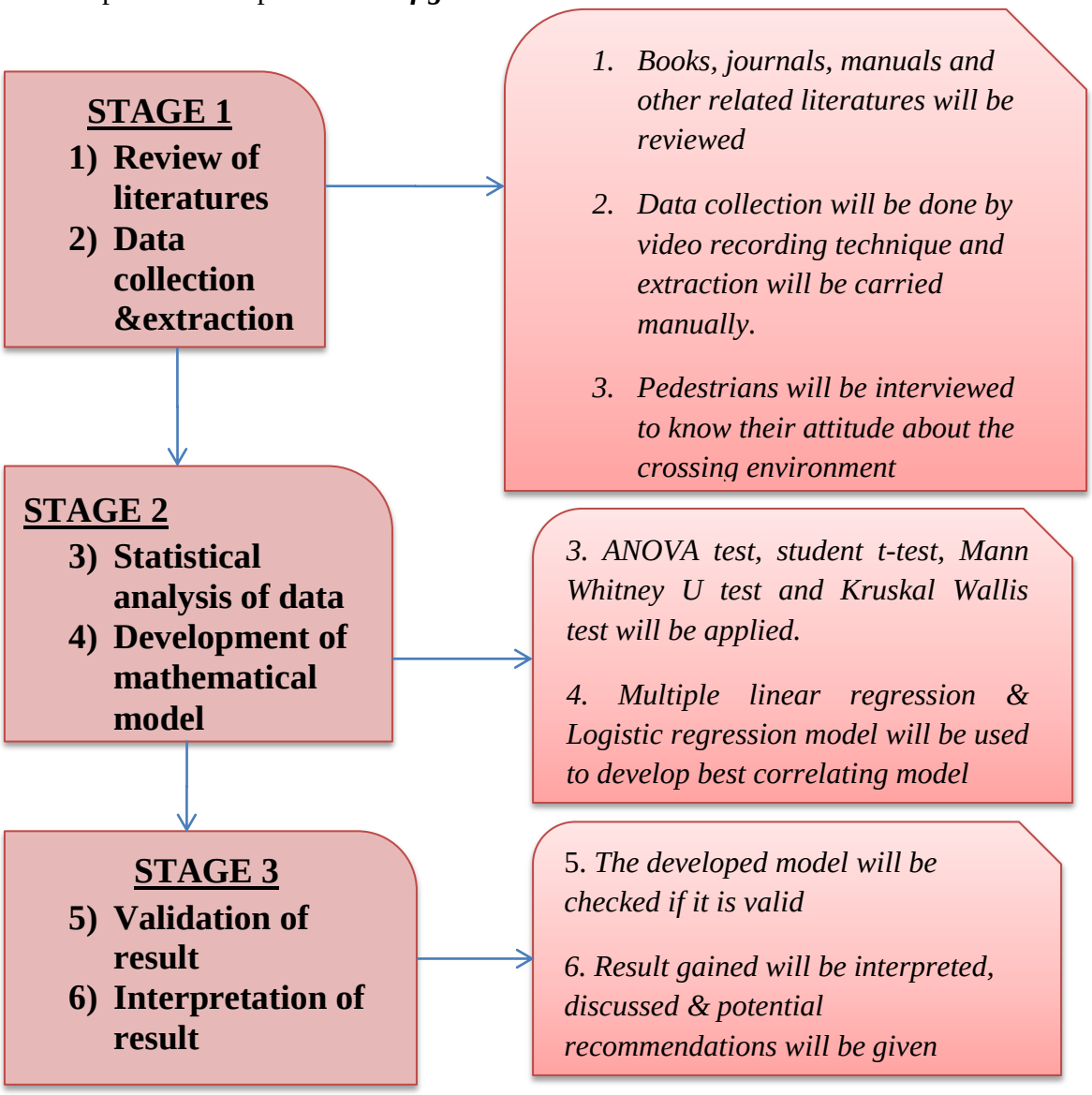


Figure 3.1: Research procedure

On the first stage review of literatures will take place as the starting line. This is done by referring into books, journals, publications, dissertation papers and other related literatures found locally and international. Though this is the first step to start the work reviewing of literatures is done throughout the study period whenever necessary. Data collection and

extraction is another task carried in this stage. Video recording technique is used to capture movement of pedestrians at intersections and extraction is done manually. Pedestrians will also be interviewed for their perception about the crossing environment. The next stage holds the major part of the research that mainly focuses on the statistical analysis of the data and development of regression models. In doing so relevant parametrical and nonparametric tests and respective models such as multiple linear and binary logistic models will be applied. The developed models will be tested for validity and final results will be interpreted and discussed in the last stage. Potential recommendations are also given in this stage.

3.4 Study design

The study design is based on the research objectives. After reviewing several researches in raw to see what parameters shall be captured in order to study the crossing behavior of pedestrians, it is proposed to look on the following data types to focus on as presented in **table 3.2** below.

In order to identify the factors that dominantly affect pedestrian crossing speed pedestrian characteristics such as gender, age group and pedestrian group size as well as traffic characteristic i.e. crossing signal phase are tested statistically for significant difference in their group mean. Here crosswalk length and crossing time are measured to compute crossing speed of each pedestrian observed in the video data.

Similarly, to determine the most significant factors affecting pedestrian signal compliance and crosswalk compliance pedestrian characteristics are captured and tested statistically. In order to identify reason of pedestrians' noncompliance of signal and crosswalk, pedestrian attitude survey is done.

To examine the effects of pedestrian characteristic and traffic characteristic on pedestrian crossing behavior, a model is developed using pedestrian characteristic and traffic characteristic parameters.

Table 3.2 Summary of study design

Objectives	Study on/ Modeling of	Focus on	Parameters to capture
To identify the factors that dominantly affect pedestrian crossing speed in the crosswalk	study on crossing speed	Pedestrian characteristics	Gender : male, female Age group: juvenile, middle aged, seniors Group size: single, 2-3, 4-5, >5
		Traffic characteristics	Crossing signal phase; pedestrian crossing on red phase, pedestrian crossing on non-red phase
		miscellaneous data	Crosswalk length, crossing time
To determine the most significant factors affecting pedestrian signal and crosswalk compliance &identify the reasons for non-compliance of signal timing and crosswalk location	Study on signal compliance	Pedestrian characteristics	Gender : male, female Age group: juvenile, middle aged, seniors Group size: single, 2-3, 4-5, >5 Attitude survey
		Traffic characteristics	Signal cycle: green time, red time, total signal cycle
	Study on crosswalk compliance	Pedestrian characteristics	Gender : male, female Age group: juvenile, middle aged, seniors Group size: single, 2-3, 4-5, >5
		miscellaneous data	Crosswalk width
To examine the effects of Pedestrian characteristic and	Modeling the effect of pedestrian characteristic on	pedestrian characteristics	Gender : male, female Age group: juvenile, middle aged, seniors Group size: single,

	traffic Characteristic on pedestrian crossing behavior	pedestrian crossing behavior		2-3, 4-5, >5
		Modeling the effect of traffic characteristic on pedestrian crossing behavior	Traffic characteristics	crossing signal phase; pedestrian crossing on red phase, pedestrian crossing on non-red phase

3.5 Data sample size analysis& determination

3.5.1 Intersection sample determination

There are 30 signalized intersections in the city of which 24 were found on function during the early stage of site visit. The list & details of the intersections is found at the appendix section. According to ***(P. Srinivas , et al. 1994)***land use is a strong explanatory variable of pedestrian arrival process. Also, land use is a factor exogenous to behavior and would thus allow unbiased estimation of behavior study and model. Furthermore, pedestrian crossing behavior is partially dependent on trip purpose and land use around the intersection in general is a good determinant of pedestrians' trip purpose.

Among these 24 intersections 2 intersections namely Lideta tsebel and Jemo Michael were found to be NON CBD areas. The rest were CBD areas, though 3 intersections listed below were exclude from selection list due to two main reasons i.e.

- ✓ *Intersection around parliament*- it was restricted area to take video recording.
- ✓ *Intersections around Semen hotel and Goma kuteba*- it was observed to have a very low pedestrian volume relative to the rest.

Finally, among 19 intersections left behind 4 intersections were selected randomly. To recall namely:-

- Estifanos intersection
- Legehar intersection

- Banko de roma intersection &
- Post office intersection



Figure 3.2 Camera set up location for Estifanos intersection



Figure 3.3 Camera set-up location for Legehar intersection

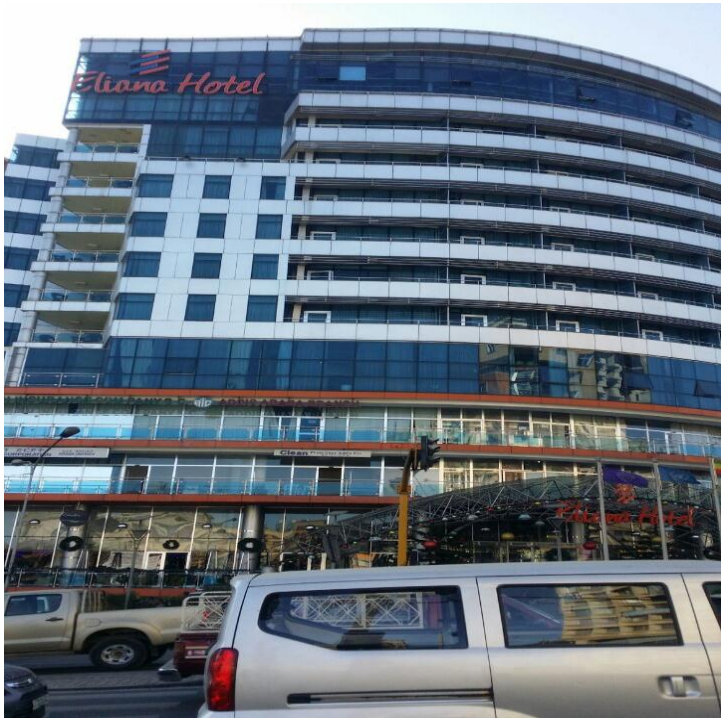


Figure 3.4: Camera set-up location for Banko de roma intersection



Figure 3.5 camera set-up location for post office intersection

3.5.2Pedestrian sample size

A) Data for Statistical Analysis

(Ann, Asha and Kevin 2012)Developed minimum sample size data needed for pedestrian and bicycle researches depending on confidence interval (CI), margin of error (E) and population size as tabulated below. The authors also stated that the values in the table were obtained by inputting values to the online calculator available at http://www.survey system.com/sscalc.htm ***(Kreizek, et al. n.d.)***

Table 3.3 sample size needed for communities with different population size (at 95% confidence level)

	Margin of error			
Population	±3%	±4%	±5%	±10%
2000	696	462	323	92
5000	880	536	357	95
10,000	965	566	370	96
20,000	1014	583	377	96
50,000	1045	593	382	96
100,000	1058	597	383	96
500,000	1065	600	384	96
1,000,000	1066	600	384	96
5,000,000	1067	600	384	96
8,000,0000	1067.75	600	384	96

Note: the last row values are calculated online by the researcher.

According to census carried on 2007 G.C the population of Addis Ababa city was 3,384,569. By 2018the population size of Addis Ababa city is estimated to be7.178 million ***(Laura 2018)***. Depending on the above information, for 95% confidence interval (CI) and ±3% margin of error (E) it is taken 1067.75≈1068 number of pedestrians as a minimum sample size. For a better statistical analysis result and conclusion 3783 number of pedestrian data is taken for statistical analysis and 1744 for validation. The data used for both the analysis is the overall peak hour data calculated at the intersections. Detailed peak hour data determination is presented in the appendix section.

B) Data for Attitude Survey

Similarly, the method used for statistical data sample size determination was applied for attitude survey sample size determination. For 95% confidence interval (CI) and ±5% margin of error (E) 385 respondents were taken as a sample size. Here response rate is determined to be 100% since it was self-administered by the researcher and took an interview form.

3.6 Research methods

3.6.1 Data collection

3.6.1.1 Primary data collection

Lenovo tablets were used to record video data of pedestrian movement at the intersections. The tablets were placed at different convenient positions so that clear view of pedestrians' movement could be provided. Data collection was conducted at the specified four intersections (Estifanos, Legehar, Banko de roma& Post office) from 29-3-2018 up to 3-5-2018 on working days, except for Monday and Friday because there exists an exaggerated traffic movement on these days, from 07:00 AM to 10:00 AM in order to capture the morning peak hour at the study locations. Video recordings were taken for each intersection for each leg. Pedestrian attitude survey data was also taken parallel to video data collection. Pedestrians using the intersections frequently (pedestrians who own shops, pedestrians that were refreshing in café and restaurants) were interviewed about the crossing environment.

3.6.1.2 Secondary data collection

Geometric data (number of lane, length of crosswalk and crosswalk width) and signal related data (Green, Red and Yellow time) were collected at the selected study sites using the following specific methodology.

- *No of lane*: counting divided lane on each approach
- *Crosswalk width*: measuring with roller meter
- *Length of crosswalk*: measuring with roller meter
- *Green, red & yellow time*: Recording at the intersections

3.6.2 Data extraction

Pedestrian characteristic and crossing characteristic data was extracted from the recorded video manually by using video playback technique and using stop watch for speed measurement.

3.7 Research materials

3.7.1 Data

Data required for the research is categorized under three main categories i.e.

- Pedestrian characteristics data
- Traffic characteristics data &
- Attitude survey data

3.7.1.1 Pedestrian characteristics data

Pedestrian characteristics data includes:

A) Pedestrian volume

-Total number of pedestrian as determined in section 3.5.2a

B) Gender

Gender of a crossing pedestrian is identified and expressed as male or female.

C) Age group

Here the pedestrians' age groups that were crossing at the intersection are assessed. According to ***(Daamen and Hoogendoorn 2003)***three classes are adequate within the peak hour of traffic study. i.e :< 20 years of age (juveniles), 20 to 55 years of age (middle aged) and > 55 years of age (seniors).

D) pedestrian group size

Pedestrian group size is categorized based on the concept of level of service explained in HCM 2000. According to HCM 2000 space & flow rate (this can be determined with speed, density & volume concepts) are used to determine the quality of pedestrians movement.

Category of pedestrian group size is presented as follows assuming pedestrians in the same categories will experience closer quality of movement &speed while crossing the road.

Table 3.4: category of pedestrian group size

No. of pedestrians	Code	Description
1 (single)	0	✓ Pedestrian is expected to achieve LOS A moving in a desired path without altering their movement in response to other pedestrian
2-3	1	✓ Pedestrian is expected to achieve LOS B or LOS C ✓ There is sufficient area for pedestrians for normal walking & by passing other pedestrians
4-5	2	✓ Pedestrian is expected to achieve LOS D or LOS E ✓ There is restricted walking speed ✓ Movements face conflicts
>5	3	✓ Pedestrian is expected to be in LOS F ✓ Walking speed is severely restricted ✓ Movements will be by shuffling

E) Crossing time

Duration that takes a pedestrian to cross the crosswalk is measured using stopwatch.

F) Crossing speed

Speed of a pedestrian is calculated as V=S/ t where V-crossing speed, S- Crossing distance and t-crossing time

3.7.1.2 Traffic Characteristics data

- Signal related data
  - ✓ Green time
  - ✓ Red time
  - ✓ Yellow time
  - ✓ Total signal cycle
- Intersection geometry related data
  - ✓ Crosswalk length
  - ✓ Crosswalk width
  - ✓ Crossing location

- ✓ Number of lane

3.7.1.3 Attitude survey data

385 pedestrians will be surveyed for a total of 8 questions. The survey will take an interview form composed with three parts. The first part inquires pedestrians' personal information. The rest two parts hold the major survey questions.

3.7.1.4 Data Requirement

Table 3.5 summary of data requirement

Data requirement	Method of data collection/extraction	Based on	Source of data	Description
1.Pedestrian characteristic				
Volume	Counting manually	Statistically determined sample size	Recorded video data	Total number of pedestrians
Gender	Observation		Recorded video data	0= Male, 1=Female
Age group	Observation		Recorded video data	0=seniors 1=Juveniles 2=Middle aged
Group size	Observation		Recorded video data	0=single pedestrian 1=2-3 pedestrians 2=4-5 pedestrians 3= above 5 pedestrians
Crossing time	Measurement using stopwatch		Recorded video data	
Crossing speed	Analyzed on desk	V=S/t ,where V=crossing speed,		

		S= crosswalk distance and t=crossing time		
Attitude survey	Response count	Statistically determined sample size	Interview	
2.**Traffic characteristic**				
Crossing signal phase	Observation		Recorded video data	0=pedestrian crossing on green phase 1=pedestrian crossing on red phase
Crosswalk location	Observation		Recorded video data	0=pedestrian crossing away from crosswalk 1=pedestrian crossing on crosswalk
Crosswalk length	Field measurement			
Crosswalk width	Field measurement			

3.7.2 Data Analysis

SPSS software is used mainly for the statistical data analysis. Parametric tests such as student t-test and one way ANOVA is used to identify factors affecting pedestrian crossing speed. Non parametric tests such as Mann Whitney U test and Kruskal Wallis one way ANOVA is used to identify factors affecting pedestrian signal and crossing compliance. Multiple linear regression model is developed to test the effect of significant factors on pedestrian crossing speed. Binary logistic regression models were developed to study the effects of significant factors on signal and crossing compliances. Interview responses of pedestrians are analyzed numerically. Detailed data analysis is presented in the next chapter.

CHAPTER4: RESULTS AND DISCUSSION

4.1 Introduction

In this chapter the research findings are presented and discussed analytically, statistically, graphically and in tabular form. In the action to do so, the chapter is divided into five parts: ***Identifying factors related to pedestrian crossing speed, Identifying factors related to signal and crosswalk compliance, Effect of pedestrian characteristic and traffic characteristic on pedestrian crossing behavior, Model validation and pedestrian attitude survey.*** Thus ***sections 4.2*** to ***section 4.6*** hold the findings respectively.

4.2Identifying Factors Relating to Pedestrian Crossing Speed

Before analyzing the differences in behavior the distribution of the dependent variable i.e. crossing speed is tested in order to choose an appropriate test. The descriptive statistics of the crossing speed is shown in **table 4.1** below. The mean crossing speed of 3783 pedestrian is found to be 1.668 with 0.048 differences from the median and fall in between 1.646 & 1.691 at 95% confidence interval. The deviation of the speed values about the mean is 0.6009 implying lesser variability and risk.

Table 4.1 Descriptive statistics for crossing speed

No.	Valid	3783
	Missing	0
Mean Speed		1.668
95% Confidence Interval	lower	1.646
	upper	1.691
Median		1.620
Variance		0.361
Standard Deviation		0.6009
Minimum		0.3
Maximum		3.3
Range		3

- Check for the normality distribution

To check if the speed data came from normal distribution **SPSS** software is used. Three familiar and reliable methods were applied to the data and the following result was obtained.

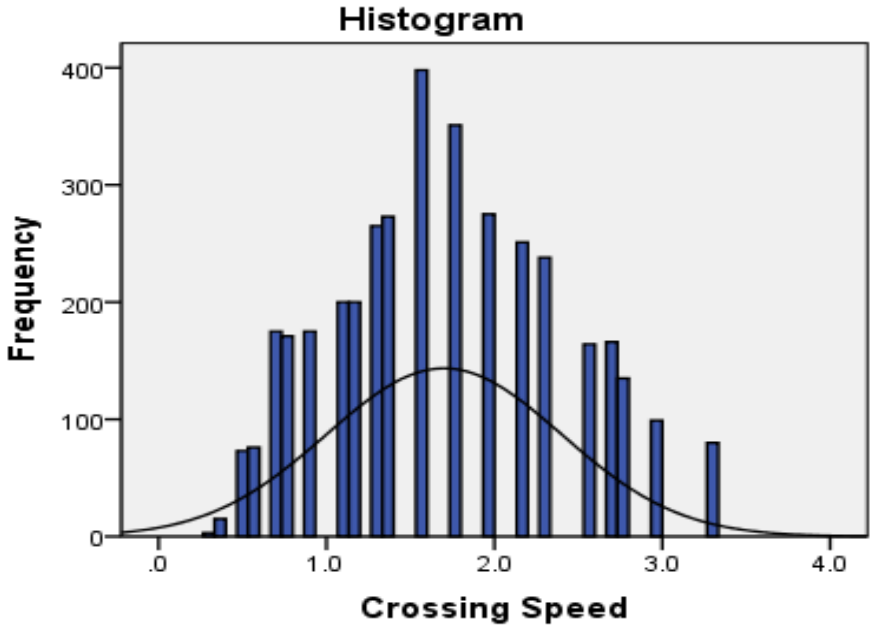


Figure 4.1: Histogram of crossing speed

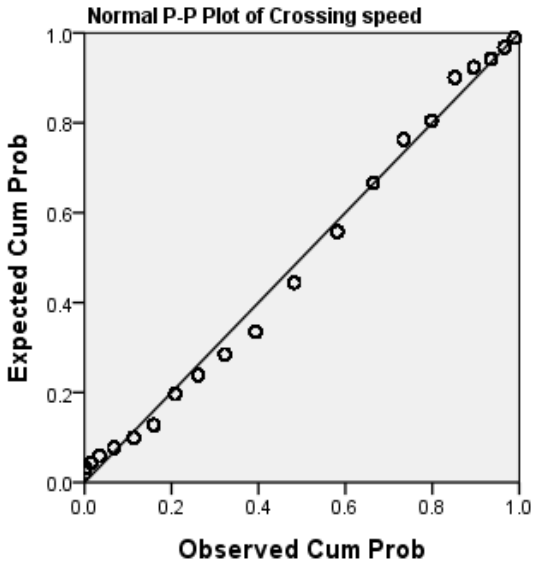


Figure 4.2: Normal p-p plot of crossing speed

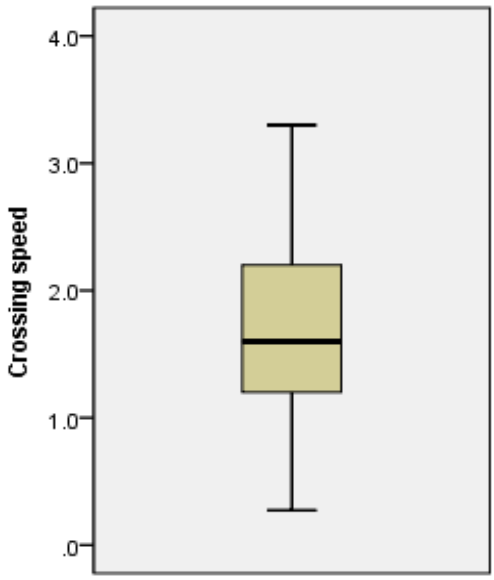


Figure 4.3: box plot of crossing speed

Interpretation:

- **Figure-4.1**shows the histogram of the data .As it can be seen from the figure the shape of the curve on the histogram approximates to a bell shape with a peak value at the middle. This shows that the data is from a normal distribution.

- The normal probability plot graph in **figure-4.2**shows the pattern of the data approximately following the straight line strengthening the conclusion that the data is from normal distribution.

- Additionally, in **figure-4.3** the box plots shows the distribution of the data about the median has lower range and appears to be found approximately at the middle of the box that shows a balanced concentration of the data. The whiskers also show no significance different in length which again emphasizes no significant skewness.

Before going into the statistical tests it is important to remind that the actual descriptive statistics for each of the following analysis is found in the appendix section.

Gender differences

To test if a significant difference in crossing speed exists between men and women the following hypothesis was drawn and an independent sample mean test was performed. The result is presented in **table 4.2** below.

Ho: no significant difference in crossing speed exists between men and women

H1: significant difference in crossing speed exists between men and women

Table 4.2: Independence sample t-test for gender differences in crossing speed

Independet sample t-test									
		equality of variances		T-test for equality of means					
		F	Sig.	t	df	Sig. (2- tailed)	Mean difference	95% confidence interval of the difference	
								Lower	Upper
Crossing speed	Equal variances assumed	0.49	0.484	3.107	3780	0.002	0.81	0.0018	0.1321
	Equal variances not assumed			3.101	1676	0.002	0.81	0.0017	0.1322

Interpretation

- From the table above, result of homogeneity of variances can be obtained from the Levene's test and group difference result from the t-test. The null and alternate hypothesis for Levene's test is :

Ho: There is no significance difference between the mean of gender groups.

H1: There is significance difference between the mean of the gender groups.

The P value expressed as "Sig. for the Levene's test (0.484) is greater than the level of significance i.e. 0.05, so that Ho is failed to be rejected and concluded that the assumption of equal variances is met.

- Moving on, the P value for the t-test expressed as Sig (2tailed)=0.002 is less than the significance level indicating that Ho can be rejected for the group differences and conclusion is drawn as, there exists a significant difference in crossing speed between men and women.

Age group differences

The hypothesis formulated to test if a significant difference exists in crossing speed among the age groups is:

Ho: no significant difference in crossing speed exists among age groups

H1: significant difference in crossing speed exists among age groups

The result of one way ANOVA test from SPSS is presented in **table 4.3** below.

Table 4.3: One way ANOVA test for the age group differences

One way ANOVA test					
	Sum of squares	Df	Mean square	F	Sig
Between groups	13.042	2	6.521	13.369	0.000
Within groups	1843.251	3781	0.488		
Total	1856.256	3783			

Interpretation

- The p-value in the table shows that it is much lower than p=0.05 hence, Ho is rejected and concluded that there is a significant difference in crossing speed among the age groups.

Difference in crossing pedestrians group

The following hypothesis is tested in order to know if a significant difference in crossing speed exists among pedestrian group sizes.

Ho: no significant difference in crossing speed exists among pedestrian group sizes.

H1: significant difference in crossing speed exists among pedestrian group sizes.

Table 4.4: One way ANOVA test result for pedestrian group size differences

One way ANOVA test					
	Sum of squares	Df	Mean square	F	Sig
Between groups	1070.56	3	356.85	1715.84	0.000
Within groups	785.73	3780	0.208		
Total	1856.29	3783			

- The P-value 0.000 which is much less than the level of significance 0.05, leads to the rejection of the null hypothesis. Therefore, at α=0.05 level of significance there exist enough evidence to conclude that a significant difference in crossing speed exists among the pedestrian group sizes.

Difference in crossing signal

Ho: no significant difference in crossing speed exists between pedestrian crossing on red phase and pedestrian crossing on non-red phase

H1: significant difference in crossing speed exists between pedestrian crossing on red phase and pedestrian crossing on non-red phase

The above hypothesis is tested and the result is displayed in the **table 4.5** below

Table 4.5: Independence sample t-test for difference in crossing signal in crossing speed

Independet sample t-test									
		equality of variances		T-test for equality of means					
		F	Sig.	t	df	Sig. (2- tailed)	Mean difference	95% confidence interval of the difference	
								Lower	Upper
Crossing speed	Equal variances assumed	0.3	0.487	1.265	3780	0.206	0.1462	-0.216	0.221
	Equal variances not assumed			1.182	804.9	0.238	0.1462	-0.26	0.346

- As it can be seen from the table since P-value for the Levene's test is greater than the significance level, the assumption of homogeneity of variance is met.

- The P-value for the independent sample t-test is i.e. 0.206 is greater than the significance level 0.05. As a result the null hypothesis is failed to be rejected and a conclusion is drawn as, there doesn't exist a significant difference in crossing speed between pedestrian crossing on red phase and pedestrian crossing on non-red phase.

4.3 Identifying Factors Relating to Signal and Crosswalk Compliance

Dependent variables crossing signal phase and crossing locations are dichotomous (discrete) variables with nominal level of measurement. As discussed in section 3.7.1.4 measurement of crossing signal was coded as 0 and 1 for pedestrians crossing on green phase and for pedestrians crossing on red phase respectively. Similarly, measurement of crossing location was coded as 0 and 1 for pedestrians crossing away from designed crosswalk and for pedestrians crossing on designed crosswalks respectively. Since, it cannot be observed continuity of a discrete data, it is impossible to test the normality (normal distribution) of it. For this reason rather than using the T-test and ANOVA it is recommended to use non parametric test which does not require an assumption of normal distribution of a data.

4.3.1 Identifying Factors Relating to Signal Compliance

Gender differences

To test mean differences in gender the Mann Whitney U-test in SPSS is used instead of T-test. The hypothesis formulated to test if a significant difference exists between the gender groups is stated as follows:

Ho: no significant difference in signal compliance exists between men and women

H1: significant difference in signal compliance exists between men and women

As shown in **table 4.7** the Mann-Whitney U independence sample mean test gives a P value of 0.432 which is greater than the significance level. Depending on this result, the null hypothesis is failed to be rejected and concluded that there doesn't exist a significant difference in gender group means.

Table 4.6: gender ranks for crossing signal

Ranks				
	Gender	N	Mean rank	Sum of ranks
Crossing signal	Male	2814	1896.7	5335415.50
	Female	969	1876.41	1818237.50
	Total	3783		

Table 4.7: Mann-Whitney U t-test for difference in gender in crossing signal

Test statistics: grouping variable -Gender	
	Crossing signal
Mann Withney U	1348272.500
Wilcoxon W	1818237.500
Z	-0.785
Asymp.sig.(2tailed)	0.432

Age group differences

To test age group differences in crossing signal, an extension of Mann-Whitney U test i.e. Kruskal Wallis one way ANOVA test is used. The result of test of the following hypothesis is presented in **table 4.8** and **table 4.9.**

Ho: no significant difference in signal compliance exists among age groups

H1: significant difference in signal compliance exists among age groups

The P value from **table 4.9** labeled as 'Asymp.sig' shows that it is much less than the significance level, so the null hypothesis is rejected. At α=0.05 level of significance there exist enough evidence to conclude that a significant difference in signal compliance exist among age groups.

Table 4.8: Age group rank for crossing signal

Ranks			
	Age group	N	Mean rank
Crossing signal	<20	402	1954
	20-55	2756	1888.78
	>55	625	1864.71
	Total	3783	

Table 4.9: Kruskal Wallis test for difference in age group in crossing signal

Test Statistics-Age group	
	Crossing signal
Chi.square	27.312
df	2
Asymp.sig.	0.006

Difference in crossing pedestrians' group size

Difference in pedestrians' group size is also tested using Kruskal Wallis one way ANOVA test. The hypothesis tested is:

Ho: no significant difference in signal compliance exists among pedestrian group size groups

H1: significant difference in signal compliance exists among pedestrian group size groups

The test result in **table 4.11** shows the P value of 0.000 which is less than the significant level. This leads to the rejection of Ho. As a result it is concluded that, a significant difference in signal compliance exists among pedestrian group size groups.

Table 4.10: pedestrian group size ranks for crossing signal

Ranks			
	Pedestrian group size	N	Mean rank
Crossing signal	1 (single)	1222	1846.32
	2–3	825	1795.67
	4–5	768	2041.84
	>5	968	1910.95
	Total	3783	

Table 4.11: Kruskal Wallis test for difference in pedestrian group size in crossing signal

Test Statistics-Pedestrian group size	
	Crossing signal
Chi.square	57.75
df	3
Asymp.sig.	0.000

4.3.2 Identifying Factors Relating to Crosswalk Compliance

Gender differences

Hypothesis to be tested:

Ho: no significant difference in crosswalk compliance exists between men and women

H1: significant difference in crosswalk compliance exists between men and women

Mann-Whitney U test for gender difference test gives a P value of 0.472 as tabulated in **table 4.13.**This leads to the failure of rejection of the null hypothesis since it is greater than the significance level. As a conclusion it is found that no significant difference in crosswalk compliance exists between the gender groups.

Table 4.12: gender ranks for difference in gender in crosswalk location

Ranks				
	Gender	N	Mean rank	Sum of ranks
Crosswalk	Male	2814	1897.63	5338037.5
	Female	969	1873.7	1815615.5
	Total	3783		

Table4.13: Mann-Whitney U t-test for crosswalk location

Test statistics: grouping variable -Gender	
	Crosswalk
Mann Withney U	1345650.5
Wilcoxon W	1815615.5
Z	-0.720
Asymp.sig.(2tailed)	0.472

Difference in crossing pedestrians' group size

Hypothesis:

Ho: no significant difference in crosswalk compliance exists among pedestrian group sizes.

H1: significant difference in crosswalk compliance exists among pedestrian group sizes.

Result:

Table 4.14: pedestrian group size ranks for crosswalk location

Ranks			
	Pedestrian group size	N	Mean rank
Crosswalk location	1 (single)	1222	1921.99
	2–3	825	1837.86
	4–5	768	1850.85
	>5	968	1931.02
	Total	3783	

Table 4.15: Kruskal Wallis test for difference in pedestrian group size in crosswalk location

Test Statistics-Pedestrian group size	
	Crossing signal
Chi.square	7.89
df	3
Asymp.sig.	0.048

For the above hypothesis test, Kruskal Wallis one way ANOVA test result in **table 4.15** shows lesser value than the level of significance 0.05. As a result the null hypothesis rejected and concluded that a significant difference in crosswalk compliance among pedestrian group sizes.

Age group differences

Kruskal Wallis one way ANOVA test for age group differences gives a P value of 0.000 as tabulated in **table 4.17**. This leads to the rejection of the null hypothesis stated below.

Ho: no significant difference in crosswalk compliance exists among age groups

H1: significant difference in crosswalk compliance exists among age groups

As a conclusion, it is stated that there exists a significant difference in crosswalk compliance among the age groups.

Table 4.16: age group rank for crosswalk location

Ranks			
	Age group	N	Mean rank
Crosswalk	<20	402	1681.39
	20-55	2756	1930.62
	>55	625	1853.82
	Total	3783	

Table 4.17: Kruskal Wallis test for difference in age group in crossing location

Test Statistics-Age group	
	Crosswalk
Chi.square	28.612
df	2
Asymp.sig.	0.000

4.4 Effect of Pedestrian Characteristic and Traffic Characteristic on Pedestrian Crossing behavior

4.4.1 Effect of Pedestrian Characteristics and Traffic Characteristics on Pedestrian Crossing Speed

In this section the effect of the factors related to crossing speed is analyzed and interpreted. To study the effect of pedestrian characteristics, multiple linear regression technique is used to develop a mathematical model for pedestrian crossing speed. SPSS 22 statistical analysis software is used as a major data analysis tool.

4.4.1.1 Testing Multiple Linear Regression assumptions

Before conducting the regression analysis, the six major assumptions of multiple linear regressions needs to be checked for violation. In order to get an appropriate result these assumptions of MLR have to be met.

Assumption 1: continuous dependent variable

The assumption in regression is that the response variable is continuous that it can take on any value within a range of values. The dependent variable in the regression model is crossing speed, which is a continuous variable taking values in between 0.3 and 3.3 as shown in the descriptive statistics above.

Assumption 2: Linear relationship between dependent and each of independent variables.

The relationship between the dependent and each of independent variables should be linear. In the **fig.4.4, fig.4.5, fig.4.6 and fig 4.7** below scatter plot of dependent variables versus each of the independent variables is presented showing that there is no significant evidence for the existence of nonlinear relationship.

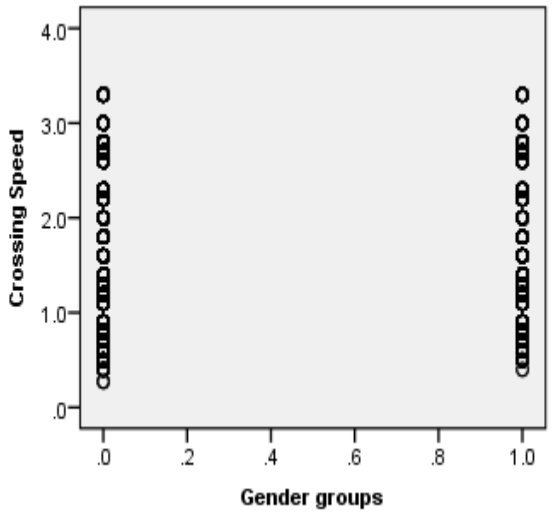


Figure 4.4 Scatter plot: Crossing speed vs. gender groups

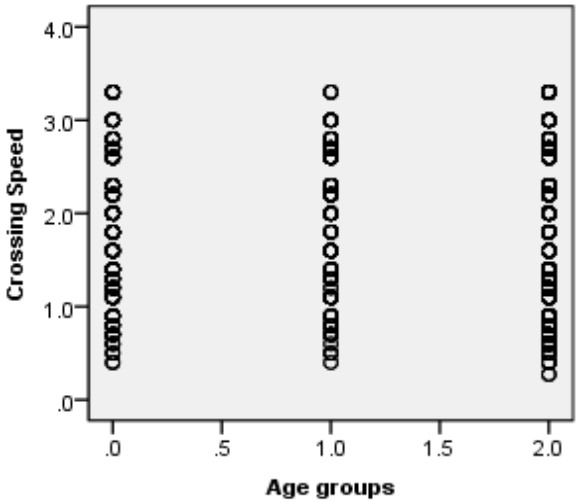


Figure 4.5 Scatter plot: crossing speed vs. age groups

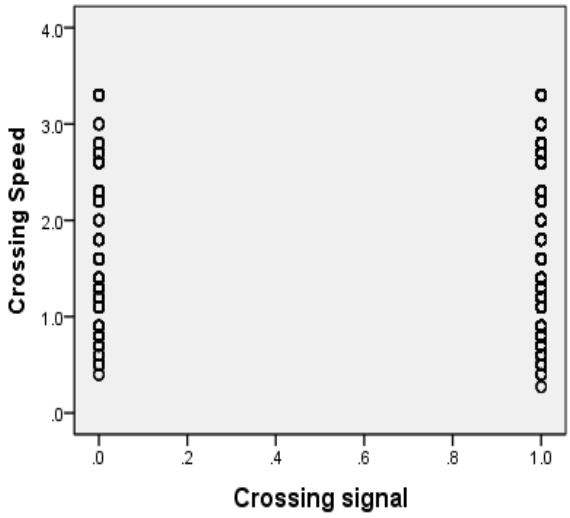


Figure 4.6 Scatter plot: crossing speed vs. crossing signal

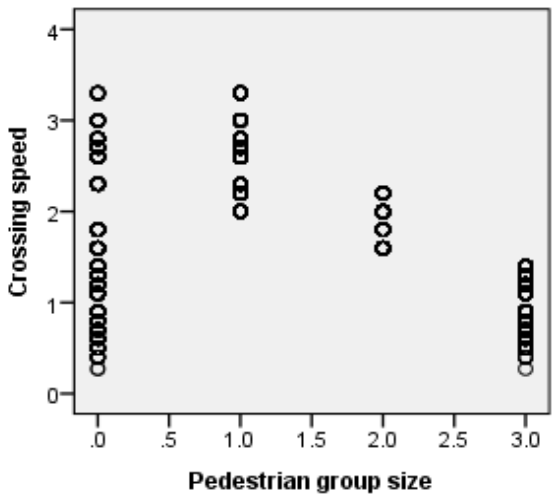


Figure 4.7 Scatter plot: Crossing speed vs. pedestrian group size

Assumption 3: Multicollinearity (the predictor variables should not be highly correlated with each other)

Computing a correlation analysis in SPSS gives the following correlation matrix presented in **table 4.18** below. If there exists a correlation coefficient greater than 0.8 then it is concluded that there is multicollinearity. The correlation coefficient for all variables are lesser than 0.8 (<<0.8) so the independent variables are not strongly correlated with each other. Furthermore to identify if one predictor variable is a linear function of a set of the other predictor variable VIF (variance inflation factor) is used. VIF basically tells if there is inflation or an increase in standard error. In order not to obtain multicollinearity the VIF value must be less than 10. As shown in **table 4.19** since none of the predictor variables have a VIF greater than ten there are no apparent multicollinearity problems. In other words, there is no variable in the model that is measuring the same relationship as is measured by another variable.

Table: 4.18 Correlation matrix between independent variables

	Gender	Age group	Pedestrian group size	Signal phase
Gender	1			
Age group	-0.030	1		
Pedestrian group size	-0.080	0.240	1	
Signal phase	-0.130	0.004	-0.26	1

Table: 4.19 Variance inflation factor for predictor variables

Variable	Gender	Age group	pedestrian group size	Signal phase
VIF	1.009	1.001	1.013	1.005

Assumption 4: Homoscedasticity (variables along the line of best fit have to remain similar as moved along the line).

To test the homoscedasticity (equality of variances) of our data, scatter plot of standardized residuals versus standardized fitted values is analyzed. As shown in the plot below, the spread of the residuals around the line seem to have approximately similar pattern.

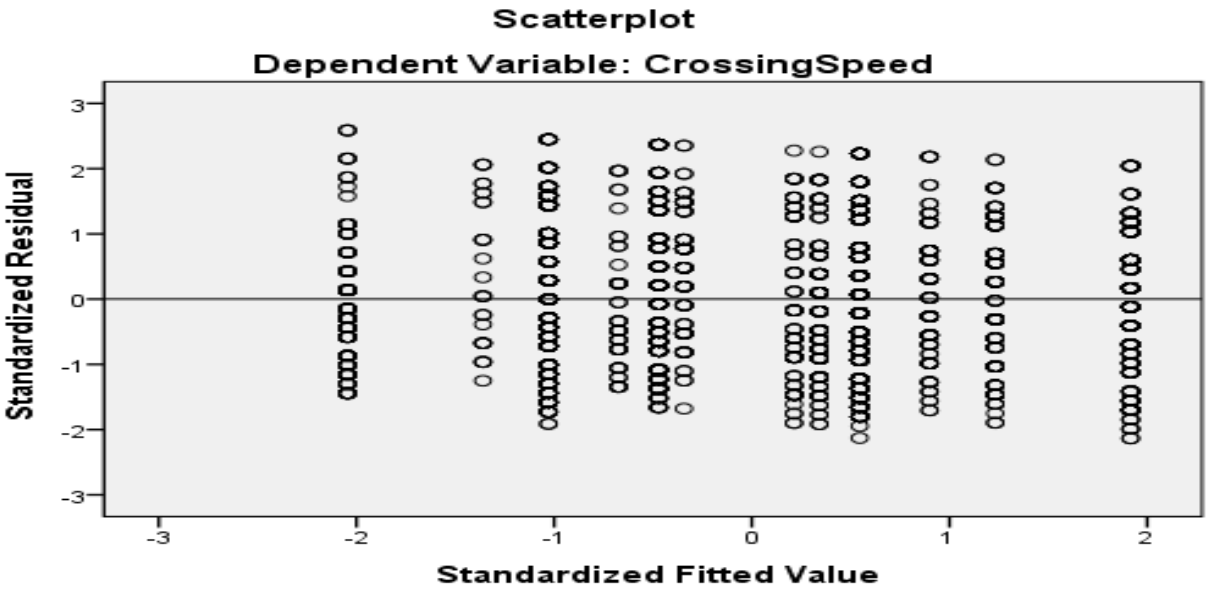


Figure 4.8: Scatter plot of standardized residuals vs. standardized fitted value

Assumption 5: There should be no significant outlier

High leverage point or highly influential points in the data set considered as significant outliers are identified and removed in order to obtain same amount of information in developing the predictive model from all the data points.

Assumption 6: Residuals are normally distributed

The errors should be approximately normally distributed. The normal p-p plot if the residuals presented below shows the spread of the residuals approximately lying on the straight line (close to the line) which shows that the residuals are normally distributed thus, assumption 6 is satisfied.

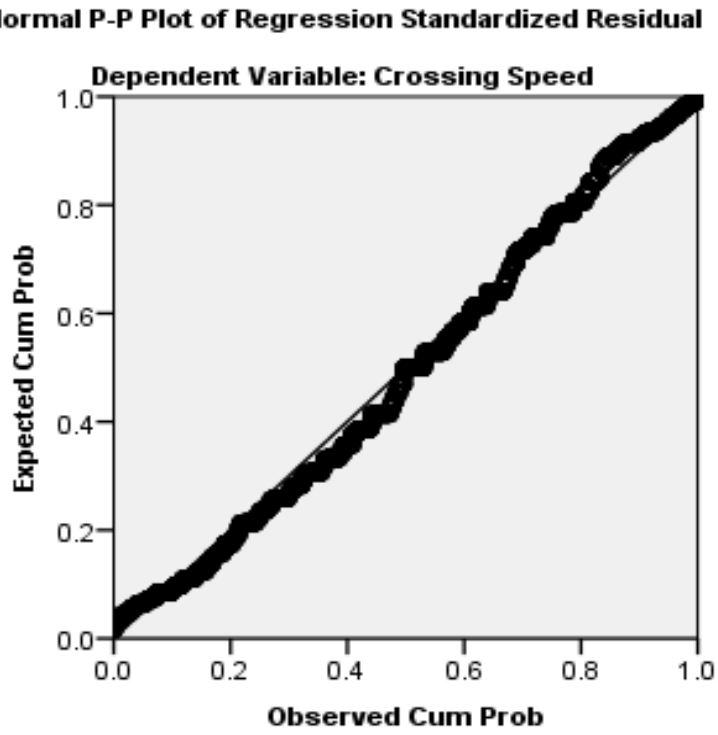


Figure 4.9: Normal p-p plot of residuals

4.4.1.2 Regression Analysis

Among the tested parameters, significant explanatory variables were selected and multiple linear regression analysis was performed to model pedestrian crossing speed at signalized intersections.

Dependent variable

-crossing speed (C_s)

Independent variables

-Gender (Male (0), Female (1))

-Age group (<20(1), 20-55 (2), >55(0))

- Pedestrian group size (single (0), 2-3 (1), 4-5 (2), >5 (3))

- Crossing signal phase (green (0), red (1))

'Enter' variable selection method is used to enter independent variable into the analysis. In this method all variables in a block are entered in a single step. **Table 4.19** summarizes the analysis result.

Table: 4.20 ML Regression output

Model (Crossing speed)	Coefficients		t	Sig.(Pvalue)	95% CI for β	
	β	Std. error				
Constant	1.751	0.026	75.618	0.000	1.695	1.842
Gender	-0.102	0.016	-3.931	0.015	-0.153	-0.051
Age group	0.063	0.015	4.374	0.000	0.042	0.095
Ped. Group size	-0.174	0.009	-18.825	0.000	-0.192	-0.156
Crossing signal phase	-0.002	0.031	-0.058	0.954	-0.063	0.052
R^2	0.8701					
Adjusted R^2	0.8598					

Interpretation

- As shown in the **table4.20** P value for the constant estimator and the first three explanatory variables is less than the significance level. This implies, except for crossing signal phase all predictors variables significantly predicted pedestrian crossing speed with R^2_{adj} =0.8598. This is interpreted as; about 85.98% of the variation in crossing speed is explained by gender, age groups and pedestrian group size.

  The final prediction model with only the significant explanatory variables is written as:

  $C_s = 1.751 - 0.102G + 0.063A - 0.174G_r$ ***.....Eqn. 4.1***

  Where:

  C_s= Crossing speed

  G= Gender

  A= Age group

  G_r=Pedestrian group size

- Gender is negatively correlated with crossing speed (coded as, male=0 and female=1), indicating that male pedestrians have larger crossing speed than female pedestrians. The

βweight indicates that crossing speed of male pedestrians is expected to exceed that of female pedestrians by 0.102 holding the other two variables constant.

- Pedestrian age group is positively correlated with crossing speed (coded as 0=seniors, 1=juveniles and 2= middle aged) indicating that middle aged pedestrians have larger crossing speed. Crossing speed of middle aged pedestrians exceed that of juveniles and seniors by 0.063 and 0.126 respectively. In addition crossing speed of juveniles exceed that of seniors by 0.063
- Pedestrian group size is negatively correlated with crossing speed (coded as 0=1 (single) pedestrian, 1=2-3 pedestrians, 2=4-5 pedestrians and 3= >5 pedestrians) indicating that single pedestrians have larger crossing speed. Crossing speed of single pedestrians exceed that of 2-3 pedestrians by 0.174. Crossing speeds of a group of pedestrians of 4-5 is less than that of single pedestrians by 0.248. Group of pedestrians containing greater than 5 have crossing speed that is lesser than single pedestrian's by 0.622. Crossing speed of 2-3 pedestrians exceed that of 4-5 pedestrians and >5 pedestrians by 0.174 and 0.248 respectively. In addition crossing speed of 4-5 pedestrians exceed that of >5 pedestrians by 0.174.
- The lesser values of standard error estimation indicate that the model best fits with less estimation error.
- The last column of the table shows the confidence intervals for the slopes of β estimators, indicating the slopes for predictor variables is somewhere between the lower and the upper value.

4.4.2 Effect of Pedestrian Characteristics on Signal Compliance

A binary logistic model is developed to predict the effect of pedestrian characteristics on signal compliance since, crossing signal takes two measurement level either 0 or 1 (section 3.7.1.4 describes detail coding for variables). As discussed in **section 2.9** binary logistic regression model is preferred model to predict binary response variable based on the predictor variables. The final predicting model is described in **table 4.21** below.

Dependent variable

-Probability of signal compliance (P_s)

Independent variables

-Gender (male (0), female (1)

-Age group (<20 (1), 20-55(2), >55(0))

- Pedestrian group size (single (0), 2-3 (1), 4-5 (2), >5 (3))

Table 4.21: BL regression output for crossing signal compliance

	variables	β	SE	Df	Sig.	Odds Ratio (Expβ)
Model (Probability of signal compliance)	Constant	1.662	0.102	1	0.000	5.269
	Gender	-0.075	0.101	1	0.360	0.927
	A0 (>55)	0.017	0.058	1	0.007	1.017
	A1(<20)	-1.160	0.024	1	0.007	0.314
	G1 (2-3)	-0.978	0.032	2	0.005	0.450
	G2 (4-5)	-0.510	0.041	2	0.015	0.600
	G3 (>5)	-0.346	0.011	2	0.003	0.707

Reference caregory:Age group(22-50)=A_2 & pedestrian group size(single (0)=G_0

Table 4.22: Hosmer-Lameshow goodness of fit test for crossing signal compliance model

Step	Chi square	df	sig
1	6.096	1	0.645

The final prediction model with only the significant explanatory variables is expressed as equation 4.2 below.

$$\text{Logit}(P_s)=\ln\left(\frac{p}{1-p}\right)=1.662+0.017A_0-1.160A_1-0.978G_1-0.51G_2-0.346G_3 \ldots \textit{Eqn.4.2}$$

Where:

P_s –Probability of signal compliance

A_0 – Age group (seniors)

A_1– Age group (juveniles)

G_1 – (2-3) Pedestrian group size

G_2 – (4-5) Pedestrian group size &

G_3 - >5Pedestrian group size

Interpretation:

- Before interpreting the estimators and odds of the model it is better to look at the goodness of fit test result. As it is shown in table 4.22 the HL goodness of fit test gives a P-value of 0.645 which is greater than the significant level. This shows that the model fit the data well.

  For the age group categorical predictor having three level of measurement SPSS creates 2 dummy variables to represent these 3 groups. Here middle age group encoded 2 is considered as a reference group to which the other two groups should be compared. Similarly for the pedestrian group size categorical predictor that has four level of measurement SPSS creates 3 dummy variables. Single pedestrian group size category encoded 0 is considered as a reference group.

- Among the three explanatory variables gender is found to be insignificant to predict the probability of signal compliance with test statistics P value of 0.360 which is much higher than the significance level

- Holding pedestrian group size constant β_1=0.017 for the seniors age groups indicates an increase in probability of a pedestrians to comply with signal with an increase in amount of seniors pedestrians.

- β_2=-1.160 for juvenile age groups indicates, a decrease in probability of a pedestrians to comply with signal with an increase in amount of juvenile pedestrians.

- Holding age group constant β_3=-0.978 for pedestrian group size of 2-3, β_4=-0.510 for pedestrian group size of 4-5 & β_5=-0.346 for pedestrians group size of >5 indicates a decrease in probability of a pedestrians to comply with signal with an increase in pedestrian group size.

- For A_0 (senior pedestrians) dummy variable the OR=1.017 means the odds of crossing signal compliance is (1.017-1) =0.017 times greater than that of the reference age group A_2 (middle aged pedestrians).
- For A_1 dummy variable the OR=0.314 means the odds of crossing signal compliance is 0.314 times that of the reference age group. In other words the odds of complying with crossing signal for middle aged pedestrian is 0.686=(1-0.314) times higher than the odds of pedestrian grouped under juvenile age group. Given the same pedestrian group size middle aged pedestrians are more likely comply with crossing signal than juveniles do.
- For G_1 dummy variable the OR=0.450 means the odds of crossing signal compliance is 0.450 times that of the reference group size group. The odds of complying with crossing signal for single pedestrian is 0.550= (1-0.450) times higher than the odds of 2-3 pedestrian groups.
- For G_2 dummy variable the OR=0.600 shows that the odds of crossing signal compliance is 0.600 times that of the reference group size group. In other words, the odds of complying with crossing signal for single pedestrian is 0.400= (1-0.600) times higher than the odds of 4-5 pedestrian groups.
- For G_3 dummy variable the OR=0.707 means the odds of crossing signal compliance is 0.707 times that of the reference group size group. The odds of complying with crossing signal for single pedestrian is 0.293= (1-0.707) times higher than the odds of >5 pedestrian groups.
- Given the same pedestrian age group, single pedestrians are more likely comply with crossing signal than grouped pedestrians do.

4.4.3 Effect of Pedestrian Characteristics on Crosswalk Compliance

As discussed in section 3.7.1.4 pedestrians' crosswalk location is coded as either 0 or 1 for pedestrians crossing away designated area or on designated area respectively. Consequently, those who cross on designated area are referred as compliers while those who don't are referred as non-compliers. Depending on this variable categorization binary logistic

regression model is developed to predict the effect of pedestrian characteristics on crosswalk compliance. The result of the regression model is presented in **table 4.23** below

Dependent variable

-Probability of crosswalk compliance (P_{Cw})

Independent variables

-Gender (male (0), female (1)

-Age group (<20 (1), 20-55(2), >55(0))

- Pedestrian group size (single (0), 2-3 (1), 4-5 (2), >5 (3))

Table 4.23: BL regression output for crosswalk compliance

	variables	β	SE	Df	Sig.	Odds Ratio (Expβ)
Model (Probability of crosswalk compliance)	Constant	0.401	0.102	1	0.000	1.493
	Gender	-0.038	0.101	1	0.623	0.962
	A0 (>55)	0.138	0.058	1	0.002	1.148
	A1(<20)	0.328	0.024	1	0.01	1.386
	G1 (2-3)	-0.766	0.032	2	0.004	0.465
	G2 (4-5)	-0.610	0.041	2	0.025	0.543
	G3 (>5)	-0.355	0.011	2	0.003	0.701

Reference caregory:Age group(22-50)=A_2 & pedestrian group size(single (0)=G_0

Table 4.24: Hosmer-Lameshow goodness of fit test for crosswalk compliance model

Step	Chi square	df	sig
1	0.000	1	1.000

$$\text{logit}\ (P_{Cw}) = \ln\left(\frac{p}{1-p}\right) = 0.401 + 0.138A_0 + 0.328A_1 - 0.766G_1 - 0.610\ G_2 - 0.355\ G_3 \ldots \quad \textbf{Eqn4.3}$$

Where;

P_{Cw}- Probability of crosswalk compliance

A_0 – Age group (seniors)

A_1– Age group (juveniles) &

G_1 – (2-3) Pedestrian group size

G_2 – (4-5) Pedestrian group size &

G_3 - >5Pedestrian group size

Interpretation:

- From table 4.24 HL goodness of fit test shows the model fits the data well since, the P value is greater than the significance level.
- Among the expected predicting explanatory variables gender is found to be insignificant to predict the probability of crosswalk compliance with test statistics P value of 0.623 which is much higher than the significance level 0.05.
- β_1=0.138 for senior age group & β_2=0.328 for juveniles indicate, an increase in probability of a pedestrians to comply with crosswalk with an increase in each age group amount.
- Holding age group constant β_3=-0.766 for pedestrian group size of 2-3, β_4=-0.610 for pedestrian group size of 4-5 & β_5=-0.355 for pedestrians group size of >5 indicates a decrease in probability of a pedestrians to comply with crosswalk with an increase in pedestrian group size.
- For A_0 (senior pedestrians) dummy variable the OR=1.148 means the odds of crosswalk compliance is (1.148-1) =0.148 times greater than that of the reference age group A_2 (middle aged pedestrians).
- For A_1 (juveniles) dummy variable the OR=1.386 means the odds of crosswalk compliance is (1.386-1) =0.386 times greater than that of the reference age group A_2 (middle aged pedestrians). Given pedestrian group size constant juveniles are more likely to comply with crosswalk location than middle aged pedestrians.
- For G_1 dummy variable the OR=0.465 means the odds of crosswalk compliance is 0.465 times that of the reference group size group. The odds of complying with crosswalk location for single pedestrian is 0.535= (1-0.465) times higher than the odds of 2-3 pedestrian groups.

- For G_2 dummy variable the OR=0.543 shows that the odds of crosswalk compliance is 0.543 times that of the reference group size group. In other words, the odds of complying with crossing signal for single pedestrian is 0.457= (1-0.543) times higher than the odds of 4-5 pedestrian groups.
- For G_3 dummy variable the OR=0.701 means the odds of crosswalk compliance is 0.701 times that of the reference group size group. The odds of complying with crossing signal for single pedestrian is 0.299= (1-0.701) times higher than the odds of >5 pedestrian groups.
- Given the same pedestrian age group, single pedestrians are more likely comply with crosswalk location than grouped pedestrians do.

4.5 Model Validation

4.5.1 Multiple linear regression model validation

External model validation technique is used to validate the regression model developed for pedestrian crossing speed.1744randomly selected test data set, from Post office intersection, is used for the validation study. The test data set is independent from the training data set and there is no any prior relationship between them. Predictive squared correlation coefficient Q^2 value estimated from external test data set is used to measure the predictive ability of the regression model.

$$Q_{F3}^2 = 1 - \frac{\sum_{i=1}^{n_{EXT}}(\hat{y}_i - y_i)^2 / n_{EXT}}{\sum_{i=1}^{n_{TR}}(y_i - \bar{y}_{TR})^2 / n_{TR}} \dots\dots\dots\dots\dots\dots\dots eqn\ 4.4$$

Where

$\hat{y}_i$ is Predicted value

Y_i Observed values

$\bar{y}_{TR}$ is Response mean of training data set

$\bar{y}_{EXT}$ is Response mean of external data set

n_{ext} is sample size of external data set

n_{tr} is sample size of training data set

The predictive squared correlation coefficient Q^2 calculated using ***eqn-4.4***is ***0.8494***. Q^2 value compares the predictive residual sum of squares (PRESS) with the total sum of squares (SS). The calculated model predictive ability measure, Q^2, value is very close to the model's R^2_{Adj} value i.e.***0.8598*** which implies that the model's ability to predict future responses is as good as its performance on the training data. The validation study suggests that the developed model is appropriate for predicting future responses.

4.5.2 Binary logistic regression model validation

The same amount of validation data that is used for multiple linear regression model validation is used for the two binary logistic regressions developed in sections 4.4.2 and 4.4.3. The data is taken also from the same intersection i.e. Post office intersection.

Hosmer-Lameshow goodness of fit test is used to obtain the summary measure of test statistic for the validation sample.

$$C_v=\sum_{j=1}^{g}\frac{(O_j-E_j)^2}{n_j\bar{\pi}_j(1-\bar{\pi}_j)} \quad \text{.....eqn4.5}$$

Where:-

C_v –Hosmer-Lameshow goodness of fit test statistic for validation sample

O_j -Observed response

E_j –Expected response

n_j –Total observation

$\bar{\pi}_j=\sum\frac{m_j\hat{\pi}_j}{n_j}$

m_j- Number of subjects

$\hat{\pi}_j$–Logistic probability for the covariate pattern

C_v is distributed as χ^2 (chi-square) with the null hypothesis H_0: the model is correct. Using the validation data χ^2 statistic result obtained for the H-L goodness of fit test statistic is 5.10 and 5.61 for probability of signal compliance logistic regression and probability of crosswalk compliance logistic regression models respectively. The respective P values are ***0.784*** and ***0.850.***This leads to the acceptance of the null hypothesis. As a conclusion, the binary logistic models developed for both signal and crosswalk compliance is found to be best predictive models.

4. 6 Pedestrian Attitude Survey

To investigate the reason of pedestrian noncompliance with traffic signal and misuse of cross walk locations, an interview with total of 8 questions was provided for 385 pedestrians. The interview questions are divided into 3 parts. The 1st part inquires for personal information of the respondent i.e. gender and age group. The second part holds 7 questions inquiring perception and attitude of pedestrians about the crossing facilities. Result of questions included in part 2is presented in **table 4.25** and **table 4.26**. The last part of the interview inquires the respondents to rank the reasons that lead pedestrians to cross on non-designated crossing locations and the result is presented in **table4.27** below. The format of the interview can be referred from appendix section.

During the survey it is tried to get a balanced number of male respondents and female respondents though, 200 participants were male and 185 were female. Among 385 respondents 263 were middle aged, 72 juveniles and 50 were seniors.

Table 4.25: Result of interview questions (1)

NO.	Question	Choice	Number of respondents	Percentage (%)
1	*crossing preference (location)*	*A) At designated crossing location*	197	51.2
		B) At any convenient location	188	48.8
		Total	385	100
	Repetition to cross at non designated	*A) Never*	24	6.2
		B)Rarely	48	12.5

2	*crosswalk location*	*C) Sometimes*	289	75.1
		D) Often	24	6.2
		E) Almost always	–	–
		Total	385	100
3	*Reason to cross at non-designated crossing location*	*A) Thinking that crossing facility is not reasonable*	48	12.5
		B) Drivers stop cars on crosswalks	193	50.1
		C) width of crosswalk is inadequate to accommodate all pedestrians crossing together	144	37.4
		Total	385	100
4	*crossing preference (signal phase)*	*A) Only when traffic light is red for vehicles (green for pedestrians)*	275	71.4
		B) At any appropriate gap	110	28.6
		Total	385	100
5	*Repetition to cross on green light (red for pedestrians)*	*A) Never*	48	12.5
		B)Rarely	48	12.5
		C) Sometimes	289	75.0
		D) Often	–	–
		E) Almost always	–	–
		Total	385	100
6	*Reason to cross on green light (red for pedestrians)*	*A) To save time*	217	56.4
		B) Allocated time is not enough	72	18.7
		C) Because other people do this	96	24.9
		D) Thinking that crossing facility is not reasonable	–	–
		E) There is no traffic police	–	–
		Total	385	100

Table 4.26: Result of interview questions (2)

		Choice					
7	*Attitude on crossing Facilities*	*Strongly agree*	*Agree*	*Neutral*	*Disagree*	*Strongly disagree*	*Total*

A) width and length are appropriate and enough	24	72	121	144	24	385
B) Maintenance conditions are good	72	96	168	49	_	385
C)crosswalk are placed conveniently	49	263	24	49	_	385
D)Traffic light scheduling is adequate	240	72	_	24	49	385

Table 4.27: Result of interview questions (3)

Reason	**Rank**			
	1	**2**	**3**	**4**
Width of cross walk is not enough to accommodate all the pedestrians crossing together	96	217	72	_
Drivers stop cars on crosswalks	217	121	24	_
Thinking crossing facility (crosswalk) is not reasonable		47	24	313
Location of crosswalk is mostly placed inconveniently	72	_	265	72

Number of respondents

Referring to the above result, pedestrians' attitude on present crossing facilities is discussed as follows.

- Approximately an equal amount of pedestrians prefer to cross on designated crossing location and at any convenient location.
- More than half of interviewed pedestrians claim drivers for stopping cars on crosswalks and raise it as the major reason not to use designated crossing locations.
- A significant amount pedestrians mention inadequacy of width of crosswalk as reason not to use designated crossing locations.
- Among the surveyed pedestrians 71.4% choose to cross only when traffic light is red for vehicles/ green for pedestrians/ while the rest choose to cross whenever they get appropriate gap between cars.

- 56.4% of the respondents mention saving their time as a reason for noncompliance with traffic signal timing, whereas, 24.9% violate traffic light rule because other people do. Least amount of pedestrians mentions inadequacy of allocated time as a reason of noncompliance.
- Out of 385 respondents 144 of them disagree with the appropriateness and adequacy of width and length of crossing facilities.
- A considerable amount of the respondents agree and strongly agree with the goodness of maintenance conditions of the crossing facilities. Approximately equal amount of respondents remain to be neutral to give an idea over this question.
- About 81% of the respondents agree on the convenience of placement of cross walk location.
- A reasonable amount of respondents agree and strongly agree on the adequacy of schedule of traffic light.
- The major leading reason the pedestrians mentioned for noncompliance with crosswalk locations is drivers usage of roads while stopping car during red phase.
- The second reason they ranked is inadequacy of width of crosswalk to accommodate all pedestrians crossing at the same time.
- ✓ The 3rd and last reasons are inconvenience of placement of crossing locations and road users' awareness towards the reasonability of crossing locations respectively.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study set out to determine the significant factors affecting pedestrian crossing behavior expressed as crossing speed, signal and crosswalk compliance. In addition it is designed to determine the effect of dominantly affecting factors on crossing behavior. In doing so, from the statistical analysis done and result obtained in the previous chapter the following conclusions and recommendations are drawn.

- Pedestrian characteristics i.e. gender, age group & group size and traffic characteristics i.e. crossing signal were tested if each of the factors significantly affect pedestrian crossing speed. As a result gender, age group and pedestrian group size were found as a dominant factors affecting pedestrian crossing speed.

- Age group and pedestrian group size are found as significant factors affecting pedestrian signal compliance and crosswalk compliance among the tested pedestrian characteristic.

- To study the effect of each predictor variable on pedestrian crossing speed multiple linear regression model is developed. Except crossing signal phase, all variables were found statistically significant to predict pedestrian crossing speed at 95% confidence level. The calculated R^2_{adj} for the regression model is 0.8598.

- Pedestrian age group is positively correlated with crossing speed while Gender and pedestrian group size are correlated negatively.

- Male pedestrians have greater crossing speed than female. Middle aged pedestrians have the greatest speed while seniors have the lowest crossing speed. Single pedestrians cross quicker than grouped pedestrians and crossing speed decreases as the number of pedestrians in the group increases.

- To study the effect of each predictor variable on signal compliance and crosswalk compliance binary logistic regression model is developed independently. Pedestrian age group and group size were found statistically significant to predict pedestrian probability of signal compliance and crosswalk compliance.

- Holding pedestrian group size constant probability of pedestrian signal compliance increases with an increase in amount of senior pedestrians while it decreases with an increase in amount of juveniles.
- Holding age groups constant probability of pedestrian signal compliance decreases with an increase in pedestrian group size.
- Holding pedestrian group size constant probability of pedestrian crosswalk compliance increases with an increase in amount of senior pedestrians as well as with an increase of juveniles.
- Holding age groups constant probability of pedestrian crosswalk compliance decreases with an increase in pedestrian group size.
- At 95% confidence level. Hosmer-Lameshow goodness of fit test significance P value for signal compliance and crosswalk compliance are 0.645 and 1.000 respectively. This leads to the acceptance of the null hypothesis i.e. the developed model is correct and predicts the data well.
- External validation was performed to validate the multiple linear regression model and the model's predictive ability, $Q^{2,}$ is ***0.8494.*** The regression model is validated and is applicable for signalized intersections of Addis Ababa.
- Similarly, to test the predictive ability of the developed binary logistic models external validation was performed using Hosmer-Lameshow goodness of fit test. H-L goodness of fit test statistic, C_v is 5.10 and 5.61 for signal compliance logistic regression and crosswalk compliance logistic regression models respectively. The respective P values are ***0.784*** and ***0.850.*** This leads to the acceptance of the null hypothesis that states the model is correct. As a conclusion, the binary logistic models developed for both signal and crosswalk compliance is found to be best predictive models.
- The most dominating reasons of pedestrians for noncompliance with crossing locations are drivers' improper usage of roads during red phase and inadequacy of width of cross walk.

Reasons for noncompliance with traffic light most likely related to the low level awareness of pedestrians and gap in enforcement and implementation of law.

5.2 Recommendations

Depending on the final results of this study the researcher recommends the following points so that it adds its own positive impact on the improvement of road users' life especially of pedestrians.

- Education & enforcement of traffic law especially for juveniles and middle aged pedestrians is essential for the improvement of pedestrians' compliance with signal as well as with crosswalk.
- Design of crosswalk width should be revised since the number of pedestrians in the city is increasing with high rate. So that, the designed crosswalk could accommodate pedestrians crossing with mass and pedestrians could comply with crosswalk.
- Enforcing laws have to be implemented for drivers on usage of roads during red signal phase so that pedestrians can use crosswalks properly.
- Awareness should be created for pedestrians on how to use crossing facilities and as well enforcing law have to be implemented and applied on noncompliant pedestrians.

In addition to the above recommendations the following future research areas related with this study are also recommended.

- Pedestrians delay model at signalized intersection
- Disabled pedestrians crossing behavior at signalized intersections
- Pedestrian crossing behavior at un-signalized intersections and at midblock.

REFERENCE

Akash, Jain, Ankit Gupta , and Rajat Rastogi. "pedestrian crossing behavior analysis at intersections." *International journal for traffic and transport engineering*, 2014: 103-116.

Alhajyaseen, W, and Asano M Iryo. "studying critical pedestrian behavioral changes for safety assesment at signalized crosswalk." *saftey science*, 2017: 351-360.

Allen T Mense. *Introduction to regression techniques.* Principal engineering fellow, n.d.

Ann, Forsyth, Weinstein Agrawal Asha, and J Krizek Kevin. "Simple inexpensive approach to sampling for pedestrian and bicycle surveys." *Journal of transportation research board*, 2012: 22-30.

Arboretti, R Giancristofaro, and L Salmaso. "Modeling performance analysis and model validation in logistic regression." *Journal of royal statistical society*, 2003.

Asaithambi, Gowri, O Kuttan Manu, and Sarath Chandra. "Pedestrian crossing behavior under mixed traffic conditions;a comparative study of an intersection before and after implementating control measures." *Transportation in developing economies*, 2016: 1-12.

Athnatios, Galanis, and Eilous Nicholas. "pedestrian crossing behavior in signalized crossing in middle size cities in Greece." Tagungsbad: REAL CORP, 2012.

Central Statistical Agency. 2013.

Consonni, V, D Ballabio, and R Todeschini. "Evaluation of model predictive abalility by external validation technique." *Journal of chemometrics*, 2010: 194-201.

Daamen, W, and Sp Hoogendoorn. *Experimental research of pedestrian walking behavior.* Annual meeting, Washington DC USA: Transportation Research Board, 2003.

Deepty, Muley, Karbache Mohammed , Alhagyaseen Wael, and Al-salem Mohammed. "Pedestrian crossing behavior at marked crosswalks on channalized right turn lane at intersection." *Science direct*, 2017: 233-240.

Ethiopian Transport Authority. 2017.

Gang, Ren, Zhu Zhuping, Wang Wei, Zhang Yong , and Wang Weijie. "crossing behavior of pedestrain at signalized intersection." *Transport research board* , 2011.

Hosmer, D W, and S Lemeshow. *Applied logistic regression 2nd Edition.* Newyork: John wiley & sons, 2000.

Jiang , Xiaobie, Wang Wuhong, Bengler Klause, and Guo Weiwei. "Analysis of pedestrian behavior on mid block unsignalised crosswalk comparing Chineese and German cases." *Advance in mechanical engineer*, 2015: 1-7.

King, Mark j, W Soule David, and Ghaoufarian Ameneh. "Illegal pedestrian crossing at signalised intersection incidence and relative risk." *accident analysis and prevention ,41 no 3*, 2009: 485-490.

Koh, P.P. "Safety evaluation of pedestrian behavior and violations at signalized pedestrian crossings." *Safety science* 70 (2014): 143-152.

Kreizek, J K, A Forsyth, and w Agrawal A. *Pedestrian and bicycling survey (PABS): User's Manual.http//www.designforhealth.net/resources/.* n.d. http://www.survey system.com/sscalc.htm. (accessed 12 30, 2018).

Krysto, Lipovac, Vujanic Milan, Maric Bojan, and Nesic Miladin. "pedestrian behavior at signalized pedestrian crossings." *Journal of Transport engineering*, 2013: 165-172.

Laura, Pathric Nichlas. *Population 2018.* 2018. http://.poplulation2018.com.

Marisamynathan, Vendagri Perumal. "Study on pedestrian crossing behavior at signalized intersections." *Journal of traffic and transportation engineering*, no. 1(2) (2014): 103-110.

Maristamynathan, S, and P Vendagri. "A statistical analysis of pedestrian behavior at signalized intersection." *European transport*, 2015: 1825-3997.

Montogomery, C Douglas, and C George Runger. *Applied statistics and probability for engineers.* USA: John Wiley and sons, 2010.

Nesic, Miladin, Krysto Lipovac, and Miroslav Rosic. "Pedestrian behavior at pedestrian crossing Regulated with traffic light." *Road accident prevention.* Belgrade serbia: XII International sympossium, 2014.

Nicholas N Ferenchak, and Matin Kitirai. "Pedestrian crossing behavior in relation to grouping and gender in a developing country context." *Global epidemology and environmental health* , 2017: 37-45.

Rosenbloom, Tova. "Crossing at red light : Behavior of individuals and groups." *Transportation research* F 12 (2009): 389-394.

Scott, H Simpson. "Creating a data analysis plan :what to consider when choosing statistics for a study." *Research primer*, 2015: vol 68.

Serge, P Hoogendoorn. "State ofthe art of vehicular traffic flow modeling." *Journal of system and control engineering. Delft university of technology, master of science thesis, Delft, Netherlands*, 2001: pp10.

Sohel, Rana, Midi Habshah, and S k Sarkar. "Validation and Performance analysis of binary logistic regression model." *WSEAS Internationl conference on environmental medicine and health science.* Serdag, Malasia, 2015.

Srinivas , Palamarthy, S Hani, Mahmassani, and B Machemhl Randi. *Models of pedestrian crosssing behavior at signalized intersections.* texas: center for transportation research, 1994.

Srinivas, Palamarty, S Mahmassini Hani, and B Randi Machmehl. "Model of pedestrian crossing behavior at signalized intersection." *Cetre for transportation research*, 1994.

Sun , Z. "study on pedestrian characteristics in crosswalks at signalized intersections." *Msc thesis, Beijing, bBeijing university of technology*, 2004.

Tasnima , Abedin, Z.I Chowuduri Mohammed, Afzal Arfen, Turin Tanvir, and F Yeasmin. "Application of binary logistic regression in clinical research." *JNHFB*, 2016: 8-11.

Tulu, Getu Segni. "why are pedestrian crash so different in developing countries? a review of relevant factors in relation to their impact in Ethiopia." Birsbane, Australia: Australasian transport research forum, 2013. page 4.

Wall. "Road markings to improve pedestrians safety at crossings." *Traffic engineering and control*, 2000: 136-140.

Washington, Simon P, G Kralaftis Mattew, and L Mannering Fred. *Statistical and econometric methods for transportation data analysis.* 3. London: Newyork; Washington DC: CRC press, 2010.

WHO. *Global status report on road safety: time for action.* Geneva: world health organizatio, 2009.

Zhang, D. "Evaluation of road traffic safety management." Beijing: China communication press, 2005.

Zhu, Ping Zhou, Shun Liu Ying, Wang Wei, and Zhang Yong. "multinomial logit model of pedestrian crossing behavior at signalized intersection." *Discrete dynamics in nature and society*, 2013: 1-9.

APPENDIX A
Detailed Description of Signalized Intersections in Addis Ababa

Table A-1: Detailed Description of Signalized Intersections in Addis Ababa

Item No	Intersection Name	Parking	Local Bus Blockage	Channelized	No of Approaches							Working Condition
					Three			Four			≥5	
					T	Skewed	Y	Right Angle	Offset	Oblique		
1	*Lebu M/Hail*	×	×	√						√		√
2	*Bole Michael*	×	×	×				√				√
3	*Agona Cinema*	-	-	-	-	-	-	-	-	-	-	×
4	*Legehar*	×	√	×				√				√
5	*Buna ena Shay*	×	√	×				√				√
6	*Gerji M/Hail*	×	×	√		√						√
7	*Imperial*	×	×	×				√				√
8	*Coca Bridge*	-	-	-	-	-	-	-	-	-	-	×
9	*I8 Mazoria*	-	-	-	-	-	-	-	-	-	-	×
10	*Semen Hotel*	×	×	×				√				√
11	*4-Kilo Parliament*	×	×	×				√				√
12	*National Theater*	√	×	×							√	√
13	*Post Office*	×	×	√				√				√
14	*ETV*	×	×	√						√		√
15	*Sengatera*	×	×	×				√				√
16	*Harambe Hotel*	×	×	×						√		√
17	*Shola Gebeya*	×	×	×	√							√
18	*GomaKuteba*	×	×	×				√				√
19	*BankoDiroma*	×	×	√						√		√
20	*Atlas*	×	×	×						√		√
21	*Meskel Square*	√	√	×						√		√
22	*St. Joseph*	√	√	√						√		√
23	*LidetaTsebel*	×	×	×			√					√
24	*Jemo Michael*	×	×	×						√		√
25	*Kera to Gofa*	×	×	×				√				√
26	*Near Kera*	×	×	×				√				√
27	*St. Marry 5-Kilo*	-	-	-	-	-	-	-	-	-	-	×
28	*Kazanchis*	-	-	-	-	-	-	-	-	-	-	×
29	*Salitemihret*	×	×	×				√				×
30	*Saris Abo*	×	×	×				√				√

APPENDIX B

Peak Hour data determination

Table B-1 Peak hour data for Estifanos- Mexico and Estifanos- Bole approaches

Counting Period		Intersection	Approach	Total Ped. Volume	From 07:00 To 08:00	From 07:15 To 08:15	From 07:30 To 08:30	From 07:45 To 08:45	From 08:00 To 09:00	From 08:15 To 09:15	From 08:30 To 09:30	From 08:45 To 09:45	From 09:00 To 10:00	Peak Hour
From	To													
7:00 AM	7:15 AM	Estifanos	Estifanos-Mexico	36	289									From 07:00 To 08:00
7:15 AM	7:30 AM			56		273								
7:30 AM	7:45 AM			176			263							
7:45 AM	8:00 AM			21				122						
8:00 AM	8:15 AM			20					151					
8:15 AM	8:30 AM			46						176				
8:30 AM	8:45 AM			35							170			
8:45 AM	9:00 AM			50								180		
9:00 AM	9:15AM			45									170	
9:15AM	9:30AM			40										
9:30AM	9:45AM			45										
9:45AM	10:00AM			40										
7:00 AM	7:15 AM		Estifanos-Bole	56	282									From 07:15 To 08:15
7:15 AM	7:30 AM			66		295								
7:30 AM	7:45 AM			95			262							
7:45 AM	8:00 AM			65				197						
8:00 AM	8:15 AM			69					180					
8:15 AM	8:30 AM			33						151				
8:30 AM	8:45 AM			30							162			
8:45 AM	9:00 AM			48								182		
9:00 AM	9:15AM			40									189	
9:15AM	9:30AM			44										
9:30AM	9:45AM			50										
9:45AM	10:00AM			55										

Table B-2 Peak hour data for Estifano- Arat kilo and Estifanos- Hayahulet approaches

Counting Period		Intersection	Approach	Total Ped. Volume	From 07:00 To 08:00	From 07:15 To 08:15	From 07:30 To 08:30	From 07:45 To 08:45	From 08:00 To 09:00	From 08:15 To 09:15	From 08:30 To 09:30	From 08:45 To 09:45	From 09:00 To 10:00	Peak Hour
From	To													
7:00 AM	7:15 AM	Estifanos	Estifanos-Arat kilo	55	248									From 07:30 To 08:30
7:15 AM	7:30 AM			53		253								
7:30 AM	7:45 AM			80			270							
7:45 AM	8:00 AM			60				250						
8:00 AM	8:15 AM			60					250					
8:15 AM	8:30 AM			70						220				
8:30 AM	8:45 AM			60							195			
8:45 AM	9:00 AM			60								188		
9:00 AM	9:15AM			30									163	
9:15AM	9:30AM			45										
9:30AM	9:45AM			53										
9:45AM	10:00AM			35										
7:00 AM	7:15 AM		Estifanos-Hayahulet	100	330									From 08:30 To 09:30
7:15 AM	7:30 AM			110		350								
7:30 AM	7:45 AM			75			280							
7:45 AM	8:00 AM			45				328						
8:00 AM	8:15 AM			120					388					
8:15 AM	8:30 AM			40						358				
8:30 AM	8:45 AM			123							398			
8:45 AM	9:00 AM			105								340		
9:00 AM	9:15AM			90									278	
9:15AM	9:30AM			80										
9:30AM	9:45AM			65										
9:45AM	10:00AM			43										

Table B-3 Peak hour data for Piassa- Biherawi and Biherawi –Piassa approaches

Counting Period		Intersection	Approach	Total Ped. Volume	From 07:00 To 08:00	From 07:15 To 08:15	From 07:30 To 08:30	From 07:45 To 08:45	From 08:00 To 09:00	From 08:15 To 09:15	From 08:30 To 09:30	From 08:45 To 09:45	From 09:00 To 10:00	Peak Hour
From	To													
7:00 AM	7:15 AM	Banko de roma	Piassa- Biherawi	47	215									From 08:15 To 09:15
7:15 AM	7:30 AM			68		226								
7:30 AM	7:45 AM			64			244							
7:45 AM	8:00 AM			36				264						
8:00 AM	8:15 AM			58					342					
8:15 AM	8:30 AM			86						359				
8:30 AM	8:45 AM			84							303			
8:45 AM	9:00 AM			114								254		
9:00 AM	9:15AM			75									160	
9:15AM	9:30AM			30										
9:30AM	9:45AM			35										
9:45AM	10:00AM			20										
7:00 AM	7:15 AM		Biherawi- Piassa	35	169									From 08:45 To 09:45
7:15 AM	7:30 AM			40		189								
7:30 AM	7:45 AM			46			194							
7:45 AM	8:00 AM			48				193						
8:00 AM	8:15 AM			55					190					
8:15 AM	8:30 AM			45						185				
8:30 AM	8:45 AM			45							213			
8:45 AM	9:00 AM			45								238		
9:00 AM	9:15AM			50									233	
9:15AM	9:30AM			73										
9:30AM	9:45AM			70										
9:45AM	10:00AM			40										

Table B-4 Peak hour data for Churchil avenue-Arat kilo and Churchil avenue-Merkato approaches

Counting Period		Intersection	Approach	Total Ped. Volume	From 07:00 To 08:00	From 07:15 To 08:15	From 07:30 To 08:30	From 07:45 To 08:45	From 08:00 To 09:00	From 08:15 To 09:15	From 08:30 To 09:30	From 08:45 To 09:45	From 09:00 To 10:00	Peak Hour
From	To													
7:00 AM	7:15 AM	Banko de Roma	Churchill avenue- Arat kilo	60	305									From 07:00 To 08:00
7:15 AM	7:30 AM			130		296								
7:30 AM	7:45 AM			60			236							
7:45 AM	8:00 AM			55				271						
8:00 AM	8:15 AM			51					256					
8:15 AM	8:30 AM			70						240				
8:30 AM	8:45 AM			95							190			
8:45 AM	9:00 AM			40								120		
9:00 AM	9:15AM			35									125	
9:15AM	9:30AM			20										
9:30AM	9:45AM			25										
9:45AM	10:00AM			45										
7:00 AM	7:15 AM		Churchill avenue -Merkato	65	230									From 09:00 To 10:00
7:15 AM	7:30 AM			65		225								
7:30 AM	7:45 AM			45			245							
7:45 AM	8:00 AM			55				280						
8:00 AM	8:15 AM			60					305					
8:15 AM	8:30 AM			85						325				
8:30 AM	8:45 AM			80							330			
8:45 AM	9:00 AM			80								325		
9:00 AM	9:15AM			80									345	
9:15AM	9:30AM			90										
9:30AM	9:45AM			75										
9:45AM	10:00AM			100										

Table B-5 Peak hour data for Mexico -Legehar and Stadium-Legehar approaches

Counting Period		Intersection	Approach	Total Ped. Volume	From 07:00 To 08:00	From 07:15 To 08:15	From 07:30 To 08:30	From 07:45 To 08:45	From 08:00 To 09:00	From 08:15 To 09:15	From 08:30 To 09:30	From 08:45 To 09:45	From 09:00 To 10:00	Peak Hour
From	To													
7:00 AM	7:15 AM	Legehar	Mexico-Legehar	34	242									From 08:00 To 09:00
7:15 AM	7:30 AM			48		279								
7:30 AM	7:45 AM			67			291							
7:45 AM	8:00 AM			93				319						
8:00 AM	8:15 AM			71					324					
8:15 AM	8:30 AM			60						320				
8:30 AM	8:45 AM			95							292			
8:45 AM	9:00 AM			98								242		
9:00 AM	9:15AM			67									178	
9:15AM	9:30AM			32										
9:30AM	9:45AM			45										
9:45AM	10:00AM			34										
7:00 AM	7:15 AM		Stadium-Legehar	118	358									From 07:00 To 08:00
7:15 AM	7:30 AM			55		310								
7:30 AM	7:45 AM			141			306							
7:45 AM	8:00 AM			44				255						
8:00 AM	8:15 AM			70					266					
8:15 AM	8:30 AM			51						226				
8:30 AM	8:45 AM			90							201			
8:45 AM	9:00 AM			55								166		
9:00 AM	9:15AM			30									146	
9:15AM	9:30AM			26										
9:30AM	9:45AM			55										
9:45AM	10:00AM			35										

Table B-6 Peak hour data for Legehar-Biherawi and Legehar- Legehar bus station approaches

Counting Period		Intersection	Approach	Total Ped. Volume	From 07:00 To 08:00	From 07:15 To 08:15	From 07:30 To 08:30	From 07:45 To 08:45	From 08:00 To 09:00	From 08:15 To 09:15	From 08:30 To 09:30	From 08:45 To 09:45	From 09:00 To 10:00	Peak Hour
From	To													
7:00 AM	7:15 AM	Legehar	Legehar- Biherawi	60	245									From 07:45 To 08:45
7:15 AM	7:30 AM			70		237								
7:30 AM	7:45 AM			60			237							
7:45 AM	8:00 AM			55				272						
8:00 AM	8:15 AM			52					257					
8:15 AM	8:30 AM			70						240				
8:30 AM	8:45 AM			95							180			
8:45 AM	9:00 AM			40								125		
9:00 AM	9:15AM			35									150	
9:15AM	9:30AM			10										
9:30AM	9:45AM			40										
9:45AM	10:00AM			65										
7:00 AM	7:15 AM		Legehar- Legehar bus station	65	230									From 8:30 To 09:30
7:15 AM	7:30 AM			65		225								
7:30 AM	7:45 AM			45			245							
7:45 AM	8:00 AM			55				280						
8:00 AM	8:15 AM			60					305					
8:15 AM	8:30 AM			85						325				
8:30 AM	8:45 AM			80							330			
8:45 AM	9:00 AM			80								325		
9:00 AM	9:15AM			80									301	
9:15AM	9:30AM			90										
9:30AM	9:45AM			75										
9:45AM	10:00AM			56										

Table B-7 Peak hour data for Biherawi- Post office and Post office- Immigration approaches

Counting Period		Intersection	Approach	Total Ped. Volume	From 07:00 To 08:00	From 07:15 To 08:15	From 07:30 To 08:30	From 07:45 To 08:45	From 08:00 To 09:00	From 08:15 To 09:15	From 08:30 To 09:30	From 08:45 To 09:45	From 09:00 To 10:00	Peak Hour
From	To													
7:00 AM	7:15 AM	Post office	Biherawi- Post office	64	271									From 08:30 To 09:30
7:15 AM	7:30 AM			50		265								
7:30 AM	7:45 AM			78			309							
7:45 AM	8:00 AM			79				339						
8:00 AM	8:15 AM			58					374					
8:15 AM	8:30 AM			94						409				
8:30 AM	8:45 AM			104							423			
8:45 AM	9:00 AM			114								374		
9:00 AM	9:15AM			93									316	
9:15AM	9:30AM			108										
9:30AM	9:45AM			59										
9:45AM	10:00AM			56										
7:00 AM	7:15 AM		Post office-Immigration	71	357									From 07:15 To 08:15
7:15 AM	7:30 AM			92		429								
7:30 AM	7:45 AM			114			420							
7:45 AM	8:00 AM			80				381						
8:00 AM	8:15 AM			143					420					
8:15 AM	8:30 AM			83						382				
8:30 AM	8:45 AM			75							374			
8:45 AM	9:00 AM			119								311		
9:00 AM	9:15AM			105									161	
9:15AM	9:30AM			75										
9:30AM	9:45AM			12										
9:45AM	10:00AM			31										

Table B-8 Peak hour data for Post office-Ambassador and Piassa- Post office approaches

Counting Period		Intersection	Approach	Total Ped. Volume	From 07:00 To 08:00	From 07:15 To 08:15	From 07:30 To 08:30	From 07:45 To 08:45	From 08:00 To 09:00	From 08:15 To 09:15	From 08:30 To 09:30	From 08:45 To 09:45	From 09:00 To 10:00	Peak Hour
From	To													
7:00 AM	7:15 AM	Post office	Piassa- Post office	88	308									From 7:45 To 08:45
7:15 AM	7:30 AM			82		304								
7:30 AM	7:45 AM			53			272							
7:45 AM	8:00 AM			85				317						
8:00 AM	8:15 AM			84					316					
8:15 AM	8:30 AM			50						299				
8:30 AM	8:45 AM			98							295			
8:45 AM	9:00 AM			84								255		
9:00 AM	9:15AM			67									202	
9:15AM	9:30AM			46										
9:30AM	9:45AM			58										
9:45AM	10:00AM			31										
7:00 AM	7:15 AM		Post office- Ambassador	129	554									From 7:15 To 08:15
7:15 AM	7:30 AM			139		575								
7:30 AM	7:45 AM			149			541							
7:45 AM	8:00 AM			137				508						
8:00 AM	8:15 AM			150					552					
8:15 AM	8:30 AM			105						492				
8:30 AM	8:45 AM			116							471			
8:45 AM	9:00 AM			181								424		
9:00 AM	9:15AM			90									319	
9:15AM	9:30AM			84										
9:30AM	9:45AM			69										
9:45AM	10:00AM			76										

Total sample size calculation for the major statistical analysis

Total sample size=$\sum x_i$

Where $x_{in}=$ peak hour data at each intersection at each leg

Total sample size=289+295+270+398+359+238+305+345+324+358+272+330

Total sample size =3783

Total sample size calculation for validationstudy

Sample size = data from post office intersection=423+429+317+575

Sample size= 1744

APPENDIX C
Descriptive Statistics for Crossing Speed of Explanatory Variables

Table C-1 Descriptive statistics for crossing speed with explanatory variables

Descriptive statistics		**Explanatory Variables**										
		Gender		Age group			Pedestrian group size				Crossing signal	
		Male	Female	<20	20-55	>55	Single	2–3	4–5	>5	Red	Green
No.	Valid	2814	969	402	2756	625	1222	825	768	968	3176	607
	Missing	0	0	0	0	0	0	0	0	0	0	0
Mean Speed		1.619	1.538	1.621	1.663	1.675	1.601	1.602	1.642	1.653	1.692	1.732
95% CI	lower	1.593	1.594	1.651	1.638	1.619	1.572	1.573	1.602	1.624	1.668	1.671
	upper	1.645	1.683	1.791	1.689	1.73	1.641	1.642	1.65	1.682	1.716	1.792
Median		1.55	1.4	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Variance		0.489	0.492	0.511	0.481	0.505	0.441	0.442	0.501	0.512	0.474	0.579
Standard Deviation		0.6993	0.7016	0.7146	0.6932	0.7106	0.6644	0.6644	0.707	0.7159	0.6885	0.761
Minimum		0.3	0.3	0.4	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.4
Maximum		3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Range		3	3	2.9	3	2.9	3	3	3	3	3	2.9

APPENDIX D
Interview Questions (English)

INTERVIEW QUESTIONS

First of all I would like to thank for your cooperation! The purpose of this survey is to get your opinion about the crossing environment. The result of this survey will be used for educational purpose.

Part I:-PERSONAL INFORMATION

Gender MALE ☐ FEMALE ☐

Age group ☐ 18-50 ☐ >50 ☐

Part II:-Please make a tick (√) mark in front of your choices

1. **Where** do you typically cross on signalized intersection?

A) On designated cross walk ☐
B) At any convenient location ☐

2. How often do you cross at **non designated crosswalk?**

NEVER ☐ RARELY ☐ SOMETIMES ☐ OFTEN ☐ ALMOST ALWAYS ☐

3. If you choose to cross at a non-designated crossing location what do you think is the main reason?

A) Because I think crossing facility design is not reasonable ☐
B) Because drivers stop cars on crosswalks ☐
C) Because the crosswalk width is not enough to accommodate all the pedestrians crossing together ☐

4. **when** do you typically cross on signalized intersection

A) Only when traffic light is RED for vehicles/green for pedestrians/ ☐
B) Whenever I get appropriate gap between cars with little interface ☐

5. How often do you cross on GREEN light (for vehicles)?

NEVER ☐ RARELY ☐ SOMETIMES ☐ OFTEN ☐ ALMOST ALWAYS ☐

6. What is your reason to cross on GREEN light (for vehicles)?

A) To save time
B) Because allocated time is not adequate
C) Because other people do this
D) Because I think crossing facility design is not reasonable
E) Because there is no traffic police
Other reasons……

7. What do you think of the present crossing facilities?

	SA	A	N	DA	SDA
Width and length are appropriate and enough					
Maintenance conditions are good					
Crosswalks are placed conveniently					
Traffic light scheduling is adequate					

SA=STRONGLY AGREE **A**=AGREE **N**=NEUTRAL
DA= DIS-AGREE **SDA**=STRONGLY DIS-AGREE

PART III:- Rank the following reasons which lead pedestrians at cross on non-designated crossing locations .

……..1. The width of the crosswalk is not enough to accommodate all the pedestrians crossing together
……..2.Drivers stop cars on crosswalks
……..3.People think crossing facilities (crosswalk) is not reasonable
……..4.Location of crosswalk is placed mostly inconvenient (distance to the designed location is high)

Thank you!

APPENDIX E
Interview Questions (Amharic)

ቃለ-መጠይቅ

በቅድሚያ ጊዜዎትን ሰውተው ቃለ-መጠይቁን እንዳደርግሎት ስለተባበሩኝ አመሰግናለሁ::የዚህ ቃለ-መጠይቅ አላማ የትራፊክ መብራት በተተከለባቸው መተላለፊያዎች አካባቢ ላይ ያሎትን አመለካከት ማወቅ ነው:: ውጤቱም ለትምህርታዊ የጥናት አላማ ብቻ የሚውል ይሆናል::

ክፍል 1:-የግለሰቡመረጃ

ፆታ ወንድ ☐ ሴት ☐

የዕድሜ ክልል <18 ☐ 18-50 ☐ >50 ☐

ክፍል 2፡- እከዎን በምርጫዎት ፊት ለ ፊት የ(√) ምልክት ያድርጉ::

1 የትራፊክ መብራት በተተከለባቸው መተላለፊያዎች አካባቢ በየት በኩል ይሻገራሉ?

ሀ) በተቀቡ የእግረኛ መሻገሪያዎች ላይ ☐

ለ) በማንኛውም ባመቸ ኝቦታ ☐

2 ለመሸጋገሪያነት ባልተቀቡ ቦታዎች ላይ ምን ያህል ጊዜ ይሻገራሉ?

በፍፁም ☐ አልፎአልፎ ☐ አንዳንድጊዜ ☐ በብዛት ☐ ሁልጊዜ ☐

3 ለመሸጋገሪያነት ባልተቀቡ ቦታዎች ላይ የሚሸጋገሩ ከሆነ ዋና ምክንያትዎ ምንድነው?

ሀ) ምክንያቱም የመሸጋገሪያ መገልገያ ንድፎች ምክንያታዊ አይደሉም ብዬ ስለማስብ ☐

ለ)ምክንያቱም አሽከርካሪዎች መኪኖቻቸውን በመሸጋገሪያዎች ላይ ስለሚያቆሙ ☐

ሐ) ምክንያቱም የመሸጋገሪያው ስፋት ባንድ ላይ ለሚሻገሩ እግረኞች በቂ አይደለም ☐

4 የትራፊክ መብራት በተተከለባቸው መተላለፊያዎች አካባቢ መቼ ይሻገራሉ?

ሀ) የትራፊክ መብራቱ ለመኪኖች ቀይ /ለእግረኞችአረጓዴ/ በሚሆንበት ጊዜ ብቻ ☐

ለ) በመኪኖች መሃል ምቹ ክፍተት ባገኘሁበት ጊዜ ሁሉ ☐

5 የትራፊክ መብራቱ ለመኪኖች አረጓዴ በሆነበት ጊዜ ለምን ያህል ጊዜ መንገዱን አቋርጠው ያውቃሉ?

በፍፁም☐ አልፎአልፎ☐ አንዳንድጊዜ ☐ በብዛት ☐ ሁልጊዜ ☐

6 የትራፊክ መብራቱ ለመኪኖች አረጓዴ በሆነበት ጊዜ የሚሻገሩ ከሆነ ምክንያትዎ ምንድነው?

ሀ) ጊዜ ለመቆጠብ

ለ) ምክንያቱም ለእግረኛ መሸጋገሪያ የተሰጠው ጊዜ በቂ ስላልሆነ

ሐ) ሌሎች ስለሚያደርጉት

መ) ምክንያቱም የመሸጋገሪያ መገልገያ ንድፎች ምክንያታዊ አይደሉም ብዬ ስለማስብ

ሠ) ትራፊክ ፖሊስ በቦታው ስለሌለ

ሌላምክንያት……

7. በአሁን ሰዓት ስላሉት መሸጋገሪያዎች ምን አይነት አስተያየት አሎት?

	በእ	እ	ም	አል	በ አል
ስፋት ና ርዝመታቸው በቂና ተመጣጣኝ ነው					
የእድሳት ሁኔታው ጥሩነው					
መሸጋገሪያዎች በምቹ ቦታዎች ላይ ነው የተሰሩት					
የ ትራፊክ መብራት የጊዜ መጠን በቂ ነው					

በእ=በደምብ እስማማለሁ **እ**=እስማማለሁ **ም**=ምንም አስተያየት የለኝም

አል= አልስማማም **በአል**= በፍጹም አልስማማም

<u>ክፍል 3</u>:-እግረኞች ባልተቀቡ መሻገሪያዎች ላይ እንዲሻገሩ የሚያስገድዷቸውን የሚከተሉትን ምክንያቶች በደረጃ ያስቀምጡ፡፡

……..1.የመሸጋገሪያው ስፋት ባንድ ላይ ለሚሻገሩ እግረኞች በቂ አለመሆን
……..2 አሽከርካሪዎች መኪኖቻቸውን በመሸጋገሪያዎች ላይ ማቆም
……..3.የመሸጋገሪያ መገልገያ ንድፎች ምክንያታዊ አይደሉም ብሎ ማሰብ
……..4.የመሻገሪያዎች አቀማመጥ ምቹ አለመሆን

አመሰግናለሁ!

APPENDIX F

DIFFERENT CAMERA VIEW AT INTERSECTIONS



Estifanos- Arat kilo



Estifanos -Hayahulet



Estifanos- Bole



Estifanos -Stadium

Figure F-1 camera view at Estifanos intersection



Legehar-Stadium



Mexico-Legehar



Legehar-Legehar bus station

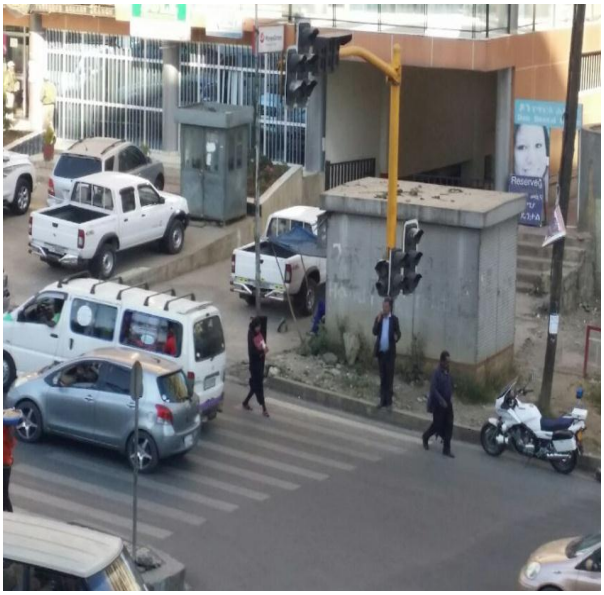


Legehar –Biherawi

Figure F-2: Camera view at Legehar intersections (for the four legs)



Piassa-Biherawi



Biherawi- Piassa



Churchil- Merkato



Churchil- Arat kilo

Figure F-3: Camera view at Banko de roma intersections (for the four legs)

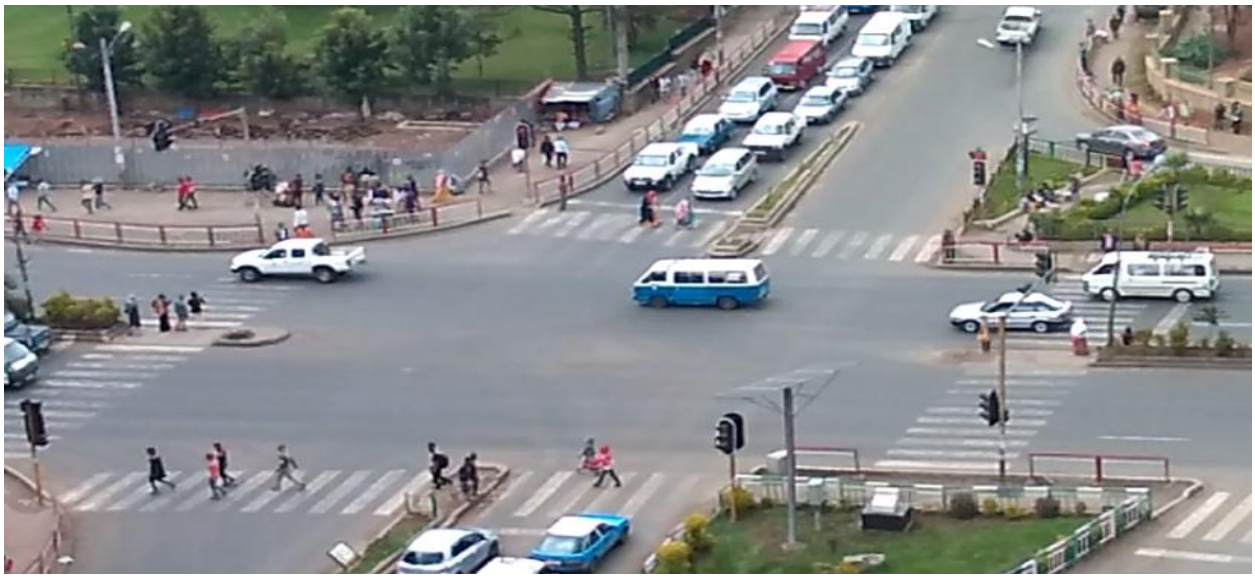


Figure F-4: Camera view at Post office intersections (for the four legs)