



ADDIS ABABA UNIVERSITY

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF GRADUATE STUDIES

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

**Pedestrian Gap Acceptance and Crossing Behavior at Signalized
Intersections**

By

Samson Belete Engida

A Thesis Submitted to the School of Graduate Studies in Partial Fulfillment of The
Requirements for the Degree of

Master of Science

In

Road and Transport Engineering

Advisor: Bikila Teklu Wodajo (Ph.D.)

November 2020

Addis Ababa, Ethiopia

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UNDERTAKING

I certify that research work titled “*Pedestrian Gap Acceptance and Crossing Behavior at Signalized Intersections*” is my original work performed under the supervision of my research advisor **Dr. Bikila Teklu**. The work has not been presented elsewhere for assessment and a degree in any other university. Where material has been used from other sources has been properly acknowledged.

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ABSTRACT

A large number of pedestrian are getting killed in traffic Road crash each year. It is known, pedestrian crash are more severe than other types of crashes. A review of pedestrian crash data shows that most of the crashes occur while the pedestrian was crossing the road. The pattern of pedestrian behavior when crossing the road is dependent on various factors such as traffic condition, pedestrian characteristics and vehicular characteristic. All these factors are pedestrian exposure to risk in relation to pedestrian crossing behavior. In this research, the main focus is leveraged on the study of gap acceptance and crossing behavior of pedestrians at signalized intersections. Because of the common and widely observed illegal crossing decisions of pedestrians at signalized intersections, it is interesting to investigate gap acceptance of pedestrians on their decision to cross at intersections. As a result, this paper has tried to cover crossing behavior of pedestrians such as: gap acceptance, compliance with signal, pedestrian-vehicle interaction in mixed traffic condition and identifying influencing factors.

For the study, a field survey was carried out at signalized intersection in Addis Ababa, Ethiopia. The collected data, from the three signalized intersection Saris, Bole Mikael and Shola, consists of gap data point which include both accepted and rejected vehicular gaps and probable factors that may influence crossing . Pedestrian road crossing behavior at the intersection selected has been modeled by the size of vehicular gap accepted by using multiple linear regression (MLR) technique. Choice model has been developed to capture the decision making process of pedestrian.

The result from the survey showed that pedestrian noncompliance arise with signalized rules because allocated green time is small, there is no facility assigned where they can avoid conflict and or being in a hurry. The MLR model shows pedestrian speed, vehicular speed, rolling gap, pedestrian speed change, driver yielding behavior, type of vehicle, gap type, age and lag or gap are important factor on size of gap acceptance. For the size of gap model the independent variable explain the dependent variable 72.7 % (R^2) and the critical gap was found to be 4 sec. The choice model represent the data 94.2%. And from model Pedestrian make the decision to cross or not based on four major factors size of traffic gap, the vehicle speed, waiting time, and the frequency of attempts before crossing. These inferences are helpful for pedestrian facility design, policy toughening and create awareness for different stake holders.

Key Words: Pedestrian, road crossing behavior, gap *acceptance*, *signalized intersection*

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LIST OF ABBREVIATION AND ACRONYMS

H₀- Null hypothesis

H₁-Alternate hypothesis

Q-Question

Eqn-Equation

OR-odds ratio

CI-confidence interval

E-margin of error

ANOVA-Analysis of variance

Sig.-significance

H-L-hosmer-lamenshow goodness of fit

MUTCD – Manual on Urban Traffic Control Devices

R – Pearson correlation coefficient

TPMO - Transport Programs Management Office

MoT-Ministry of Transport and

AACRA -Addis Ababa City Roads Authority

CHAPTER ONE – INTRODUCTION

1.1. Introduction

Walking is one of the most important modes of transport. People tend to choose walking for multiple purposes such as: to visit a nearby neighbor's house, for errands, to go to school, markets and formal meetings (e.g. business meetings). In addition, people also consider walking for recreational activities, health benefits or for the pleasure of enjoying nature and its wonders. (Lindelöw, D.2016). Moreover, every journey starts and ends with walking.

The decision of people to choose walking as a mode of transport or not depends majorly on the pedestrian demographics as well as socioeconomic characteristics of the locale. It is because the net benefit of walking has to be quantified and be found to be larger than any other competing alternative modes, as far as mobility is concerned with choosing the low cost and convenient mode of transportation. For convenience of walking, the pedestrian level of service on walkways and the suitability of pedestrian crossing locations are given due attention. Moreover, if we may think in larger scale, pedestrian crossings are critical elements in the traffic system from both pedestrian (primarily safety) as well as traffic flow (primarily interruption to flow) point of view.

Pedestrian crossings are usually built around road intersections. The road safety crashes at these locations has been a major concern in urban traffic operations for long time now. Crashes involving pedestrians is a major traffic safety problem, as pedestrian fatality is very highly likely to occur at the places of such crashes. In developing countries, many factors have indirect and direct causes for such crashes, such as: high population density, rapid modernization and urbanization, and lack of compliance to traffic regulation by both driver and pedestrians.

Traffic crashes involving pedestrians usually occur at locations where pedestrians cross the road, and precisely at places where certain pedestrians do illegal crossings (Chih-Wei,2016). But nonetheless, these crashes may also occur at designated pedestrian crossing facilities as well. As a result, pedestrian crossing behavior is essential to investigate as it has high correlation with the vulnerability of pedestrians to traffic crashes. It is primarily better characterized by the gap acceptance theory/model which reasonably assumes that each pedestrian has respective critical

gap to cross a road. It is known that the distance between a vehicle and a pedestrian appear to influence the minimum gap often accepted by pedestrians.

In Ethiopia, even though the mobility of people has increased due to the economic growth achieved in recent years; the adverse consequences of pedestrian crashes have become a more apparent problem. Since most people commute by walking, road crashes have always been severe (sometimes fatal) because road crashes usually involve pedestrian crashes. Classifying countries according to the share of their traffic fatalities in their total deaths, Ethiopia ranks number 22 among 193 countries with a share of 4.27 percent According to the World Health Organization (WHO) statistics for traffic fatalities, pedestrians, cyclists and motorcyclists have a share of 50 percent in all traffic fatalities in the world (Chan, 2013). In July 2018, The Addis Ababa police commission report data showed that yearly on average, 2950 pedestrians are victims of traffic crash in Addis Ababa city alone.

For most of the time, traffic researches and studies focus on vehicles and drivers, thus the concerns for safety, comfort and convenience for pedestrians always comes next while designing roadways. The development of sound models that represent the behavior of pedestrians while crossing road intersections can contribute in improving the efficiency and safety of pedestrian at crossing facilities. While crossing, pedestrians select an appropriate gap in vehicular stream depending on their demographic, vehicular and pedestrian behavioral characteristics which will be represented by the model.

In this research, the main focus is leveraged on the study of gap acceptance and crossing behavior of pedestrians at signalized intersections. Under ideal conditions, studying gap acceptance of pedestrians does not make sense to do at signalized intersections, since pedestrians are usually given green times to cross safely. But for common and widely observed illegal crossing decisions of pedestrians at signalized intersections, it is interesting to investigate gap acceptance of pedestrians on their decision to cross at intersections. As a result, this paper has tried to cover crossing behavior of pedestrians such as: gap acceptance, compliance with signal, pedestrian-vehicle interaction in mixed traffic condition and identifying influencing factors.

1.2. Statement of the Problem

The study by (Haile, 2018) gave the intuition that 62 % of total trips in Addis Ababa are made with walking but despite this figure, most streets lack adequate designated crossing facilities. It is customary to see more pedestrian regularly on the road from morning to night. As more pedestrians exist on the road, more people are exposed to the vehicular traffic (especially when crossing). In a city where inadequate facility and system (pre timed light) exist for the existing traffic flow, the competition of pedestrians and vehicles is inevitable, leading to pedestrian-vehicle conflicts.

Most of the irrational pedestrian behaviors on the roads are primarily from the carelessness of the individual regarding the direction, speed and timing of crossing decision and lack of proper road discipline to govern the behavior of pedestrians. Lack of civility of some pedestrian as a result of first time exposure (for instance, individuals who migrated to Addis Ababa from the countryside) on the road will increase the risk of pedestrian crashes. Moreover, as evidenced in the past with the number of vehicles increasing, the probability of road traffic crash would be very high and it is highly likely to expect pedestrian crashes as well.

This research mainly focuses on gap acceptance and crossing behavior of pedestrians at road intersections with an operating pre-timed traffic signal. The pedestrian's unwillingness to wait for the red light to signal for the traffic or to wait for the occurrence of safe gap is observed and quantified. In addition, it is also evident that installing signal and crosswalk markings create a false sense of safety, which in turn tend the pedestrians to take more dangerous gap in the traffic.

Therefore, assessing pedestrian crossing and gap acceptance behaviors at signalized intersections can result in a more effective signal operation, and can further allow future development and evaluation of efficient strategies to deal with irrational crossing behaviors of pedestrians.

1.3. Research Question

Many research questions can be raised and asked in relation to the picked research area. The first and foremost doubt is around the necessity of gap acceptance studies at signalized intersections where pedestrians are expected to wait for a 'Walk' signal to show and pedestrians cross the road while the conflicting traffic has stopped. It definitely makes sense to study such studies at unsignalized intersections and certain road segments of interest. But nonetheless, it is highly essential and beneficial to study the irrational crossing behaviors of pedestrians at signalized

intersections in Addis Ababa, in complying to this widely observed pedestrian crossing characteristics. Generally, the following and more questions can be asked:

- ✚ What are the key factors affecting crossing behaviors of pedestrians at selected signalized intersections in Addis Ababa?
- ✚ How is the pedestrian gap acceptance behavior at selected signalized intersections in Addis Ababa?
- ✚ What is the minimum gap accepted by pedestrians at selected signalized intersections in Addis Ababa?
- ✚ Is there any compliance behavior of pedestrians at selected signalized intersections in Addis Ababa?

1.4. Objectives of the Study

1.4.1. General Objectives

The general objective of this thesis is to determine the pedestrian gap acceptance and crossing behavior at selected signalized intersections in Addis Ababa.

1.4.2. Specific Objectives

The specific objectives are:

- ✚ To identify factors that affect gap acceptance and crossing behavior at selected signalized intersections in Addis Ababa,
- ✚ To model pedestrian gap acceptance or selection behaviors,
- ✚ To determine the critical gap acceptance of pedestrians at selected signalized intersection in Addis Ababa and
- ✚ To assess pedestrian compliance behaviors at selected signalized intersections in Addis Ababa.

1.5. Scope and Limitations of the Study

1.5.1. Scope of the Study

This research only focuses on signalized intersections in Addis Ababa with multilane (long) one stage crosswalks and to investigate the corresponding gap acceptance and crossing behavior of pedestrians.

1.5.2. Limitations of the Study

The study does not prove to tell adequate about the following issues:

- ✚ The cases of disabled pedestrian groups,
- ✚ The involvement of road traffic police in the traffic management,
- ✚ The disturbance due to considerable pavement distresses,
- ✚ The disturbance due to seasonal variation and
- ✚ The disturbance due to holidays, early closing and special events.

1.6. Significance of the Study

The study is conducted to determine the behavior of pedestrians in accepting gaps at signalized intersections (i.e., which is an irrational behavior). Thus, the results will be of a great help to inform pedestrians, drivers/motorists, students and traffic engineers/highway designers.

The results of the study shall provide benefits to the following beneficiaries:

1.6.1. Pedestrians

This study is concerned about investigating pedestrian behavior and associated with risk taking on selected locations. The occurrence of a possible crash will cause congestion, which leads to discomfort to people, drivers and pedestrians as well, in addition to loss of life and injury. The results of this study will provide details on the locations' safety (to take precaution) and traffic regulations. Thus, the knowledge will create awareness especially to those who uses the crosswalk during green (pedestrian red).

1.6.2. Drivers and/or Motorists

The study will provide information and other details on the location. Furthermore, the knowledge about the signalized location will help drivers and motorists to practice safety and responsible driving speeds to prevent future crashes.

1.6.3. Traffic Engineers and/or Highway Designer

The study will be able to contribute additional knowledge for the enhancement of signs and other traffic signals that are needed on the signalized intersections. Moreover, a keen designing and/or development is a key for the comfort, convenience and safety of both pedestrians and drivers. And it will give a high attention for designers to consider pedestrian behavior in signalized intersection design and timing.

1.6.4. Government Agencies

Addis Ababa Transport Programs Management Office (TPMO), Ministry of Transport (MoT) and Addis Ababa City Roads Authority (AACRA). The study will present the results to these agencies in contributing to future innovations in highway design, policy making and planning programs.

1.7. Organization of the Thesis

This study is organized in five chapters. Chapter one describes the general background of the study, statement of the problem, research question, the general and specific objectives of the study and scope and limitation of the research. Chapter two deals with literature review including definition of pedestrian, factors affecting crossing decision and gap acceptance, types of gap and modeling pedestrian behavior. Chapter three describes research methods and materials including description of the study area, data analysis methodology, sample size determination, study design, data collection methodology, and data extraction methodology. Chapter four deals with analysis and discussion, detailed data analysis and discussion of results is presented in this chapter. The last chapter of the study is conclusion and recommendation main findings of the study along with recommendation for future studies are presented in this chapter.

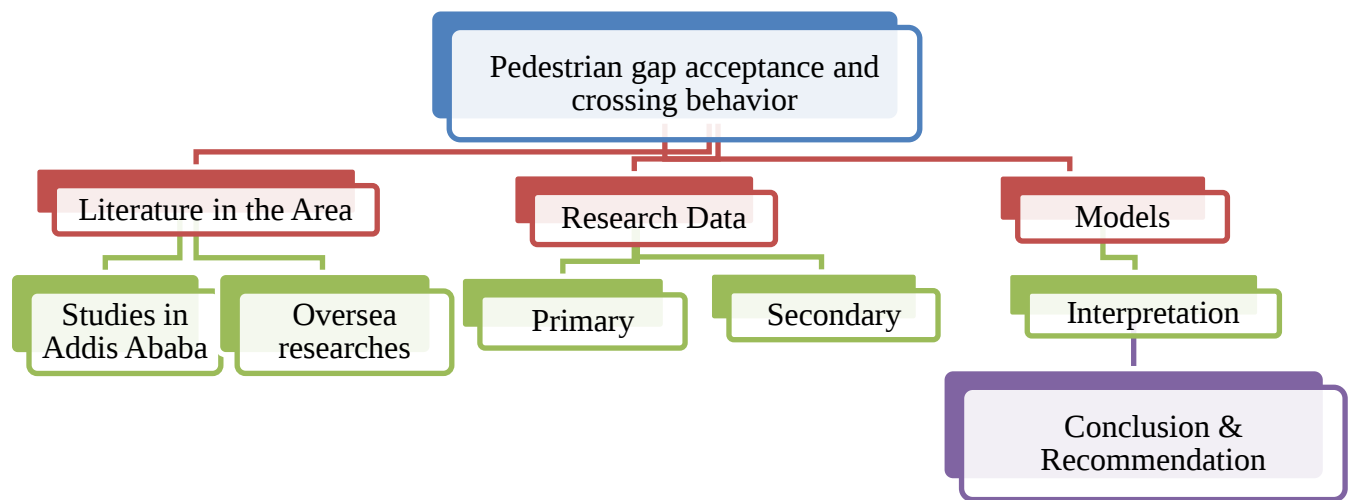


Figure 1.1: Organization of the thesis

CHAPTER TWO – LITERATURE REVIEW

2.1. Introduction

The population growth of pedestrians in major urban and suburban areas of Ethiopia is increasing at an alarming rate. This growth can be seen to be parallel with the rapid increment of pedestrian in Ethiopia. In relation to this, we can deduce that “The increment in number of walk commuters have a huge effect in road crash” (Tulu, 2015). On the other hand, pedestrians are the most vulnerable to traffic crash involving pedestrian crashes, whenever they are at roadway intersections and pedestrian crossing facilities (Li, 2013). With the existence of high traffic congestion in Ethiopia, particularly in the capital Addis Ababa, this situation can lead to conflicts between the movement of vehicles and pedestrians. These conflicts sometimes can make crashes involving pedestrian crashes.

In this chapter, a comprehensive literature review is presented. The formal definition of pedestrians along with the discussions of their different walking and behavioral characteristics are presented. Moreover, measurement metrics and characteristics of pedestrians with respect to accepting gaps at intersections and pedestrian crossing facilities is given due attention – which has motivated the main theme of this thesis.

2.2. Pedestrians

2.2.1. What is a pedestrian?

Walking is one of the most usual ways of moving from place to place for a healthy and able to walk person. Such person can be usually termed as pedestrian. Basically, under formal definition, a pedestrian is usually defined as “a person who goes on foot or who utilizes assistive devices to facilitate them to walk”. Each type of transportation mode used for mobility also involves some movement on foot, for the objective of walking to and from stops, terminals, drop off and pick up points.

Moreover, in other perspective, walking can be categorized as one of the main modes of transport (when we look at its popularity in heavily congested cities) and it is healthier for human society (which makes it highly beneficial) (Kadali & Perumal, 2012). As a result, we can claim that

walking pedestrians are one of the key elements in the transportation system traffic and arrangement, especially in urban traffic.

To mention some of the pedestrian parameters that are essential to be considered in the design and planning of pedestrian facilities include (but not limited to): the pedestrian walking speed, pedestrian flow, density, and pedestrian space. In addition, pedestrian perceptions need to be taken into consideration in the planning of pedestrian facilities such as: the current (actual in situ) operating speed, density, and pedestrian space, that are used for theoretical planning.

Another important parameter in characterizing pedestrian movements is decision making. The decision making of pedestrians to cross the road is influenced by two factors namely: internal factors (age, gender, physical condition, psychological condition, etc.) and external factors such as traffic conditions (Purwanto & Siregar, 2019).

2.2.2. Crossing Behavior of Pedestrians

Previous researches have made impactful theoretical and methodological contributions to a practical understanding of an individual pedestrian's behavior and the interaction between the driver and the pedestrian at pedestrian crossings (Sun et al, 2011). Pedestrians arriving at a pedestrian crossing (designated or not) look for acceptable gaps between vehicles in the traffic stream. They either accept or reject such gaps in their decision process of making the move to either cross the road or not.

Pedestrians' street-crossing behavior is the outcome of interaction between pedestrians and vehicles. We first introduce the notation that describes traffic flow, pedestrians and traffic signal setting respectively. (Li, 2013) argues that, when vehicular speed is capped by a relatively low speed limit in urban areas (especially in the city/town centers), the most important traffic variable that affects pedestrians' street-crossing behavior is vehicle time headway because it characterizes the gap between two consecutive vehicles and hence provides a measure of opportunity for a pedestrian to cross the street during the red-man phase.

2.2.2.1. *Why study pedestrian crossing behavior?*

Most literature that studied pedestrian crossing behavior indicated that environmental designs and urban forms could play a very crucial role in pedestrian travel behavior. A proper design of facilities can encourage walking without compromising safety and convenience (Hine, 1996).

Besides, improvements in safety and comfort for pedestrians can be obtained without major side effects on vehicle travel (Carsten, Sherborne and Rothengatter, 1998). Also it is evident that pedestrian safety can be affected by changes in the signal settings at signalized crosswalks (P., 1989). A study by (Forsythe, M. J., & Berger, 1973) presented the results of interviews with pedestrians crossing unsafely during DONT WALK signal indication or pedestrian red interval. It was reported that the reason for unsafe crossing was mainly time-related.

2.2.2.2. *Why there is lack in compliance with pedestrian signals?*

A need to hurry or a desire to keep moving was the main reason behind the lack of compliance with pedestrian signals. The major responsibility of providing physical facilities that encourage pedestrian travel and help protect the pedestrians resides with traffic engineers. Such facilities include roadways, sidewalks, TCDs, medians, etc. Pedestrian friendly and safe environments involve separation of pedestrian and vehicle traffic, control of flow of pedestrians and vehicles, improvement of visibility, proper communication through signs, and assistance of pedestrians with special needs (Sisiopiku & Akin, 2003).

2.2.3. Factors Affecting Pedestrian crossing

Pedestrian crossing behavior usually gets influenced by various factors related to: pedestrian characteristics, pedestrian movements, traffic conditions, road conditions and environmental surroundings. (Rosenbloom et al, 2008) observed unsafe crossing behavior of children such as: not stopping at the curb, not looking before crossing, attempting to cross when a vehicle is nearing and running across the road. On the other hand, female pedestrians are observed to accept more gaps and less risk compared to male pedestrians.

(Oxley *et al.*, 2005) have done experimental studies on the effect of age of pedestrian in gap selection. The study reported that, for all age groups, gap selection is primarily based on vehicle distance and speed. (Hamed, 2001) presented that approaching traffic volume and vehicle speeds are instrumental in determining the pedestrian's waiting time (delay) and the number of crossing attempts. Pedestrians, who accept higher risk, have to cease their waiting time, whereas pedestrians, who are likely to lower the risk, have to extend their waiting time at pedestrian crossings. (Guffey, 2009) differently reported that pedestrian's belief, motives and situational factors can affect their crossing behavior at signal-controlled crossings. Situational factors like the presence of other pedestrians and their behavior towards 'Walk' and 'Don't Walk' signs affect the

behavior of female pedestrians and traffic volume affect the behavior of male pedestrians at signalized crossings.

2.2.3.1. Frequency of attempt

Pedestrians at designated crossing facilities usually make a number of attempts before the successfully crossing the street. They carry out these attempts because they keep waiting to decide to take an acceptable and/or safe gap to cross. Pedestrians will remain waiting at curbside (except for risk takers) and make further attempts until successful. (Hamed, 2001)

2.2.3.2. Pedestrian platoon

The time spent waiting for a safer gap depends on whether the pedestrian is alone or in groups. Pedestrians tend to cross illegally (cross on red) if a member of the group initiates the illegal cross. From observations made, male pedestrians were more likely to cross on red compared to females (Lobjois & Cavallo, 2007). In addition to this, the number of pedestrians waiting in a group also affects the behavior of pedestrians in that group. Smaller groups tend to make more illegal crosses compared to larger ones.

2.2.3.3. Walking speed

In accepting gaps to cross, each pedestrian has a different perception on choosing the safest gap. Their physical characteristics affect their movement, i.e. walking speed. Taller pedestrians accept smaller gaps compared to shorter pedestrians due to them generally being able to walk faster (Al Bargi *et al.*, 2017).

2.2.3.4. Gender

Gender is one of the influential factors in many researches in making crossing decisions. (Tom and Granié, 2011) explore gender differences in pedestrian rule compliance and in gaze targets before and during crossing. Found that the temporal crossing compliance rate is lower among male pedestrians, but spatial crossing compliance does not differ between genders. Furthermore, different gaze patterns emerge between genders before and during crossing, notably as women particularly focus on other pedestrians during these two periods whereas men focus on vehicles.

2.2.3.5. *Waiting time*

A study in Dakar Studied the impact of pedestrian waiting time at an intersection on the proportion and type of pedestrian violations and dangerous crossings. Findings show that pedestrians did not want to wait more than 20–30 s to cross the road. Furthermore, the waiting time of the pedestrians varied with intersection control type, gender, age, minimum gap, waiting location, and vehicle flow. Findings of this study will help to alleviate traffic safety problems by designing an effective intersection control system (Zafri, Rony and Adri, 2019).

2.2.3.6. *Age*

(Holland and Hill, 2010) examined a simulation study using filmed real traffic. With increasing age, women were shown to make more unsafe crossing decisions, to leave small safety margins and to become poorer at estimating their walking speed. Men differed from women in that age was not a major factor in predicting unsafe crossing decisions. Rather, reduced mobility was the key factor, leading them to make more unsafe crossings and delay longer in leaving the curb. Also (Lobjois and Cavallo, 2007) experimented to study how age affects street-crossing decisions in an estimation task, with particular emphasis on how oncoming vehicle speed and a time constraint influence the time gap deemed acceptable for crossing. And found all age groups selected a shorter time gap for the higher speed. This was associated with a large number of missed opportunities for the low speed and many unsafe decisions for the high speed. In the second experiment, which had no time constraint, young pedestrians operated in a constant-time mode regardless of speed, whereas older pedestrians accepted shorter and shorter time gaps as speed increased. The results seem to indicate that the effect of speed is due to a mixed operating mode of participants, whose decisions may be based on either time or vehicle distance, depending on the task requirements and on the participant's own ability to meet those requirements.

2.2.3.7. *Speed change*

(Iryo-Asano and Alhajyaseen, 2017) explored a methodology to quantitatively model the sudden speed changes of pedestrians as they cross signalized crosswalks under uncongested conditions. A Monte Carlo simulation was applied for the entire speed profile of the pedestrians. The results showed that the model can represent the pedestrian travel time distribution more accurately than the constant speed model.

2.3. Gaps

Gap is a time interval calculated from the moment the pedestrian will cross right until the nearest vehicle moves to the point of crossing. Decisions taken by pedestrians related to crossings depend on existing gap conditions (available gaps, acceptable gaps, and rejected gaps). The critical gap is the smallest gap that can be accepted by pedestrians to cross the existing traffic conditions (Purwanto & Siregar, 2019).

2.3.1. Types of gaps

There are gaps defined by the characteristics of the site (referred to as adequate gaps and critical gaps) and gaps dependent on the conditions present at the time a pedestrian attempt to cross (referred to as available, accepted, and rejected gaps). The available gap is the gap present for a pedestrian. If the pedestrian accepts the available gap (i.e., crosses the street within that gap), then it is an accepted gap, otherwise it is a rejected gap. The adequate gap for a site is determined by dividing the crossing distance by the walking speed and adding an appropriate start-up time. However, while an approximate walking speed is used for such a calculation, the actual walking speed for each pedestrian will vary, largely depending on age and physical ability, along with the conditions present at the site. The Highway Capacity Manual (HCM) defines the critical gap as “the time in seconds below which a pedestrian will not attempt to begin crossing the street. If the available gap is greater than the critical gap, it is assumed that the pedestrian will cross, but if the available gap is less than the critical gap, it is assumed that the pedestrian will not cross.” (2) The term adequate gap is used in the Manual on Uniform Traffic Control Devices (MUTCD) and is assumed to be the same as the critical gap in the HCM.

2.3.2. Modelling of Pedestrian Behavior

Pedestrian modelling at the operational level is a complex behavioral and engineering issue. Of interest to urban transport planners are the behavioral issues of how pedestrians move in relation to other pedestrians, how they decide to cross the road, how they vary their speed; and, on the engineering side, how traffic control measures affect pedestrian travel times. Various Modelling approaches have attempted to take into account some of these elements; however, there is still no ideal method available to integrate the modeling of pedestrian and vehicular traffic. Pedestrian behavioral characteristics are much more diverse and complex in comparison with those of vehicle drivers. Parameters such as pedestrian desired speed, acceptable interpersonal distance, and

acceptable gaps in traffic for road crossing decisions, likely depend on a number of different parameters such as demography, land use, weather, and time of day. In existing models there is no simple way to set default values for these parameters.

Some of these behavioral issues have been considered by pedestrian-only modelling tools. However, pending a combined model that independently includes traffic micro-simulation behavioral algorithms with enhanced detail on pedestrian behavior, the options available to a researcher is to make best use of the traffic simulation tools available by stretching the limits of the pedestrian modelling options available. (Ishaque & Noland, 2008) discusses this in some detail and proposes one approach. A better understanding of pedestrian operational issues is necessary hopefully to improve these modelling approaches, in particular, interactions at street crossings. This is discussed below with previous studies with a view towards formulating a theory of the various decisions made by pedestrians when travelling and interacting with motorized traffic.

2.3.3. Previous studies

(Rosenbloom, 2009) surveyed the crossings while the red light was illuminated by observing the behavior of individual as well as groups of pedestrians. He found that, compared to female pedestrians, male pedestrians more often crossed the road at the red light. He also confirmed the hypothesis that pedestrians were more prone to crossing the road at the red light if they were alone at the pedestrian crossing than pedestrians waiting as a group for the green light.

(Koh & Wong, 2014) studied the gap acceptance of non-compliant pedestrians who cross during red light at seven stretches of signalized pedestrian crossings in Singapore. Video recordings were made during the evening peak hour. 188 rejected gaps and 104 accepted gaps were extracted from the recordings. The mean accepted gap of the rolling gaps was 8.4 s. For near end crossing 6.3 s of gap acceptance was observed while for the far end crossing the gap acceptance was 5.2 s, lower than the near end crossing. Logistic regression results revealed that a pedestrians' gap acceptance probability increases 1.4 times for near end and 1.7 times for far end for every 1 s increase in the time gap.

2.4. Pedestrian Studies in Addis Ababa

This research looked at several local studies with regard to pedestrians and their crossing behaviors to look for unexplored areas of interest. The work by (Admassu, 2016) aimed to investigate the

possible types of pedestrian mobilities at around a highly congested intersection in Addis Ababa. At peak hours of the day, crossing pedestrian volume and speed of pedestrian were measured to be very high as compared to movements on the walkway facilities, and in addition jay walking was the most popular one. Nonetheless, the gaps that these pedestrians took when jay walking were not studied.

The study by (Haile, 2018) gave the intuition that 62 % of total trips in Addis Ababa are made with walking but despite this figure, most streets lack adequate designated crossing facilities. It also presented that some streets with 50 – 80 km/hr operating speeds of vehicles with no provision of designated crossing facilities have made the streets to be vulnerable sites for fatal pedestrian crashes. For that reason, overpass crossing facilities were made for pedestrians to cross the streets, even though they are not that much preferred by walk commuters. The study investigated pedestrian speed, volume, v/c ratio, etc. to investigate why pedestrians don't use these overpass facilities for their crossing decisions.

(Getahun, 2018) particularly focused on assessing pedestrian crossing behavior and traffic crashes that led severe to fatal pedestrian crashes that are usually caused by illegal crossing decisions of pedestrians. The researcher detected contributing factors that directed pedestrians to go for illegal crossing decisions, which has for long been the major reason for traffic crash on the Addis Ababa ring road. Of all the traffic crashes, 75% of the crash occurred on pedestrians which 52% of the crash on the pedestrians resulted while the pedestrian attempted to cross the road. The major factor for pedestrian illegal crossing is pedestrian's improper road crossing behavior.

Therefore, after looking at previous studies (cited here and others) that studied illegal crossing behaviors at roundabouts, ring road sections and unsignalized intersections of Addis Ababa, this research was motivated to further investigate illegal crossing of pedestrians at signalized intersections. To not leave the discussion on the table qualitatively, it attempted to study measured gaps accepted by corresponding pedestrians at the crossing sites, that may lead to pedestrian crashes, if inadequate for safe crossing.

CHAPTER THREE – METHODS AND MATERIALS

3.1. Introduction

This chapter provides details of the study area, types of data required for the study, sampling techniques and the methods that were used for collecting the various data along with the tools employed. It also discusses and describes in detail the overall research procedure to analyze the data that yields answer to the research question raised in Chapter 1.

3.2. Description of the Study Area

Since the project was motivated to study signalized intersections where pedestrians do illegal crossings (meaning, crossing the intersection approach while exposed to physically conflict with a vehicle operating on green), the researcher selected road segments which had pretimed signalized intersections at the corresponding junctions, here in the city of Addis Ababa. The Study sites are randomly selected from a list of all signalized intersections, but the candidate list will be refined by excluding the sites that were considered to be significantly different (primarily according to their layout).

Therefore, the study site was chosen on merits of:

- ✚ The pedestrian volume was quite high,
- ✚ The vehicular traffic flow was continuous (i.e. there is a halt for pedestrian crossings allowing the vehicular traffic flow for longer time, that accumulates pedestrian queue),
- ✚ The pedestrian age composition is of mixed type (i.e. it evenly composes the young and elder age groups),
- ✚ The pedestrian composition also evenly comprised of either sex, fast/slow walkers etc. and
- ✚ The unavailability of adequate pedestrian crossing facilities in nearby, for a long distance.

3.2.1. Study Location

Empirical observation is essential to study the gap acceptance and illegal crossing behavior, at the signalized intersections of Addis Ababa, since conditions, behaviors and characteristics largely vary from location to location. Therefore, video data was collected at three signalized intersections under various pedestrian and vehicular traffic conditions.

The three signalized intersections selected for this study are:

- ✚ Bole Michael,
- ✚ Shola and
- ✚ Saris Abo signalized intersections.

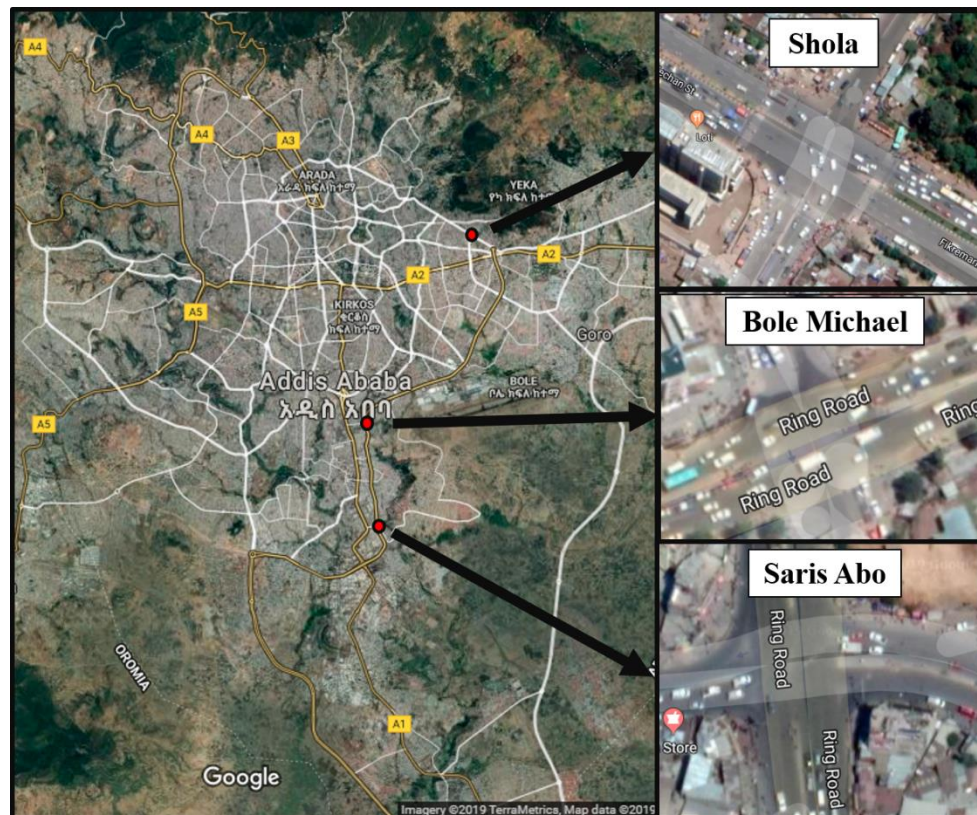


Figure 3.1: Illustration of study locations (Source: Google Maps, 2019)

3.2.2. Description of the Intersections

The detailed descriptions of the three studied intersections are presented in the following tables and notes. (photo of each site is found in Appendix B)

3.2.2.1. Bole Michael Signalized Intersection

This intersection situated in a commercial district is well observed to have high pedestrian movement and vehicular traffic from different approaches presented in Table 3.1. The high volume in pedestrians is because the intersection is surrounded by retail shops, stores and services such as: pharmacies, mobile shops, bus and taxi transport terminals, hotel, school, small local market, church, mosque, bank, tele center, beauty spa and other different kinds of shops.

Table 3.1: Bole Michael signalized intersection site description

Name of Intersection		Bole Michael		
Item No.	Approach	No. of lanes	Approach width (m)	Parking/loading unloading
1	Saris - Michael	3	11	no
2	Bole - Michael	3	11	no
3	Rwanda - Michael	2	6	no
4	Bulbula - Michael	1	5	no

3.2.2.2. Shola Signalized Intersection

Similar to the Bole Michael intersection, this intersection is also situated in a commercial district well observed to have high pedestrian movement and vehicular traffic from different approaches presented in Table 3.2. The high volume in pedestrians is because the intersection is surrounded by: a school, printing houses, police station, court, cafe, huge local market, bus and taxi transport terminals, hotel, church, mosque, bank, tele center, beauty spa and other different kinds of shops. This intersection is located near to the second largest market(Shola market) in the city.

Table 3.2: Shola signalized intersection site description

Name of Intersection		Shola		
Item No.	Approach	No. of lanes	Approach width (m)	Parking/loading unloading
1	Megenagna - Shola	3	10.5	no
2	Denebrwa - Shola	3	10.5	no
3	Lem Hotel - Shola	3	9.6	no
4	Shola Gebeya -Shola	3	9.6	no

3.2.2.3. Saris Abo Signalized Intersection

This signalized intersection is located where vehicles and trucks exiting and entering the city are passing through. The location has many shops, stores and services as the Shola and Bole Michael intersections where walking pedestrians walk to gain access to. Therefore, the intersection location is quite busy, and it is subjected to high volume of vehicular traffic and pedestrians. The study site is surrounded by a church, bus and taxi transport terminal, café, bank, pharmacy, and an LRT station on the parallel road connected to the intersection by the very short leg named Saris – Abo in Table 3.3.

Table 3.3: Saris Abo signalized intersection site description

Name of Intersection		Saris Abo		
Item No.	Approach	No. of lanes	Approach width (m)	Parking/loading unloading
1	Bole -Abo	4	11.58	no
2	Kaliti-Abo	4	11.94	no
3	Bulbula- Abo	3	9.18	no
4	Saris - Abo	2	6.96	no

3.3. Study Design

This research aims to investigate and model pedestrian road crossing behaviors at the selected three signalized intersections. Two aspects of pedestrian crossing behaviors are examined. They are: the size of traffic gaps accepted by pedestrians and the decision of pedestrians to either cross the road or not, illegally.

3.3.1. Research Data

The basic data that are required for the research are listed in the table below, with a specific description of the variables that are presumed to affect the pedestrian gap acceptance and illegal crossing behaviors, in general. Table 3.4 gives detailed descriptions.

Table 3.4: Description of variables

Data	Variable with type	Unit or code	Description
Pedestrian behavioral characteristic	Movement of pedestrian (discrete)	0 (curb) or 1 (median)	The place where the pedestrian started movement
	Waiting time (continuous)	Time in second	Time spent at the curb or median
	Frequency of attempt (continuous)	Number	Number of attempts made by the pedestrian
	Pedestrian platoon (discrete)	0 (single), 1 (two) or 2 (more than two)	Makes to accept the vehicular gap
	Gender (discrete)	0 (female) or 1 (male)	Male or female
	Age (discrete)	0 (elder), (middle aged) or 2 (young)	Visual appearance chosen by discretion of researcher. 3 groups:- Estimated age group: young (<30): 2, middle (30–50):1, elderly (>50): 0
	Pedestrian speed (continuous)	m/sec	The speed of the pedestrian while crossing the road
	Pedestrian speed change (discrete)	Yes or no	Whether a pedestrian changes speed while crossing the road or not
	Pedestrian rolling gap (discrete)	Yes or no	Whether pedestrian rolls over the available small gaps
Vehicular characteristic	Vehicle speed (continuous)	Km/hr	Speed of the vehicle at the crosswalk area
	Driver behavior (discrete)	Yes or no	Whether the driver reduces speed or changes their vehicular path, when pedestrian is already on the carriageway
	Type of vehicle (discrete)	0 (motor cycle), 1 (car), 2 (taxi) or 3 (heavy)	Motor cycle (0):- any two wheel motorized vehicles, Cars (1):- any passenger car capable of holding <= 5 passengers, Taxis (2):- minibuses and ambulances up to 12 passenger seats, heavy(3):-trucks and buses
Traffic characteristic	Gap type (discrete)	0 (near) or 1 (far)	Whether the gap is close to the curb or median.
	Accepted lag or Gap (discrete)	0 (lag) or 1 (gap)	Whether the pedestrian accepts the lag (first vehicular gap) or successive gaps
	Accepted gap size (continuous)	Time, in seconds	The time headway between vehicles that pedestrian accepts the gap of
	Gap rejected size (continuous)	Time, in seconds	The time headway between vehicles that pedestrian rejects the gap of
	Gap acceptance (discrete)	0 (rejected) or 1 (accepted)	Whether a pedestrian is accepting or rejecting a gap

3.3.2. Sample Size Determination

3.3.2.1. Sample Size for Modelling

In order to determine the sample size for the statistical analysis study groups of population (i.e. group of pedestrians crossing the road at the signalized intersections and specifically those that are non-complaints to the signalized system), it is very large or unknown exactly. Hence, for a population that is too large or precisely unknown, the sample size (n) is determined using the (Cochran, 1963:75) which is shown below,

$$n = \frac{(z^2 * p * q)}{e^2} \quad (3.1)$$

Where: n = sample size, z^2 = the abscissa of the normal curve that cuts of an area α at the tails ($1-\alpha$ equals the desired confidence level), e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q is $1-p$.

Using the commonly used value of 95% Confidence Interval (CI) which has a Z-score of 1.96 with margin of error $e = 5\%$ and standard deviation of $p = 0.05$. This would yield:

$$n = \frac{(1.96^2 * 0.5 * 0.5)}{0.05^2} = 384.16$$

Therefore, we can take 385 samples for modelling.

3.3.2.2. Data for Attitude Survey

Applying the same procedure for the pedestrian questionnaire, 385 minimum number of pedestrians will be selected randomly.

3.4. Research Method

3.4.1. Data collection

3.4.1.1. Primary Data

Primary data was collected at the study intersection areas by video-taping using camera. The traffic operation of pedestrian crossings was videotaped on a height secured above the observation area with an additional benefit that the video field of view included the intersection entire crosswalk and the traffic flow.

The data were collected during years 2018 to 2019 at the three signalized intersections (Bole Michael, Shola and Saris Abo) located in Addis Ababa on working days, except for Monday and Friday because the research wanted to avoid exaggerated traffic flow. The times of study on the other week days was from 07:00 AM to 10:00 AM, in order to capture morning peak. The weather at the times of data collection was dry and sunny (clear blue sky. Pedestrian attitude survey data was also taken in parallel to video data collection.

3.4.1.2. Secondary Data

General information about the study sites was gathered prior to the selection of site (format for conducting site reconnaissance is available in the Appendix) such as:

- + Geometric layout of intersection,
- + Median type,
- + Pedestrian crosswalk,
- + Vehicle speed limit (km/hr),
- + Number of travel lanes,
- + Pedestrian related crashes (from traffic police),
- + Surrounding land use pattern,

The above data will be used for supporting the study and for calculation of variables such as speed of vehicles and pedestrian.

3.4.2. Data extraction

The data extracted from videotape focused on those pedestrians who intended to cross the street. More specifically, only those pedestrians that crossed the street, either immediately or after several attempts (i.e. accepting the first traffic gap available or rejecting several gaps before crossing) were captured. Pedestrians who abandoned the crossing task after some attempts, and sought for a crossing opportunity elsewhere, were not included in the sample.

Particular care was taken in that study data were recorded only during the green signal of the nearby traffic lights, so that pedestrians would make an unprotected crossing by interacting with the incoming vehicles.

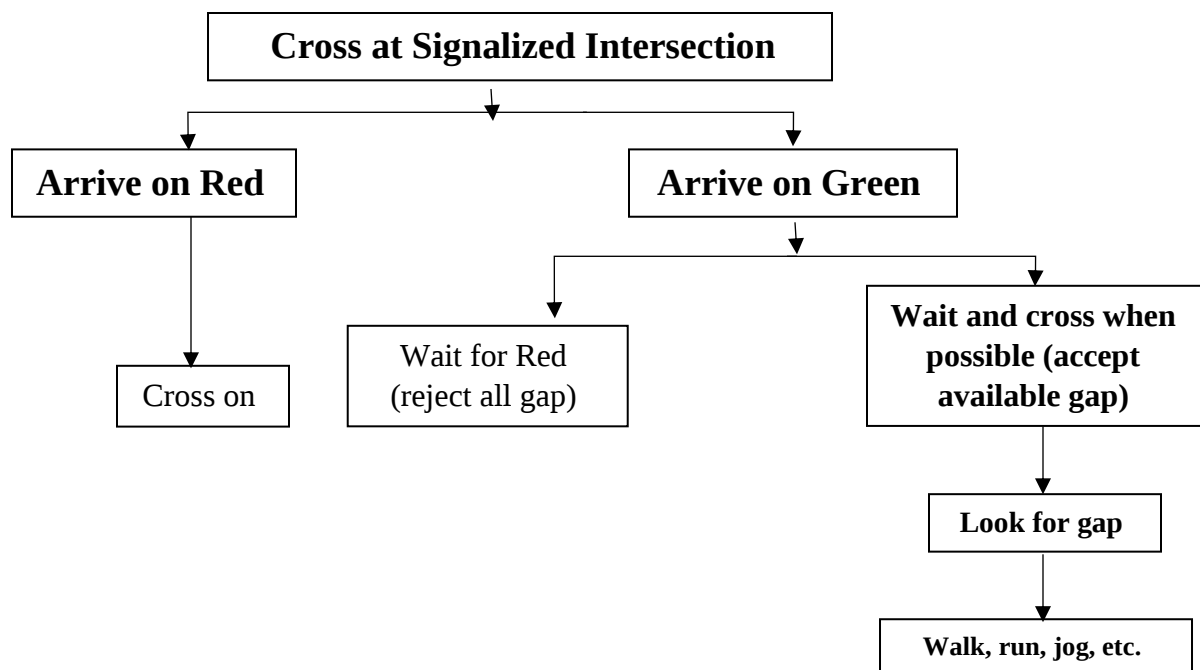


Figure 3.2: Frame work for the choice of study groups

The continuous variables are extracted depending on their unit of measure. The traffic gap accepted was calculated as the difference between two time points: at the first point, the leading car crossing the cross way when pedestrian is just ready to set foot on the street, in the second point, the next vehicle arriving after the pedestrian crossed the road any other gap not accepted to the light turn red is considered rejected gap. Gap type and whether a pedestrian accepted lag or gap was also extracted in relation to rejection and acceptance. The waiting time of the pedestrian started when someone approached the pavement until he set foot on the street to accept the available gap.

This extraction also recorded the frequency of crossing attempt a pedestrian makes due to the increase in waiting time at the curb or median. Pedestrian rolling gaps were also extracted. The speed of the incoming vehicle was measured at the moment when the pedestrian just started to cross and was calculated by dividing the distance between the two virtual lines by the time the vehicle took considered to be constant during the pedestrians crossing time. Type of vehicle and driver behavior whether he/she yield or change direction or speed were also captured. Pedestrian speed was calculated by dividing the length of the cross walk and time a pedestrian took to cross.

From each snapshot, individual characteristics were collected, which include pedestrian gender, age, speed change and whether he/she was accompanied by another pedestrian.

3.5. Research procedure

The main emphasis of this study is on gap acceptance and crossing behavior. That is determining the gap between vehicles that a pedestrian accepts or rejects at signalized intersection. The data were collected during 2018-2019 at three signalized intersection located in Addis Ababa. The weather was fine (clear sky) on the day of data collection. All road users who entered the observed sites were recorded on video, but only the pedestrians who approached the intersection during red light phases and traveled through the intersection were coded. The pedestrians who approached the intersection during the green light were not valid samples and were excluded in this study.

The video camera was installed at the selected signalized intersection in such a way that it captures the pedestrian crossing characteristics starting from the curb to the finished crossing as well as the approaching vehicle. The crossing movement of pedestrian and approaching vehicles at each location were captured for three hours. Later these data were played using KM player to extract data by play back technique.

The way of recording the independent variables have been defined well in advance. The main independent variables and their definitions are listed in Table 3.4. The approaching vehicle movement towards the pedestrian location and pedestrian crossing maneuver were observed and the following data were extracted. Firstly, the variables of personal characteristics were gender and estimated age group. As to the age concern, pedestrians were classified into three groups: the young (less than 30 years), the middle-aged (in the 30–50 years), and the elderly (over 50 years). Secondly, the variables describing pedestrian movement information included the movement of pedestrian (whether they start to cross from the curb or median), waiting time, frequency of attempt, pedestrian platoon (whether they are alone, couple or more than two), pedestrian speed while crossing, if there was speed change or not and pedestrian rolling gap. When we come to vehicular characteristic vehicle speed, driver behavior (whether he yields or change direction), type of vehicle (based on the classification above it could be motor cycle, small car, mini bus, or heavy (bus and truck)). In addition, the situational factors included the gap accepted type; the gap accepted size and gap rejected size.

A statistical analysis was performed on the data to establish the crossing and gap acceptance behavior of pedestrian and correlation between the variables. The effect of selected variables on the pedestrian road crossing behavior at intersection is modeled with the help of multiple linear

regression technique. In the model the accepted vehicular time gap size by pedestrian will be estimated with pedestrian behavioral characteristics.

The probability of accepting vehicular time gap was modeled with the choice model technique. The purpose of modelling pedestrian crossing decision is to develop a linear function of the selected independent variable. The binary logit model would provide either accept (which is coded one “1”) and reject (which is coded zero “0”).

The critical gap was estimated using raff graphical method for estimating by graphing the Frequency of rejected data and gaps accepted. Crossing these two curves gave a value of t sec for a critical gap.

For the survey was conducted among pedestrians using questionnaire which is included in the appendix part (Appendix A). The researcher would first explain the purpose of the survey to the pedestrians. Then respondent felt the questionnaire. In order not to affect the research the questionnaire was given prior to crossing.

SPSS statistical software was used to create a file containing the responses from each questionnaire. This package has the capability to perform statistical analysis as well as produce graphs and data summaries. Each survey form was coded to a single row and a serial number will be assigned in the first column as tracking ID. In order to get enough sample at intersection pedestrian selection for questionnaire will be random.

3.6. Model framework

The effect of selected variables on the pedestrian road crossing behavior at signalized intersection is modeled with the help of multiple linear regression technique. In this model, the minimum accepted vehicular time gap size by pedestrian was estimated with pedestrian behavioral characteristics. The probability of accepting vehicular time gap was modelled with discrete choice model technique. In discrete choice models, instead of increase or decrease in gap value like in MLR model, it is regressing for the probability of a categorical outcome. In simplest form, it means that considering a binary outcome variable i.e., pedestrian accepts available gap or rejects in terms of probability. The behavior of the pedestrian can be predicted by choices made with different available gaps with the binary logit model by discrete choice modelling technique. In both the models, the functional relationship between input and output variables can be easily represented.

3.6.1 Multiple Linear Regression model (MLR model)

The MLR model is useful for finding out the accepted gap size for pedestrians. The minimum pedestrians' gap acceptance value is represented by a regression model. The collected vehicular gap data is with an accuracy of 1 second. The pedestrian may reject more number of available small gap size values and they may accept higher gap size values. To develop the minimum gap acceptance model, a normal regression was selected by considering that pedestrian accepted gaps which followed a normal distribution. The accepted gap sizes are best fitted by a normal distribution. The general model framework is given below:

$$\text{Gap} = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \dots + \beta_n X_n \quad (3.2)$$

Where Gap= accepted gaps; X_{i-n} = explanatory variables; β_{1-n} = are estimated parameters from the model; β_0 = constant.

3.6.2 Binary Logit Model (BL Model)

In this study, the pedestrian decision-making condition is described by the binary logit model (BL Model). The probability of selecting an alternative (accept/reject) is based on a linear combination function (utility function) expressed as:

$$U_i = \alpha_i + \beta_{i1} X_1 + \beta_{i2} X_2 + \beta_{i3} X_3 + \beta_{i4} X_4 + \dots + \beta_{in} X_n \quad (3.3)$$

Where U_i =the utility of choosing alternative i;

i= the alternative (accept/reject)

n= number of independent variables;

α = constant and

β = coefficients.

The utility of alternative 'i' has to be transformed into a probability in order to predict whether a particular alternative will be chosen or not. The probability of choosing alternative 'i' is then calculated using the following function:

$$P(i) = 1 / [1 + \exp(-U_i)] \quad (3)$$

3.7. Research Material

The following list of software were used:

- ✚ Microsoft Word for text writing,
- ✚ Microsoft Excel for analysis and data analysis plot,
- ✚ SPSS 16.0 for statistical analysis and
- ✚ KM player to analyze the video by play back method.

CHAPTER FOUR – RESULTS AND DISCUSSION

4.1. Introduction

This section discusses the result and findings of the study. This section is divided into six (6) subsections. After this introduction section, Section 4.2 summarizes general qualitative observations/remarks on the research and some quantitative results. The quantitative results come from descriptive statistics on the collected data. Following these discussion, Section 4.3 presents some of the factors affecting gap acceptance and irrational crossing behavior of pedestrians is discussed. The remaining discussions are on the results from Critical Gap, Model Framework and Pedestrian Attitude Survey presented in Section 4.4, Section 4.5 and Section 4.6, respectively.

4.2. General observations

It is a complex task for the pedestrian, to make decision while crossing the road. Pedestrians gap selecting behavior is supposed to be influenced by pedestrian's physical characteristics, available gap size and vehicles speed. For the analysis there were a total of 4079 rejected gaps and 2014 accepted gaps extracted from the video footages at the three locations (excluding the validation data). There were almost twice as many rejected gaps than accepted gaps because many of these violators were green violators. Table 4.1 summarizes all the frequency the minimum and maximum value of potential factors that may affect crossing behavior of pedestrian.

As observed from the Table 4.1 the values for Skewness and the Kurtosis indices are very small which indicates that all the variables most likely do not include influential cases or outliers. Skewness statistics provide preliminary information about the existence of outliers. Skewness values outside of -1 and 1 suggest that outliers may be present. The report shows that skewness values for all regions fall within -1 to 1 range, suggesting no outliers. We can examine box plots to confirm these in section and appendix part.

Of the 6093 valid observations, 2014 (33.05%) pedestrians accepted the traffic gap. The average accepted gap size of all samples was 3.81sec, with a standard deviation of 2.00 sec. The maximum accepted gap size was 9sec and the minimum was 1sec. The latter means that people cross the street without waiting. The estimation of the waiting duration with censored data will be discussed later means that pedestrians sometimes do not wait for all the lanes to be completely clear before

stepping onto the road. This typically occurs when the approaching vehicle is in the outer lane or far side (relative to the pedestrian).

Table 4.1: Descriptive Statistics of Extracted Variables

	Descriptive Statistics						
	Minimum	Maximum	Mean	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Movement of pedestrian	0	1	0.51	-0.038	0.05	-2.001	0.10
Waiting time	0	124	23.26	1.119	0.05	0.093	0.10
Frequency of attempt	0	5	0.96	1.313	0.05	1.079	0.10
Pedestrian platoon	0	3	1.68	-1.748	0.05	1.809	0.10
Gender	0	1	0.6	-0.408	0.05	-1.836	0.10
Pedestrian speed	0.85	3.81	1.9032	0.27	0.05	-0.84	0.10
Pedestrian speed change	0	1	0.59	-0.351	0.05	-1.879	0.10
Pedestrian roller gap	0	1	0.28	0.967	0.05	-1.066	0.10
Vehicle speed	2.14	10.67	5.1398	0.371	0.05	-0.684	0.10
Driver behavior	0	1	0.67	-0.727	0.05	-1.472	0.10
Type of vehicle	0	3	1.45	1.071	0.05	0.021	0.10
Gap type	0	1	0.41	0.357	0.05	-1.874	0.10
Accepted lag or gap	0	1	0.57	-0.283	0.05	-1.922	0.10
Age	0	2	1.48	-0.664	0.05	-0.515	0.10
Gap accepted size	1	9	3.81	0.125	0.05	-0.758	0.10

The pedestrians anticipated that the lane would clear by the time they reached it and they used a partial gap (known as “rolling gap”) to cross the street (Brewer et al.,2005). In other words, there was a separate gap for each lane of traffic as the pedestrian proceeded across the street. These kinds of behaviors are considered as high risk. This descriptive statistic cannot reflect the exact gap accepting behavior because it doesn’t take the censored data into account.

4.3. Factors Affecting Pedestrian Crossing Behavior and Gap Acceptance

To find the impact of the pedestrian characteristics, vehicular characteristic, and traffic condition on the pedestrian crossing behavior and gap acceptance, various parametric, and non-parametric statistical tests were carried out.

For conducting those tests, first, the outlier values of all continues variables (waiting time, frequency of attempt, pedestrian speed, vehicular speed and gap accepted and rejected size) were checked using a Skewness and the Kurtosis indices. As shown in Table 4.1 the values for Skewness and the Kurtosis indices are very small which indicates that all the variables most likely do not include influential cases or outliers.

4.3.1. Check Normality Assumption

The normality assumption means that the randomly collected data are assumed to be normally distributed, roughly in the shape of the normal curve. We check this assumption by examining histograms of each group. The figure shows the histogram of the gap accepted data (dependent variable) .As it can be seen from the figure the shape of the curve on the histogram approximates to a bell shape. This shows that the data is from a normal distribution.

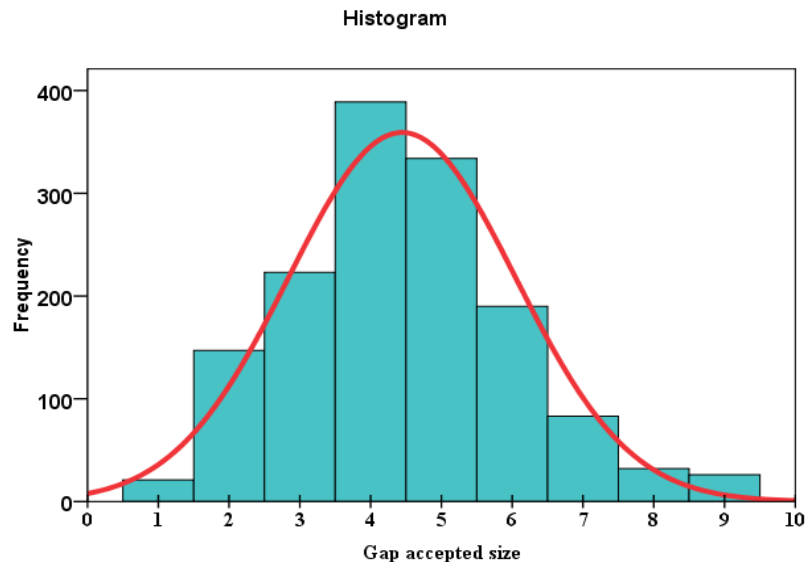


Figure 4.1: Normal Distribution Curve of Gap Accepted Size

The box plots show the distribution of the data about the median and appears to be found approximately with slight skewness to the lower side. The whiskers also show no significance difference in length which again emphasizes no significant skewness.

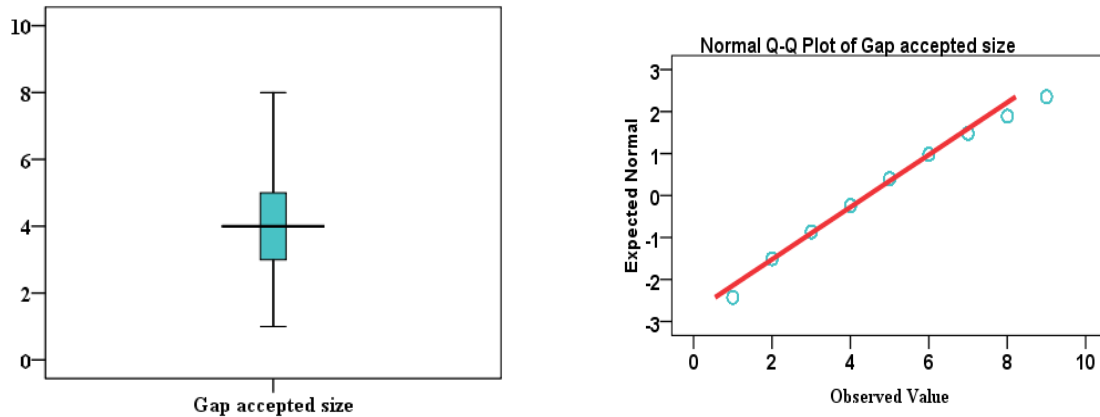


Figure 4.2: (a) Box plot of accepted gap; (b) Normal Q-Q plot of gap accepted size

The normal probability plot graph in shows the pattern of the data proximately following the straight line strengthening the conclusion that the data is from normal distribution

As the dependent variable (gap accepted size) was normally distributed, an ANOVA test was carried out for the categorical predictors having more than two outcomes to identify the influential factors; an independent t-test was carried out for the predictors having two outcomes. Levence's test was carried out to examine the equality of variances between two or more groups. If the result of this test was not significant ($p\text{-value} > 0.05$) then the variances were equal. In this case, statistics found for one-way ANOVA test were used to evaluate the relationship between size of gap accepted and predictors,

4.3.2. Movement of pedestrian differences

To test if a significant difference in size of gap accepting exists between from where the pedestrian started the cross 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 gap size acceptance exists between pedestrian crossing from median or curb

H1: significant difference in gap size acceptance exists between pedestrian crossing from median or curb

Table 4.2: Independent Sample T Test of Movement of Pedestrian

		Independent Samples Test							
		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2- tailed)	Mean Difference	95% Confidence Interval of the Difference	
Gap accepted size	Equal variances assumed	0.001	0.97	-2.661	2012	0.008	-0.238	-0.413	-0.063
	Equal variances not assumed			-2.664	2.01E+03	0.008	-0.238	-0.413	-0.063

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

H1: There is significance difference

The P value expressed as "Sig. for the Levine's test (0.97) is greater than the level of significance i.e. 0.05, failed to reject the null hypothesis and concluded that the assumption of equal variances is met. Moving on, the P value for the t-test expressed as Sig (2 tailed) = 0.008 Note that since the p-value given by SPSS is 2-tailed, you need to divide it in half for a 1-tailed test. In the above table the 1-tailed p-value would be .004, which is less than the Significance level indicating that Ho can be rejected and for the movement of pedestrian differences and conclusion is drawn as, there is significant difference in size of gap accepting between pedestrian starting from curb or median.

Table 4.3: Independent Sample T Test of different Dichotomous Variable

Independent Samples Test									
		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2- tailed)	Mean Differenc e	95% Confidence Interval of the Difference	
								Lower	Upper
Gender	Equal variances assumed	2.008	0.16	0.759	2012.00	0.45	0.069	-0.11	0.25
	Equal variances not assumed			0.753	1683.00	0.45	0.069	-0.111	0.25
Pedestrian speed change	Equal variances assumed	38.132	0.00	1.165	2012.00	0.24	0.106	-0.072	0.28
	Equal variances not assumed			1.196	1937.00	0.23	0.106	-0.068	0.28
Pedestrian Rolling gap	Equal variances assumed	67.914	0.00	26.213	2012.00	0.00	2.249	2.08	2.42
	Equal variances not assumed			23.732	863.40	0.00	2.249	2.063	2.43
Driver Behavior	Equal variances assumed	18.455	0.00	17.234	2012.00	0.00	1.531	1.357	1.71
	Equal variances not assumed			17.121	1293.00	0.00	1.531	1.356	1.71
Gap type	Equal variances assumed	86.335	0.00	-5.546	2012.00	0.00	-0.5	-0.677	-0.32
	Equal variances not assumed			-5.772	1981.00	0.00	-0.5	-0.67	-0.33
Accepted lag or gap	Equal variances assumed	103.44	0.00	23.229	2012.00	0.00	1.864	1.706	2.02
	Equal variances not assumed			24.246	2010.00	0.00	1.864	1.713	2.01

An independent t-test was carried out to examine the effect of gender, pedestrian speed change, pedestrian rolling gap, driver behavior, gap type and accepted gap lag or gap on gap acceptance size. To test if a significant difference in size of gap accepting exists between the dichotomous variable the following hypothesis was drawn and an independent sample mean test was performed. The result is presented in Table 4.3 above.

The null and alternate hypothesis for Levene's test and t test is:

For Gender

Ho: There is no significance difference in gap size acceptance between male and female pedestrian

H1: There is significance difference in gap size acceptance between male and female pedestrian

For pedestrian speed change

Ho: There is no significance difference in gap size acceptance weather a pedestrian change speed or not

H1: There is significance difference in gap size acceptance weather a pedestrian change speed or not

For pedestrian rolling gap

Ho: There is no significance difference in gap size acceptance weather role over available gap or not

H1: There is significance difference in gap size acceptance weather role over available gap or not

For driver behavior

Ho: There is no significance difference in gap size acceptance weather a driver yields or not

H1: There is significance difference in gap size acceptance weather a driver yields or not

For gap type

Ho: There is no significance difference in gap size acceptance weather the gap is far side or near

H1: There is significance difference in gap size acceptance weather the gap is far side or near

Accepted lag or gap

Ho: There is no significance difference in gap size acceptance weather the gap is lag or gap

H1: There is significance difference in gap size acceptance weather the gap is lag or gap

For gender and pedestrian speed change it was found p value for t test greater than the significance level. The null hypothesis was accepted there was no significant difference in the size of gap accepted by women and men or if there is crossing speed change or not, despite for gender Levine's test the null hypothesis failed. For the rest pedestrian rolling gap, driver behavior, accepted lag or gap and gap type the null hypothesis was rejected showing significant difference.

4.3.3. Age group differences

To understand the relationship between gaps accepted size and the age group of the pedestrian, a one-way ANOVA test was conducted. The hypothesis formulated to test if a significant difference in size of gap accepted among the age groups is:

Ho: no significant difference in exists among age groups

H1: significant difference in among age groups exists

The result of one-way ANOVA test from SPSS is presented in Table 4.4 below.

Table 4.4: The Result of One-Way ANOVA Test for Age Group Difference

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	389.147	2	194.574	50.692	0
Within Groups	7718.873	2011	3.838		
Total	8108.02	2013			

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 size of gap accepted among the age groups.

4.3.4. Difference in Crossing Pedestrians Platoon

The following hypothesis is tested in order to know if a significant difference in size of gap accepted exists among pedestrian group sizes.

Ho: no significant difference exists in size of gap accepted by among pedestrian group sizes.

H1: significant difference in size of gap accepted by among pedestrian group sizes.

Table 4.4: The Result of One-Way ANOVA Test For pedestrian platoon size Difference

ANOVA					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	91.021	3	30.34	7.607	0
Within Groups	8016.999	2010	3.989		
Total	8108.02	2013			

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 $\alpha=0.05$ level of significance there exist enough evidence to conclude that a significant difference exists in size of gap accepted among the pedestrian group sizes. A Pearson Correlation was performed between continues independent variable and the dependent variable. The result is shown in the table below.

Table 4.5: Pearson Correlation Table between Independent and Dependent Variable

Correlations					
	GAS	WT	FOT	PS	VS
Gap accepted size	1				
Waiting time	.067**	1			
Frequency of Attempt	-0.031	.506**	1		
Pedestrian speed	-.523**	-.083**	0.024	1	
Vehicle speed	.317**	.224**	.088**	-0.023	1

The results indicate a, moderate positive correlation between gap accepted size which is the dependent variable and the independent variables vehicle speed and waiting time. Negative correlation between dependent variable and pedestrian speed and frequency of attempt. But all the independent variables are significant except frequency of attempt.

4.4. Critical Gap

One method for analyzing critical gaps is to use graphical methods applied by Raff and Hart as outlined in Traffic and Highway Engineering. Frequency of rejected data and gaps accepted. In the graphical method, there are two cumulative curves, one of which is connecting the length of gap time with the number of gaps accepted less than t seconds and the other connecting t with the number of rejected gaps larger than t . Crossing these two curves gives a value of t for a critical gap as shown in Figure 4.3 below.

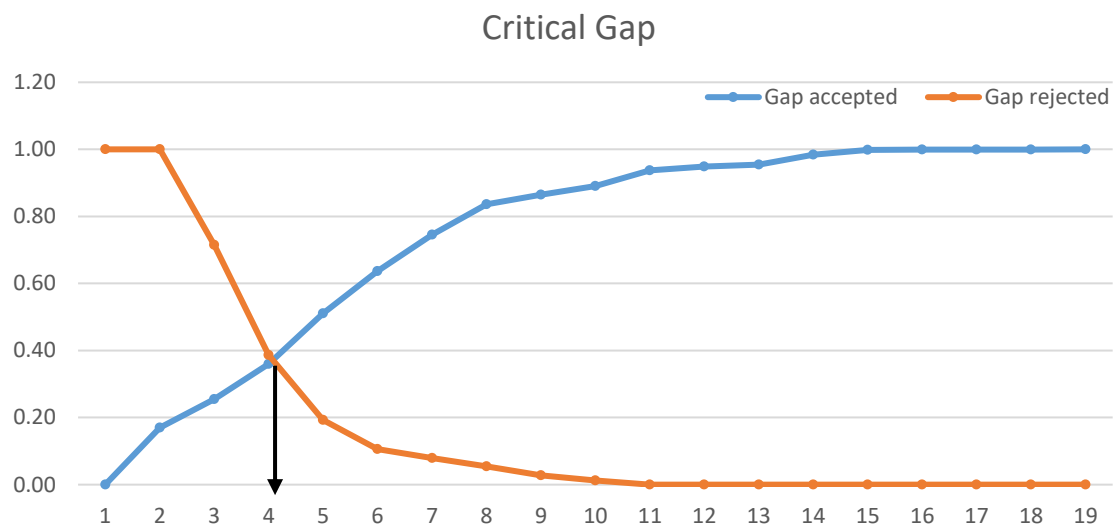


Figure 4.3: Critical gap

The calculation procedure is to find the probability value of each interval gap that exists, then poured into the form of graphs. The purpose of the probability here is the magnitude of the possibility of crossing at a time when the flow of traffic provides a certain gap value. In this study, the gap interval is set at 1 seconds from 0 to 20 seconds for the time gap.

In the graph above there are two lines, where the blue curve represents the acceptable gap probability, and the red curve represents the gap probability of being rejected. The critical gap value can be found from the point of intersection of the gap accepted and gap rejected. So the critical gap value is 4 sec.

4.5. Model Framework

The effect of selected variables on the pedestrian road crossing behavior at signalized intersections location is modelled with the help of multiple linear regression technique. In this model, the minimum accepted vehicular time gap size by pedestrian was estimated with pedestrian behavioral characteristics. The probability of accepting vehicular time gap was modelled with discrete choice model technique. In discrete choice models, instead of increase or decrease in gap value like in MLR model, it is regressing for the probability of a categorical outcome. In simplest form, it means that considering a binary outcome variable i.e., pedestrian accepts available gap or rejects in terms of probability. The behavior of the pedestrian can be predicted by choices made with different available gaps with the binary logit model by discrete choice modelling technique. In both the models, the functional relationship between input and output variables can be easily represented.

Analysis data is one of the processes to develop a model. All the data that have been collected has been analyzing for accuracy and suitability. Before beginning the analysis, there are several elements that should be recognized. This is very important to make sure the process will not affect for developing the model. A factor that must have to the identification of variables that to be included in the analysis are continuous variables and discrete variable. Data from video recording focused on the pedestrian crossing on the road either use crossing facilities or not use. The collected variables are shown in Appendix part.

4.5.1. MLR Model

4.5.1.1. *Testing Multiple Linear Regression Assumptions*

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

A preliminary analysis was run to examine the output, including findings with regard to multicollinearity, whether the model should be trimmed (i.e., removing insignificant predictors), violation of homogeneity of variance and normality assumptions, and outliers and influential cases.

In terms of model trimming the result show movement of pedestrian, frequency of attempt, pedestrian platoon, and gender are not significant. They will be removed for the rerun analysis. (Detail analysis is found in Appendix D)

-
- **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 accepted gap size, which is a continuous variable taking values in between 1 and 10 as shown in the descriptive statistics above **Section 4.1**.

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

Another multi linear regression assumption is that the relationship between the dependent and independent variables is linear. We can check this assumption by examining scatterplots or correlation plot of the dependent and independent variables.

Computing a correlation analysis in SPSS gives the following correlation matrix table is presented in Appendix part. If there exists a correlation coefficient greater than 0.7 then it is concluded that there is multicollinearity. The correlation coefficient for all variables are lesser than 0.7 so the independent variables are not strongly correlated with each other.

The results indicate a, moderate positive correlation between vehicle speed, type of vehicle, waiting time and gap type, and negative correlation between pedestrian speed, pedestrian rolling gap, age, accepted lag or gap, driver behavior and pedestrian speed change. But all the independent variables are significant except frequency of attempt, pedestrian platoon and gender.

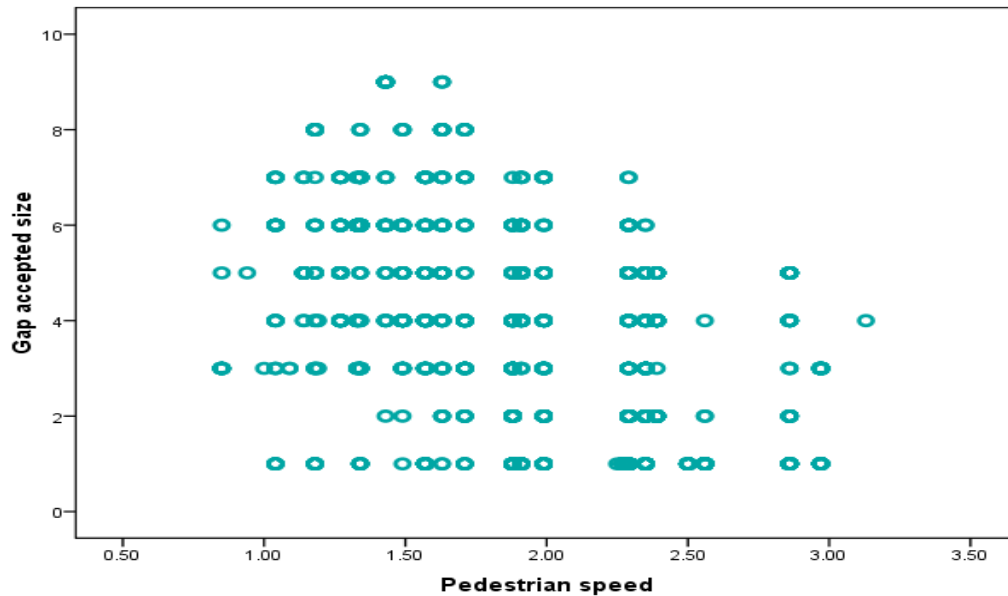


Figure 4.4: Scatter plot of pedestrian speed against gap accepted size

Sample scatter plots of size of gap accepted continuous dependent variable with the independent variable continuous variable pedestrian speed is shown in the above figure to further check linear relationship between the dependent and independent variable. Although the graphs suggest that the linearity assumption may be violated here, the research will keep self-concept in the model because its correlation with reading scores were significant. The rest of scatter plot figures are found in Appendix part.

- **Assumption 3:** multicollinearity

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 4.6 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. In order to examine whether there is a high degree of linear dependence between some of the independent variables, multicollinearity tests were carried out such as the variance inflation factor (VIF)-estimate and tolerance. If multicollinearity exists (high VIF-estimates), this may possibly mean that the

coefficient estimates cannot be partially interpreted. More specifically, according to O'Brien (2007), the VIF estimate was calculated as follows:

Table 4.6: VIF values of different independent variables

Variable	VIF
waiting time	1.25
Pedestrian speed	1.226
Pedestrian speed change	1.061
Pedestrian roller gap	1.546
Vehicle speed	1.522
Driver behavior	1.189
Type of vehicle	1.078
Gap type	1.111
Accepted lag or gap	1.562
Age	1.066

- **Assumption 4:** Homoscedasticity

We examine a scatter plot of the residuals against the predicted values to evaluate homoscedasticity (variables along the line of best fit must 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.

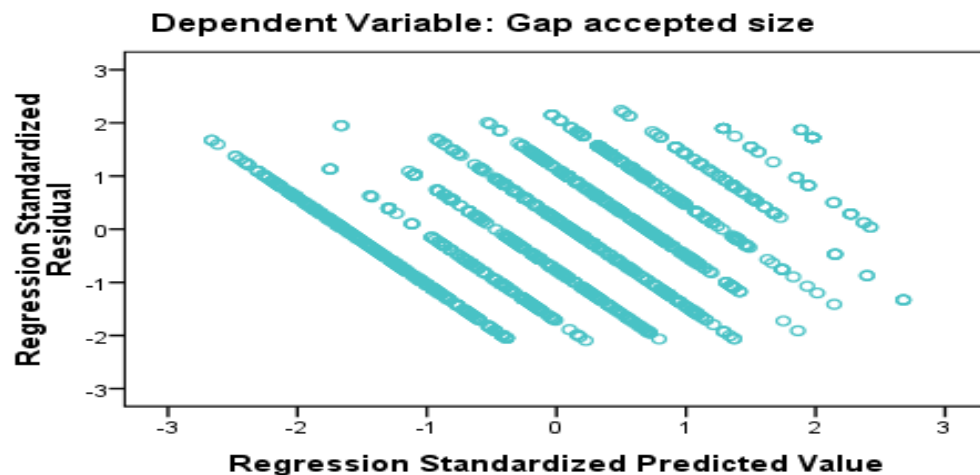


Figure 4.5: Scatter plot of the residuals against the predicted values

- **Assumption 5:** There should be no significant outlier

The outlier test aims to investigate the extreme values of a data set. 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 as seen in Section 4.2.

- **Assumption 6:** Residuals are normally distributed

The errors should be approximately normally distributed. The histogram of residuals allows us to check the extent to which the residuals are normally distributed. The residuals histogram shows a fairly normal distribution. Thus, based on these results, the normality of residuals assumption is satisfied. The mean is close to zero and the standard deviation is close to one.

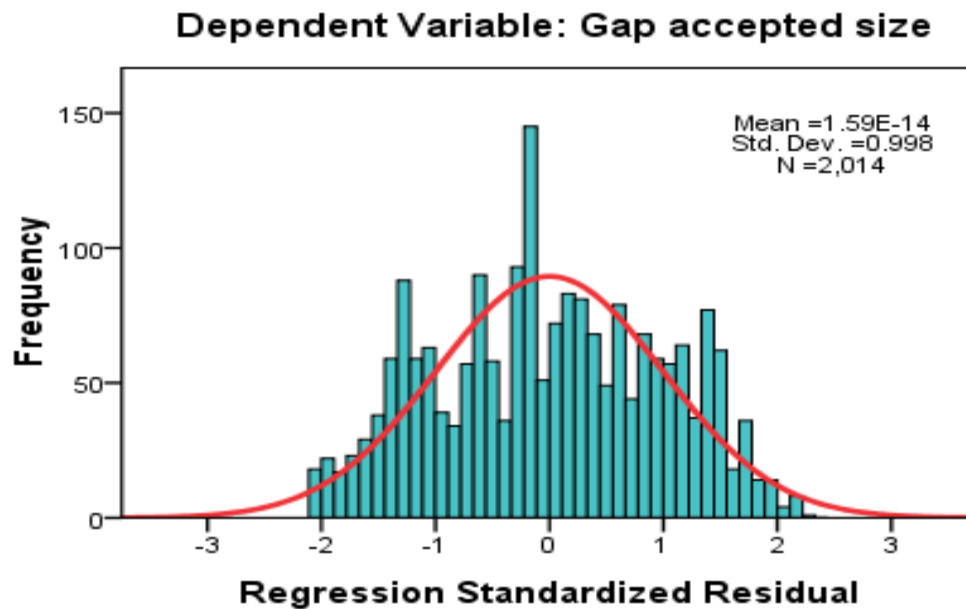


Figure 4.6: Normal distribution residuals

Also the normal p-p plot of the residuals found in the appendix 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. Hence all the assumptions for MLR are satisfied we can proceed to the analysis.

4.5.1.2. Multiple Linear Regression Analysis

After finalizing the predictors, several MLR models were developed and a best fit model was identified based on the highest R^2 value. There were several assumptions that needed to be fulfilled for multiple linear regression analysis, which were checked for the best-fitting model. The model was developed using (SPSS) software package. The accepted gap size was considered as the dependent variable and the remaining variables are independent variables.

Dependent Variable: Gap accepted size

Independent Variables: pedestrian speed (PS), vehicle speed (VS), Age (Age), Accepted lag or gap (AGOL), Gap type (GAT), pedestrian speed change (PSC), waiting time (WT), pedestrian rolling gap (PRG), Driver behavior (DB), Type of vehicle (TOV)

A partial correlation matrix was used to find the variables that are highly correlated with the dependent variable and to find the independent variables that are correlated. After a number of

trials on different groups of independent variables, the final model which has the best statistical results are presented. Among the tested parameters, significant explanatory variables were selected, and multiple linear regression analysis was performed to model pedestrian crossing speed at signalized intersections.

Table 4.7: Model summary

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.524651	0.275259	0.274899	1.708972
2	0.66878	0.447266	0.446717	1.492826
3	0.716415	0.51325	0.512523	1.40124
4	0.76048	0.57833	0.57749	1.304529
5	0.799275	0.638841	0.637942	1.207604
6	0.828518	0.686442	0.685505	1.125492
7	0.843927	0.712213	0.711208	1.078519
8	0.850563	0.723457	0.722354	1.057502
9	0.852533	0.726813	0.725586	1.051329
10	0.853678	0.728765	0.727411	1.047827

The accepted gap size was considered as the dependent variable and the remaining variables are independent variables. The MLR model represents the size of accepted gap value which includes significant explanatory variables at 95% confidence interval. This model represents the size of gap required for pedestrian to cross the road. The model calibration was considered with 80% data and remaining data was used for validation of the model. The calibrated R^2 value was found as 0.728. This means that the independent variables explain 72.7% of the variation in the dependent variable. The descriptive statistics of MLR test, t and p -values are summarized in Table 4.8. Reported t -values and p -values are the statistical test values of each independent variable.

Table 4.8: Coefficients of MLR Model

Coefficients					
	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
(Constant)	5.892	0.146		40.27	0.00
waiting time	0.012	0.001	0.186	14.315	0.00
Pedestrian speed	-1.286	0.051	-0.328	-25.439	0.00
Pedestrian speed change	0.429	0.049	0.105	8.79	0.00
Pedestrian roller gap	-0.991	0.064	-0.222	-15.368	0.00
Vehicle speed	0.292	0.017	0.248	17.243	0.00
Driver behavior	-1.278	0.054	-0.299	-23.583	0.00
Type of vehicle	0.621	0.033	0.226	18.682	0.00
Gap type	-0.234	0.050	-0.057	-4.678	0.00
Accepted lag or gap	-1.962	0.059	-0.484	-33.277	0.00
Age	-0.153	0.040	-0.046	-3.797	0.00

In terms of significance, the results show that all the variables are significant predictors of the dependent variable from standardized reading scores. No variable need to be removed from the model.

4.5.1.3. Model fitting and interpretation

$$\text{GAS} = 5.892 + .012\text{WT} - 1.286\text{PS} + 0.429\text{PSC} - 0.991\text{PRG} + .286\text{VS} - 1.275\text{DB} + 0.619\text{TOV} - 0.234\text{GT} - 1.954\text{AGOL} - 0.153\text{AGE}$$

Where:- GAS= Gap Accepted size, WT=waiting time, PS=Pedestrian speed, PSC=Pedestrian Speed change, PRG=Pedestrian roller gap, VS=Vehicle speed, DB=Driver behavior, TOV=Type of vehicle, GT= Gap type, AGOL=Accepted lag or gap and AGE = Age.

The goodness of fit measure R^2 is equal to 0.728 for this model whereas all the above variables were statistically significant at 95%. A residual analysis took place in order to test the good fitness

of the model. It was found that the residuals follow the normal distribution. Their mean value was almost zero and they had equal variances (homoscedasticity tests). It was also confirmed that the recorded gaps are normally distributed as well.

Model validation was done by inserting the twenty percent of the data that was set aside for validation. And correlation was done between the predicted and the observed value to assess how well the model represent the data.

Table 4.9 Correlation Table between Observed and Predicted Values

		Correlations	
		Gap accepted size	Predicted Gap size
Gap accepted size	Pearson Correlation	1	.673**
	Sig. (2-tailed)		0
	N	505	505
Predicted Gap size	Pearson Correlation	.673**	1
	Sig. (2-tailed)	0	
	N	505	505

** . Correlation is significant at the 0.01 level (2-tailed).

And According to correlation table above between the model output value of gap and the actual gap size, the goodness of fit of the model results are given. The result of the significance test, being less than 0.05, the correlation is highly significant, and the person value shows the model represent the data 67.3%. Therefore, the proper fitness of the model to the observations is confirmed in this test.

4.5.2. Modeling Pedestrian Crossing Decision

The purpose of modeling pedestrian crossing decision is to develop a linear function of the selected independent variable. In this study, there are four factors that been determined to influence pedestrian crossing decisions which are the approaching vehicle speed, the waiting time either in the curve or median, the frequency of attempt a pedestrian make to cross and the size of the gap between vehicles (time head way).The binary logit model will provide either accept (which is coded one “1”) and reject (which is coded zero “0”).

4.5.2.1. Analysis of Binary Logit Model

Dependent variable: Gap acceptance or rejection

Independent variable: Vehicle speed (VS), waiting time (WT), frequency of attempt (FOA) and gap size (Gsiz)

In standard regression, the coefficient of determination (R-square) values gives an indication of how much variation in y is explained by the 'model summary, table gives the values for two pseudo R-square values which try to measure something similar.

Table 4.10: Model Summary of BLM

Model Summary			
Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	540.480a	0.696	0.964

Form the above table, we can conclude that the model in block one can explain the decision of a pedestrian to accept or reject a gap between 69.6% and 96.4%.

Table 4.11: The Hosmer and Lemeshow test table

Hosmer and Lemeshow Test			
Step	Chi-square	df	Sig.
1	2.233	8	0.973

4.5.2.2. Hosmer and Lemeshow Test

In the Hosmer and Lemeshow test table it tell whether the model fit the data or not under the sig. column the P value should be greater than .05 in order to say the model does fit the data.in the above table the p value is much greater than .05 so we can say the model fit the data.

Table 4.12: Variables Value in the Binary Logit Equation

		Variables in the Equation					
		B	S.E.	Wald	df	Sig.	Exp(B)
Step 1a	WT	0.172	0.053	10.406	1	0.001	1.188
	FOA	4.211	1.638	6.613	1	0.01	67.456
	VS	-4.852	0.31	245.071	1	0	0.008
	Gsiz	0.263	0.064	17.019	1	0	1.3
	Constant	25.932	1.797	208.305	1	0	1.83E+11

4.5.2.3. *Model fitting and interpretation*

$$P(1) = \exp(y') / (1 + \exp(y'))$$

$$Y' = 25.932 + 0.172WT + 4.211FOA - 4.852VS + 0.261Gsiz$$

Where: - Y' = the utility of choosing alternative (1), WT=waiting time, FOA=frequency of attempt
VS=Vehicle speed, GAS= Gap Accepted size,

From the above Table 4.12 only four variables are significant factors in which a pedestrian makes a decision to accept or rejects available gap on the traffic stream. Among the four variables the three variables (waiting time ($\beta=0.172$), frequency of attempt ($\beta=4.211$) and gap size ($\beta=0.263$)) have positive relationship meaning, with an increase in one of the variable will increase in the probability of accepting gap or the reverse is true. The probability of accepting gap will decrease in an increases of vehicular speed ($\beta=-4.852$).

Table 4.13: Correlation between Observed and Predicted Data

<i>Correlations</i>			
		Gap accepted and rejected	Predicted group
<i>Gap accepted and rejected</i>	Pearson Correlation	1	.942**
	Sig. (2-tailed)		0
	N	6093	6093
<i>Predicted group</i>	Pearson Correlation	.942**	1
	Sig. (2-tailed)	0	
	N	6093	6093

And According to correlation table above between the model output value of gap and the actual gap size, the goodness of fit of the model results are given. The result of the significance test, being less than 0.05, the correlation is highly significant, and the person value shows the model represent the data 94.2%. Therefore, the proper fitness of the model to the observations is confirmed in this test.

4.5.3. Discussion

The pedestrian road crossing behavior is quite unpredictable at signalized location. Different pedestrian behavioral and vehicular characteristics were considered for minimum gap size model, out of which only few (ten) variables could explain the pedestrian road crossing behavior. Among the different variables waiting time, pedestrian speed, pedestrian speed change, rolling gap, vehicle speed, driver yielding behavior, type of vehicle, gap type, lag or gap and age are the most influencing variables. Variables such as movement of pedestrian, frequency of attempt, pedestrian platoon and gender does not affect the pedestrian road crossing behavior in terms of gap accepted size in this study.

Pedestrians are willing to accept vehicular gap without much endurance after arriving at the curb or median. They rely on rolling gap and driver yield behavior. Due to the increase in use of rolling gap there is a decrease in pedestrian safety. Observed from the MLR model the waiting time have positive relationship with the size of gap accepted. Despite the influence in the model as the waiting time increase the size of gap pedestrian accepts also increase. The chance of a pedestrian to taking risk will be minimized. Pedestrian speed is highly influenced by the size of gap selected by the pedestrian. as the gap size decreases the speed of the pedestrian increase and vice versa.

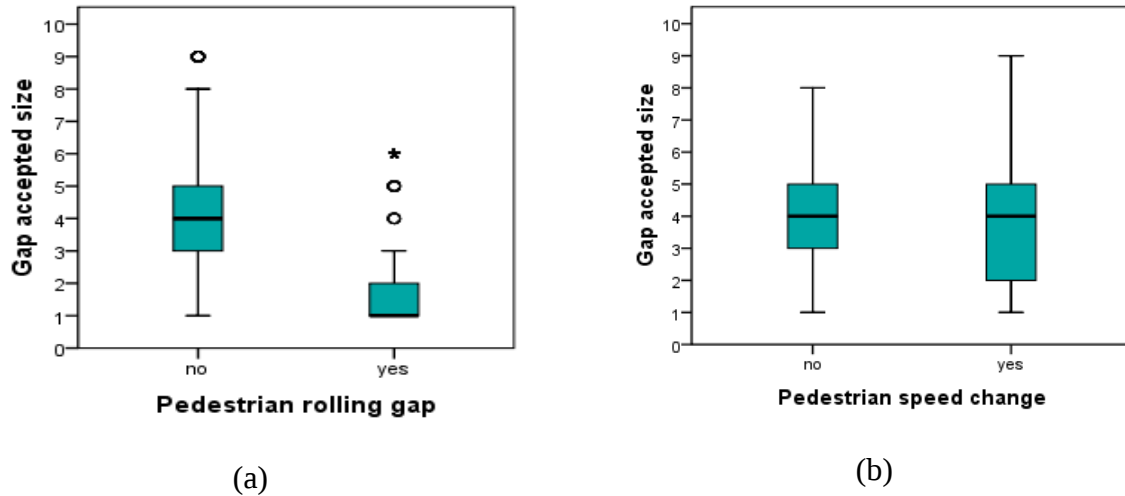


Figure 4.7: (a) Mean accepted gap size under pedestrian rolling gap behavior; (b) Mean accepted gap size under pedestrian speed change behavior

Pedestrian rolling gap behavior is the most important variable introduced in this study. While pedestrians roll over the gaps, they choose small gap sizes and, in this situation, other pedestrian tactics (speed change condition, crossing path change condition etc.) also comes into picture. Speed change condition as seen from the above figure occurs mostly when the gap is small and this also can be justified with the model because gap size and pedestrian speed change have positive relation. Figure 4.6 shows the pedestrian rolling gap behavior with available vehicular gap size. The mean accepted gap sizes in seconds without rolling and with rolling gap are 4 and 1 respectively. It can be observed that there is a drastic change in mean accepted gap size when pedestrians use rolling gap. If pedestrians choose rolling gap they are more likely to accept the minimum gap sizes. Hence, it is a statistically significant variable for the minimum gap size in the MLR model. Which also show negative (reverse) relationship between gap size and pedestrian rolling gap. While “rolling gaps” are a behavioral adaptation made by many pedestrians, the design assumption that pedestrians will wait for all lanes to clear produces a more conservative design that minimizes the potential for crashes and injuries for pedestrians who do not accept “rolling gaps.”

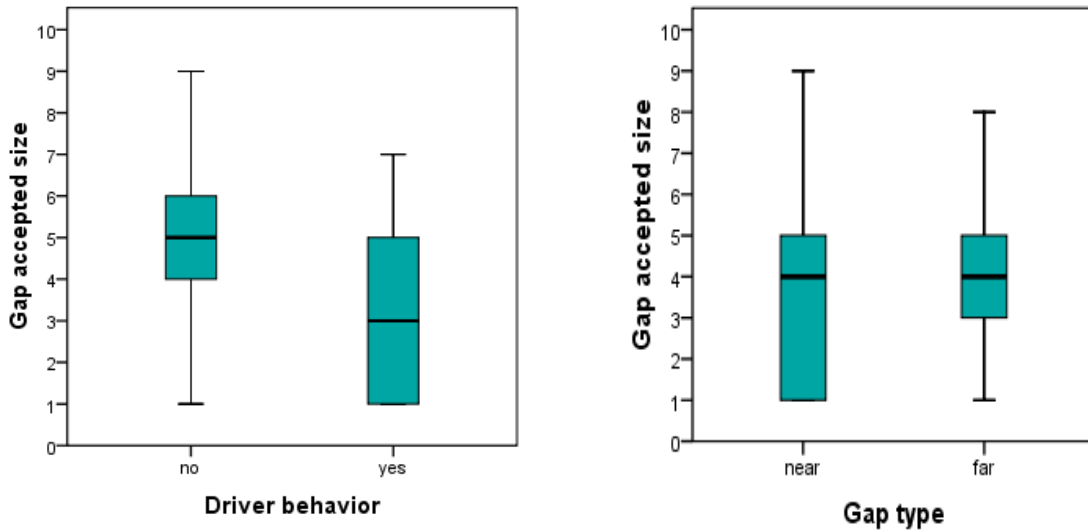


Figure 4.8: (a) Pedestrian mean accepted gap size based on driver yielding behavior; (b) Pedestrian mean accepted gap size based on gap type.

Driver yielding behavior, gap type and type of vehicle also plays a major role as observed in this study. If pedestrians are already in the middle of the carriageway, the driver yielding behavior becomes important. While pedestrians are commendably crossing the road, drivers may effectively reduce vehicular speeds or may change their vehicular paths to yield to the pedestrians. Due to this driver yielding behavior (reducing vehicle speeds or change their vehicular paths), pedestrians are accepting small vehicular gap sizes. Figure 4.8(a) shows the pedestrian driver yielding behavior with vehicular gap size. The mean accepted gap sizes in seconds without driver yielding and with driver yielding are 5 and 3 respectively. It can be observed that there is a significant reduction in mean accepted gap size when vehicular drivers yield to pedestrians from the MLR model also. If vehicular drivers continuously yield to pedestrian, then the vehicular flow characteristic decreases drastically which also interrupt the signal cycle. However, the pedestrian may be benefited with this driver yielding behavior, but driver may not always yield. Hence, it is a statistically significant variable for the minimum gap size in the MLR model. Type of gap accepted by a pedestrian is another variable used in the model. While pedestrians cross the tend to choose where the gap they will accept are located from the direction or their position they are attempting to cross as seen from the above figure pedestrians are more willing to cross when the gap is near to their position where they intent to cross the signalized intersection. Figure 4.8(b) shows the type of gap accepted with available vehicular gap size. The mean accepted gap sizes in seconds for near and far side both is

4 second. It can be observed that there is a not drastic change in mean accepted gap size by the type of gap chosen by pedestrian nevertheless the model shows there is negative relationship between the gap size and weather the gap is far or near. Interpreting that pedestrian will choose to accept small gaps when there to them than on the far side of the crossing at the intersection.

Vehicular speed is and Size of vehicle is an important factor for accepting the gaps (Yannis et al., 2010), despite small vehicles having high speed pedestrian tend to accept the available gap. This observation is strongly supported by the model. Therefore, the pedestrian may accept the available gaps with small vehicle in mixed traffic condition at higher speeds and sometimes heavy vehicle gaps may be accepted due to less speed. So due to this, speed of the vehicle plays important roles in both the models (MLR and BL models) having positive relationship that shows pedestrian tend to take longer gap as the speed of vehicle increase. Accepted lag or gap is also important variables in MLR model for pedestrian accepting consecutive gaps and singular gap reducing gap size. If pedestrians accept the lag (initial vehicle gap size), it represents the higher gap size than regular gap size.

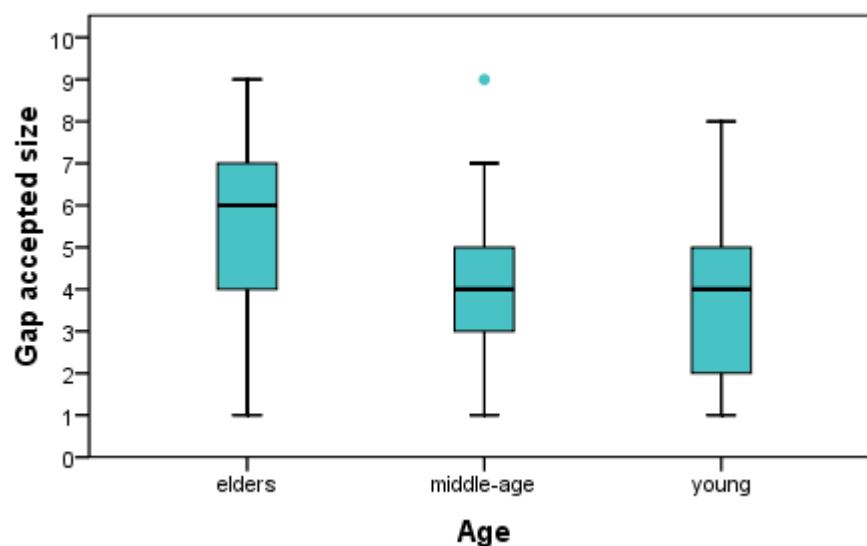


Figure 4.9: Mean accepted gap size for different age group of pedestrians

Pedestrian age is statistically significant for minimum gap size and there is a significant difference between elders and young pedestrian age groups, which can be observed in Figure 4.9 and from the ANOVA test performed. Also this figure shows the mean accepted gap size for different pedestrian age groups. The MLR model indicates that as age increase the accepted gap size also

increase from Table 4.8 this is supported by Figure 4.9 the pedestrian chooses small gap sizes with decrease in age at the signalized location, but there is not much difference between middle and young age groups. The mean accepted gap sizes in seconds for elders, middle and young age groups are 6.25, 4 and 4 respectively. It is also logical from the field data, that selecting the rolling gaps by young and middle age group is very high when compared to elders groups. So the rolling gap criteria makes the age as one of the important factor to reduce gap sizes.

In the BL model for pedestrian gap acceptance, only four variables such as gap size, waiting time, frequency of attempts and vehicular speed were significant and included in the model. Pedestrian road crossing behavior can be correctly predicted by choice model by consideration of the above variables. Moreover, there is a probability of increasing pedestrian gap acceptance with the increase of the gap size, rolling gap and frequency of attempts, whereas, it reduces with the increase in vehicle speed.

4.6. Results of Attitude Survey

Of a total of 647 distributed questionnaires, only 440 completed the provided questionnaires that became the base for analyzing responses. 10 questionnaires were completed by those who have expertise on the field and had the chance to study pedestrians and in addition, 26 questionnaires (i.e., out of the completed 440 questionnaires) with lots of missing data were subtracted from the total sample size. Thus, the rest (416 questionnaires) were used to interpret the results.

4.6.1. Descriptive of Survey Respondents

Out of the 416 studied pedestrians, 229 (55%) were male pedestrians and the rest (187 pedestrians, or 45%) were female. The percentage of respondents that are 18 years or younger was 17.8 %, between 18 and 35 years of age was 67.8%, between 35-65 years of age was 13.5% and the remaining 1% was over +65 years of age. The fairly normal distribution of age data of the survey respondents is an indication of a representative and properly diverse sample population. Given the fact that the study population primarily belongs to active community, age distribution may be closely related to willingness of the respondent for survey. Almost 91.6% work (44%) and live (47.6%) in the study areas accounting for 89.2 % everyday users and the rest 10.8% are occasional users which use the sites once or twice a week.

4.6.2. Users' Perceptions with Respect to Crossing Choice

A number of questions were asked in order to assess the perceived level of how users cross the street (walking running or jogging) and the type of crossing weather they cross alone or in a group. It was found that a 42.8% of pedestrians using the study site believe that they cross signalized intersection by running(quickly) and 42.3% of walk with normal speed and the rest jog with medium speed while crossing. It should be noted that majority of pedestrian prefer running than waking with normal speed while crossing.

When asked “what type of crossing they prefer?” the majority (62%) of respondents answered that they prefer group crossing than individual crossing which was preferred by 38% of the respondents. The pedestrian replies show that the majority of users prefer group crossing than to cross the street alone.

4.6.3. Assessment of Factors that Affect Pedestrian Crossing Choices

Pedestrians were asked to state in group crossing if they were influenced with behavior of pedestrian in the group and out of the 62% that preferred group crossing the majority (77.5%) respond “yes’ meaning they were influenced by behavior of pedestrians in the group and the rest (22.5%) were pedestrians doesn’t influenced by people in the group.

With respect to waiting time, more than half of the respondents complained that the waiting time is long the time set for pedestrian to cross signalized intersection is small. This has been, also, verified by field observations. In most the pedestrians are subjected to halt for a long time at the curb or median because of the time set to cross allocated for the pedestrian is small.

And pedestrian respond to the question “whether or not the waiting time have effect on their crossing decision”, only 34.1% of the users replied that the waiting time doesn’t have effect on their crossing decision and 65.9 % responded it have effect. This situation is sited as a reason for pedestrians choosing not to comply with the signal.

4.6.4. Pedestrian Crossing Choice and Crossing Compliance

Characteristics of a pedestrians when crossing signalized intersection, conditions under which pedestrians decide to cross and pedestrian crossing compliance with traffic control are extremely important factors both from the safety and operational perspectives under the assumption that pedestrians have always more than one alternative to choose for their crossing activity. Meaning the can either comply with the traffic signal by waiting for their signal phase or by not-complying

with the signal and crossing by taking risk. As Table 4.14 shows a majority of pedestrians don't comply with the signal rules sometimes (31.5%), rarely (26.0%), almost never (25.2%) and the one that comply frequently and almost always account for 14.4%. The remaining 2.9% pedestrian don't remember the frequency of compliance to the signal rule. This means that the crossing compliance rate with respect to the crosswalks location is 59%, based upon the user survey data.

Table 4.14: Compliance rate

Compliance Rate			
	Frequency	Percent	Valid Percent
Almost never	105	25.2	25.2
Rarely	108	26.0	26.0
Sometimes	131	31.5	31.5
Frequently	40	9.6	9.6
Almost always	20	4.8	4.8
Don't know	12	2.9	2.9
Total	416	100	100

Table 4.15: Factors that raise non compliance

Factors that raise non compliance			
	Frequency	Percent	Valid Percent
Distance to proper facility	101	24.3	24.3
Amount of traffic on the road	82	19.7	19.7
Weather other pedestrian are doing the same thing	46	11.1	11.1
Speed of traffic on the road	43	10.3	10.3
Being in a hurry	144	34.6	34.6
Total	416	100	100

Table 4.15 shows that factors that raise noncompliance in which majority of the respondent don't comply because of being in a hurry (34.6%), 24.3% doesn't comply because the distance to proper facility is long, 30% of the respondent don't comply by analyzing the traffic situation weather the

amount of traffic is small or the speed is slow and the rest are influenced by people that don't comply.

4.6.5. User Perceptions with Respect to Traffic Conflict and Safety

A number of questions were asked in order to assess the perceived level of safety (based on the speed of traffic) and user's opinions about personal crossing habit. It was found that a more than 80% of pedestrians cross or accepts gap if the driver yields or stops despite the right of way is for vehicle (on green phase time) and only 6.3% of pedestrians disagreed with crossing the street without compiling with the signal despite vehicle has yielded.

With respect to speed of vehicular traffic, more than half of the respondents agree that they will cross the street if the traffic is moving slow and disregarded there crossing if the traffic is moving fast. Making their decision based on the traffic speed in the intersection.

When asked, "When do you feel like to cross?", the majority (45.2%) of respondents answered that they start to cross the street when traffic is completely clear. 32.9% felt that pedestrians should always wait for the pedestrian green light and the rest 21.9% responded they will cross the street when there is little interference with traffic. Pedestrian replies show that the majority of users don't comply with the rule set at signalized intersection and are willing to compromise their safety by taking unnecessary risk.

CHAPTER FIVE-CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This paper has reported pedestrian behavioral study that was carried out in Ethiopia, Addis Ababa, in order to investigate pedestrian traffic gap acceptance for signalized intersection street crossing in an urban setting where the road and traffic environment is less adapted for pedestrians' needs, and the pedestrians themselves are less compliant with traffic signals rules. A multi linear regression and binary logit model were considered to be the most appropriate methods to analyses the size of the accepted traffic gaps and the probability to cross the street, respectively. an attitude survey was also conducted to asses' perception of the pedestrian.

A regression model was developed in order to examine the effect of various parameters on the size of traffic gaps accepted by pedestrians. It was found that the accepted gaps depend on the pedestrian speed, waiting time, speed of incoming vehicle, the pedestrian rolling gap, the pedestrian speed change in crossing, type of vehicle, driver behavior, type of gap, and age.

The gap size compared with Pedestrians walking speed was found to have inverse relationship which showed pedestrian speed choice is dependent on the gap size and pedestrian choose gaps that they can take over depending on their speed or wait. But Pedestrian are accepting vehicular gap size without much waiting after arriving at the curb or median. They often timed their crossing maneuvers to take advantage of an adequate gap in each individual lane, and thus complete their crossings even though the approach as a whole did not have a critical gap during their crossings.

In general vehicle speed and type is important factor for accepting the gaps, but in this study it is found that vehicular speed are more influential than type of vehicle. It can be justified by the fact that small vehicles may yield easily despite they come with higher speeds. So, the pedestrian accept the available gaps with small vehicles in mixed traffic condition at higher speeds and sometimes heavy vehicle gaps may be accepted due to less speed.

If the driver yielding behavior increases there is a drastic increase in pedestrian accepting small gap sizes. If pedestrian accepts the lag, it indicates that the accepted lag value is higher than the usual gap size. So, from the model used in this study (MLR model) it can also be concluded that the accepted gap size will increase when the pedestrian accepts lag (first vehicular gap). In accepting lag (first vehicular gap) case the pedestrian shows normal behavior (no use of rolling

gap condition) and they cross the road with higher safety. However, the available lag in mixed traffic condition is very rare so the pedestrian usually apply tactics to reduce their waiting time.

Older adults were more conservative in their crossing behaviors than their younger counter parts by accepting larger size gaps to cross. Young and middle age pedestrian are the observed to be non-compliant and causing high conflicts with motor vehicles by accepting small gaps.

A binary Logit model was also developed in order to examine the effects of various parameters on the decision of pedestrians to cross the street or not. The results suggest that pedestrians' decision to cross the street depends on the size of traffic gap, the vehicle speed, waiting time, and the frequency of attempts before crossing.

As waiting time rises, the probability to cross the street (violation) will also increase. This means that risk takers are not willing to wait longer until a safe gap appears rather they cross the street earlier and accept a smaller gap. Frequency of the attempt, due to increase in waiting time at the curb or median when pedestrians may frequently attempt available gaps. When they succeed with small vehicular gaps, the probability of gap acceptance also increases. On the other hand the probability of pedestrian accepting gap will decrease with increase in vehicular speed. When vehicles are coming with high speed or close to pedestrians, the efforts of searching vehicular gap reduces because of this frequency of disturbance of the vehicle.

Pedestrians' individual characteristics were not found to be significant in this research. On the contrary, traffic conditions were found to be the most important determinants of crossing decision. This may be attributed to the fact that all survey participants can be considered to have a strong familiarity with the survey site, as this is located in a very central area, resulting in less uncertainty in the decisions of those groups of pedestrians that are often associated with particular behaviors (e.g. young and elderly). Because of the fact that little information was available about pedestrians' personal characteristics (such as trip purpose, origin, destination, etc.,)

From the survey pedestrian noncompliance arise from different reason it can be from an availability of crossing facility that can help pedestrian avoid conflict with vehicular traffic or being in a hurry that waiting time assigned for pedestrian to cross is viewed extremely long. Because of the above two major reason pedestrian look for gaps (when there is time difference between vehicles) in the traffic stream to cross.

5.2 Recommendations

It is believed that the developed models and study findings may be quite useful to the policy makers to regulate pedestrian irrational behavior at signalized intersection. It is my opinion that the developed models perform quite well in mixed traffic condition in developing countries to study crossing behavior of pedestrian.

Education programs on road safety for the elderly might also be designed to prevent occurrence of crashes among this vulnerable group of pedestrians, though research is needed to understand how to best design and promote such programs. Finally, how to provide in-vehicle pedestrian detection systems for drivers is also worth further exploration.

Further research Suggestion for further study based on limitation of the current study. First, pedestrian's age was considered based on the physical appearance. There is need to consider the exact age of pedestrian, individual age data would improve the present model. Second, speed of the vehicle is also considered within the crosswalk area only due to minimal video coverage. The pedestrian speed change and path change condition obtained in this study cannot be generalized (just considered as binary condition). Pedestrians may walk faster or may reduce their speed in various situations (e.g., in rolling gap condition pedestrian may reduce or increase their speed according to the available gap and there are multiple path change conditions). Third the cases of disabled pedestrian groups must be seen separately including condition of seasonal variation and flow disturbance due to holidays. Finally the involvement of traffic police should also be conceder because it have high effect both on flow of pedestrian and vehicles.

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Appendix A
Questioner in English and Amharic
&
Site Assessment Sample Form



Addis Ababa University (AAiT)

Pedestrian study survey

Research Title: - Pedestrian Gap Acceptance and Crossing Behavior in Signalized Intersections .The research is conducted on gap acceptance and crossing behavior of pedestrians in intersection for the outcome will be used to create effective pedestrian facility and to consider pedestrian characteristics in future study and designs.

Purpose of the survey:-this survey helps the study to have complete information about compliance of pedestrian, pedestrian perspective view and behavior towards the current facilities and system.

Please provide us with some information about yourself this information will be treated as absolutely confidential.

Part I General information

- Q1. **Gender** _____1.Male _____2. Female
- Q2. How old are you? **Age** _____1. <18 _____2. 18-35 _____3. 35-65 _____4. >65
- Q3. How familiar are you to the area under study? **Familiarity**
 _____1. Live in this area _____2. Work in this area _____3. Other please specify _____
- Q4. How often do you use this crossing? **Frequency**
 _____1. More than once a day
 _____2. Everyday
 _____3. Once or twice a week
 _____4. Once or twice a month
 _____5. Just today
- Q5. How do you cross the road? **Speed**
 _____1. Walk _____2. Run _____3. Jogging
- Q6. What **type of crossing** do you prefer?
 _____1. Individual _____2. Group
- Q7. If you say in group, did behavior of people you're walking with **influence** way you crossed? **Behavioral influence**
 _____1. Yes _____2. No
- Q8. On average how long do you wait to cross? **Waiting time**
 _____1. 20 sec _____2. 30 sec _____3. 50 sec _____4. >50sec
- Q9. What do you feel about the waiting time? **Personal view of waiting time**
 _____1. Its long _____2. Its short _____3. No opinion _____4. Normal

Q10. Does waiting time have effect on your decision to cross? **Effect of waiting time**

☐ 1. Yes ☐ 2. No

Q11. What affects whether you cross outside of a crosswalk or not (check all that apply)?
(Factors that raise non-compliance)

- ☐ 1. Distance to crosswalk or intersection
- ☐ 2. Amount of traffic on the road
- ☐ 3. Whether other pedestrians are doing the same thing
- ☐ 4. Speed of traffic on the road
- ☐ 5. Being in a hurry

Other: _____

Q12. As a pedestrian, how often do you comply with the signal? **(compliance rate)**

- ☐ 1. Almost never ☐ 2. Rarely ☐ 3. Sometimes ☐ 4. Frequently
- ☐ 5. Almost always ☐ 6. Don't know

Q13. As a pedestrian wanting to cross at a marked crosswalk with no signal for pedestrian, what do you normally do? (Check all that apply) **(Frequency of attempt)**

- ☐ 1. Wait on the curb
- ☐ 2. Take one step into the street
- ☐ 3. Take 2-3 steps into the street
- ☐ 4. Make eye contact with the driver
- ☐ 5. Put your hand out or make other signal

Q14. How much do you agree or disagree with the following statements? **(Vehicle speed)**

	1 strongly agree	2 agree	3 undecided	4 disagree	5 strongly disagree
I always wait for gaps or for someone to stop before crossing					
If traffic is moving slower than 30km/hr,I usually begin to cross the street regardless of whether cars are already slowing down					
If traffic is moving faster than 30km/hr,I usually begin to cross the street regardless of whether cars are already slowing down					

Q15. When do you feel like to cross? (**Decision making**)

- ___1. Only when pedestrian traffic is green
- ___2. When traffic clears completely
- ___3. Whenever you feel that you can cross with little interference with automobile traffic

Q16. As a pedestrian how do you cross? (**Gap acceptance**)

- ___1. I will always wait for gaps
- ___2. I usually wait for gaps
- ___3. I sometimes wait for gaps
- ___4. I don't wait for gaps

Thank you Very much for your time!!!!



አዲስ አበባ ዩኒቨርሲቲ

ስለእግረኛ ጥናት መጠይቅ

የምርምር ርዕስ: የመብራት ምልክት በተደረገባቸው የመንገድ መገናኛዎች እግረኞች በመኪናዎች መሃከል የጊዜ ልዩነት አቀባበልና የመሻገር/የማቋረጥ ባሕርይ፡፡ ጥናቱ የተካሄደው በመንገድ መገናኛዎች ላይ የእግረኞች በመኪናዎች መሃከል የጊዜ ልዩነት አቀባበልና የመሻገር/የማቋረጥ ባሕርይን በመለካት በሚገኘው ውጤት መነሻነት አመቺ የሆነ የእግረኞች መገልገያ ለማዘጋጀት እና ለወደፊት ጥናቶች እና ዲዛይኖች የእግረኞችን ባሕርይ ከግምት ለማስገባት እንዲያስችል ነው፡፡

የቅኝቱ ዓላማ: የዚህ ቅኝት ጥቅም ጥናቱ ስለ እግረኛ ዓይነት፣ አሁን ባለው መገልገያ እና ሥርዓት አንፃር ስለ እግረኛው እይታ፣ አመለካከትና ባሕርይ የተሟላ መረጃ ለማግኘት ማገዝ ነው፡፡ እባክዎን ስለ እራስዎ ጥቂት መረጃ እንዲሰጡን ትብብርዎን ስንጠይቅ የሚሰጡት መረጃ ምሥጢራዊነት የሚጠብ መሆኑን እናረጋግጣለን፡፡

ክፍል 1: አጠቃላይ መረጃ

1. ፆታ _____ 1. ወንድ _____ -2. ሴት

2. ዕድሜ _____ 1. ከ18 በታች _____ 2. 18-35 _____ 3. 35-65 _____ 4. ከ65 በላይ

3. ስለሚጠናው አካባቢ ምን ያክል እውቀት አለዎት _____ 1. መኖሪያ ቦታዬ ነው _____ 2. የሥራ ቦታዬ ነው _____ 3. ሌላ መልስ ካለ ያብራሩ

4. በዚህ መንገድ ምን ያክል ጊዜ ይሻገራሉ?

_____ 1. በቀን ከ1 ጊዜ በላይ

_____ 2. በየቀኑ

_____ 3. በሳምንት አንዴ ወይ ሁለቱ

_____ 4. በወር አንዴ ወይ ሁለቱ

_____ 5. ገና ዛሬ

5. መንገድ እንዴት ነው የሚሻገሩት/

_____ 1. በእርምጃ

_____ 2. በኑጫ

_____ 3. ዱብ ዱብ እያልኩ

6. የትኛውን አይነት መሻገር ይርጣሉ?

_____ 1. ለብቻ

_____ 2. በቡድን

7. በቡድን ካሉ አብሮት የምሄድ ሰው የመሻገር ስልትዎ ላይ ተጽእኖ ያደርጋል?

_____ 1. አዎ

_____ 2. አይ

8. በአማካይ ለመሻገር ምን ያክል ይጠብቃሉ?

_____1. 20 ሴከንድ _____2. 30 ሴከንድ _____3. 50 ሴከንድ _____4. ከ50 ሴከንድ በላይ

9. ስለ መጠበቂያው ጊዜ ምን ያስባሉ?

_____1. ረጅም ነው _____2. አጭር ነው _____3. ሀሳብ የለኝም _____4. የተለየ ነገር የለውም

10. የመጠበቂያው ሰዓት ለመሻገር ውሳኔዎት ላይ ታጽእኖ ያደርጋል?

_____1. አዎ _____2. አይ

11. መሻገሪያን ለመጠቀም እና ላለመጠቀም ምን (የሚመለከተው ላይ ሁሉ ምልክት ያድርጉ) ?

_____1. ወደ መሻገሪያ ቦታ ያለው ርቀት
_____2. መንገድ ላይ ያለው የትራፊክ ፍሰት ብዛት
_____3. ሌሎች እግሮች መጠቀማቸው እና አለመጠቀማቸው
_____4. መንገድ ላይ ያለው የትራፊክ ፍጥነት
_____5. ችኮላ

ሌላ ካለ _____

12. እንደ እግረኛ ምን ያክል ጊዜ ከተሰመረ መሻገሪያ ውጪ ይሻገራሉ?

_____1. መቼም አልሻገርም _____2. ከሰከንት አንዴ _____3. አልፎ አልፎ _____4. በአብዛኛው
_____5. ሁል ጊዜ _____6. አላውቅም

13. የሚያስቆምም ሆነ ሌላ ምልክት የሌለበት የተሰመረ መሻገሪያ ላይ መሻገር እንደሚፈልግ እግረኛ ምን ያደርጋሉ (የሚመለከተው ላይ ሁሉ ምልክት ያድርጉ)?

_____1. ጫፍ ላይ ቆሜ እጠብቃለው
_____2. አንድ እርምጃ ወደ መንገዱ ውስጥ እወስዳለው
_____3. ከ2-3 እርምጃ ወደ መንገዱ ውስጥ እወስዳለው
_____4. ከሹፌሩ ጋር አይን ለአይን እተያያለው
_____5. እጄን አወጣለው ወይም ሌላ ምልክት አሳያለው

14. ከሚከተሉት ሀሳቦች ጋር ምን ያክል ይስማማሉ?

	1 በጣም እስማማለሁ	2 እስማማለሁ	3 ለመወሰን ያዳግታል	4 አልስማማም	5 በጣም አልስማማም
ክፍተት እስካገኝ ወይም ሌላ ሰው እስኪሻገር ሁሌ እጠብቃለሁ					
መኪና በሰዓት ከ25 ኪ.ሜ በታች የሚሄድ ከሆነ ለሎች መኪናዎች ፍጥነታቸውን ባይቀንሱም እሻገራለሁ					
መኪና በሰዓት ከ25 ኪ.ሜ በላይ የሚሄድ ከሆነ ለሎች መኪናዎች ፍጥነታቸውን ባይቀንሱም እሻገራለሁ					

15. መሻገር የሚያስቡት መቼ ነው?

- _____ 1. የእግረኛ መብራት አረንጓዴ ሲበራ ብቻ
- _____ 2. የትራፊክ ፍሰት መላ ለመላ ሲያልቅ
- _____ 3. ከመኪና ጋር ትንሽ ያለዉ ግንኙነት ትንሽ ከሆነ

16 እንደ እግረኛ እነዴት ነዉ ሚሻገሩት ?

- _____ 1. ሁሌ በመኪና መካከል ክፍተት ሳገኝ
- _____ 2. ብዙ ጊዜ በመኪና መካከል ክፍተት ሳገኝ
- _____ 3. አንዳንድ ጊዜ በመኪና መካከል ክፍተት ሳገኝ
- _____ 4. ክፍተት አልጠበቅም

ስለ ትብብርዎ አመሰግናለሁ ! ! !

Appendix A Site Assessment			Form	page
Name of Site	Grid ref.			
Location Description				
Crosswalk Type	Single lane	multi-lane		
	Individual crossing	Group crossing		
	One stage crossing	multi stage crossing		
Crosswalk width	Dimension			
	Comments			
Refuge island(if existing)	Dimension			
	Comments			
lane number	no.			
	Dimension			
	Comments			
Sign existence	yes			
	no			
	Comments			
Marking Existence	yes			
	no			
	Comments			
Surrounding Facilities likely to generate pedestrian demand	Route to /from school?	Yes	No	
	remark			
	Route to /from shop?	Yes	No	
	remark			
	Route to/from housing /hospital?	Yes	No	
	remark			
	Route to/from religious places?	Yes	No	
	remark			
	Route to/from taxi/bus station or stop?	Yes	No	
	remark			
	Route to/from taxi/bus leisure facilities?	Yes	No	
	remark			
Speed of traffic	posted speed limit km/hr			
Data collected by				
Data collected day/time				

Appendix B

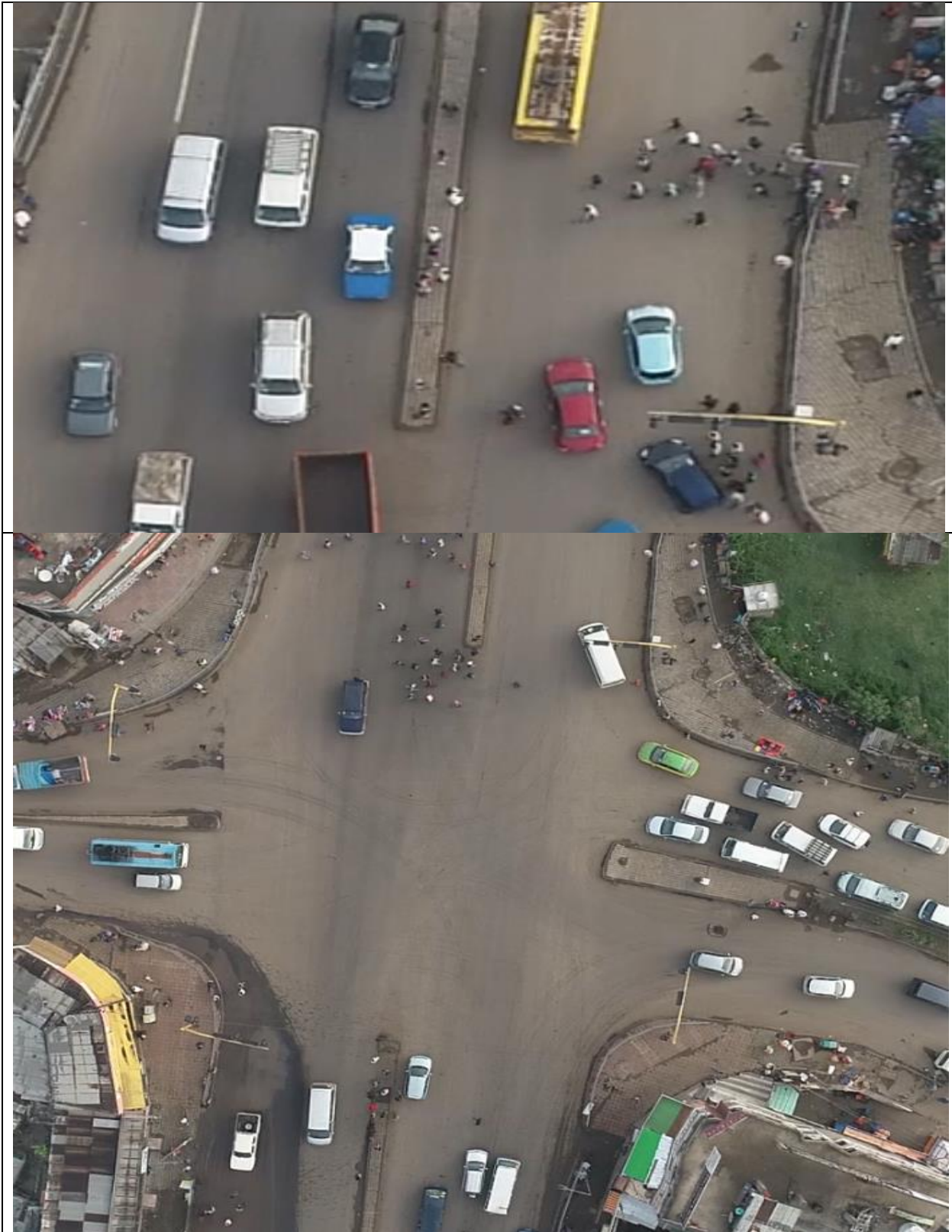
Photo of site



Bole Mikael Intersection Photo



Shola Intersection Photo

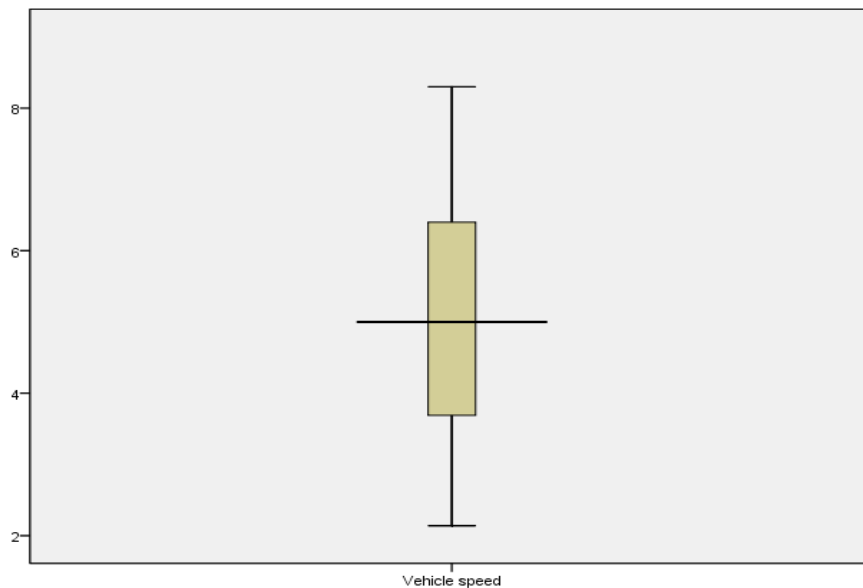


Saris Abo Intersection Photo

Appendix C

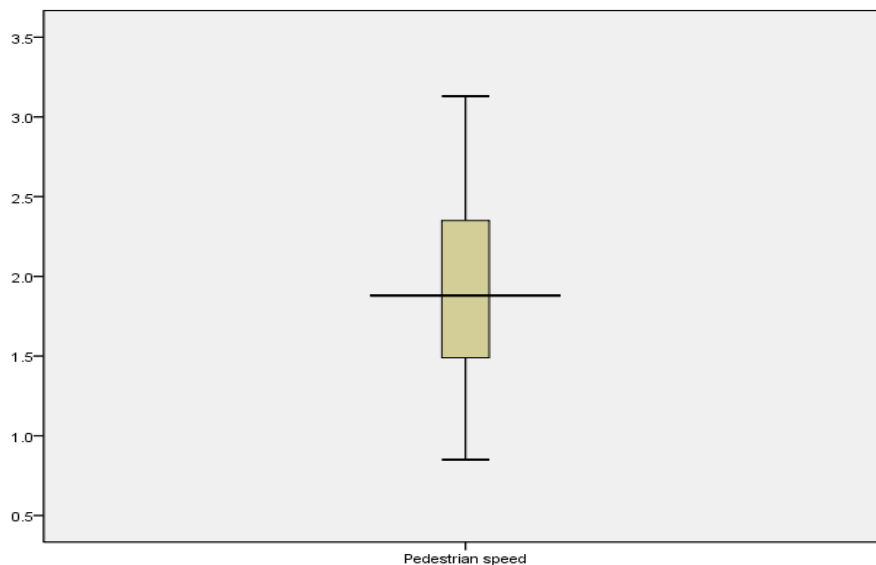
Box Plot and Outlier Determination

The box plot or whisker plot displays the five number summary of a set of data under single graph. This type of graph is used to show the center and spread of the data which helps to identify skewness and outliers.



Box plot of vehicle speed (m/s)

The graph shows that an average of 5m/s (18km/hr) of vehicle speed. With a maximum speed of 8 m/s and minimum 2m/s from the graph shows no outlier or skewness.



Box plot of pedestrian speed (m/s)

The graph shows that an average of 1.9 m/s of vehicle speed. With a maximum speed of 3.13 m/s and minimum 0.89m/s from the graph shows no outlier or skewness.

Appendix D

Detail Regression Analysis

MULTIPLE LINEAR REGRESSION ANALYSIS

Preliminary Analyses

Dependent Variable: Gap accepted size

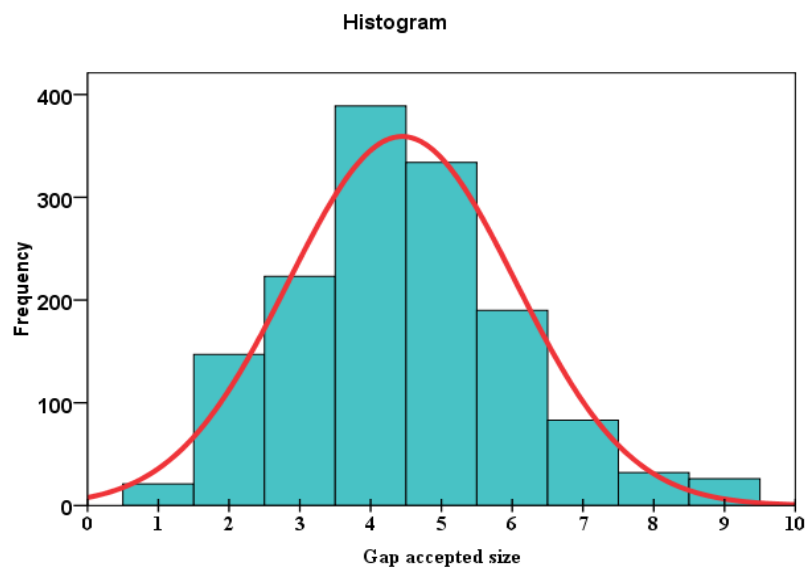
Independent Variables: Movement of pedestrian(MOP),Frequency of attempt (FOA),Pedestrian gender (PG),Pedestrian platoon(PP), pedestrian speed (PS), vehicle speed (VS), Age (Age), Accepted lag or gap (AGOL), Gap type (GAT), pedestrian speed change (PSC), waiting time (WT), pedestrian rolling gap (PRG), Driver behavior (DB), Type of vehicle (TOV).

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Movement of Pedestrian	2014	0	1	.51	.500
Waiting Time	2014	0	124	23.26	29.973
Frequency of Attempt	2014	0	5	.96	1.196
Pedestrian Platoon	2014	0	3	1.68	.618
Gender	2014	0	1	.60	.490
Pedestrian Speed	2014	.85	3.13	1.9026	.51163
Pedestrian Speed Change	2014	0	1	.59	.493
Pedestrian Rolling Gap	2014	0	1	.28	.450
Vehicle speed	2014	2.14	8.30	5.1305	1.69964
Driver behavior	2014	0	1	.67	.470
Type of vehicle	2014	0	3	1.45	.729
Gap type	2014	0	1	.41	.492
Accepted lag or gap	2014	0	1	.57	.495
Age	2014	0	2	1.48	.597
Gap accepted size	2014	1	9	3.81	2.007
Valid N (listwise)	2014				

The values for Skewness and the Kurtosis indices are very small which indicates that the variables most likely do not include influential cases or outliers.

The normality assumption means that the randomly collected are assumed to be normally distributed, roughly in the shape of the normal curve. We check this assumption by examining histograms of each group. The figure shows the histogram of the gap accepted data (dependent variable). As it can be seen from the figure the shape of the curve on the histogram approximates to a bell shape. This shows that the data is from a normal distribution.



Normal Distribution Curve of Gap Accepted Size

The preliminary analysis is run to examine the output, including findings with regard to multicollinearity, whether the model should be trimmed (i.e., removing insignificant predictors), violation of homogeneity of variance and normality assumptions, and outliers and influential cases.

Model Summary^b

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.854 ^a	.730	.728	1.047	.628

The R^2 is .73. This means that the independent variables explain 73 % of the variation in the dependent variable.

ANOVA^b

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5916.409	14	422.601	385.460	<u>.000^a</u>
	Residual	2191.611	1999	1.096		
	Total	8108.020	2013			

The p value for the F statistic is $< .05$. This means that at least one of the independent variables is a significant predictor of the DV (standardized reading scores). The “Sig.” column in the Coefficients table shows which variables are significant.

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
1 (Constant)	5.806	.171		33.920	.000		
Movement of Pedestrian	-.073	.048	-.018	-1.521	.128	.936	1.068
Waiting Time	.013	.001	.190	12.868	.000	.623	1.606
Frequency of Attempt	-.024	.023	-.014	-1.016	.310	.711	1.407
Pedestrian Platoon	.062	.041	.019	1.528	.127	.870	1.149
Gender	-.052	.049	-.013	-1.065	.287	.963	1.039
Pedestrian Speed	-1.275	.051	-.325	-24.771	.000	.786	1.272
Pedestrian Speed Change	.436	.049	.107	8.879	.000	.932	1.073
Pedestrian Rolling Gap	-.985	.065	-.221	-15.172	.000	.637	1.570
Vehicle speed	.297	.017	.252	17.415	.000	.647	1.546
Driver behavior	-1.289	.055	-.302	-23.543	.000	.822	1.216
Type of vehicle	.627	.033	.228	18.803	.000	.922	1.085
Gap type	-.233	.051	-.057	-4.594	.000	.874	1.144
Accepted lag or gap	-1.956	.059	-.483	-33.164	.000	.638	1.566
Age	-.146	.040	-.043	-3.597	.000	.932	1.073

It appears multicollinearity is not a concern because the VIF scores are less than 3. In terms of **model trimming**, if the significant (sig) <.05 the variable is significant and should be kept. If sig>.05 then the variable is not a good predictor and can be removed from the model. The result

show movement of pedestrian ,frequency of attempt, pedestrian platoon, gender are not significant. They will be removed for the rerun analysis.

Rerun

Dependent Variable: Gap accepted size

Independent Variables: pedestrian speed (PS), vehicle speed (VS), Age (Age), Accepted lag or gap (AGOL), Gap type (GAT), pedestrian speed change (PSC), waiting time (WT), pedestrian rolling gap (PRG), Driver behavior (DB), Type of vehicle (TOV)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.853 ^a	.727	.726	1.050

The R^2 is .727. This means that the independent variables explain 72.7% of the variation in the dependent variable.

ANOVA^b

Model	Sum of Squares	df	Mean Square	F	Sig.
1 Regression	5897.682	10	589.768	534.446	.000 ^a
Residual	2210.338	2003	1.104		
Total	8108.020	2013			

The p value for the F statistic is < .05. This means that at least one of the independent variables is a significant predictor of the DV (standardized reading scores). The “Sig.” column in the Coefficients table shows which variables are significant.

Coefficients^a

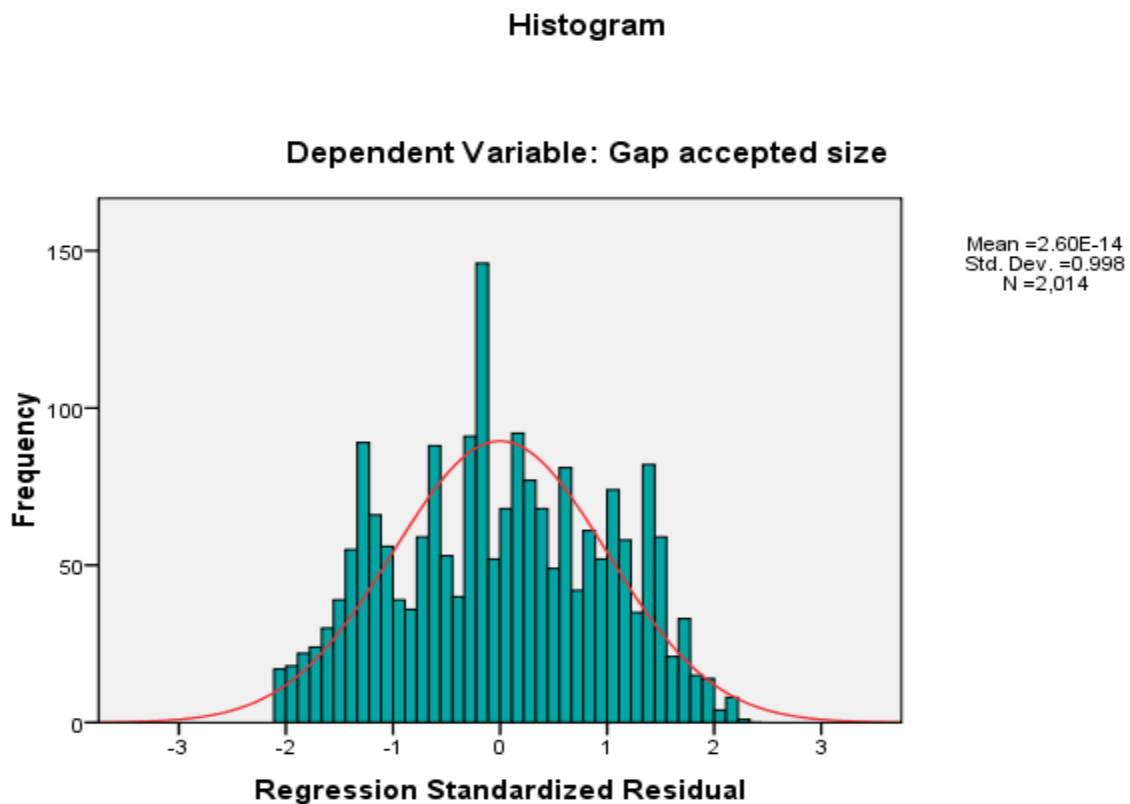
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1 (Constant)	5.929	.145		40.783	.000					
Pedestrian speed	-1.291	.050	-.330	-25.591	.000	-.523	-.496	-.299	.818	1.223
Pedestrian roller gap	-.997	.065	-.224	-15.415	.000	-.505	-.326	-.180	.646	1.547
Age	-.153	.040	-.045	-3.769	.000	-.200	-.084	-.044	.938	1.067
Accepted lag or gap	-1.954	.059	-.482	-33.120	.000	-.460	-.595	-.386	.642	1.556
Driver behavior	-1.275	.054	-.299	-23.446	.000	-.359	-.464	-.274	.839	1.192
waiting time	.012	.001	.186	14.198	.000	.067	.302	.166	.796	1.256
Pedestrian speed change	.429	.049	.105	8.763	.000	-.026	.192	.102	.943	1.061
Gap type	-.229	.050	-.056	-4.562	.000	.123	-.101	-.053	.900	1.111
Type of vehicle	.619	.033	.225	18.578	.000	.104	.383	.217	.928	1.078
Vehicle speed	.286	.017	.245	17.030	.000	.317	.356	.199	.655	1.526

a. Dependent Variable: Gap accepted size

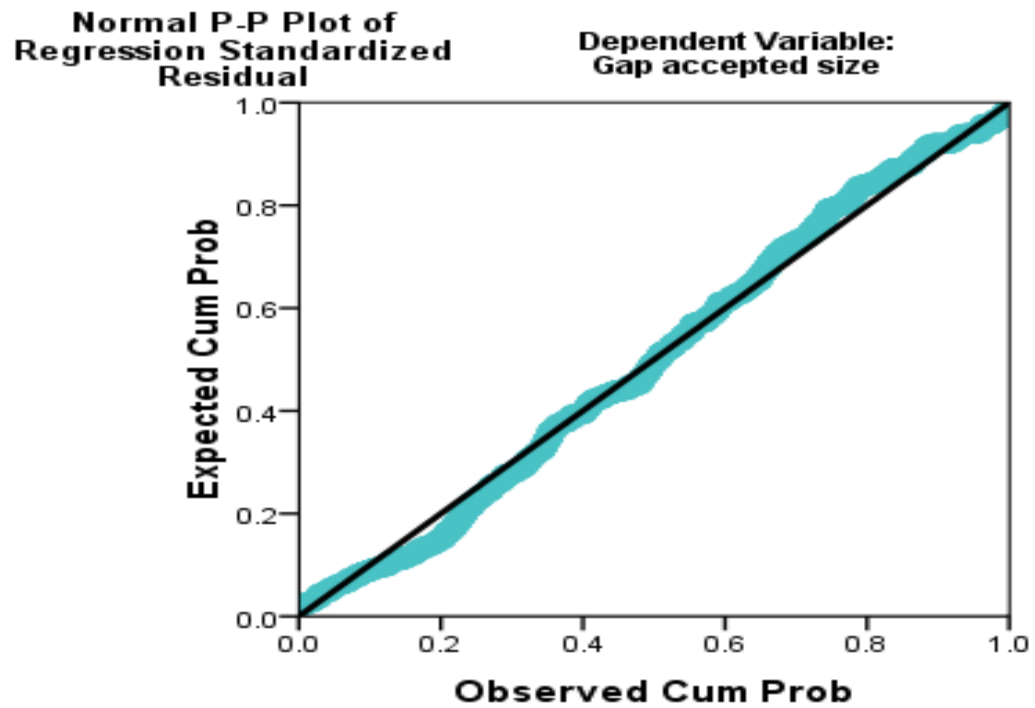
✚ It appears **multicollinearity** is not a concern because the VIF scores are less than 3.

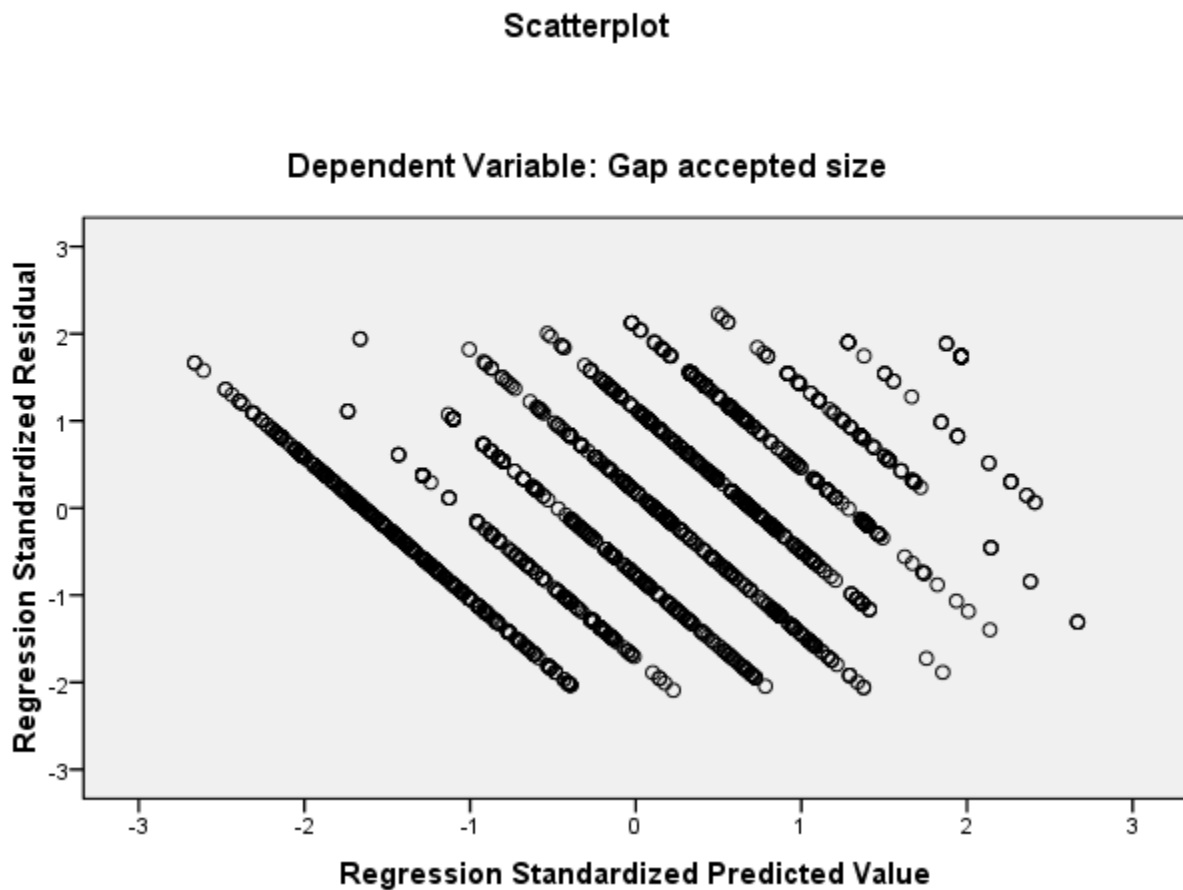
✚ In terms of **significance**, the results show that all the variables are significant predictors of the dependent variable from standardized reading scores. No variable need to be removed from the model.

The histogram of residuals allows us to check the extent to which the residuals are normally distributed. The residuals histogram shows a fairly normal distribution. Thus, based on these results, the normality of residuals assumption is satisfied.



We examine a scatter plot of the residuals against the predicted values to evaluate whether the **homogeneity of variance** assumption is met. If it is met, there should be no pattern to the residuals plotted against the predicted values. In the following scatter plot, we see a slanting pattern, which suggests **heteroscedasticity**, (i.e., violation of the homogeneity of variance assumption).





Finally, we examine the values of the standardized DfBetas and standardized residual values to identify outliers and influential cases. Large values suggest outliers or influential cases. Note that the results thus far (histograms and scatter plots of the continuous variables and residuals) showed no data point(s) that stood out as outliers. Thus, it is unlikely that we will find large standardized DfBetas or standardized residual values. Nonetheless, the standardized DfBeta values can verify this.

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
Standardized DFBETA Intercept	2014	-.10901	.10884	-1.225E-6	.02374296	-.341	.055	3.198	.109
Standardized DFBETA PS	2014	-.09436	.16452	-7.914E-7	.02226090	.318	.055	3.343	.109
Standardized DFBETA PRG	2014	-.12395	.06887	...	.02221949	-.231	.055	2.531	.109
Standardized DFBETA AGE	2014	-.10734	.11290	-2.660E-6	.02343101	-.411	.055	2.988	.109
Standardized DFBETA AGOL	2014	-.06873	.10758	...	.02267073	.138	.055	1.271	.109
Standardized DFBETA DB	2014	-.06784	.09195	...	.02208673	.338	.055	.859	.109
Standardized DFBETA WT	2014	-.11209	.07688	-5.090E-6	.02278585	-1.113	.055	4.395	.109
Standardized DFBETA PSC	2014	-.06027	.06743	-2.323E-8	.02180547	-.030	.055	-.527	.109
Standardized DFBETA GAT	2014	-.06934	.07622	...	.02266448	.167	.055	-.037	.109
Standardized DFBETA TOV	2014	-.10512	.10148	...	.02158936	.287	.055	4.737	.109
Standardized DFBETA VS	2014	-.11943	.07207	...	.02157630	-.188	.055	3.544	.109
Valid N (listwise)	2014								

The results show no standardized Dfbeta values < -2 or > 2 . We can conclude that the dataset does not include outliers or influential cases.

Model

Coefficients^a

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1 (Constant)	5.929	.145		40.783	.000					
Pedestrian speed	-1.291	.050	-.330	-25.591	.000	-.523	-.496	-.299	.818	1.223
Pedestrian roller gap	-.997	.065	-.224	-15.415	.000	-.505	-.326	-.180	.646	1.547
Age	-.153	.040	-.045	-3.769	.000	-.200	-.084	-.044	.938	1.067
Accepted lag or gap	-1.954	.059	-.482	-33.120	.000	-.460	-.595	-.386	.642	1.556
Driver behavior	-1.275	.054	-.299	-23.446	.000	-.359	-.464	-.274	.839	1.192
waiting time	.012	.001	.186	14.198	.000	.067	.302	.166	.796	1.256
Pedestrian speed change	.429	.049	.105	8.763	.000	-.026	.192	.102	.943	1.061
Gap type	-.229	.050	-.056	-4.562	.000	.123	-.101	-.053	.900	1.111
Type of vehicle	.619	.033	.225	18.578	.000	.104	.383	.217	.928	1.078
Vehicle speed	.286	.017	.245	17.030	.000	.317	.356	.199	.655	1.526

a. Dependent Variable: Gap accepted size

$$\text{GAS} = 5.929 - 1.291\text{PS} - 0.997\text{PRG} - 0.153\text{AGE} - 1.954\text{AGOL} - 1.275\text{DB} + .012\text{WT} - 0.229\text{GT} + 0.619\text{TOV} + .286\text{VS}$$

Where:-

GAS= Gap Accepted size

PS=Pedestrian speed

PRG=Pedestrian roller gap

Age

AGOL=Accepted lag or gap

DB=Driver behavior

WT=waiting time

PSC=Pedestrian speed change

Gap type

TOV=Type of vehicle

VS=Vehicle speed

Correlations			
		Gap accepted size	predicted value
Gap accepted size	Pearson Correlation	1	.854**
	Sig. (2-tailed)		0
	N	2014	2014
predicted value	Pearson Correlation	.854**	1
	Sig. (2-tailed)	0	
	N	2014	2014
** . Correlation is significant at the 0.01 level (2-tailed).			

Binary logit model

Modeling pedestrian crossing decision

The purpose of modeling pedestrian crossing decision is to develop a linear function of the selected independent variable. In this study, there are four factors that have been determined to influence pedestrian crossing decisions which are the approaching vehicle speed, the waiting time either in the curve or median, the frequency of attempt a pedestrian make to cross and the size of the gap between vehicles (time head way). The binary logit model will provide either accept (which is coded one “1”) and reject (which is coded zero “0”).

Dependent variable: Gap acceptance or rejection

Independent variable: vehicle speed (VS), waiting time (WT), frequency of attempt (FOA) and gap size (Gsiz)

Case Processing Summary

Unweighted Cases ^a		N	Percent
Selected Cases	Included in Analysis	6093	100.0
	Missing Cases	0	.0
	Total	6093	100.0
Unselected Cases		0	.0
Total		6093	100.0

a. If weight is in effect, see classification table for the total number of cases.

Iteration History^{a,b,c,d}

Iteration		-2 Log likelihood	Coefficients				
			Constant	Gsiz	WT	FOA	VS
Step 1	1	2967.239	2.106	.170	.011	.398	-.521
	2	1576.092	4.437	.254	.023	.663	-.991
	3	991.244	7.068	.336	.036	.982	-1.508
	4	737.462	10.075	.407	.049	1.401	-2.087
	5	621.984	13.733	.430	.067	1.968	-2.758
	6	566.353	18.321	.375	.095	2.702	-3.551
	7	544.227	23.066	.288	.145	3.311	-4.353
	8	540.656	25.488	.262	.171	3.844	-4.772
	9	540.482	25.910	.262	.173	4.146	-4.848
	10	540.480	25.931	.263	.172	4.210	-4.852
	11	540.480	25.932	.263	.172	4.211	-4.852
	12	540.480	25.932	.263	.172	4.211	-4.852

Omnibus Tests of Model Coefficients

		Chi-square	df	Sig.
Step 1	Step	7262.365	4	.000
	Block	7262.365	4	.000
	Model	7262.365	4	.000

The omnibus Tests of Model Co-efficients table gives the result of the Likelihood Ratio (LR) test which indicates whether the inclusion of this block of variables contributes significantly to model fit. A p-value (sig) of less than 0.05 for block means that the block 1 model is a significant

improvement to the block 0 model. Therefore since all the significant values are less than .005 block one is a significant improvement for the model than block zero.

Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	540.480 ^a	.696	.964

In standard regression, the coefficient of determination (R-square) values gives an indication of how much variation in y is explained by the 'model summary, table gives the values for two pseudo R-square values which try to measure something similar.

From the above table, we can conclude that the model in block one can explain the decision of a pedestrian to accept or reject a gap between 69.6% and 96.4%.

Hosmer and Lemeshow Test

Step	Chi-square	df	Sig.
1	2.233	8	.973

In the Hosmer and Lemeshow test table it tells us whether the model fits the data or not under the sig. column the P value should be greater than .05 in order to say the model does fit the data. In the above table the p value is much greater than .05 so we can say the model fits the data.

Contingency Table for Hosmer and Lemeshow Test

	Gap accepted and rejected = rejected		Gap accepted and rejected = accepted		Total
	Observed	Expected	Observed	Expected	
Step 1 1	542	542.000	0	.000	542
2	618	617.999	0	.001	618
3	701	700.997	0	.003	701
4	501	500.988	0	.012	501
5	739	738.960	0	.040	739
6	588	585.654	4	6.346	592
7	339	340.114	272	270.886	611
8	0	1.287	641	639.713	641
9	0	.002	611	610.998	611
10	0	.000	537	537.000	537

Classification Table^a

Observed				Predicted		
				gap accepted or rejected		Percentage Correct
				reject	accept	
Step 1	gap	accepted	or reject	3971	57	98.6
	rejected		accept	101	1964	95.1
Overall Percentage						97.4

a. The cut value is .500

In the classification table the percentage correct in the overall percentage row. This is the total accuracy of the model should at least be 80% .in the table above the percentage correct value is

97.4% so it meet the criteria.

Variables in the Equation

	B	S.E.	Wald	df	Sig.	Exp(B)
Step 1 ^a WT	.172	.053	10.406	1	.001	1.188
FOA	4.211	1.638	6.613	1	.010	67.456
VS	-4.852	.310	245.071	1	.000	.008
Gsiz	.263	.064	17.019	1	.000	1.300
Constant	25.932	1.797	208.305	1	.000	1.828E11

a. Variable(s) entered on step 1: WT, FOA, VS, Gsiz.

$$P(1) = \exp(y') / (1 + \exp(y'))$$

$$Y' = 25.932 + 0.172WT + 4.211FOA - 4.852VS + 0.261Gsiz$$

Goodness of fit

Correlations

		Gap accepted and rejected	Predicted group
Gap accepted and rejected	Pearson Correlation	1	.942**
	Sig. (2-tailed)		.000
	N	6093	6093
Predicted group	Pearson Correlation	.942**	1
	Sig. (2-tailed)	.000	
	N	6093	6093

**. Correlation is significant at the 0.01 level (2-tailed).

Sample scatter plots of size of gap accepted continuous dependent variable with the independent variable continuous variable pedestrian speed have been shown in the above figure to further check linear relationship between the dependent and independent variable. Although the graphs suggests that the linearity assumption may be violated here, the research will keep self-concept in the model because its correlation with reading scores were significant.

