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Pedestrian Gap Acceptance At Mid-Block Crosswalk Locations Of Road Crossings In Bahir Dar City, Ethiopia

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PEDESTRIAN GAP ACCEPTANCE AT MID-BLOCK CROSSWALK LOCATIONS OF ROAD CROSSINGS IN BAHIR DAR CITY, ETHIOPIA

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Co-Advisor: Nurhussen Hassen

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DECLARATION

I, the undersigned, declare that the thesis comprises my own work. In compliance with internationally accepted practices, I have acknowledged and refereed all materials used in this work. I understand that non-adherence to the principles of academic honesty and integrity, misrepresentation/ fabrication of any idea/data/fact/source will constitute sufficient ground for disciplinary action by the University and can also evoke penal action from the sources which have not been properly cited or acknowledged.

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Date of submission: 11/01/2020

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To Kiros Malede (my postgraduate classmate who was passed away by traffic accident while crossing the road at Amhara Martyrs Memorial Office crosswalk)

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ABSTRACT

In Ethiopia there is low car ownership (2 cars to 1,000 people); so walking is the mode choice that has a lion share over other modes. While pedestrians move from place to place, there will be crossing somewhere across the road; in doing so, they have no idea on how to utilize the system to maneuver. In addition, drivers don't give way to the waiting pedestrians. Furthermore, there is no proper planning for pedestrian crossings. This increases the need for a careful local study which can provide the best solution. The aim of this research is to investigate, and model pedestrian gap acceptance and crossing choice at mid-block road crossings. In line with this, the pedestrian attitudinal survey on factors related to road crossings was also conducted.

To investigate and model pedestrian gap acceptance, a filed survey was applied; which was carried out at four mid-block crosswalk locations in different streets of Bahir Dar city. In a field survey, the pedestrian crossing was videotaped in real traffic conditions and the data was extracted using playback technique using AVS Video Editor Software. The collected extracted data includes pedestrian crossing behavior as well as pedestrian, vehicular and roadway characteristics. Statistical analysis on combined site data results in 5sec and 7.2sec for 50% and 85% pedestrian accepted gap sizes respectively. Whereas, the mean accepted gap size was 8.49sec. MLR model was developed in order to examine the effect of various parameters on pedestrian gap acceptance. It was found that pedestrian safety margin and vehicular arrival rate have a significantly higher effect on the size of gap acceptance. BL regression model was also developed in order to examine various factors on the probability of pedestrian gap acceptance. The results suggested that pedestrian waiting place, vehicular travel lane, crossing initiation and gap size have a significantly higher effect on crossing choice.

An attitudinal survey of a questionnaire was designed aiming to capture key human factors related to crosswalks. The descriptive analysis of the questionnaire responses revealed that most pedestrians prefer crosswalks to minimize accident exposure and to be legal. A PCA was implemented resulting that, crossing outside crosswalk locations increases exposure to an accident. And also, it suggests that illegal behavior of divers like refusal to give way at crosswalks, aggressive and careless behaviors were cause for the accident.

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BL	Binary Logistic
BDU	Bahir Dar University
CBD	Central Business District
CSA	Central Statistical Authority
E.C.	Ethiopian Calendar
ERA	Ethiopian Road Authority
G.C	Gregorian calendar
GIS	Geographic Information System
HCM	Highway Capacity Manual
MLR	Multiple Linear Regression
PCU	Passenger Car Unit
PCA	Principal Component Analysis
SPSS	Statistical Package for Social Science
VIF	Variation Inflation Factor

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1. INTRODUCTION

1.1 Background

Pedestrians defined as people who go on foot or who utilize assistive devices to facilitate them to walk. Walking is one of the most usual ways of moving for each person. Each type of mode transportation used also involves some by movement on foot-walking can be categorized as one of the key elements of a balanced transportation system that has often been ignored when planning any transportation facility. Walk mode is an environmentally friendly mode in the transportation system (Kadali & Vedagiri, 2019). Walk mode is inexpensive, emission-free, uses human power rather than fossil fuel, offers important health benefits, is equally accessible for all -except those with substantially impaired mobility – regardless of income, acts as a crucial link for intermodal transfers in major activity centers, and for many citizens is a source of great pleasure. Pedestrians are subjected to a wide set of actions and dynamic behavior due to vehicular movements. Individuals' judgment about when and where to cross the road is very complex. If the pedestrian decides to walk, then they cross the road somewhere and pedestrian behavior changes dynamically. As pedestrians share the roadway at crossings with motor vehicle traffic, there are increasing in a traffic accident. The growth in pedestrian in Ethiopia is parallel with the increment in population. The increase in the number of pedestrians and motor vehicles is caused by the increase in a traffic accidents. The increase in a traffic accidents is due to competing of pedestrians for utilizing any available open space in the roadway. The behavior of pedestrians is particularly non- compliant and often risk-taking, resulting in more likelihood of people being on the streets facing the risk of being hit by vehicles(Serag, 2014). High pedestrian density caused by various adjacent land use facilities increases the number of crosswalks required for road crossings (Kadali & Vedagiri, 2016). There are different types of vehicles present in the traffic on major roads of Bahirdar city.

All these different types of vehicles move on the same road space-occupying any position on the road depending on the availability of free space at a given instant of time without complying with any lane discipline. This heterogeneity in traffic causes severe conflicts on pedestrians with motorized vehicles and results in a decline of pedestrian safety, particularly at crosswalk locations of free space at a given instant of time without obeying to any lane discipline.

In Ethiopia, 4352 peoples lost their lives annually due to a road traffic crash (Organization, 2019). The main contributing factors for road crashes in the country were due to walking takes the lion mode share (the share of cars to people in Ethiopia is 2 cars to 1,000 people - one of the lowest rates of car ownership in the world), luck of proper pedestrian crossing facility planning, and poor understanding of the traffic system by pedestrians for crossing the road (pedestrians inability to estimate the speed of conflicting vehicles and poor assessment of their crossing time to the oncoming vehicle speed, etc.). Furthermore, in the country crashes frequently occur in mid-block or roadways (Tulu, 2015). He further investigates pedestrian crossings at unprotected (uncontrolled) mid-block crosswalk locations that are hazardous having significant pedestrian-vehicle conflicts. The unprotected mid-block crosswalk locations are the typical median openings without traffic signboards and with or without zebra markings. A recent study in Bahir Dar on traffic accidents investigated that traffic crash at mid-block section was 3.5 times traffic crash at intersection location(Mamaru, 2018). Mamaru also investigated that 89% of road fatalities were on pedestrians caused mainly by no give way to pedestrians. Research studies have shown that there is an increase in pedestrian collisions and most of these collisions are related to midblock crosswalk locations (Mohan, Tsimhoni, Sivak, & Flannagan, 2009). Moreover, different factors like pedestrian behavior and characteristics, vehicular and roadway characteristics such as median width, and roadway width (number of lanes) also have a significant impact on pedestrian-vehicle interaction.

Unplanned pedestrian mid-block crossing plays an important role in analyzing pedestrian safety and mobility because pedestrian crossing makes complex interaction with vehicular traffic at such locations. To modify pedestrian risky crossing behaviors, manage or control, this study aims to establish a pedestrian’s vehicular gap acceptance at mid-block crosswalks in the city of Bahir Dar. Pedestrian crossing behavior is mainly governed by the gap acceptance theory (Kadali & Vedagiri, 2019; Serag, 2014; Yannis, Papadimitriou, & Theofilatos, 2013). As a result, the study was focused on gap acceptance of pedestrians with different factors such as vehicular, traffic and roadway characteristics with driver and pedestrian's behavioral characteristics. To characterize the effect of those factors on pedestrians accepting the available vehicular gap, mathematical models should be done between the size of vehicular gaps accepted by pedestrians and those selected contributing factors. The vehicular gap can be defined as the time difference between the leader and the follower vehicle with reference to the pedestrian crossing path. The gap acceptance theory indicates that each pedestrian or group of pedestrians has a critical vehicular gap acceptance for crossing the road (Brewer, Fitzpatrick, Whitacre, & Lord, 2006; Sun, Ukkusuri, Benekohal, & Waller, 2003). In general, pedestrians need to search vehicle gaps while crossing the road at unprotected mid-block crosswalks (unprotected mid-block crosswalk crossings are typical median). In this process, the gap acceptance mechanism (pedestrian accepting or rejecting the approaching vehicle time gaps) is important and the pedestrian may succeed or fail in such a process to accept approaching vehicle gaps. In this study, the time gap is considered as approaching vehicle time arrival corresponding to the pedestrian crossing path. While pedestrians make such decisions (accept or reject) they may use different behavioral characteristics which range from rolling behavior, change in path, or increasing in speed, etc. which significantly influences the accepted gap size. The pedestrian accepted gaps are important for controlling pedestrian risky crossing behavior, for managing and controlling vehicular characteristics, and for designing of pedestrian facilities. In this context, the objective of the study is evaluation of pedestrian accepted gap size, and formulating a model for a minimum size of vehicular gaps accepted by pedestrians and the pedestrian probability of accepting the available gap with varied pedestrian crossing behavior and characteristics, vehicular and roadway characteristics. Furthermore, for exploring the unexplained part in the model, an attitudinal survey was conducted. The survey includes pedestrian demography, road crossing preferences, pedestrians assessing drivers and themselves using well-prepared questionnaires'. Based on the above, it is clear that pedestrian safety and mobility is the main issue for transport planners, traffic engineers, and policymakers.

1.2 Motivation

One hundred and thirty-two countries of the world have national design standards for the provision of safe crossings for pedestrians and cyclists (Organization, 2019). Transportation planners in developing countries strive for better pedestrian facilities to provide for diverse users (the elderly, disabled people, etc.) and safe as well as efficient road crossings. Moreover, it is advisable to build efficient crosswalk facilities, within budget constraints, which will result in a reduced delay for both the pedestrians and vehicle drivers with significantly fewer crashes. As a result, this study made interesting findings which help the country for developing crosswalk design standard or crosswalk warrant basic inputs.

The main motivation of this study was to investigate the pedestrian gap acceptance, and modeling pedestrian minimum vehicular gap acceptance and modeling of crossing choice (probability of gap acceptance) with different vehicular, roadway characteristics with different pedestrian road crossing behavior. In line with this, the attitude of pedestrians on factors related to crosswalk was investigated for investigating the unexplained part in the gap acceptance mathematical modeling.

This research is helpful to control pedestrian risky crossing behavior, to manage and control vehicular accident cause characteristics. Also, it is helpful to policymakers, planners and designers for developing new crosswalk facilities training into consideration pedestrian behavioral characteristics. Further, these results may also assist the traffic engineers to install traffic control measures to control the main factors like drivers' aggressive behavior which causes an accident on roadways under mixed traffic conditions at the existing crosswalks. The model results estimate the minimum required vehicular gap and the probability of accepting/rejecting the available gap for different pedestrians with different external factors.

1.3 Problem Statement

In Ethiopia, pedestrians usually cross the road at unprotected mid-block crosswalks either due to ease of access or non-availability of crosswalks near their origin/destination of the trips. But, higher pedestrian crashes were investigated caused by pedestrians have no idea on how to maneuver the traffic system, drivers didn't give way to the waiting pedestrians, and lack of proper planning for pedestrian crossing. Individuals' judgment about when and where to cross the road are very complex and are normally represented by various factors such as comfort, convenience, ease of crossing. The availability of larger vehicular gaps in traffic streams is very rare, so the behavior of pedestrians varies with the availability of small gaps and they try to accept smaller gaps with tactical behavior. As a result, those pedestrians are risk-prone. Over 4352 people annually die due to a traffic accident in Ethiopia (Organization, 2019). The report further states that "In Ethiopia, the number of deaths due to traffic accidents is reported to be amongst the highest in the world. Most of the road traffic crashes in Addis Ababa were due to the driver does not yield to pedestrians (Abdi et al., 2017). In Bahirdar, 89% of fatal injuries were pedestrians(Mamaru, 2018). Crashes in Ethiopia frequently occur in mid-block (Tulu, 2015). Furthermore, pedestrian crossing behavior is the most unsafe phenomenon at mid-block sections of Ethiopian cities like Bahir Dar. Pedestrians often misjudge the available gaps and randomly accept smaller ones while crossing the road and thus rendering themselves toward crash risks. The traffic crashes at pedestrian crosswalk locations may cause by a lack of well-planned designated crosswalks and movement priorities for pedestrians especially at crosswalk areas. As a result, a local in-depth study was required for controlling pedestrian risky crossing behavior, and for managing and controlling vehicular accident cause characteristics using pedestrian vehicular gap acceptance at mid-block crosswalk areas. Pedestrian crossing behavior at the mid-block location was modeled and gap acceptance were investigated in this study which helps for the design of the pedestrian facility. But, road and traffic characteristics on pedestrian safety and mobility appear to explain only small part of pedestrian crossing behavior in urban areas, attitudinal survey should be conducted in the improved design and planning of the road and traffic environment, and consequently to the improvement of pedestrian comfort and safety (Papadimitriou, Lassarre, & Yannis, 2016).

1.4 Objective

1.4.1 General objective

The core objective of this research work is to investigate pedestrian gap acceptance at mid-block crosswalk locations of main roads in the city of Bahir Dar city.

1.4.2 Specific Objectives

The specific objectives of this research work are to:

- Investigate pedestrian gap acceptance between incoming vehicles at the mid-block section of selected streets using video graphic survey and attitude of pedestrians on selected factors related to road crossings using a questionnaire.
- Develop a model for determining minimum vehicular gap size accepted by pedestrians and crossing choice of pedestrians using pedestrian's characteristics and crossing behaviors, vehicular and roadway characteristics at mid-block sections of Bahirdar City.
- Propose possible recommendations to enhance pedestrian safety and mobility at mid-block crosswalk locations.

1.5 Scope of the study

The scope of this study is limited to investigate pedestrians' vehicular gap acceptance, developing a mathematical model for both sizes of gap acceptance and crossing choice for accepting/ rejecting the available gap at mid-block crosswalk location of main roads in the city of Bahir Dar. A field survey was to be carried out at a selected location in the city of Bahir Dar using videotape to determine pedestrian traffic gap acceptance and crossing choice at selected mid-block road crossings locations, in line with this, pedestrian's attitudinal survey on factors related with pedestrian road crossings using a well-prepared questionnaire. Relevant road geometric features were also be measured.

1.6 Significance of the study

This study will contribute for determining of pedestrian's minimum vehicular gap needed to cross the road with considerations of contributing factors, those factors were help for identification of the main contributing factors to control pedestrian risky crossing behavior, manage or control vehicular accident cause characteristics. Until now the pedestrian gap acceptance at mid-block crosswalk locations is not clearly known in Ethiopia particularly in the city of Bahirdar. So, this research will contribute by setting the main contributing factors on pedestrian's traffic gap acceptance. The inference of models developed for pedestrian's gap acceptance will be useful to assess existing facilities and suggest suitable corrective measures for improving pedestrian safety and mobility at crosswalk locations.

But, without knowing the attitude, perception and risk-taking behaviors of pedestrian's, investigating traffic gap acceptance by itself is not complete for greatest facility design, so that incorporating attitudinal data make the research sound and finally, indication of candidate recommendations for improving the safety and mobility of pedestrians were done. As a result, studying gap acceptance at mid-block crosswalk location will have higher importance to:

- Control pedestrian risky crossing behavior (indicated in the recommendation part), and manage or control vehicular road crash characteristics at mid-block crosswalk areas.
- Policy-makers to develop new crosswalk facilities by controlling pedestrian behavioral characteristics (indicated in the recommendation part).
- Traffic engineers to install traffic control measures in order to control influencing factors on pedestrian safety and mobility of roadways under mixed traffic conditions at the existing crosswalks.
- Estimate the minimum required vehicular gap for different categorical variables to cross the road safely with varied traffic characteristics which is useful to design of pedestrian facility.

2. LITERATURE REVIEW

The amount of road traffic deaths stays to rise steadily, reaching 1.35 million in 2016. Road traffic injuries are the eighth (8th) leading cause of death for all age groups and it is the leading (1st) cause of death for children and young adults aged 5–29 years. The danger of a road traffic death is more than three times higher in low-income countries than in high-income countries where the average rate is 8.3 deaths each 100,000 populations. The rates of road traffic death are highest in Africa (26.6/100,000 people). More than half of all road traffic losses are amongst vulnerable road users: pedestrians, cyclists, and motorcyclists. Particularly, pedestrians and cyclists represent 26% of all deaths. Pedestrian death in Africa has the highest proportion of pedestrian and cyclist mortalities with 44% of deaths(Organization, 2019). 80% of the world's vehicle is owned by 15% of the world's population. Paradoxically, more than 85% of fatalities and more than 90% of dis-ability road traffic occur in developing countries. In South Africa, 80% of all trips are made by public transport and 20% are in private cars. The cause of the accident on pedestrians was due to a lack of coordination between land use and transport planning, and poor transport planning.

In Ethiopia, 1,296 pedestrians were killed and 3,003 pedestrians were injured during 2008/09. Moreover, fatal crashes including pedestrians included 50% of the total fatal crashes in the country and 35% of the injuries. Everywhere in the country pedestrians cross the road illegally (fully or partially access controlled roads)(Tulu, 2015). A recent study by world health organization (2019) investigates 4352 pedestrians who were killed by road traffic crashes in Ethiopia. On average, about 89% of the road traffic crash fatalities are pedestrians in Bahirdar city and the main reason of the accident is a failure to give-way for the vehicle, failure to priority for pedestrians and following too closely in among vehicles. In addition, Monday day and wends days were comparatively higher road traffic crash occurred(Mamaru, 2018).

Urban road traffic accidents in India have been increasing at about 8% annually and most of them (60%) victims are pedestrians and 85% of these fatalities occur at mid-block locations (Mohan et al., 2009). Another study in Indian found that 54% of accidents are associated to the road crossing activity, the frequency of attempting gap and pedestrian rolling behavior at uncontrolled mid-block locations increased the likelihood of accidents (Kadali, Rathi, & Perumal, 2014). Crossing at mid-block locations in Greece accounts for most of the injuries from attempting to cross the street, crossing at mid-block point's outcomes in more pedestrian fatalities than crossing at junctions (Yannis et al., 2013). Several researchers showed that pedestrian mid-block crossing safety is depending on traffic, roadway and vehicular characteristics with various vehicle driver and pedestrian behavioral characteristics. Pedestrian crossing behavior is mainly ruled by the gap acceptance theory (Alajnaf, Emhamed, & Almadani, 2016; Kadali & Perumal, 2012; Kadali & Vedagiri, 2019; M Paul, Rajbongshi, & Ghosh, 2018; Rafe & Khavarzade; Serag, 2014; Yannis et al., 2013). A lag in traffic is the space and time between vehicle and pedestrian (Nor et al., 2017). Some people might accept the available gap in traffic, but some people may not be. Whether or not a gap is acceptable to rest on on the person's level of risk acceptance, how much the person confidences that the drivers will stop, and the person's perception of how long the gap is that perception may not be correct. Pedestrians continuously change their actions with respect to their crossing behavioral, vehicular and environmental characteristics, several researchers have attempted to identify factors influencing pedestrian gap acceptance and crossing choice to cross the street (Ishaque & Noland, 2008). Researchers investigate that the distance between the vehicles and the pedestrians appears to influence the minimum gap accepted by pedestrians (Das, Manski, & Manuszak, 2005; Oxley, Ihsen, Fildes, Charlton, & Day, 2005; Yannis et al., 2013).

2.1 Pedestrian gap acceptance with respect to significant variables

Gap acceptance with respect to pedestrian gender

Road crossing behavior regarding gender has been observed in numerous studies. A study in Egypt explored that males tend to show more hazardous road crossing behavior than females due to less waiting time (Serag, 2014). Another study in India showed that males walk significantly quicker than females while crossing the roads (Kadali & Perumal, 2012; Kadali & Vedagiri, 2019). Moreover, female pedestrians accept higher gaps than males, suggests that they are more safety sensible on road than male (Madhumita Paul & Rajbonshi, 2014). Another study founded that, the minimum gap size for men, women and both are 3.5, 4.6 and 4.1second respectively(Nor et al., 2017). A study in Greece departs from the above findings as men appear to take fewer risks than women as they generally accept larger gaps (Yannis et al., 2013). As a result, studying effect of gender on gap acceptance is well-meaning for knowing which sex is more prone to risk.

Gap acceptance with respect to pedestrian age

To select the appropriate gaps depends on capability to determine the speed of approaching vehicles and the time needed to cross the street, and it was varies with age and physical limitation (Oxley et al., 2005). Studies in Egypt showed that mean accepted gap sizes in seconds for elders (>60 years old), middle (30-60 years old), and young (<30 years old) age groups were 5.85, 3.38, and 3.37 respectively, this shows that pedestrian chooses small gap sizes with decrease in age, but there is not considerable difference between middle and young age groups(Serag, 2014). In India, the mean accepted gap size in seconds for elders, middle and young age groups are 4.75, 3.35 and 3.504 respectively. The maximum and minimum accepted gap sizes in seconds for different age groups are 6.496 and 2.81 for elders, 6.49 and 1.79 for middle, 6.6 and 1.79 for young (Kadali & Perumal, 2012). Researchers also recognized that the younger groups have accepted smaller gaps than the elder age groups in smaller number of lanes, also elders show risky crossing behaviors while using far lane than near lane(Oxley et al., 2005).

Gap acceptance with respect to rolling behavior

Rolling gap simulates, pedestrian cross the street following zigzag path to move over the smaller gaps instead of waiting for larger gaps. Behavioral analysis revealed that pedestrians favor rolling gap instead of waiting for larger gaps (Brewer et al., 2006; Kadali & Vedagiri, 2013, 2019). A study in Egypt explored that the mean accepted gap sizes in seconds with and without rolling gap are 2.76 and 5.22, respectively, which is extreme difference(Serag, 2014). From this one can understand that pedestrian in Egypt are non-compliant and often risk-taking, which is common in many developing countries like Ethiopia, also in India(Kadali et al., 2014). Rolling gaps was used by young and middle age group when compared to elder's groups. Increase in age results in increase in accepted gap size, this is because of younger pedestrians take rolling behavior (Kadali & Perumal, 2012). Individual pedestrians are more usually using rolling behavior or speed change behavior than the group of pedestrians(Kadali & Vedagiri, 2019). Similarly, another researcher in India defined as the mean accepted gap sizes in seconds without rolling and with rolling gap founded as 5.38 and 3.05 (Kadali et al., 2014). From this one can understand, if pedestrians chosen rolling gap, they are more probable to accept the minimum gap sizes. In recent year in India indicated that, pedestrian can accept smaller gap with usage of rolling behavior and speed change condition (Kadali & Vedagiri, 2019). They further argued that size of gap decreases with rolling behavior substantially at two-lane undivided than the six-lane divided road way characteristics. It indicates that the pedestrians are usually using more pedestrian behavioral characteristics at low number of lanes due to less vehicle speed than at the six-lane roadway. So, this give a hint that studying pedestrian rolling behavior for two lanes which have in Bahirdar city is worthy. Kadali & his friend added that, the use of pedestrian behavior such as speed change condition and rolling behavior significantly decreases the pedestrian accepted gap size.

Gap acceptance with respect to crossing speed change condition

Speed change may cause by higher waiting time for deciding smaller gap acceptance using speed change. Studies identified that walking speed has strong relationship with gap acceptance(Brewer et al., 2006). Researchers in India investigated that, the use of pedestrian behavior such as speed change condition and rolling behavior significantly decreases the pedestrian accepted gap size (Kadali & Vedagiri, 2019). Furthermore, Kadali & his friend indicated that, pedestrians accepted gap size decreases with speed change condition significantly at six-lane divided roadway as compared to the two-lane undivided roadway. They also concluded that, pedestrians usually increase their crossing speed for a greater number of vehicle lanes than the two-lane undivided roadway characteristics.

Gap acceptance with respect to pedestrian platoon size

Studies found that pedestrian accepted gap size increases with increase in pedestrian platoon size. The increase in platoon size also indicates that they are waiting for adequate vehicle gap size (Kadali & Vedagiri, 2019).

Gap acceptance with respect to stage of crossing

(Brewer et al., 2006) observed that pedestrians crossing maneuver can be simplified in to three sage of crossing; single stage, two stages and rolling. In single stage of crossing, the pedestrians cross the road regardless of crossing width. In two stage of crossing pedestrians cross up to median in one go and then cross the far side.

Gap acceptance with respect to waiting time

Pedestrian waiting time can be defined as, the overall time in second spent by a pedestrian on curb or median to cross the road. At uncontrolled crosswalks, pedestrians want to wait for a long time to accept a reasonable gap while crossing the road. Due to the long waiting time, they become impatient, and often do the wrong judgment of available gaps and arbitrarily accept smaller gaps thereby rendering themselves towards crash risk. Thus, pedestrian crossing behavior at uncontrolled mid-block section is self-controlled as they need to accept the available gap as safe or not based on their own personal decision. Researchers identified that the average waiting time of pedestrians (at the beginning of crossing) was calculated 1.09 seconds (Alajnaf et al., 2016). Also, a study in India indicated that, as pedestrian waiting time increases at the curb or median, they may lose their patience and this leads to an increase in the rolling gap behavior to cross the road (Kadali & Vedagiri, 2013). This pedestrian behavior in Bahirdar is very common due to, lack of give way of the vehicle driver to waiting pedestrians. Furthermore, a study in Greece indicated as pedestrians keep waiting to cross the street, the probability to cross is declining (Yannis et al., 2013). Those pedestrians who intend to wait for a long time to cross the street are most cautious and will not take risks. As per recent literature, the waiting pedestrian or pedestrians with unsuccessful attempts may change their crossing path while finding adequate available approaching vehicle gaps; due to this the accepted gap size increases while pedestrians change their crossing path (Kadali & Vedagiri, 2019).

Gap acceptance with respect to frequency of attempt

The increase in several attempts shows that pedestrian fails to cross with the available vehicular gaps and wait for another approaching adequate vehicular gap and with time platoon size also increases. Studies found on frequency of attempt showed as, the duration and number of times (frequency) they are proving available gaps in traffic affect the pedestrian gap acceptance behavior. Continuously observing at approaching vehicle gaps reduces the accepted gap size, with an increase in several attempts, pedestrian platoon size, and path change behavior (Kadali & Vedagiri, 2019). The increases in several attempts show that pedestrian fails to cross with available vehicular gaps and wait for another approaching suitable vehicular gap and during course of time platoon size also increases. This is an indication for investigation of such behaviors in Bahirdar due to non-yield behavior of drivers, in line with this pedestrians cross the road carelessly.

Gap acceptance with respect to jaywalking behavior

Researchers have been observed that pedestrian jaywalking behavior is higher at the uncontrolled mid-block location due to less regulation of pedestrian activities (Kadali & Vedagiri, 2013). It leads accident caused due to less safety at an uncontrolled mid-block location as compared to the other locations. Studies were also conducted on legal versus illegal pedestrian road crossing behavior at a mid-block location in China (Cherry, Donlon, Yan, Moore, & Xiong, 2012). Jaywalkers concentrate more on near side gaps than the far side gaps.

Gap acceptance with respect to driver yield behavior

In developing countries like Ethiopia, driver yield behavior (yield to pedestrian) for waiting pedestrians is not common. However, impatient pedestrians use different crossing behaviors like speed change conditions, rolling behavior, path change etc. The approaching vehicle speed has a significant influence on driver yield behavior. Studies have shown that with the increase in vehicle speed there is a decline in driver yield behavior (Hakkert, Gitelman, & Ben-Shabat, 2002). The mean accepted gap sizes in seconds without and with driver yielding are 4.05 and 2.84 respectively (Kadali & Vedagiri, 2013). These are because of reducing vehicle speeds or change their vehicular paths due to prioritizing pedestrians, as a result, pedestrians can accept small vehicular gap sizes. It is also found that the driver yield behavior has an insignificant effect on a six-lane divided roadway (Kadali & Vedagiri, 2019). They also observed that there are 2 s and 1 s decrease in mean pedestrian accepted gap size due to driver yield at the two-lane undivided and four-lane divided roadway, respectively. Also, a study in India investigated that pedestrian gap size significantly diminishes with an increase in driver yield behavior at crosswalk locations (Sun et al., 2003). Moreover, with increases in driving speed, there are decreases in drivers yielding to pedestrians.

Gap acceptance with respect to crossing initiation

Researchers have also renowned that pedestrian crossing initiating from curb or median has a significant effect on the gap acceptance (Das et al., 2005). Mean accepted gap size with median and without median were investigated as, 4.55 and 5.5 seconds respectively. Pedestrians are securely crossing with the availability of median in two stages which decreases the accepted gap size (Kadali & Vedagiri, 2019).

Gap acceptance with respect to pedestrian number of observation

In South Africa, an average number of head movements made at the curb ranged between 2 and 5 whereas it ranged between 3 and 5 when pedestrians were crossing (Nteziyaremye, 2013). A minimum of 4 head movements is suggested; look to the right side, look to the left side, look to the right side again and to the ahead position(Manual, 2010). Studies also have explored the effect of pedestrian duration of observing at traffic and different behavioral effects on pedestrians accepted gap size (Kadali & Vedagiri, 2013).

Gap acceptance with respect to crosswalk width

In Egypt, pedestrians accept smaller gaps with short crossing distances (Serag, 2014). In the USA, statistical analysis revealed that the 11 approaches had 85th percentile accepted gaps between 5.3 and 9.4 seconds, with a tendency of increasing gap length as crossing distance increased (Brewer et al., 2006).

Gap acceptance with respect to zebra cross

At such location, the pedestrian crossing is more unsafe and complex due to more number of pedestrian-vehicle conflict. A study on the effect of zebra cross on gap acceptance showed that the effect of zebra marking is less on accepted gaps under mixed traffic conditions (Kadali & Vedagiri, 2019). Studies were showed on the pedestrian road crossing behavior at the unmarked location (Zhuang & Wu, 2014).

Gap acceptance with respect to incoming vehicle

A study on vehicle speed on gap size at crosswalks showed instead of vehicle type and size, pedestrians are accepting vehicular gaps to vehicle speed and because small vehicles may originate with higher speeds (Cherry et al., 2012; Kadali & Vedagiri, 2013). Another study found a change (reduction) in the vehicle speed, the probability of the gap acceptance is increased (Alajnaf et al., 2016). Six-lane divided roadway characteristics have a higher mean vehicle speed than the two-lane undivided and four-lane divided roadway (Kadali & Vedagiri, 2019). As a result, smaller gap acceptance was perceived on a smaller number of lanes. Pedestrians accept larger gaps when facing larger vehicles, has the third higher elasticity affecting gap (Yannis et al., 2013). Another study in India indicates that the type of vehicle has a significant effect at two-lane and four-lane divided roadways as compared to the six-lane divided roadway (Kadali & Vedagiri, 2019). But, in Egypt and in another study in India showed, the type of vehicle is not a significant effect on gap acceptance (Kadali & Vedagiri, 2013; Serag, 2014). Serag also showed that pedestrians accept vehicular gaps with respect to vehicle speed rather than vehicle type.

Gap acceptance with respect to safety margin

Researchers studied pedestrian safety to the gap acceptance mechanism, the accepted gap has an important contribution in the margin of pedestrian safety with approaching vehicles (Lobjois & Cavallo, 2007; Oxley et al., 2005).

Gap acceptance with respect to number of disturbance on waiting pedestrians

The researches also focused on vehicle disturbance on pedestrians wait to cross the street as when vehicles are coming with high speed or near to pedestrians, the efforts of searching vehicular gap reduces because of this frequency of disturbance of the vehicle. In this condition, the pedestrian may look for higher vehicular gap sizes (Kadali & Vedagiri, 2013; Serag, 2014).

Gap acceptance with respect to illegal parking

As more roadway space was covered by parked vehicles then, the probability to cross the street was higher. But, as parking increases, then the crossing pedestrian needs a higher magnitude of gaps to be accepted by waiting for pedestrians (Yannis et al., 2013). Researchers identified that illegal parking made pedestrians more careful and acceptant of larger gaps, crossings where there are no illegal parking's showed more than 90% of pedestrians accept a gap value of 4.5 seconds. Furthermore, if there is an illegal parking, the probability to cross the street if the time gap is slightly smaller than 2 seconds varies from 5 to 25% and on the other hand, when there are no illegally parked vehicles, the equivalent probability varies from approximately 8 to 50% (Kadali & Vedagiri, 2013). Findings on illegal parking were significant in Bahirdar city.

Gap acceptance with respect to traffic density

Studies found that an increase in traffic density leads to smaller accepted gaps (Kadali & Vedagiri, 2013; Serag, 2014). Due to high traffic volume on the roadway, the waiting of the pedestrians increases at the curbside (Kadali & Vedagiri, 2013), and then the pedestrian favors to cross the road by a rolling gap. Researchers also investigated that pedestrians critical gap decreases with an increase in volume and increases with roadway width (Chandra, Rastogi, & Das, 2014).

Gap acceptance with respect to type of gap

The type of gap was used to classify a gap as lag or gap. Lag is the first gap that crossing pedestrian faces. Studies showed that pedestrians' have lower accepted gap size while they are using near gaps than the far gaps; this is because of the fast-moving vehicles utilize median lanes more than the curb lanes which influence the pedestrian accepted gaps (Kadali & Vedagiri, 2019).

Gap acceptance with respect to vehicular arrival rate

Instead of estimating traffic flow rates on carriageway based on 15min or 1hr data, the concept of instantaneous conflicting traffic flow was suggested. Furthermore, pedestrians waiting to cross the carriageway are considered identical to the vehicle on minor roads and vehicles playing on carriageway define the instantaneous conflicting flow. Their findings result, as the conflicting flow rate increases the gaps accepted by the pedestrian's declines(Chandra et al., 2014).

2.2 Probability of pedestrians' gap acceptance

The available gap can be defined as the gap present for a pedestrian, whereas, the accepted gap can be defined as the time interval between departure and arrival of the following vehicles where a pedestrian may choose to cross the road within the available gap and complete his/her maneuver safely. Moreover, the rejected gap can be defined as the time interval that the pedestrian fails to step foot on the road for crossing due to the incessant vehicular flow. Researchers investigated that the decision to accept or reject the available gap depends more on the distance between the vehicle and the pedestrian not much on the associated time gap (Sun et al., 2003; Yannis et al., 2013). The average gap accepted length was calculated 1.5 seconds in the rejected gaps and 3.28 seconds in the accepted gaps (Alajnaf et al., 2016). A study in South Africa investigated that, pedestrians generally agreeable to cross the road when lags greater than 2.19 seconds and gaps greater than 2.28

seconds were available on two-lane roads, and for four-lane roads, they attempted to cross when lags greater than 3.90 seconds and gaps greater than 3.08 seconds were accessible on four-lane roads (Nteziyaremye, 2013). A study in the USA conducted using statistical analyses has shown that the 85th percentile accepted gap is 9.4 s (Brewer et al., 2006). A study in Greece investigated that, the traffic gap has the highest effect on pedestrians' decision to cross the street or not (Yannis et al., 2013). Furthermore, it was found that, as expected, the higher the available gaps, the easier the crossing. Research studies have decided that the accepted gap, as well as pedestrians waiting time, have significant contributions in the decision-making process (probability of acceptance) at two-lane mid-block crosswalks (Sun et al., 2003; Yannis et al., 2013). Studies also explored that the effect of approaching speed and age on time to arrival in crossing decisions and results decided that the effect of speed is invalidated by subjective time gaps (estimated time to arrival) than the objective time gaps (Petzoldt, 2014). Studies on the effect of the built environment on pedestrian gap acceptance were concluded that pedestrians more often take the right choice in central business areas than the outskirt of the city (Granié, Brenac, Montel, Millot, & Coquelet, 2014). Some studies have found that the decision of pedestrians to accept/reject the available gap depends more on the distance between the oncoming vehicle and waiting for pedestrian, not so much on the relating time gaps (Sun et al., 2003). As a result, pedestrians may choose inappropriate time gaps, because they are not able to estimate the actual speed of the incoming vehicle. Another factor identified in crossing choice was the presence of police enforcement and the behavior of leading behavior (Lobjois & Cavallo, 2007; Oxley et al., 2005).

2.3 Pedestrians' critical gap acceptance

It is the minimum average time gap, which is just equivalent to the crossing time of a pedestrian. (Manual, 2010) defined critical gap as the minimum time gap in seconds for a pedestrian to attempt to cross the road, or else, the time at which half of the pedestrians favored to cross the street. If the available gap is greater than the critical gap, it is expected that the pedestrian will cross the road, but if the available gap is lesser than the critical gap, it is expected that the pedestrian will not cross the road. In South Africa, the critical lag on the two-lane road was found to be 2.19 seconds while the critical gap was 2.28 seconds on four-lane roads. Further, the critical lag at four-lane roads indicated to be 3.90 seconds and 3.08 seconds at two-lane roads (Nteziyaremye, 2013). In Egypt, the critical gap was 4.87 second, assessed by the Raffs method (Serag, 2014). In India, the critical gap was 5.37 second, assessed by the Raffs method (Kadali & Vedagiri, 2013). Also, the study results show that pedestrian groups with compliant behavior have higher critical gaps than single pedestrians with noncompliant behavior and female pedestrians had higher critical gap values compared with male pedestrians, and elderly had higher critical gap values than did other age groups (middle-aged and young pedestrian groups) at all chosen sites (KADALI & PERUMAL, 2016).

2.4 Pedestrians' gap acceptance and crossing choice modelling technique

Experimental studies showed that pedestrian road crossing behavior at uncontrolled midblock has been modeled by the size of vehicular gaps accepted by pedestrian using multiple linear regression (MLR) technique, also choice model has been established to capture the decision making process of pedestrian i.e., accepted or rejected vehicular gaps based on the discrete choice theory (binary logistic regression model) (Kadali & Perumal, 2012; Kadali et al., 2014; Kadali & Vedagiri, 2013, 2019; Serag, 2014; Yannis et al., 2013). Almost all of the literature on pedestrian gap acceptance indicated that a lognormal regression model is functional to examine the effect of various parameters on the size of traffic gaps accepted by pedestrians and a binary Logit model is applied to observe the effects of various parameters on the decision of pedestrians to cross the street or not. Researchers in India argued that the established models and study findings may be quite beneficial to the policymakers to regulate pedestrian jaywalking behavior at uncontrolled mid-block locations (Kadali & Vedagiri, 2013). Moreover, (Sun et al., 2003) studied gap acceptance behavior using probabilistic models and binary logit models. The study mainly targets towards finding pedestrian gap acceptance and motorist yield behavior at mid-block sections. The study clarifies combined driver and pedestrian behavior during the pedestrian crossing.

2.5 Pedestrian attitudinal survey on factors related with crosswalk areas

A study in Greece indicated that it is emphasized that road and traffic factors appear to explain only a small part of pedestrian walking and crossing behavior in urban areas (Papadimitriou et al., 2016). Papadimitriou’s & her colleagues further indicated that the understanding of pedestrian behavior in urban areas may contribute the improved design and planning of the road traffic environment, and subsequently to the improvement of pedestrian comfort and safety. They used a questionnaire data to estimate human factors (components) of pedestrian crossing behavior through principal component analysis, and they indicated that human factors have supplementary explanatory power over road and traffic factors of pedestrian behavior. A study in Nigeria assessed that twenty-three percent (23%) of respondents, attempted to use a designated crosswalk, but did not use the crosswalk correctly. Close to 54% of the respondents preferred zebra crossing followed by signalized crosswalks, which recorded 25.6% endorsement from the respondent. Close to fifty-nine percent (59%) of respondents indicated that the crossing delay practiced at a crosswalk was considered to be very critical in the selection of where to cross on a road. The majority of respondents (79%) showed that they have received some level of education or safety awareness in crossing a road correctly. Forty-seven (47%) of respondents showed that they learned how to crossroads at school. Forty-six percent (46%) of respondents showed they sourced them training through the print and electronic media (audiovisual). The majority of respondents eight seven percent (87%) are willing to improve their road crossing behaviors if given more education and sensitization (Gambrah, 2016).

Finally, the results of all reviewed researches cannot be transferred and used in a national location like the one of Ethiopia, because the Ethiopian road and transport network has different characteristics and operational conditions. Not only is the infrastructure and traffic control for pedestrian movement is not appropriate, but also pedestrians did not understand the traffic system to cross the road, and often non-compliant and risk-taking. This reflected in the increased percentage of road accidents involving pedestrians in Ethiopia. When planning at grade crossings, providing adequate time which enables all pedestrians to complete the road crossing maneuver before traffic begins to move. To bring it in reality, a carful local study is essential (O'Flaherty, 2018).

3. METHODOLOGY

3.1 Introduction

The research methods, materials, and procedures used in the study are presented in this chapter. All the necessary data were collected from direct field measurements using videotaping and from residents of the city using a questionnaire. The methodology in this study applies different methods and techniques for data collection and analysis.

This chapter is organized into different sub-sections. The description of the study area is discussed in section 3.2 followed by study design in section 3.3. In section 3.4 the sample size determination for the different data types is presented, and then the research methods and materials are presented in sections 3.5 and 3.6 respectively. Finally, the data collection details are presented in section 3.7.

3.2 Study Area Description

This study was conducted on the selected uncontrolled mid-block locations of major highway corridors (arterial roads) in the city of Bahirdar. Astronomically Bahirdar city is located at the geographic coordinates of 11°38’ north latitudes and 37°15’ east longitudes. In relative terms, it is located at the distances of 567 km from Addis Ababa. According to the 2007 census, the total population of Bahir Dar metropolitan area was 180 174 and projected to become 243,300 in 2015. Bahir Dar has remained to be one of the fast-growing cities in the country. In particular, the city has made dramatic growth in population size and area in the last two decades. As per the census, in the last 15 years, the average result shows that the population growth rate is nearly 7.5%, which is one of the highest in the country.

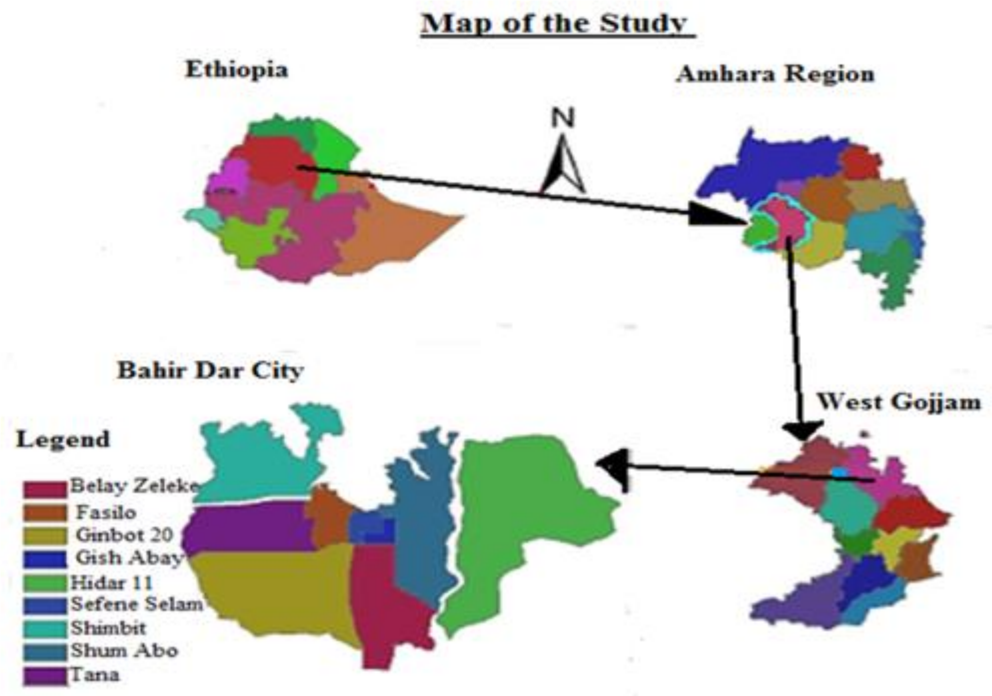


Figure 3. 1 Location of Bahirdar City

3.2.1 Site Selection for field survey

Bahirdar city is the area where pedestrian gap acceptance at mid-block street crossing is going to be investigated and main factors affecting pedestrian road crossing at those mid-block locations were identified using videotaping, in line with this pedestrian's attitude on human factors related with road crossings were surveyed using a questionnaire.

The study mid-block sections were identified by the following points:

- Land uses
- Higher accident recorded location (black spot area)
- Continuous vehicular volume
- The intensity of pedestrian traffic movement
- The smaller volume of turning vehicles, and
- clear and unobstructed observation

Before the field survey, the researcher interviewed the urban road management center for incorporating blackspot sections of the city at mid-block sections. In line with this, the researcher also conducted a field survey along the main road of the city along:

Visit-1: St. Gabriel - Wisdom Tower-Papyrus Hotel-China Camp

Visit-2: St. Gabriel - St. George- Amhara Rural Road Authority

Visit-3: St. George – Papyrus Hotel

Visit-4: Selam Campus - Bale Egziyabher Church

To check the continuity of pedestrian flow, consider mid-blocks having a pedestrian flow of 100 within an hour (Chandra et al., 2014).

Marked crosswalks were associated with a higher pedestrian crash rate compared with an unmarked crosswalk (Cherry et al., 2012). This finding may justify, higher accident rates due to a higher number of pedestrians at crosswalks which luck appropriate controlling of vehicles and pedestrian movement.

- By considering the above criteria's the following sites were selected:

Site-1: In front of Habesha Gust House (**Residential area & inlet and outlet of the city**)

Site-2: In front of Amhara Martyrs Memorial Office (**Office & Reactional area**)

Site-3: In front of Zenbaba Pension (**Mixed used**)

Site-4: In front of Kuchit Market Center (**Market area & Taxi station**)

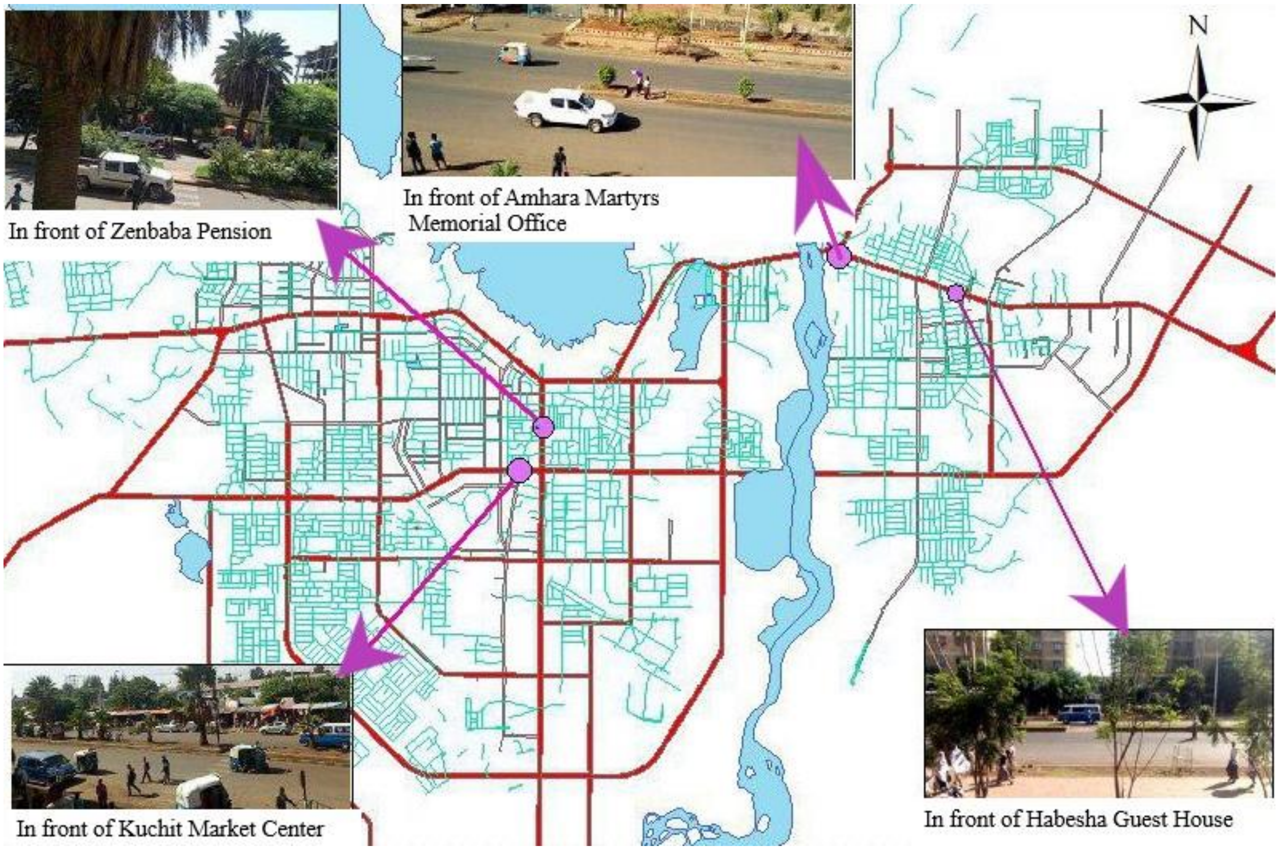


Figure 3. 2 Selected site locations

3.2.1.1. Geometrical description of mid-block section in front of Habesha Guest House

Table 3. 1 Geometrical measurements for mid-block section in front of Habesha Guest House

Crosswalk Measurements at Habesha Guest House		
Description	Near side of Habesha Gust House (m)	Far side of Habesha Gust House (m)
Lane width	10.3	10.3
Median opening along crossing path	1.9	1.9
Median opening perpendicular to crossing path	2.83	2.83
Length of marking for speed measurement	12	12
Length of zebra markings	3	Unmarked

Width of zebra markings	0.28
Spacing b/n zebra markings	Not visible
Number of markings	

3.2.1.2 Geometrical description of mid-block section in front of Amhara Martyrs Memorial Office

Table 3. 2 Geometrical measurements for mid-block section in front of Amhara Martyrs Memorial Office

Crosswalk Measurements at Amhara Martyrs Memorial Office		
Description	Near side of Amhara Martyrs Memorial (m)	Far side of Amhara Martyrs Memorial (m)
Lane width	10.3	10.3
Median opening along crossing path	1.9	1.9
Median opening perpendicular to crossing path	2.7	2.7
Length of marking for speed measurement	11.2	11.2
Length of zebra markings	Unmarked	Unmarked
Width of zebra markings		
Spacing b/n zebra markings		
Number of markings		

3.2.1.3. Geometrical description of mid-block section in front of Zenbaba Pension

Table 3. 3 Geometrical measurements for mid-block section in front of Zenbaba Pension

Crosswalk Measurements at Zenbaba Pension		
Description	Near side of Zenbaba Pension (m)	Far side of Zenbaba Pension (m)
Lane width	10.3	10.3
Median opening along crossing path	2.5	2.5

Median opening perpendicular to crossing path	2	2
Length of marking for speed measurement	13.2	13.2
Length of zebra markings	2	Unmarked
Width of zebra markings	0.52	
Spacing b/n zebra markings	0.58	
Number of markings	9	

3.2.1.4. Geometrical description of mid-block section in front of Kuchit market center

Table 3. 4 Geometrical measurements for mid-block section in front of Kuchit Market Center

Crosswalk Measurements at Kuchit Market Center		
Description	Near side of Kuchit Marketing center (m)	Far side of Kuchit Marketing center (m)
Lane width	10.4	10.5
Median opening along crossing path	2.55	2.55
Median opening perpendicular to crossing path	3.5	3.5
Length of marking for speed measurement	16.2	16.2
Length of zebra markings	2	Unmarked
Width of zebra markings	0.5	
Spacing b/n zebra markings	Not visible	
Number of markings		

3.3 Study Design

Here in the study design, the data collection methodology and analysis were organized to ensure that the objectives were met. The pedestrian road crossing behavior at an uncontrolled mid-block location can be predicted by two types of models. The first model is used to predict the minimum accepted vehicular time gap by pedestrians using multiple linear regression (MLR) techniques. In this model, the minimum accepted vehicular time gap size accepted by pedestrian were estimated with pedestrian behavioral, vehicular and roadway characteristics. The second model is used to predict the mid-block crossing choice. In this model, the probability of accepting a vehicular time gap was modeled with a binary logistic regression model technique. In binary logistic models, instead of increase or decrease in gap value like in the MLR model, it is regressing for the probability of a categorical outcome (accepting/ rejecting the available gap size). In addition to modeling, for improving pedestrian safety and comfort, understanding of pedestrian's attitude on statements related to pedestrian behavior, roadway, and vehicular characteristics can explain the unobserved part of the field survey. In both models, the functional relationship between input and output variables were easily represented. In order to model both multiple linear regression and binary logistics, several studies were reviewed and the general modeling setup can be discussed as follows:

a) Determination of gap size accepted by pedestrians

The minimum pedestrian's gap acceptance value was represented by a regression model. The pedestrian may reject a number of available small gap size values and they may accept higher gap size values. The advantage of a multiple linear regression model was contributing to pedestrian facility design and upgrading of the existing facility. The minimum accepted vehicular time gap was modeled with the help of multiple linear regression (MLR) technique. A normal distribution could be successfully fitted to the logarithm of the gaps (but not to the initial values of the gaps). A lognormal regression model was developed using Statistical Package for the Social Sciences (SPSS 20.0) software package to find out the minimum accepted vehicular gap size due to the pedestrian road crossing behavior, vehicular and roadway characteristics at mid-block crosswalk location. A logarithm of the accepted gap size was considered as the dependent variable and the remaining variables are independent variables (Alajnaf et al., 2016; Arman, Rafe, & Kretz, 2015; Avinash, Jiten, Arkatkar, Gaurang, & Manoranjan, 2019; Kadali & Perumal, 2012; Kadali et al., 2014; Kadali & Vedagiri, 2013, 2019; Kaparias, Hirani, Bell, & Mount, 2016; Naser, Zulkiple, Khalifa, & Daniel, 2017; M Paul, Rajbongshi, & Ghosh, 2012; Rafe & Khavarzade; Serag, 2014; Sun et al., 2003; Yannis et al., 2013).

The general model framework is given below:

$$Log - Gap = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots\dots\dots\dots + \beta_n X_n \tag{1}$$

Where; Log-Gap= logarithm of accepted gaps;

X_{i-n}= explanatory variables depending on their significant value;

β_{1-n}= are estimated parameters;

β_0= constant

b) Determination of decision of pedestrians to accept the gap

The pedestrian decision-making condition were described by the binary logistic linear regression model (Alajnaf et al., 2016; Arman et al., 2015; Kadali & Perumal, 2012; Kadali et al., 2014; Kadali & Vedagiri, 2013; Kaparias et al., 2016; Naser et al., 2017; M Paul et al., 2012; Rafe & Khavarzade; Serag, 2014; Sun et al., 2003; Yannis et al., 2013). The probability of selecting an alternative (accepting/ rejecting) is based on a linear combination function (utility function) expressed as:

$$U_i = \alpha_i + \beta_{i1} X_1 + \beta_{i2} X_2 + \dots\dots\dots\dots\dots\dots + \beta_{in} X_n \tag{2}$$

Where;

U_i=the utility of choosing alternative i;

i= the alternative (accept/reject)

n= number of independent variables;

α= constant; β = coefficients

The utility of alternative ‘i’ were transformed into a probability in order to predict

Whether a particular alternative were chosen or not.

The probability that a pedestrian crosses the street is as follows:

$$p(i) = \left(e^{u_i}/_{e^{u_i}+1}\right) * 100 \qquad (3)$$

Where; Ui: the utility of choosing to cross the road at mid-block which is expressed in terms of independent variables like pedestrian behaviors, roadway and traffic characteristics.

P (i): The probability of choosing alternative ‘i’; where i=1 for the gap is acceptance and i=0 for gap is rejected

c) Pedestrians attitudinal survey

Road and traffic factors appear to explain only a small part of pedestrian crossing behavior in urban areas (Papadimitriou, Lassarre, & Yannis, 2017). Further, they indicated that understanding of pedestrian attitude in urban areas may assist in improved design and planning of the road and traffic environment, and consequently to the improvement of pedestrian comfort and safety. The attitudinal survey aims to capture and analyze key components affecting pedestrian safety and comfort, were identified by using their attitude, perceptions, behavior, and habits related to crosswalks.

It can be carried out for capturing pedestrians frequently do, and what cannot do while crossing the road.

Video graphic survey

Video recording was performed on each site at the same time. The recording was performed at the time of 7:00-10:00 am to 15:30-18:30 pm on Monday, May 27, Wednesday, May 29 and Saturday, June 1 of the year 2019 GC, using high pixel a video camera. The traffic was collected using AVS video editor for accuracy of data using playing back technique.

Attitudinal survey

After in-depth revising of literature for incorporating the necessary variables in the questionnaire, the researcher conducts a pilot survey to know easily understanding the prepared questions by the respondents. Questions related to crosswalks like attitude and perceptions on crosswalks, behavior, and habits frequently do and not do by pedestrians were incorporated, but their distribution to the residents was translated in local language called Amharic attached in appendix 6, and the questions entitled were incorporated in the data collection detail.

The questionnaire was carried out at areas of the city which can yield unbiased sample, from those areas the majors are schools, shopping areas, and community centers.

3.4 Sample Size

3.4.1. Sample size for Pedestrian gap acceptance

For modeling gap acceptance only the accepted gaps were used (Yannis et al., 2013). From the beginning, three days (Monday, Wednesday and Saturday) were selected and the video graphic survey was conducted. After conducting of video graphic survey extraction of necessary data were done in AVS video editor for accuracy of data, from those three days Monday were selected for further analysis due to higher vehicular and pedestrian flow, and higher vehicular speed. A recent study in the city indicated that Monday is the day at which higher accident was recorded (Mamaru, 2018). Table 3.5 was revised for fixing several data for gap acceptance.

Table 3. 5 Literature review on number of accepted gaps per site

Researcher	Country	Number of mid-blocks considered	Video Recording duration	Total number of accepted gaps extracted	Average number of gaps accepted per site
(Kadali & Vedagiri, 2019)	India	8	2 to 3 hours	5890	737
(Brewer et al., 2006)	USA	42	4 hours	605	15
(Serag, 2014)	Egypt	9	30 minute		
(Pawar & Patil, 2015)	India	2	2hour	1107	554
(Kadali & Perumal, 2012)	India			2230	
(KADALI & PERUMAL, 2016)	India	6	2 to 3 hours	4656	776
(Chandra et al., 2014)	India	17	1 hour	5083	299

(M Paul et al., 2018)	India	4	6 hours	1846	462

To fix the total hour considered for extraction of the required number of data, the initial traffic count was done at each site shown in table 3.6.

Table 3. 6 Initial pedestrian and vehicular count for considering peak hour volume during extraction

Site	Duration of time at which peak volume observed	Peak vehicular volume (heaviest direction)	Peak pedestrian volume
Habesha Guest House	7:00:00-9:00:00	1240	84
Amhara Memorial Office	07:45:00-9:00:00	1208	108
Zenbaba Pension	8:00:00-9:30:00	1532	251
Kuchit Market Center	7:00:00-9:30:00	1091	797

The number of accepted gaps extracted from each site were summarized in table 3.7.

Table 3. 7 Total accepted gaps extracted from videography

Site	Duration of time	Total number of gap/lags acceptance extracted
In front of Kuchit Market Center	30minute	324
In front of Zenbaba Pension	1 hour	176
In front Amhara People Martyrs Memorial Monument Office	1 hour	69
In front of Habesha Guest House	2 hours	157
Total number of gaps accepted for analysis	726	

3.4.2. Sample size for pedestrian crossing choice

In the decision to accept the gap or not can be done by considering both the accepted gaps and the largest one of the rejected gaps were used (Yannis et al., 2013). For the decision to accept or reject the available gap, all accepted gaps except lags (the first gap) and the largest rejected gap for each accepted gap were taken.

Table 3. 8 Vehicular accepted gap and Maximum rejected gap data extracted from videography

Site	Number of gaps accepted after removing of lags	Total number of gaps rejected	Number of largest gaps rejected for analysis	Total number of gaps for choice analysis
In front of Kuchit Market Center	237	1016	307	544
In front of Zenbaba Pension	124	565	160	284
In front Amhara People Martyrs Memorial Office	35	266	48	83
In front of Habesha guest house	95	413	114	209
Total number of gaps accepted for analysis	491	2260	629	1120

3.4.3. Sample size for Pedestrian Attitudinal survey

The sample size (n) for observation survey were decided based on population size (N), level of precision (e) and the available resource allocation (time, economy).

$$n = N/(1 + N * e^2) \qquad (4) \qquad \text{(Ellen, 2012)(General Formulae)}$$

To estimate N (population in 2019); the researcher uses the population of Bahirdar city was 243,300 (Ethiopian national census, 2015) and the population growth rate of 7.5% as a basis of the forecast.

N=243,300(1+0.075) (2019-2015) =324,920

Where; n = sample size

N = population size=324,920

e = margin of error=5%=0.05

$$n = \frac{N}{1+N*e^2} = \frac{324920}{1+324920*0.05^2} = 399.50 \approx 400$$

- For factor of safety for un effective response= 20%

Desirable sample size (n) = 400+0.2*400=480

- Including distributed pilot survey questionnaire, a total of 498 attitudinal survey were taken for analysis.

3.5 Research Methods

General steps followed for the research were framed after detail revising of literature. Using appropriate data collection method desirable number of data were collected and then data were analyzed with the right analysis method. Finally, recommendations and conclusions were stated. In simple terms, the research methods of the study are summarized in the chart shown in figure 3.4.

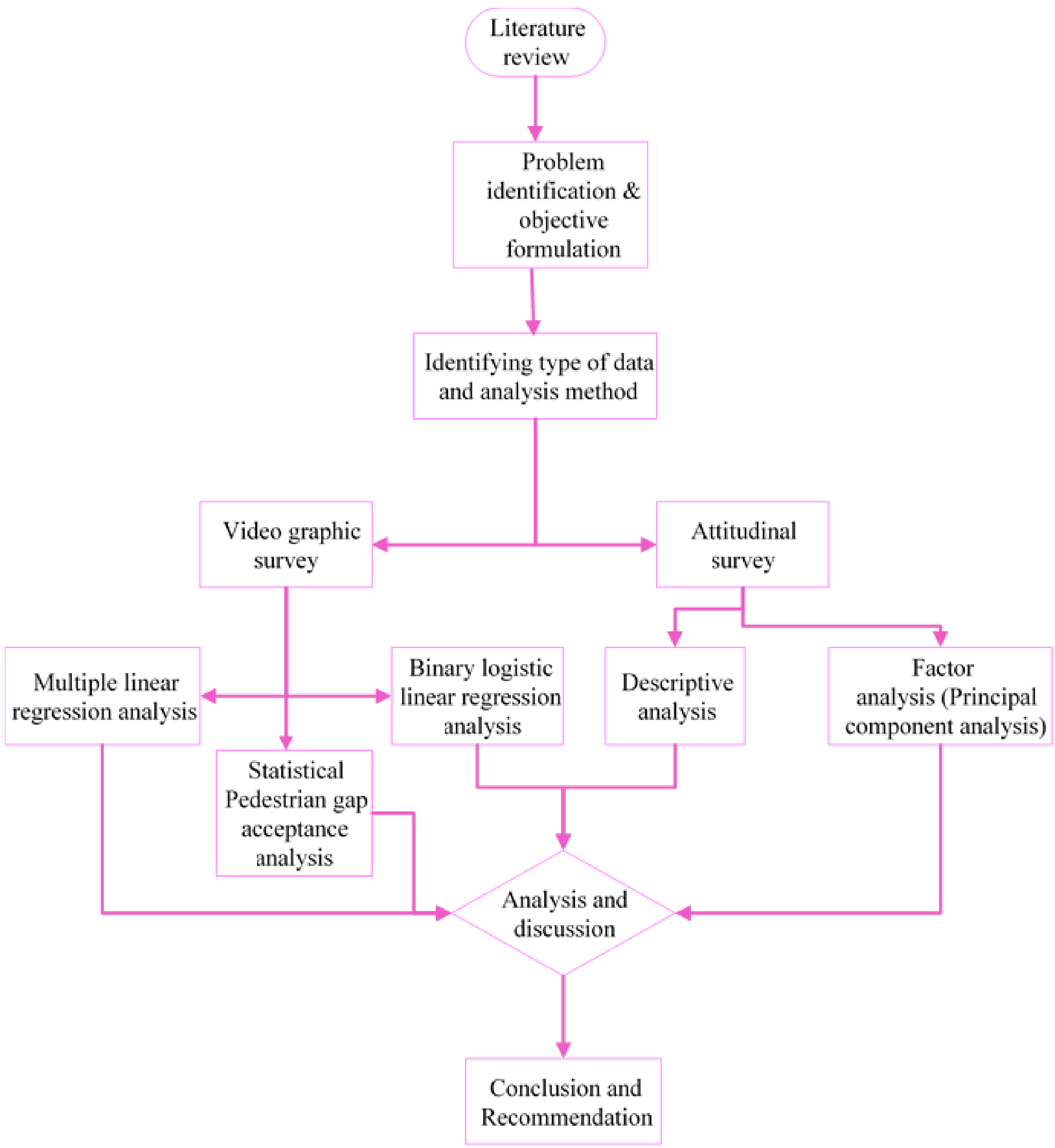


Figure 3. 3 Flow chart of the study

3.6 Research Materials

For the field data collection purposes, different instruments were used for different data type measurements. The measuring tape was used to measure different length measurements like carriageway width, length of vehicular speed marking points, crosswalk length and width and other related geometric parameters used in the study. A video recording high pixel cameras were used for recording both vehicular and pedestrian traffic flow at selected crosswalk locations. AVS video editor was used for accurate extraction of all required data using the playback technique in a microsecond. A questionnaire was distributed uniformly throughout the city collecting of attitudinal survey of pedestrian's attitude, perception, and habits on at crosswalk locations.

Different analysis software was used in this study. Microsoft Excel was used for simple calculations and table formatting. For statistical analysis, SPSS-20 software was used and the sigma plot and origin were used for drawing graphs and histograms. Finally, the documentation was performed on Microsoft word.

Table 3. 9 Materials used in the research and their purpose

Materials	Purpose
Camera	Videography
Questionnaire	Attitudinal survey
Tape	Measuring geometry at crosswalk location
AVS video editor	For extraction of the video graphic data
SPSS, Excel, Origin, Sigma plot	for data analysis
Microsoft word	Documentation

3.7 Data Collection Details

Different input data were collected for this research. In this research work, both attitudinal and feed observation data's were collected, in filed observation data were collected from four mid-block crosswalks in the city of Bahir Dar by videotaping using high pixel camera's seated at vantage point in real traffic conditions, whereas in attitudinal data a questionnaire was applied in the residents of the city located at schools, shopping areas, and community centers. The data collection was conducted starting from May 27, 2019. During videography, the days were in normal weather conditions. These data collection details are summarized in table 3.10.

Table 3. 10 Data collection detail and their schedule

Data type	Method of data collection	Sample size	Execution duration
Traffic data at crosswalks	Video graphic survey	4 sites	3-hour morning (7:00-10:00AM) & 3-hour noon (15:30-18:30) on May27, May29, June01,2019)
Attitudinal data	Questionnaire	498	From June02 to June12,2019
Vehicular gap for pedestrians to cross the main road	Playback in AVS video editor	762 pedestrians either in group or individually	From June13 to October21,2019
Geometrical data at crosswalk's	Measurement using tape	Length, Width, and other required data at crosswalk location	October21,2019

3.7.1 Pedestrian gap acceptance data collection details

After completion of field video recording, the videos were processed in the desk using AVS video editor to an analyzed accepted vehicular gap (time gap in seconds) by a pedestrian with various characteristics (vehicular and roadway characteristics, pedestrian crossing behavior, etc.). The data extracted from videotape focused on those pedestrians who intended to cross the selected crosswalks. More specifically, only pedestrians who actually crossed the street, either immediately or after several attempts (accepting the first vehicular gap or rejecting several gaps before crossing) were captured. Disabled pedestrians, pedestrians carry loads heavier than laptop baggage, pedestrians with kids, pedestrians with a bicycle, larger vehicular gaps, zero gaps, and pedestrians cancel their crossing and go back to their crossing initiation after they start crossing were not incorporated in the extraction.

The data such as pedestrian individual characteristics (age and age), whether pedestrians are using mobile phone or carrying bags, pedestrians group size or platooning, time of arrival, time of crossing initiation, crossing speed, approaching vehicle type & speed, driver yield behavior (stop their vehicles at crosswalks), and pedestrian behavior (speed change condition, crossing path, rolling behavior) were extracted for each pedestrian in person or in group using AVS video editor using playback technique. The pedestrian crossing behavior was determined based on physical appearance. Vehicular characteristics were studied to understand their impact on the gap acceptance for pedestrians. Several attributes were extracted, including vehicular speed, vehicular arrival rate, and vehicle type. The vehicle speed data were extracted using trap length which is marked on the ground prior to the video survey. Also, the yielding behavior of drivers was recorded. The traffic gap was calculated as the difference between two-time points: at the first point, the pedestrian is just ready to set foot on the street, in the second point, the head of the vehicle has just passed through the center of the crosswalk. The researcher has taken the following data samples for easily understanding of the gap acceptance extraction method.

Table 3. 11 Sample of gap acceptance extraction data

Ped.no.	Ped. arrival (mm.ss.µs)	Ped. departure (mm.ss.µs)	Waiting time (sec)	Veh. arrival (mm.ss.µs)	Vehicle Arrival rate(veh/sec)	Gap/Lag (sec)	Max. Rejected Gap(sec)
8	13.10100		0	13.10500		0	3
8			2	13.11700		1	
8			3	13.12900		1	
8			6	13.15800		3	
8			8	13.17800		2	
8			8	13.18300		0	
8		13.19500	9	13.31600	0.33	13	Gap accepted

Moreover, the waiting time of the pedestrian started when someone approached the pavement until he/she set foot on the street for crossing the road. Waiting time was calculated in each arrived vehicles until the pedestrian accepts the adequate gap to cross the road. The pedestrian may use different gestures to cross the road. For example, a pedestrian may use frequency of attempt makes due to the increase in waiting time at curb or median, or they may use a rolling gap (pedestrian cross in a zigzag path to roll over the smaller vehicular gap instead of waiting for larger gaps). So, all individual characteristics, include pedestrian gender, age, and whether he/she was accompanied by another pedestrian were collected. The collected variables are shown in table 3.12.

Table 3. 12 Video graphic data extraction details

Name of the variable	Description
Gender	Male=0 Female=1 Both =2
Age	<18(Child)=0 18-30(young)=1 31-50(middle aged) =2

	>51(elder)=3
pedestrian speed change condition	Yes=0 no=1
pedestrian path change condition	Yes=0 no=1
pedestrian usage of cell phone	Yes=0 no=1
stage of crossing	Number of independent accepted gap for one directional flow of vehicles
pedestrian platoon	single=0 Two=1 Three or more=2
pedestrian rolling behaviour	Yes=0 no=1
Pedestrian baggage effect	yes = 0 no = 1
Tactic of crossings	Street (90 degree) =0 Skewed=1 Others=2
Pedestrian Crossing direction	Pedestrians crossing towards east direction (EB)=0 Pedestrians crossing towards west direction (WB)=1 Pedestrians crossing towards north direction (NB)=2 Pedestrians crossing towards south direction (SB)=3
Pedestrian Waiting place	Pavement=0 Other than pavement=1 Not necessarily=2
Crossing initiation/crossing step	Curb=0 Median=1
Frequency of attempt	no. of trials made to cross the road

Vehicular gap size in seconds	Time difference between arrival of successive vehicles
Pedestrian safety margin in seconds	Time difference between pedestrian cross finishing and arrival of vehicles
Pedestrian waiting time in seconds	Time difference between arrival of pedestrian and departure of vehicles
Pedestrian speed in m/sec	dividing length of crosswalk by time to traverse
Accepted lag or gap	lag=0 gap=1
Decision to Cross	Yes = 1 no = 0
Vehicle travel Lane	Vehicle in nearside lane = 0 Vehicle in far-side lane = 1
Vehicle type	Motor cycle=0 Three-wheeler=1 Cars/Taxi=2 Utilities (Pickups, Jeeps, Vanes,4-WD) =3 Small bus=4 Large bus=5 Light truck=6 Medium and heavy truck=7 Articulated truck=8 Others (Grader, loader, Tractor, etc.) =9
Vehicle speed	Speed of vehicle measured at crosswalks
Driver yielding	yes = 0 no= 1
Vehicular travel direction	Vehicle moving towards east direction (EB)=0 Vehicle moving towards west direction (WB)=1 Vehicle moving towards north direction (NB)=2 Vehicle moving towards south direction (SB)=3

3.7.2 Pedestrian attitudinal data collection details

It is aimed at exploring human factors of road crossing behavior in the city of Bahirdar, using what they do not do, and what they cannot do.

A questionnaire was designed aiming to capture key human factors of pedestrian crossing behavior including their risk perception while crossing the road, their crossing behavior and compliance to traffic rules, their self-assessment, their opinion on drivers and crosswalks, etc. The questionnaire include 27 questions, out which the first two questions deal about demographics of pedestrians, and the next two questions deals about most preferred crossings with their reasons, while the rest is a 5-point Likert scale (14 Likert questions were answered by scales from “strongly agree” to “strongly disagree”, while the rest questions were answered by using Likert scales from “never” to “always”.

Part one of the questioner deals with the sex of pedestrians and the age category of pedestrians was incorporated. Age category were adopted from police commission accident report for aligning of each age category’s attitude, compliance and risk-taking behaviors with the accident occurred on it, this may help for giving training to the identified risk-prone categories. The questionnaire applied to capture the attitude of pedestrians were presented as shown in table 3.13, but the statements distributed to the residents were translated to the local language called “Amharic”, incorporated in appendix 6.

Table 3. 13 Demography of pedestrians

Sex of pedestrian	Male
	Female
Age category of pedestrian	<18
	18-30
	31-50
	>50

Table 3. 14 pedestrian's preference to cross the main road

As a pedestrian, which place do you use for crossing the road	Pedestrian crosswalks Any convenient place
Reason for choosing crosswalks to cross the road	Safe from the traffic accident Convenient to cross the road Drivers yield place for pedestrians Presence of traffic police To be legal Other pedestrians cross the road at crosswalks To save time Any other reason for preferring the crosswalk
Reason for crossing the road at any convenient place	To reach my destination quickly I am good enough to cross the road between oncoming vehicles Drivers do not stop their vehicles for pedestrians at crosswalks crosswalks are not sufficient Absence of traffic police Drivers do not yield to pedestrians at crosswalks Other pedestrians cross the road outside crosswalks Any other reason for crossing at any place

Table 3. 15 Pedestrians agreement on the statements

No.	Statement	Strongly disagree	Disagree	Neither Disagree nor agree	Agree	Strongly agree
1	Crossing main road is difficult in the city of Bahirdar					
2	Crossing the main road outside crosswalks can save time					

3	Crossing roads outside crosswalk locations increase the risk of accident
4	Distance between crosswalks is long
5	pedestrian Crosswalks have not enough width
6	Crosswalks are inconvenient
7	crosswalk markings are not visible
8	posts for pedestrian yielding are not visible
9	Drivers do not yield to pedestrians at crosswalks
10	Drivers are aggressive and carless
11	Drivers stop their vehicles at crosswalks
12	When there is an accident, it is the driver's fault most of the time
13	During crossing the road, I am more careful than other pedestrians
14	During crossing the road, I am faster than other pedestrians

Table 3. 16 Pedestrians frequency of doing the statements

No.	Statement	Never	Rarely	Sometimes	Often	Always
1	I cross roads diagonally					
2	I cross the road after checking whether there is an adequate gap between oncoming vehicles					
3	I cross the road with paying attention to oncoming vehicles					

4	I cross the road in a rolling manner between vehicles to save time	
5	During crossing the road parking vehicles, buildings and trees obstruct my visibility of oncoming vehicles	
6	I cross the road other than crosswalks	
7	I cross while taking on my cellphone or listening to music's	
8	I try to make a few road crossings as possible	
9	I let a car go by, even if I have the right-of-way	

4. RESULTS AND DISCUSSION

4.1 Introduction

This research was performed to study pedestrian gap acceptance at mid-block crosswalk locations. In this section, the research findings are presented, analyzed and discussed empirically, statistically, graphically and in tabular form. The discussion in each sub-topic shows the implication of the results by considering the relevant research works.

4.2 Statistical gap analysis and probability of acceptance

Pedestrian gap acceptance can be analyzed by using behavioral and statistical analysis. Statistical analysis was concerned with providing a mathematical model to determine the gap size for a particular probability of acceptance. Whereas, Behavioral analysis was concerned with identifying actions and patterns that pedestrians commonly use in crossing events (Brewer et al., 2006). Behavioral analysis justifies that pedestrians did not wait to cross the street until all lanes completely clear. Rather, they used other behaviors like stage crossing, rolling behavior, etc. The minimum accepted gap has been estimated at 2 seconds and the mean accepted gap at 8 seconds (Das et al., 2005). The utility function for accepting or rejecting the available gap can be obtained in SPSS as shown in table 4.1.

Table 4. 1 Utility function and percentage of gap acceptance

Site	Utility function	Percentage of accepting gap in sec.		
		50% (critical gap)	85%	100%
Amhara Martyrs memorial Office	U=-13.955 +2.065*G	6.8	7.6	11
Kuchit Market center	U=-3.793+0.868*G	4.4	6.4	14
Zenbaba Pension	U=-4.84+1.005*G	4.8	6.5	13
Habesha Gust House	U=-4.279+0.663*G	6.5	9.1	18
Combined Data	U=-3.816+0.768*G	4.97	7.2	15
Where; G = gap size in second				

Studies indicated by researchers of India (Pawar & Patil, 2015) and USA (Brewer et al., 2006), pedestrians accept a critical gap range from 4.1 to 4.8 second (in India) and 5.1 to 5.9 second (in the USA); which proves pedestrians in Bahirdar accept higher gaps. Furthermore, the 85th percentile accepted gap range from 5 to 5.8 second (in India) and 5.8 to 7.3 second (in the USA); which also less than gaps accepted in Bahirdar. Using the utility function for accepting/rejecting the available gap a graph can be generated for showing the cumulative distribution of pedestrians either accepting or rejecting the available gap. For example, the equation for the combined data is:

U= -3.816 + 0.768*Vehicular Gap Size; the percentage of pedestrians accepting a 3-second gap would be:

$$\boldsymbol{P}ercentage\ of\ accepting = \left(\frac{e^{-3.816+0.768*3}}{1+e^{-3.816+0.768*3}}\right) * 100 = \mathbf{18.06}\%$$

The percentage of rejecting the available gap was obtained as the percentage of rejecting a gap=100-percentage of accepting the gap. Thus, the probability of rejecting the 3-second gap is: Percentage of rejecting 3 seconds = 100-18.06 = **81.94%;** applying the same principle, and was summarized table 4.2 for combined data.

Table 4. 2 Gap size and its cumulative probability of choice

Combined Data: U=-3.816+0.768*G		
Gap size (second)	Percentage of accepting the gap	percentage of rejecting the gap
0	2.2	97.8
1	4.5	95.5
2	9.3	90.7
3	18.1	81.9
4	32.2	67.8
5	50.6	49.4
6	68.8	31.2
7	82.6	17.4
8	91.1	8.9
9	95.7	4.3
10	97.9	2.1
11	99	1
12	99.6	0.4
13	99.8	0.2
14	99.9	0.1
15	100	0

Using table 4.2, a graph for showing the cumulative percentage of pedestrians accepting/ rejecting gaps of various length were plotted, using Raff's method (intersection of probabilities of gap accepting and rejecting curves on the same plane). In this thesis work, the maximum gap size accepted by pedestrians were 15 seconds for combined data.

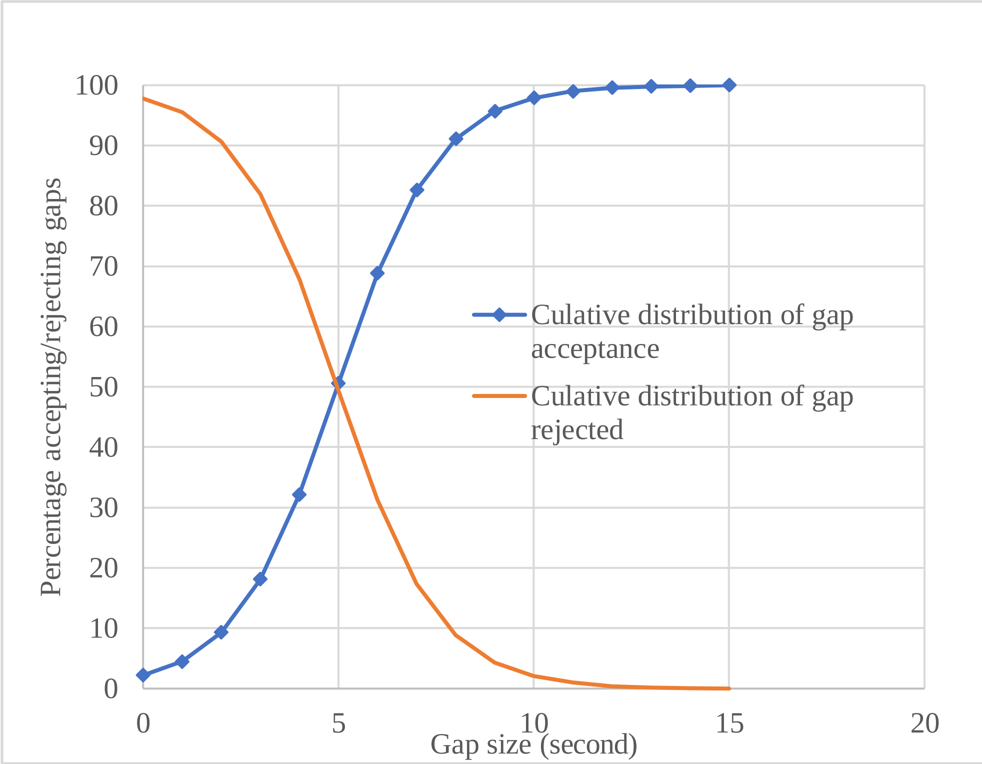


Figure 4. 1 Cumulative distribution of gaps for combined data

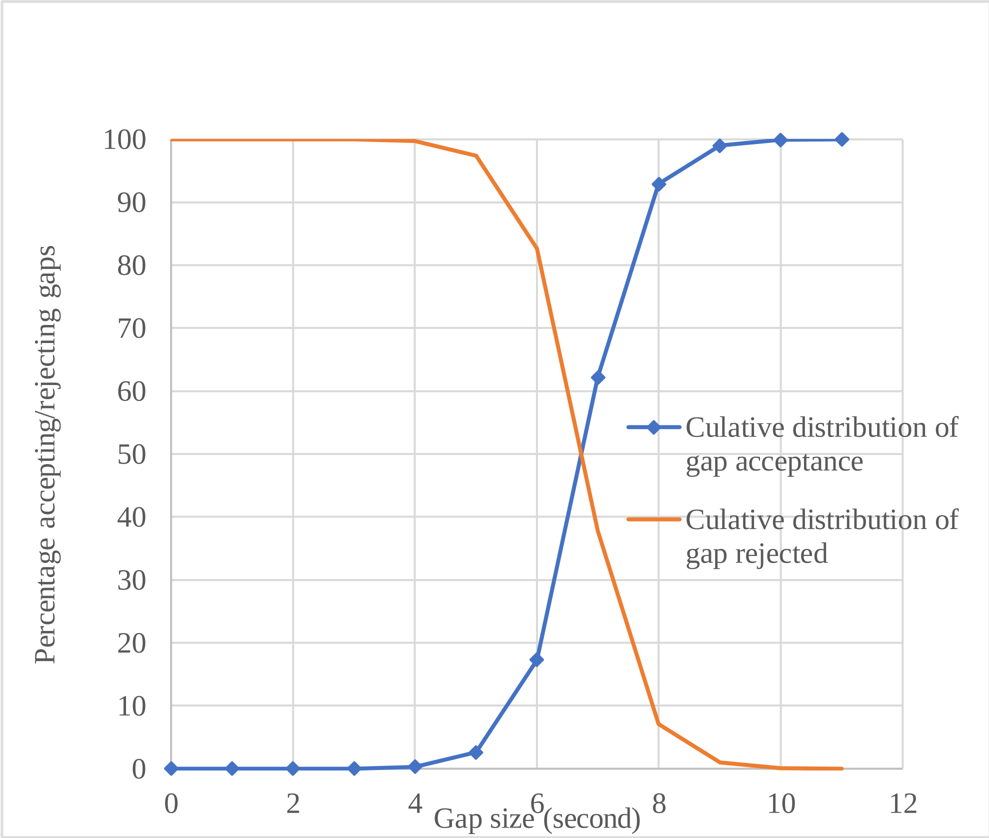


Figure 4. 2 Cumulative distribution of gaps at Amhara Martyrs Memorial Office

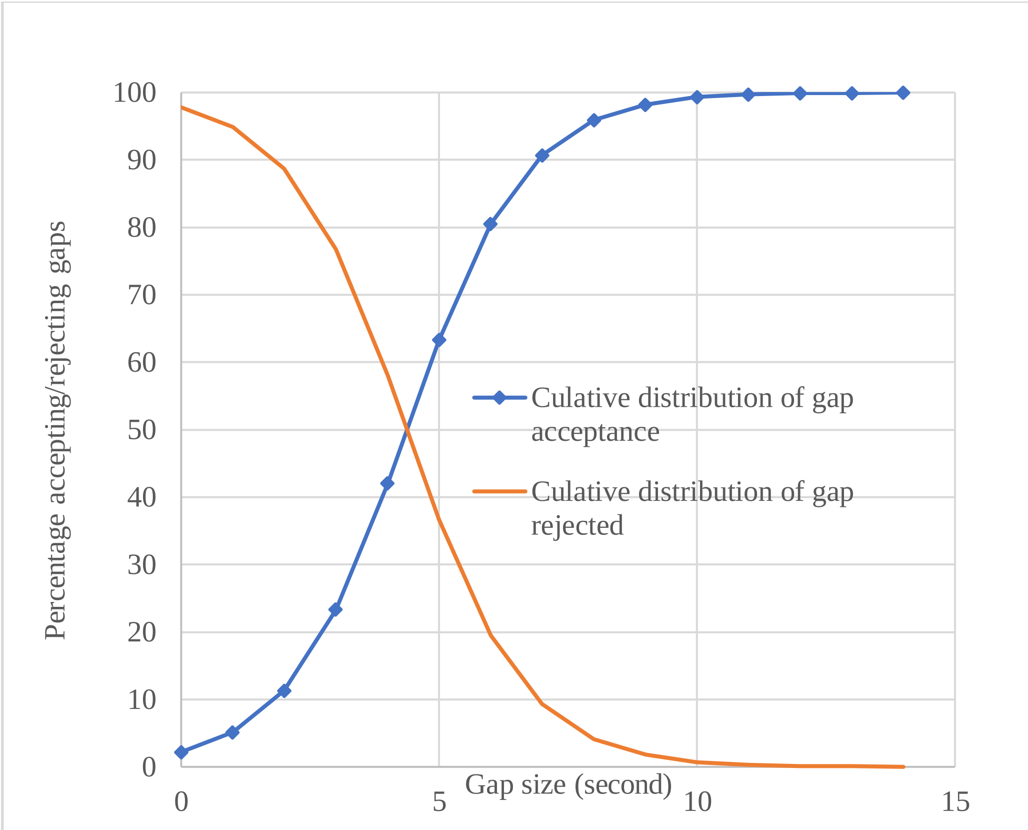


Figure 4. 3Cumulative distribution of gaps at Kuchit Market Center

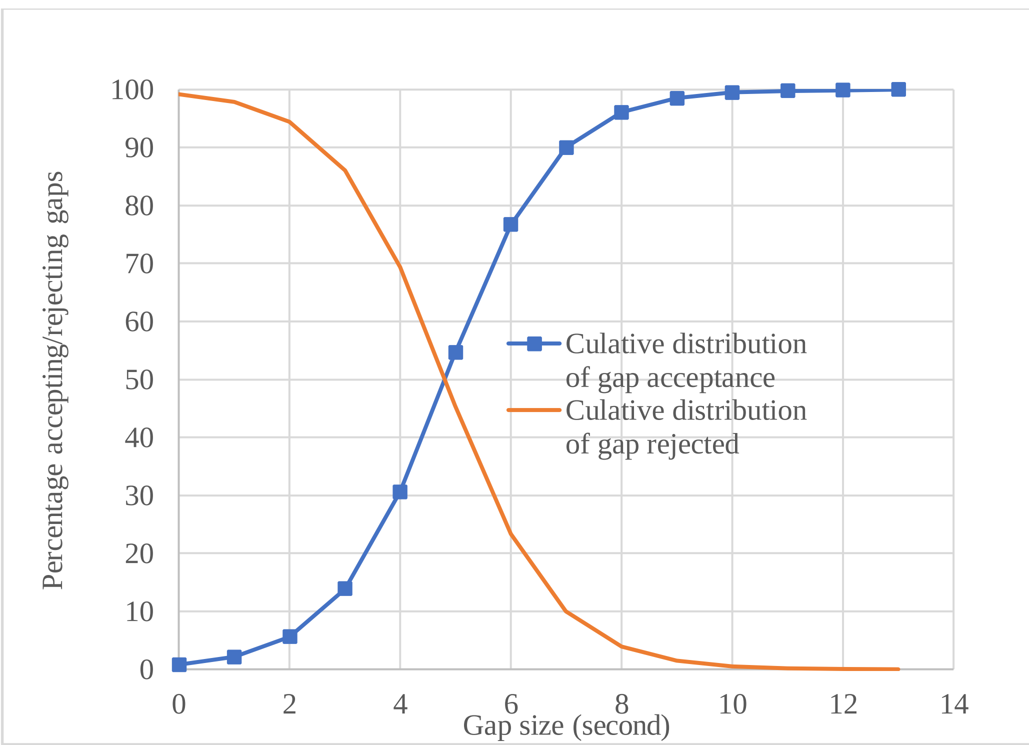


Figure 4. 4 Cumulative distribution of gaps at Zenbaba Pension

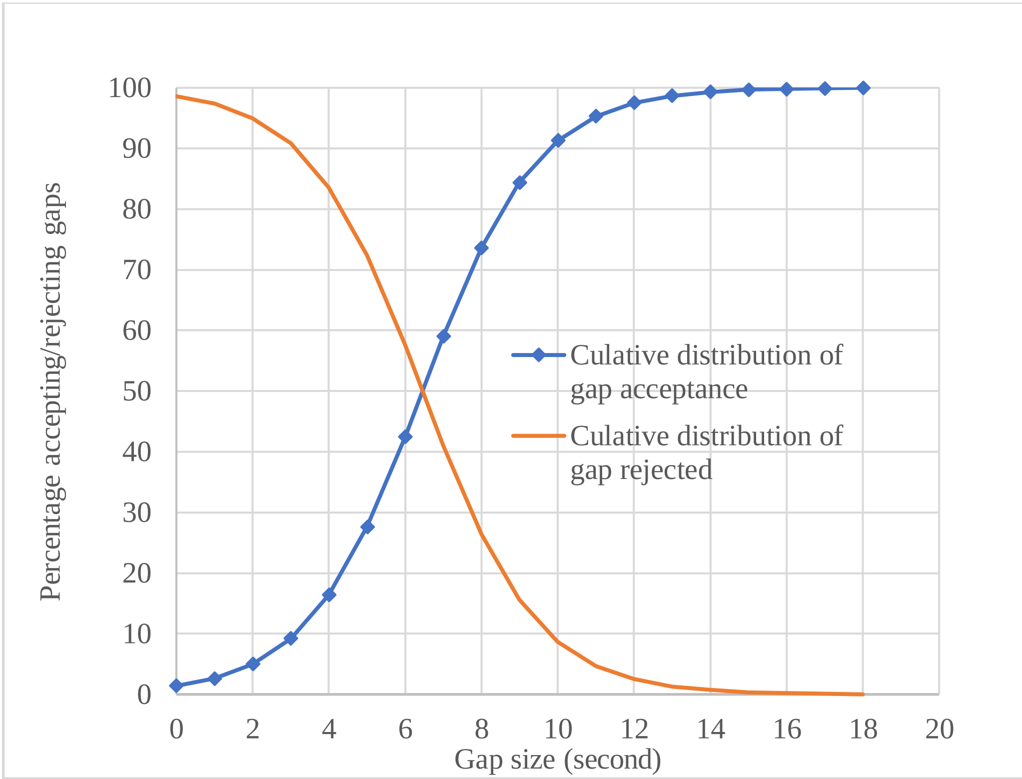


Figure 4. 5 Cumulative distribution of gaps at Habesha Guest House

Each pedestrian has a critical gap to cross the street. According to HCM, the critical gap can be defined as the time below which a pedestrian will not attempt to begin crossing the street, and it can be obtained by making the probability of 50%, which means half of all pedestrians to safely cross the street. As a result, if accepting gaps less than a critical gap, then the pedestrian is at risk. 50% of pedestrians accepting the gap for combined data is 4.97second; which means pedestrian will attempt to cross the street if the available gap is greater than 4.97 seconds.

Critical gap determined by (Manual, 2010) as:

$$critical\ gap = \left(\frac{l}{Vs}\right) + ts \quad (5)$$

Where l-is the crosswalk length= 10.3m,

Vs= ideal crossing speed of the site (1.2m/s for less than 20% of elders) and

ts = crossing startup time (not covered in this thesis work).

Let's consider the speed of pedestrian=1.51m/s (from table 4.3) and

Crossing startup time =2second (from HCM) then the critical gap would be:

Critical gap= (10.3/1.51)+2=8.82second

But, if we use 1.2m/s crossing speed (HCM recommendation).

Then, the critical gap would be: Critical gap = 10.3/1.2 + 2 = 10.58second; from these, it is possible to conclude that pedestrian of Bahir Dar city was forced to increase their crossing speed as compared to the developed countries. The average and 85th percentile used crossing speed of pedestrians at each site were summarized in table 4.3.

Table 4. 3 pedestrian crossing speed at each site

Site	Crossing speed in m/s	
	Average	85th-percetile
Amhara Martyrs Memorial Office	1.35	1.58
Habesha Gust House	1.59	2
Kuchit Market Center	1.57	1.98
Zenbaba Pension	1.4	1.73
Combined data	1.51	1.87

As a result, improving the given facility was required for accounting the speed of pedestrians which results in efficient and safe to cross the roadway.

Effect of crosswalk markings on pedestrian gap acceptance

Assessments proved that all crosswalk locations require an improvement in assuring pedestrian safety and mobility. Before such recommendations indicated let's check the effect of zebra cross on size of pedestrian gap acceptance. All sites except Amhara Martyrs Memorial office have both marked and unmarked crosswalk locations (to the left and right of median one is marked and the other were unmarked), but in Amhara martyrs memorial office crosswalks in both sides of the median were unmarked. To indicate the effect of crosswalk marking on pedestrian gap acceptance, one-way analysis of variance (ANOVA) was conducted for each site having both marked and unmarked crosswalks using mean gap accepted at marked and unmarked crosswalks.

The tested hypothesis was;

H_0: Mean gap accepted at marked crosswalk = Mean gap accepted at an unmarked crosswalk

H_a: Mean gap accepted at marked crosswalk ≠ Mean gap accepted at an unmarked crosswalk

Table 4. 4 Analysis of variance on the effect of crosswalk marking on pedestrian gap acceptance

ANOVA						
Sites		Sum of Squares	df	Mean Square	F	Sig.
At Habesha Guest House	Between Groups	75.032	1	75.032	1.922	.168
	Within Groups	6010.988	154	39.032		
	Total	6086.019	155			
At Kuchit Market Center	Between Groups	19.853	1	19.853	1.496	.222
	Within Groups	4260.407	321	13.272		
	Total	4280.260	322			
At Zenbaba Pension	Between Groups	35.868	1	35.868	1.707	.193
	Within Groups	3613.425	172	21.008		
	Total	3649.293	173			

But, from table 4.4 reveals that there is no significant difference between the mean pedestrian gap acceptance of marked crosswalk and unmarked crosswalk at three considered crosswalk locations having Sig. < 0.05, hence the null hypothesis (H_0) was accepted and the alternative hypothesis (H_a) was rejected. Although the priority rule at such locations is clear; pedestrians have the absolute right of way over vehicles, the driver often competes with pedestrians over the right of way which risks pedestrian safety and imposes extra delays on pedestrians. As a result, vehicles do not give right of way to pedestrians, leaving them with the only choice to wait until an accepted gap is available like that of the unmarked crosswalk. Drivers usually hijack the right of way from pedestrians which often causes a traffic accident. Therefore, pedestrians lose the reason for crossing at these designed locations pushing them to cross at arbitrary locations increasing their safety risk. As a result, various strategies need to be applied to improve driver-yielding behavior to provide a safe crossing for pedestrians at marked crosswalk areas. For instance, advanced yield markings have proven to improve driver scanning for pedestrians and reduce the conflicts between vehicles and pedestrians at marked crosswalks. This observation was strongly supported by a recent study in India (Kadali & Vedagiri, 2019).

4.3 Model framework for Pedestrian gap acceptance and crossing choice using Behavioral analysis

Model framework was required for incorporating selected pedestrian behavioral, roadway and vehicular characteristics for accepting of vehicular gap size. The pedestrian road crossing behavior at a mid-block location can be predicted by two types of models. The first model is used to predict the minimum accepted vehicular time gap using multiple linear regression techniques. The second model is to predict mid-block crossing choice using binary logistic linear regression technique. In both models, the results and discussion for these models are illustrated in the following sections.

4.3.1 Modelling pedestrian accepted traffic gap

The traffic gap is the difference between the pedestrian is just ready to set foot on the street and vehicles has just passed through the vertical line indicating the pedestrians crossing the path. The pedestrian may accept the lag (first) vehicular gap or accept after rejecting the successive vehicle gap then accept a gap appropriate for a particular pedestrian to cross the road. It is the dependent variable in the study where 1 and 0 were designated during extraction for representing gaps accepted and rejected respectively. The minimum accepted vehicular time gap was modeled with the help of multiple linear regression (MLR) technique. A lognormal regression model was selected given that a normal distribution could be successfully fitted to the logarithm of the gaps. It is noted that lognormal regression assumes a normal distribution for the logarithm of the dependent variable, and was thus preferred over log-linear regression (Kadali & Perumal, 2012; Kadali et al., 2014; Kadali & Vedagiri, 2013, 2019; Serag, 2014; Yannis et al., 2013).

A stepwise multilinear regression model analysis was applied for modeling of multiple linear regression using Statistical Package for the Social Sciences (SPSS-20). In preliminary analysis descriptive statistics of continuous variables, normality and linearity assumptions of the MLR model were tested. Further, a linearity assumption (relation between the independent and dependent variable is linear) was tested with scatter plots of the dependent and independent variables. Table 4.5 was summarized descriptive data, which have a mean value of continuous data and mean accepted vehicular gap size (sec) for categorical data.

Table 4. 5 Descriptive statistics of variables used in the gap acceptance model frame work

Variable		% of value	Mean	Standard deviation
Pedestrian safety margin [s]		-	1.57	4.597
Vehicle arrival rate [Veh/s]		-	0.24	0.126
Pedestrian crossing speed [m/s]		-	1.51	0.447
Waiting time [s]		-	4.05	6.451
Vehicle speed [km/h]		-	30.36	11.859
Stage of crossing		-	0.08	0.306
Vehicular gap size [s]		-	8.49	4.991
Number of observations before crossing		-	1.00	0.074
Number of observations during crossing		-	0.63	0.628
Frequency of Attempt		-	0.00	0.053
Frequency of step backward		-	0.01	0.074
Type of Gap [s]	0=Lag	32.5	8.94	5.163
	1=Gap	67.5	8.27	4.897
Tactic of crossing [s]	0=street	76.1	8.26	4.816
	1=skew	23.9	9.23	5.463
Pedestrian path change condition [s]	0=yes	22.8	9.26	5.492
	1=no	72.2	8.26	4.815
Pedestrian waiting place [s]	0=pavement	52.7	7.88	4.766
	1= other than pavement	17.4	9.65	5.063
	2=not required	29.7	8.88	5.199
Vehicular travel lane [s]	near = 0	58.1	7.95	4.769
	far = 1	41.9	9.24	5.198
Driver yield behaviour [s]	0=yes	0.8	7.17	2.714
	1=no	99.2	8.50	5.005
Vehicular direction [s]	East=0	0	-	-

	West=1	0	-	-
	North=2	49	8.78	5.462
	South=3	51	8.21	4.483
Pedestrian gender [s]	male = 0	58.1	8.29	4.630
	female = 1	27	9.29	5.887
	Both = 2	14.9	7.82	4.417
Pedestrian age [s]	child (<18) = 0	7.3	9.66	4.918
	young (18-30) = 1	42.6	8.64	4.990
	middle (31-50) = 2	41.2	8.35	5.177
	elders (>50) = 3	8.9	7.47	3.928
Pedestrian platoon size [s]	single = 0	60.3	8.72	5.306
	two = 1	25.4	8.41	4.586
	three or more = 2	14.2	7.66	4.195
Pedestrian speed change behaviour [s]	yes = 0	13.4	6.85	3.770
	no = 1	86.6	8.74	5.110
Pedestrian usage of cell phone [s]	yes = 0	1.9	8.64	3.713
	no = 1	98.1	8.49	5.015
Pedestrian rolling behaviour condition [s]	yes = 0	30	7.51	4.696
	no = 1	70	8.91	5.060
Pedestrian baggage effect [s]	Yes=0	10.2	8.11	4.387
	No=1	89.8	8.53	5.056
Pedestrian Crossing direction [s]	East = 0	43.3	8.54	5.260
	West = 1	56.7	8.45	4.782
	North = 2	0	-	-
	South =3	0	-	-
Type of vehicle [s]	Motor cycle = 0	4.7	7.91	3.848
	Three-wheeler = 1	45.5	7.67	4.667
	car/ taxi = 2	8	8.05	3.891
	Utilities =3	9.5	9.72	4.875
	Small bus =4	23.9	9.10	5.431
	Large bus =5	2.4	13.18	5.780

	Light truck =6	0.6	9.00	2.450
	Medium & heavy truck =7	4.1	9.17	6.487
	Articulated truck =8	1.2	10.89	4.676
	Others (Loader, Grader, etc.) =9	0	-	-
Crossing initiation [s]	Curb = 0	50.8	8.50	4.988
	Median = 1	49.2	8.48	5.000
Decision (for decision model) [s]	Gap rejected =0	67.9	2.91	1.706
	Gap accepted =1	32.1	8.48	5.705

To show the distribution of data, the skewness and the kurtosis values in table 4.6 were low which indicates that there are no extreme outliers present in the data. The normality assumption was tested with the distribution of selected variables satisfied the assumption with little skew. Positive skewness value shows more data is concentrated on above the mean and vice versa.

Table 4. 6 Descriptive statistics for the continuous data used in the gap acceptance model frame work

Descriptive Statistics								
Variables	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
					Statistic	Std. Error	Statistic	Std. Error
Gap/Lag(sec)	1.00	33.00	8.49	4.991	1.633	.091	3.037	.182
VS (Km/hr.)	3.03	80.64	30.36	11.859	1.171	.091	2.399	.182
VAR(veh/sec)	.02	.74	0.24	0.126	.789	.091	.605	.182
PCS (m/s)	.59	3.88	1.51	0.447	1.797	.091	4.927	.182
WT (sec)	0	50	4.05	6.451	3.000	.091	13.228	.182
SM (sec)	-6	24	1.57	4.597	1.795	.091	3.851	.182
SOC	0	3	0.08	0.306	4.548	.091	24.408	.182
NOBC	0	2	1.00	0.074	.000	.091	178.994	.182

NODC	0	3	0.63	0.628	.513	.091	-.468	.182
FATM	0	1	0.00	0.053	18.974	.091	358.989	.182
FSB	0	1	0.01	0.074	13.360	.091	176.985	.182
Valid N				723				

To understand the impact of collected variables on pedestrian accepted gap size, the MLR model was developed at each location as well as with combined data of four locations with stepwise regression. For combined model calibration 80 % of the data (582 accepted gaps) was used whereas 20% (144 accepted gaps) were used for model validation. The contributed variables were confirmed with t-statistic value and are encompassed at a 95% confidence level with t-statistics of ±1.96 for both individual (at each site location) as well as combined data models. The individual models of each selected location presented in table 4.7. The goodness of fit measure R^2 at Habesha guest house was higher than the other sites. This is because, there is a relatively higher speed at this location, as a result, pedestrian fear for accepting different gaps and cause for uniform behavior on pedestrians for accepting the available vehicular gap size, and results in the nearly same size of the gap. But, when we see the goodness of fit for Kuchit marketing center, there is higher variation in accepting the available gap caused by peoples are in harry and speed of vehicles were relatively low, which force pedestrians to use different gestures and aggressive behavior for competing to use any free space in the road facility, which results in smaller R^2. In each site, a residual analysis took place to test the goodness fit test. It was found that the residuals follow the normal distribution. Their mean value was almost zero and they had equal variances (homoscedasticity test). It was also confirmed that the recorded log-gaps are normally distributed as well. The most powerful factors which have a significant impact of minimum vehicular gap size are safety margin, pedestrian crossing speed, type of gap, vehicular arrival rate, and rolling behavior. The model obtained at Amhara martyrs memorial office has a smaller number of explanatory variables. Whereas, at the Kuchit market center there is a higher number of explanatory variables. Meaning, at Kuchit most of the survey participants try to compete with the moving motorized vehicles using different crossing gestures due to lesser travel speed and lesser arrival rate observed on vehicles, but at Amhara martyrs memorial office the pedestrian's fear of taking smaller gap size due to higher arrival rate and higher travel speed observed on vehicles. Sites located around CBD area pedestrians were in harry and a strong familiarity with the survey site, resulting in higher effect using pedestrian crossing behaviors like crossing speed change, crossing path change, platooning, and a number of observations before crossing, etc.

Table 4. 7 Pedestrian accepted gap size models at each selected location

Location	Pedestrian accepted gap size MLR model equation	R-square
In front of Amhara Martyrs memorial office	Log-gap=1.254+0.03*SM-0.212*PCS+0.107*TOG-0.412*VAR-0.033*Rbeh	0.915
In front of Habesha Gust house	Log-Gap=0.988+0.026*SM-0.089*PCS+0.161*TOG-0.747*VAR+0.039*Rbeh+0.038*PWP+0.002*WT	0.942
In front of Kuchit marketing center	Log-gap=0.8+0.037*SM-0.607*VAR+0.111*Rbeh-0.102*PCS+0.007*WT+0.138*TOG+0.053*PWP-0.035*NODC+0.034*VTL+0.047*PScc+0.016*PPS+0.023*PCD	0.802
In front of Zenbaba Pension	Log-gap=1.306+0.034*SM-0.617*VAR+0.008*WT-0.298*NOBC-0.112*PCS-0.086*SOC+0.051*Rbeh+0.026*VD	0.894

Notes: The contributed variables were selected at 95% confidence level with p-value<0.05 using stepwise linear regression.

Where: Log-gap: Logarithm of pedestrian accepted gap size; SM: Safety margin (sec.); PCS: Pedestrian crossing speed (m/s); TOG: Type of gap ; VAR: Vehicular arrival rate (Vehicle/ second); Rbeh: Rolling behavior ; PWP: pedestrian waiting place ; NODC: number of observation to the incoming vehicles; VTL: vehicular travel lane ; PScc:

pedestrian speed change condition ; PPS: Pedestrian platoon size ; SOC: Stage of crossing; VD: Vehicular direction.

The overall significance of the combined multiple regression MLR model is tested with F-test and it has been estimated whether the regression coefficients are different from zero or not the overall significance of combined MLR model results are shown in Table 4.8.

Table 4. 8 Pedestrian accepted gap size combined model fitting results

ANOVA					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	26.188	14	1.871	206.075	0.000
Residual	5.074	559	0.009		
Total	31.262	573			

The calculated F-Value 206.075 with p-value 0.000 shows that there is a strong correlation between the dependent variable (minimum accepted gap) and independent variables.

The tested hypothesis was;

H_0: No contribution of selected pedestrian behavioral, vehicular and roadway characteristics on accepted gap size

H_a: There is at least one selected independent variable that influences the dependent variable accepted gap size. But, the above combined model fitting table reveals that there is a strong relationship between 14 independent variables and dependent variables with F-statistics 206.075, $p < 0.05$ with 14 degree of freedom, hence the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted.

The calibrated combined model results relationship between the dependent and independent variables which is the so-called goodness of fit test, and was assessed in terms of R-square and resulted as 0.837; which indicates a strong relationship between the two. The analysis was conducted using a stepwise linear regression technique, which removes the insignificant variables in the model formulation after doing many iterations. But, before the insignificant variables were removed, R-squared of 0.838 was obtained. As a result, the change in R-square due to removing of insignificant variables obtained as 0.12%, which justifies removing of insignificant variables was logical.

Table 4. 9 Gap Acceptance Model summary for goodness of fit test

R	R Square	Adjusted R Square	Std. Error of the Estimate
.915	.837	.833	.09565

The variation inflation factor (VIF) less than 10 reveals that there is no multicollinearity between independent variables. The significance of each regression coefficient in the regression model was tested with a 95% confidence interval. The estimated coefficient β represents the change in the output variable (gap acceptance) due to unit change in the input (independent variables like rolling, path change, number of observation before starting to cross, safety margin, crossing speed, etc.). The sign of beta indicates that there is an increasing or a decreasing in accepted gap size with a change in independent variables. The negative coefficients designate that there is a decrease in pedestrian accepted gap size with an increase vehicular arrival rate, pedestrian crossing speed, driver yield behavior, stage of crossing, pedestrian use of skewed crossing, pedestrian path change condition and number of observation before crossings. The positive coefficients designated that there is an increase in pedestrian accepted gap size, all independent variables which are significant to the dependents having a positive value of beta indicates an increasing effect, meaning an increase in their value there should have a higher gap size to be accepted, and vice versa.

$$\begin{aligned}\mathrm{Log}-\mathrm{gap} = 1.274 &+ 0.03 * \mathrm{SM} - 0.78 * \mathrm{VAR} + 0.006 * \mathrm{WT} - 0.106 * \mathrm{PCS} + 0.052 \\ &* \mathrm{Rbeh} + 0.126 * \mathrm{TOG} + 0.042 * \mathrm{PWP} + 0.023 * \mathrm{VTL} + 0.001 * \mathrm{VS} \\ &- 0.131 * \mathrm{DYB} - 0.036 * \mathrm{SOC} - 0.1 * \mathrm{PCT} - 0.097 * \mathrm{PPcc} - 0.089 \\ &* \mathrm{NOBC}\end{aligned}$$

Where: Log-gap: Logarithm of pedestrian accepted gap size; SM: Safety margin (sec.); PCS: Pedestrian crossing speed (m/s); TOG: Type of gap; VAR: Vehicular arrival rate (Vehicle/ second); Rbeh: Rolling behavior ; PWP: pedestrian waiting place ; WT: waiting time (sec.); NOBC: number of observation to the incoming vehicles before starting to cross; VTL: vehicular travel lane ; PPcc: pedestrian path change condition ; DYB : driver yield behavior ; PCT: Pedestrian crossing tactics; SOC: Stage of crossing ;VS: Vehicle speed at crosswalk locations (km/hr).

Table 4. 10 Descriptive statistics results for the MLR gap acceptance model

Variables	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		
	B	Std. Error	Beta			Lower Bound	Upper Bound	VIF
(Constant)	1.274	0.074		17.196	0.000	1.129	1.42	
SM	0.03	0.001	0.585	25.708	0.000	0.027	0.032	1.785
VAR	-0.78	0.055	-0.411	-14.087	0.000	-0.889	-0.671	2.929
WT	0.006	0.001	0.158	7.956	0.000	0.004	0.007	1.354
PCS	-0.106	0.01	-0.207	-11.079	0.000	-0.125	-0.088	1.204
Rbeh	0.052	0.01	0.1	5.174	0.000	0.032	0.071	1.296
TOG	0.126	0.02	0.254	6.427	0.000	0.088	0.165	5.38
PWP	0.042	0.01	0.159	4.286	0.000	0.023	0.061	4.712
VTL	0.023	0.008	0.048	2.723	0.007	0.006	0.039	1.062
VS	0.001	0	0.052	2.8	0.005	0	0.002	1.187
DYB	-0.131	0.049	-0.047	-2.663	0.008	-0.228	-0.034	1.054
SOC	-0.036	0.014	-0.046	-2.593	0.01	-0.063	-0.009	1.085
PCT	-0.1	0.018	-0.198	-5.459	0.000	-0.136	-0.064	4.552
PPcc	-0.097	0.02	-0.178	-4.901	0.000	-0.136	-0.058	4.535
NOBC	-0.089	0.043	-0.036	-2.074	0.038	-0.174	-0.005	1.017

The standardized beta describes the point elasticity of each of the variables. For example, an increase of 1 % in safety margin results in an increase of 58.5% of the traffic gap accepted. In addition, a 1% increase in vehicle arrival rate results decreases in traffic gap acceptance by 41.1%.

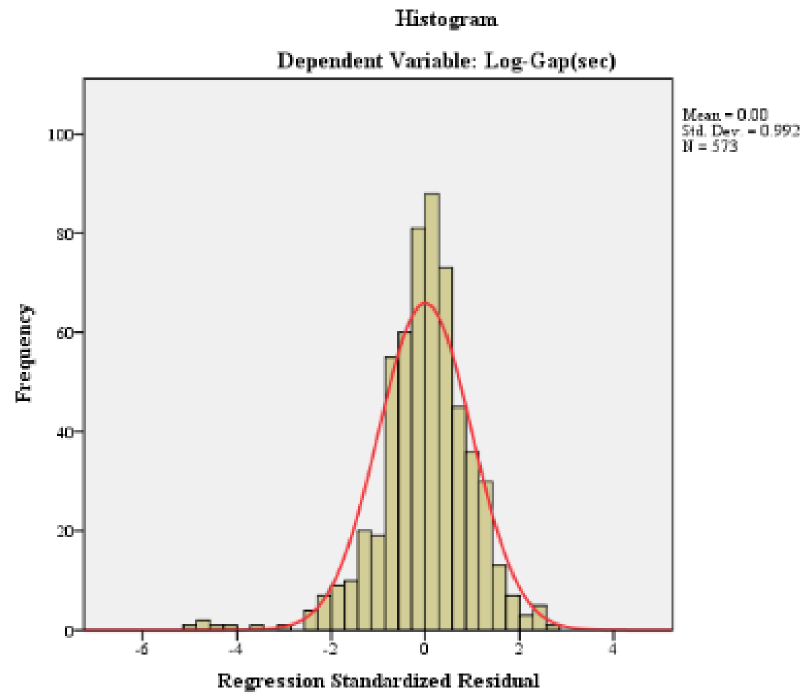


Figure 4. 7 Histogram of combined data used for gap acceptance modeling

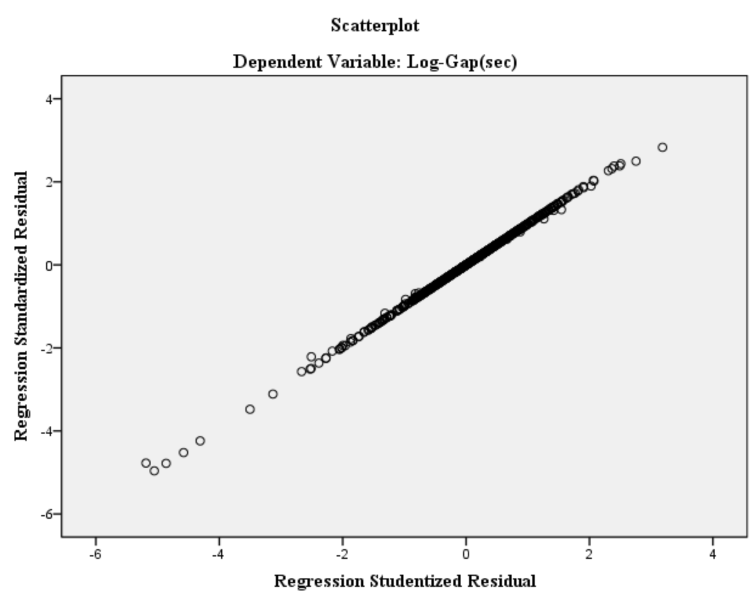


Figure 4. 6 Scatter plot of combined data used for gap acceptance modeling

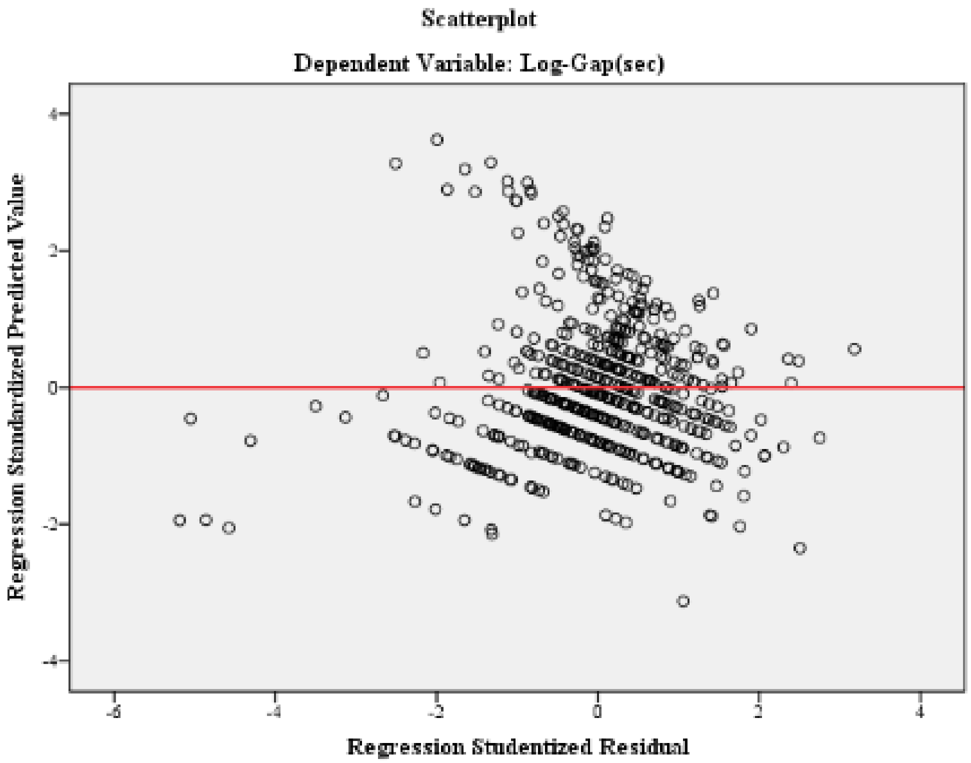


Figure 4. 8 Standardized residual plot for the combined data used for gap acceptance modeling

A homoscedasticity test has been performed to ensure the normality of error in terms of the accepted gap parameter. From the plot, there is a constant variance residual test (figure 4.8), indicated by equal distribution from zero line results mean zero. The summation of residuals were almost zero, it can be proved by equal distribution from the zero line. A smaller value of residual proves the data was normally distributed. Normality can also be evaluated using histogram, from the histogram their nearly smaller skewness. Furthermore, the scatter plot was used to show a linear relationship between a dependent (logarithm of pedestrian gap acceptance) and independent variables (Pedestrian behavior, roadway, and vehicular characteristics). Pedestrian gap acceptance model can be conducted of a homoscedasticity test or comparing the mean value of the field observed and predicted gap size. The model was validated using 20% of the data (144 accepted vehicular gaps). Model validation was done in SPSS-20 using scatter plot and Pearson correlation, results in R-square of 0.887; which indicates a very good validation.

Table 4. 11 Pearson correlation between observed and predicted log-gap

Correlations			
		Log-Gap observed (sec)	Log-Gap estimated (sec)
Log-Gap observed (sec)	Pearson Correlation	1	.942**
	Sig. (2-tailed)		0
Log-Gap estimated (sec)	Pearson Correlation	.942**	1
	Sig. (2-tailed)	0	

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

Listwise N=139

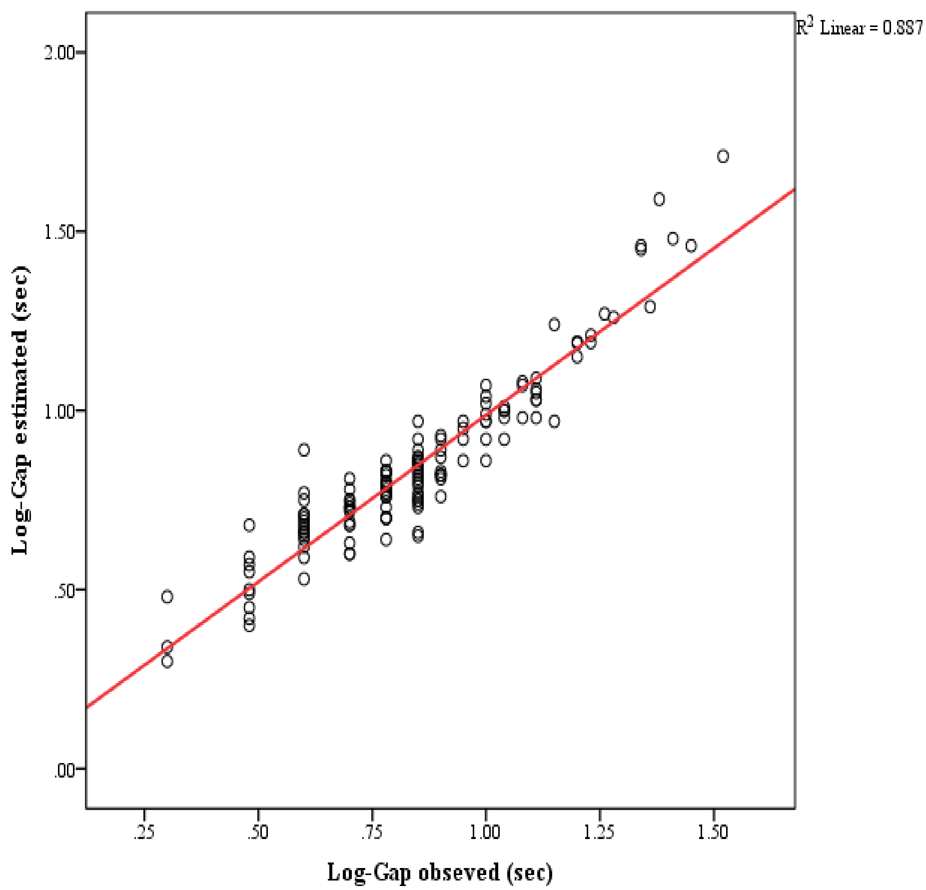


Figure 4. 9 Scatter plot between observed and predicted log-gap

To show clearly to which extent each of the independent variables affects the dependent variables (log-gap), an analysis of elasticities (beta) is carried out, as shown in table 4.12. Moreover, the relative effect (B*), as a normalization of the estimated point elasticities to the lowest elasticity, is calculated to compare the magnitude of effects of all independent variables. The calculation of relative elasticity was straightforward. If the variable "number of observation before crossing" has an elasticity of 1, then the variable "safety margin" has elasticity of 16.25, which means it affects the gap acceptance 16.25 time more than the number of observation before crossing. Then the vehicle arrival rate will have 11.42 greater effect on the size of gap and so on.

Table 4. 12 Elasticity of the gap acceptance model parameters

Variables	Standardized Coefficients	
	Point Elasticity (Beta)	Relative Elasticity (Beta*)
SM	0.585	16.25
VAR	-0.411	-11.42
WT	0.158	4.39
PCS	-0.207	-5.75
Rbeh	0.1	2.78
TOG	0.254	7.06
PWP	0.159	4.42
VTL	0.048	1.33
VS	0.052	1.44
DYB	-0.047	-1.31
SOC	-0.046	-1.28
PCT	-0.198	-5.5
PPcc	-0.178	-4.94
NOBC	-0.036	-1

The impact of vehicle arrival rate and Pedestrian crossing speed on the size of gap acceptance were strongly supported by (Chandra et al., 2014).

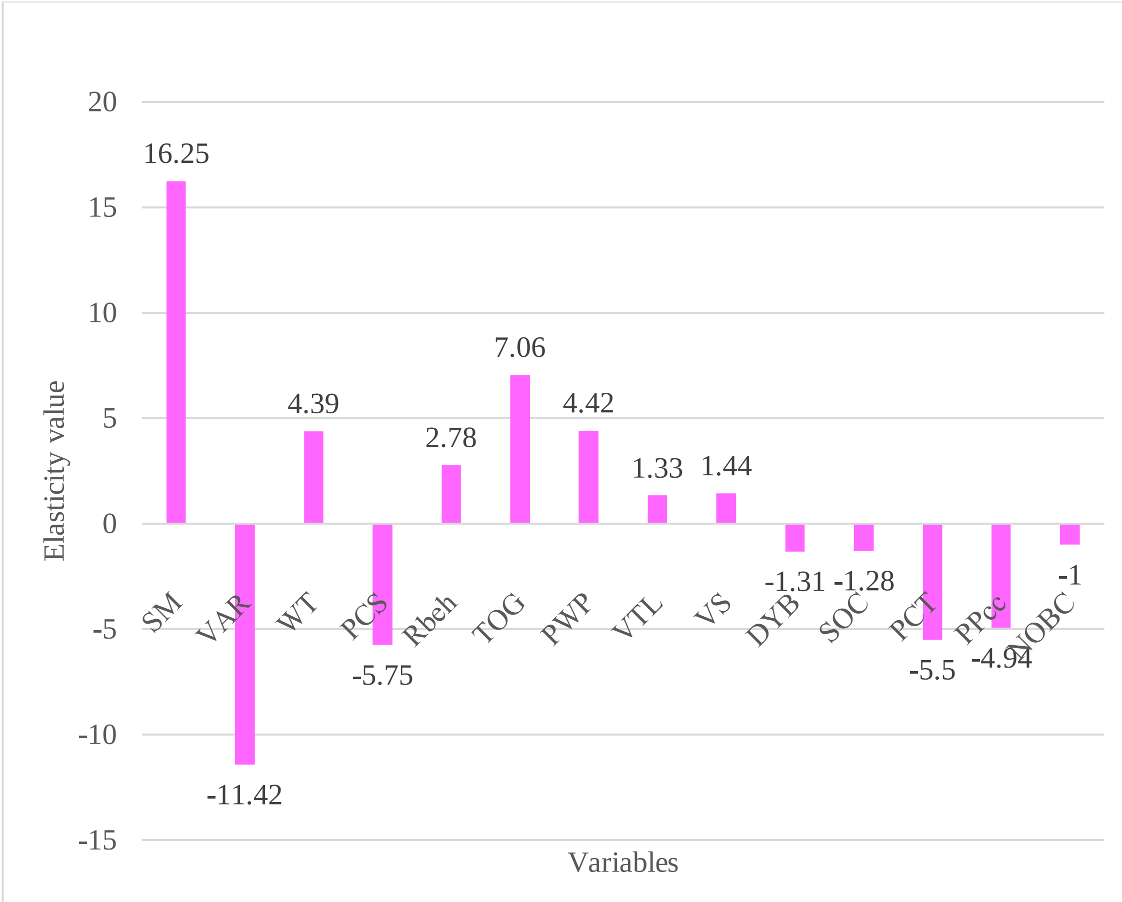


Figure 4. 10 Elasticity of significant variables on gap acceptance model

The elasticity analysis shows that, among the different variables, pedestrian safety margin and vehicular arrival rate are the most influencing variables on gap acceptance as they have the highest elasticities. Type of gap, waiting time, pedestrian crossing speed, pedestrian crossing tactics, and pedestrian path change condition have a medium effect while pedestrian rolling behavior, vehicular travel lane, vehicular travel speed, driver yield behavior, stage of crossing, and the number of observation before crossing have low effect on gap size. Although the type of vehicle is an important factor for accepting the gaps, in this study, it is observed that pedestrians accept the traffic gap concerning vehicle arrival rate, vehicular travel lane, and vehicular travel speed. It is true, because small vehicles may arrive at higher speeds which resulted in rejecting the gap (Cherry et al., 2012; Kadali et al., 2014; Serag, 2014). Therefore, the speed of the vehicle plays an important role in the multiple linear regression model.

4.3.2 Modelling pedestrian crossing choice

In this model both accepted gaps and the largest one of the rejected gaps were used, whilst in the previous model only the accepted gaps were used. Crossing choice is a judgment made about whether it is possible to complete a crossing before the oncoming vehicle arrives at the gap. The pedestrian decision making to crossing the road or not as described by the binary logit regression model (BL Model)(Kadali & Perumal, 2012; Kadali et al., 2014; Kadali & Vedagiri, 2013, 2019; Serag, 2014; Sun et al., 2003; Yannis et al., 2013).

The overall significance of the model is tested with Hosmer and Lemeshow test results are shown in Table 4.13:

Table 4. 13 Choice model fitting results

Hosmer and Lemeshow Test		
Chi-square	df	Sig.
22.126	8	.005

The calculated chi-square value 22.126 with p-value 0.005 shows that there is a strong correlation between dependent (probability to accept the gap) and independent variables.

The tested hypothesis was;

H_0: No contribution of selected pedestrian behavioral, vehicular and roadway characteristics on the probability to accept the vehicular gap

H_a: There is at least one selected independent variable that influences on the dependent variable probability to accept the vehicular gap. But, from table 4.14, there is a strong relationship between 9 independent variables and dependent variables with chi-square 21.967, $p < 0.05$ with 8 degrees of freedom, hence the null hypothesis (H_0) was rejected and the alternative hypothesis (H_a) was accepted. The calibrated model results in a relationship between the dependent and independent variables and was assessed in terms of Nagelkerke R Square of 0.681; which indicates a strong relationship between the two. But, before the insignificant variables were removed, R-squared of 0.688 was obtained. As a result, the change in R-square due to removing of insignificant variables obtained as 1%, which justifies removing of insignificant variables was logical.

Table 4. 14 Choice model summary for goodness of fit test

Model Summary		
-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
737.902	.508	.681

The significance of each regression coefficient in the regression model was tested with a 95% confidence interval. The estimated coefficient beta represents the change in the output variable (Probability to accept the available gap) due to unit change in the input (independent variables like gap size, vehicle type, vehicle speed, vehicular direction, vehicular travel lane, waiting time, pedestrian age, pedestrian waiting place and place of crossing initiation). The sign of beta indicates that there is an increasing or a decreasing in probability to accept the available gap size with a change in independent variables. The negative coefficient designates, there is a decrease in probability to accept the available gap size with an increase in vehicle size, increase in vehicle speed, change in traffic volume, and vehicles move in the far lane, increase in waiting time, and waiting place is other than pavement. The positive coefficients designated that there is an increase in probability to accept the available gap size like with an increase in gap size, increase in age, and crossing initiation is median. The probability (p) that a pedestrian crosses the crosswalks at mid-block is:

$$p = e^U/(e^U + 1);$$

$$U = -1.667 + 0.988 * Gap - 0.178 * VT - 0.022 * VS - 0.565 * VD - 1.444 * VTL + 0.297 * Age - 0.072 * WT - 1.621 * PWP + 0.706 * CRI$$

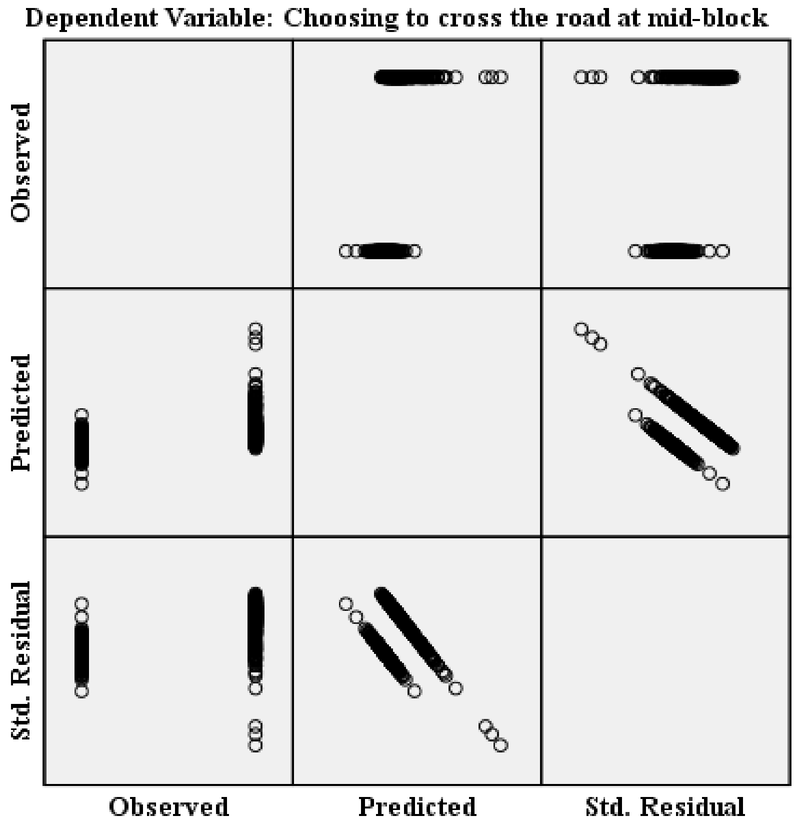
Where: U: the utility function of choosing to cross the road at mid-block crosswalks; CRI: Pedestrian crossing initiation; PWP: pedestrian waiting place; WT: waiting time (sec.); VTL: vehicular travel lane; VD: Vehicular direction; VS: Vehicular speed (km/hr); VT: Vehicle type; Age: age of pedestrian; Gap = time difference between following vehicles.

Table 4. 15 Descriptive statistics results for binary logistic crossing choice model

Variables	B	S.E.	Wald	df	Sig.	Exp(B)	95% C.I.for EXP(B)	
							Lower	Upper
Gap	.988	.062	253.791	1	.000	2.685	2.378	3.032
VT	-.178	.055	10.468	1	.001	.837	.752	.932
VS	-.022	.010	4.910	1	.027	.979	.960	.997
VD	-.565	.198	8.116	1	.004	.568	.385	.838
VTL	-1.444	.203	50.730	1	.000	.236	.159	.351
Age	.297	.125	5.673	1	.017	1.345	1.054	1.717
WT	-.072	.018	15.715	1	.000	.931	.899	.964
PWP	-1.621	.268	36.474	1	.000	.198	.117	.335
CRI	.706	.228	9.560	1	.002	2.026	1.295	3.169
Constant	-1.667	.579	8.284	1	.004	.189		

Crossing initiates from the median was the higher probability to be accepted have supported with a study in India by (Das et al., 2005). In the BL model for mid-block crossing choice, only nine variables were significant and included in the model. It is interesting to note that none of the pedestrians' individual crossing behavior was found to be significant in crossing choice model; it is likely that these effects are included in the 'traffic gap' variable, given that this variable was found to be affected by certain characteristic of pedestrians like number of observation before crossing, crossing tactics, and rolling behavior. This attributed the fact that most of the survey participants may have a strong familiarity with the survey site, located in a very central area, particularly for the Kuchit market Center and Zenbaba pension crosswalks, resulting in less uncertainty in the decisions of those pedestrians that are often associated with particular behaviours. These results were strongly supported by (Serag, 2014).

Figure 4.11 is presented for showing the relation between observed and predicted probabilities which gives very minimum residual indicates a strong relationship.



Model: Intercept + Gap + VT + VS + VAR + VD + VTL + DYB + Gen + Age + WT + Puoc + PPS ...

Figure 4. 11 Scatter plot of predicted and observed probabilities to accept the gap data using with residuals

Model have a smaller error, which was checked by using residual plot between observed and predicted probability plot named residual plot. As shown in figures 4.11, there is nearly zero residual as a result choice model can be applied. The model was validated using the Pearson correlation of predicted (obtained in logistic regression) and observed data. Pearson correlation gives an R-square of 0.582, which shows a good validation of the model. Pearson correlation justifies that 58.2% of any data can be predicted using a model developed by a binary logistic linear regression model. Model validation percentage was obtained using the squaring of Pearson correlation probability (0.763).

Table 4. 16 Pearson correlation between observed and predicted gap accepting probabilities

Correlations			
		Choosing to cross the road at mid-block	Predicted probability
Choosing to cross the road at mid-block	Pearson Correlation	1	.763**
	Sig. (2-tailed)		.000
	N	1116	
Predicted probability	Pearson Correlation	.763**	1
	Sig. (2-tailed)	.000	
	N	1116	
**. Correlation is significant at the 0.01 level (2-tailed).			

To show clearly to which extent each of the independent variables affects the dependent variables (Probability to cross the road), an analysis of elasticities (beta) is carried out, as shown in table 4.17. Moreover, the relative effect (B*), as a normalization of the estimated point elasticities with to the lowest elasticity, is calculated to compare the magnitude of effects of all independent variables. Relative elasticity on probability of accepting an available gap were determined as , if the variable "vehicle speed" has an elasticity of 1, then the variable "gap size" has an elasticity of 45.6, meaning the effect of gap size on the probability of accepting the available gap 45.6 times more than the "vehicular speed". Crossing initiation will have a 32.6 greater effect on the probability of acceptance compared with vehicular travel speed. Point elasticity was obtained by the natural logarithm of Exp (B).

Table 4. 17 Elasticities for the crossing decision model parameters

Variables	Exp(B)	Point elasticity (Beta)	Relative elasticity (Beta*)
Gap	2.685	0.988	45.6
VT	.837	-.178	-8.2
VS	.979	-.022	-1.0
VD	.568	-.565	-26.1
VTL	.236	-1.444	-66.6
Age	1.345	0.297	13.7
WT	.931	-.072	-3.3
PWP	.198	-1.621	-74.8
CRI	2.026	0.706	32.6

Point elasticity describes that an increase of 1% in waiting time results in a 7.2% decrease in the probability of acceptance, this observation was strongly supported by research conducted in Greece (Yannis et al., 2013). Whereas, an increase of 1% gap size results in a 98.8% increase in the probability of accepting that increased gap.

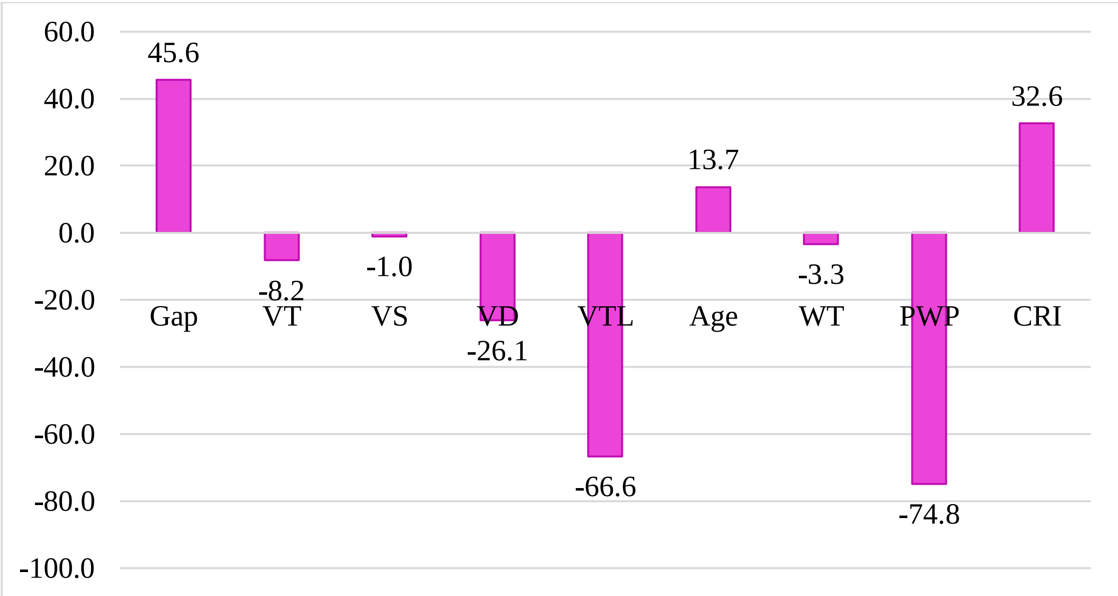


Figure 4. 12 Elasticity of significant variables in the crossing decision model

The elasticity analysis shows that, among the different variables, pedestrian waiting place, vehicular travel lane, crossing initiation, and gap size are the most influencing variables on the probability to accept the available gap as they have the highest elasticities. Vehicular direction and age of pedestrians have a medium effect while vehicle type, waiting time and vehicular speed has a low effect on the probability to cross the road. Moreover, pedestrian waiting place (waiting at pavement), increase in the size of the gap, vehicles travel in the near lane, decrease in vehicle speed, smaller incoming vehicle, increase in pedestrian age and crossing initiation (crossing initiates from the median) increases the probability of accepting the gap and vice versa. As an increase in vehicular gap size and incoming smaller vehicles cause acceptance of the available gap was strongly supported by (Yannis et al., 2013).

Sensitivity of significant variables on probability of gap acceptance

After all that a sensitivity analysis was carried out to comprehend the effect of the independent variables on the dependent variable.

Sensitivity of pedestrian waiting place on probability of gap acceptance

In figure 4.13, it can be observed that the sensitivity of gap acceptance increased for pedestrian crossing initiates from the pavement. But, there may have a higher probability of pedestrians hit by the incoming vehicles during searching an adequate gap while waiting at the pavement than pedestrians wait at curb or green area. For gaps greater than 14 seconds, there is a 100 % probability of acceptance for pedestrians wait other than pavement, for pedestrians wait at pavement the gap should greater than 16 seconds to be accepted by 100% probability.

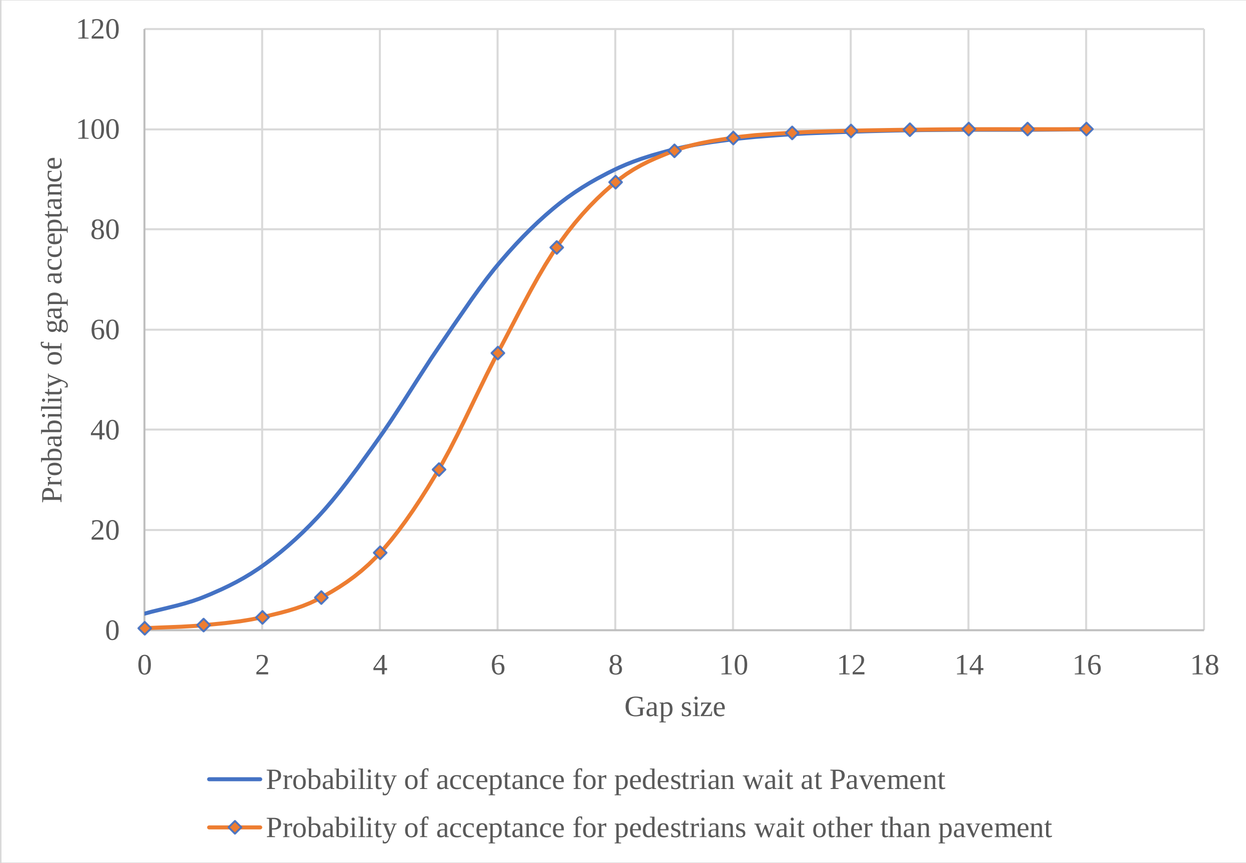


Figure 4. 13 Effect of pedestrian waiting place on probability of gap acceptance

Sensitivity of vehicular travel lane on probability of gap acceptance

In figure 4.14, it can be observed that the sensitivity of gap acceptance increased for vehicles coming on the near lane than far lane. But, there may have a higher probability of pedestrians hit by the incoming vehicles on pedestrians who accept near lane without checking the adequacy of gaps in the far lane. Also, gaps greater than 15 seconds, there is a 100 % probability of acceptance for vehicles coming either in far or near lane. This observation was strongly supported by a study in India (Kadali & Vedagiri, 2019).

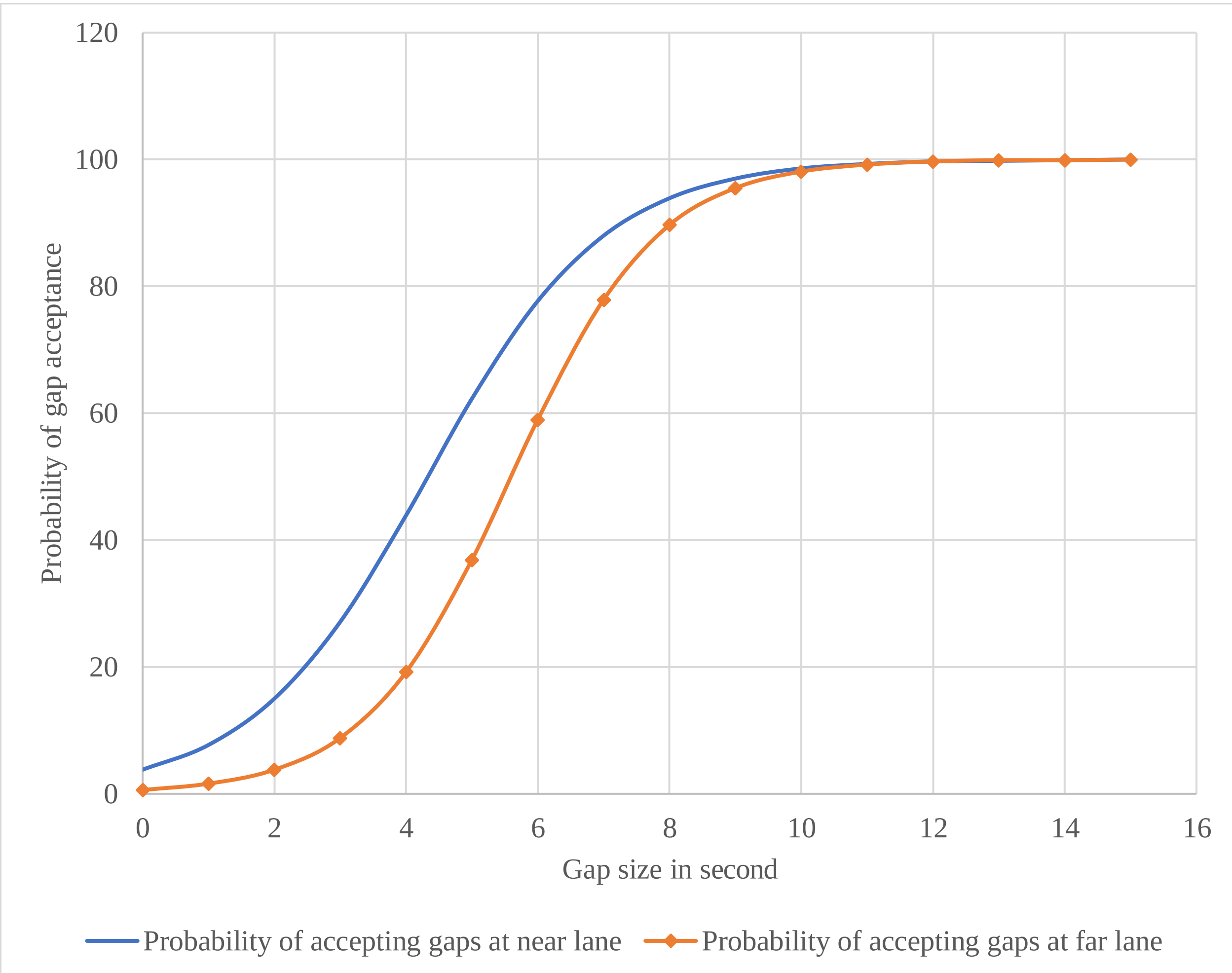


Figure 4. 14 Effect of vehicular travel lane on probability of gap acceptance

Sensitivity of crossing initiation on probability of gap acceptance

In figure 4.15, it can be observed that initially, the sensitivity of gap acceptance increased for gaps initiated from the curb, but after a while, there was a higher probability of acceptance for pedestrians initiated from the median. The cut point was the 5-second vehicular gap. Pedestrians initiated from the median have a higher visibility for the gaps between oncoming vehicles, as a result, those pedestrians initiated from median possibly scan the adequate gap for both the near and far lanes to cross the street, and pedestrians initiated from the median has higher safe than pedestrians initiated from the curb. From the plot, pedestrians have an equal probability of accepting 5-second vehicular gaps. Gaps greater than 17 seconds, 100% probability of acceptance by crossing initiates from either of the two. These findings were strongly supported by a recent observation in China(Zhao, Malenje, Tang, & Han, 2019).

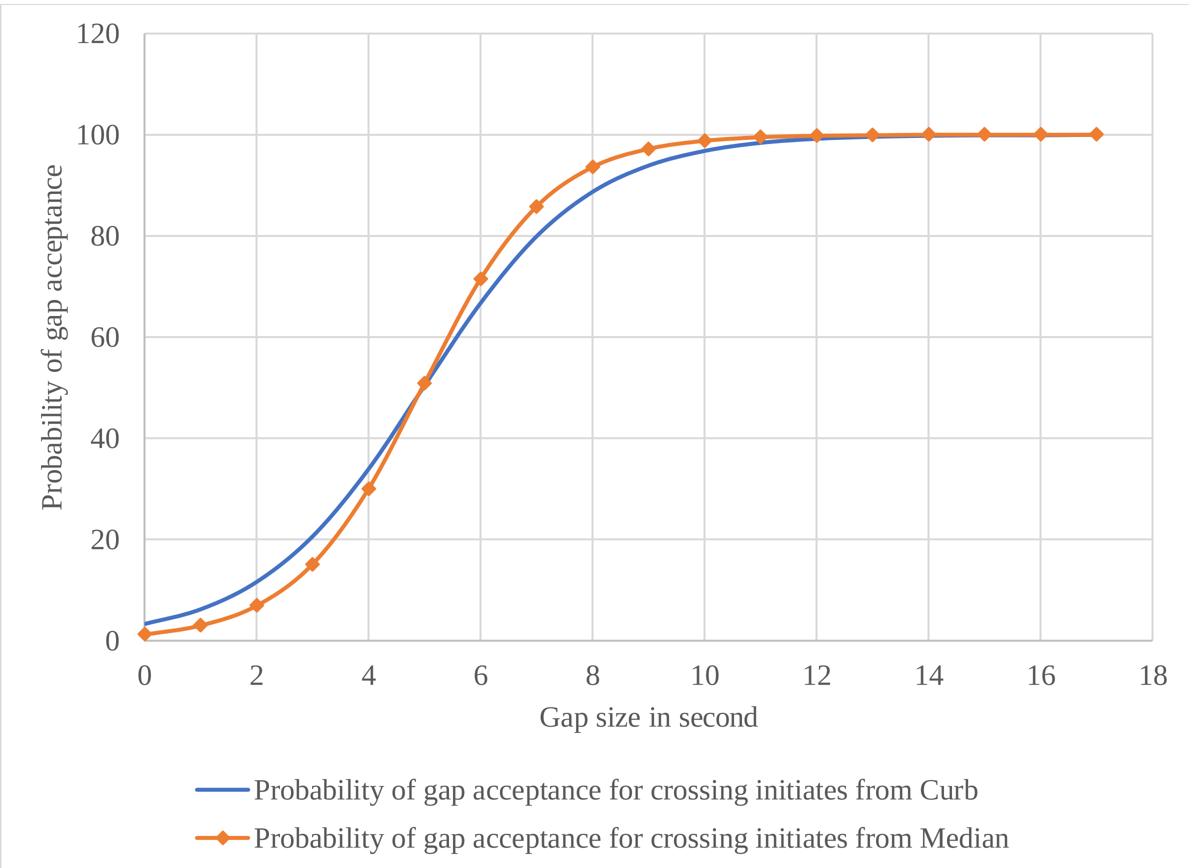


Figure 4. 15 Effect of crossing initiation on probability of gap acceptance

Sensitivity of vehicle type on probability of gap acceptance

In figure 4.16, it can be observed that the sensitivity of gap acceptance increased for three-wheelers incoming to pedestrians waiting to cross the street, whereas, the lesser probability for the incoming truck. From this, it is possible to say pedestrians accept smaller gaps if the incoming vehicle size were smaller, without considering the speed of the vehicle. This finding was strongly supported by a study in Greek (Yannis et al., 2013), but contradicted by a study in Egypt (Serag, 2014).

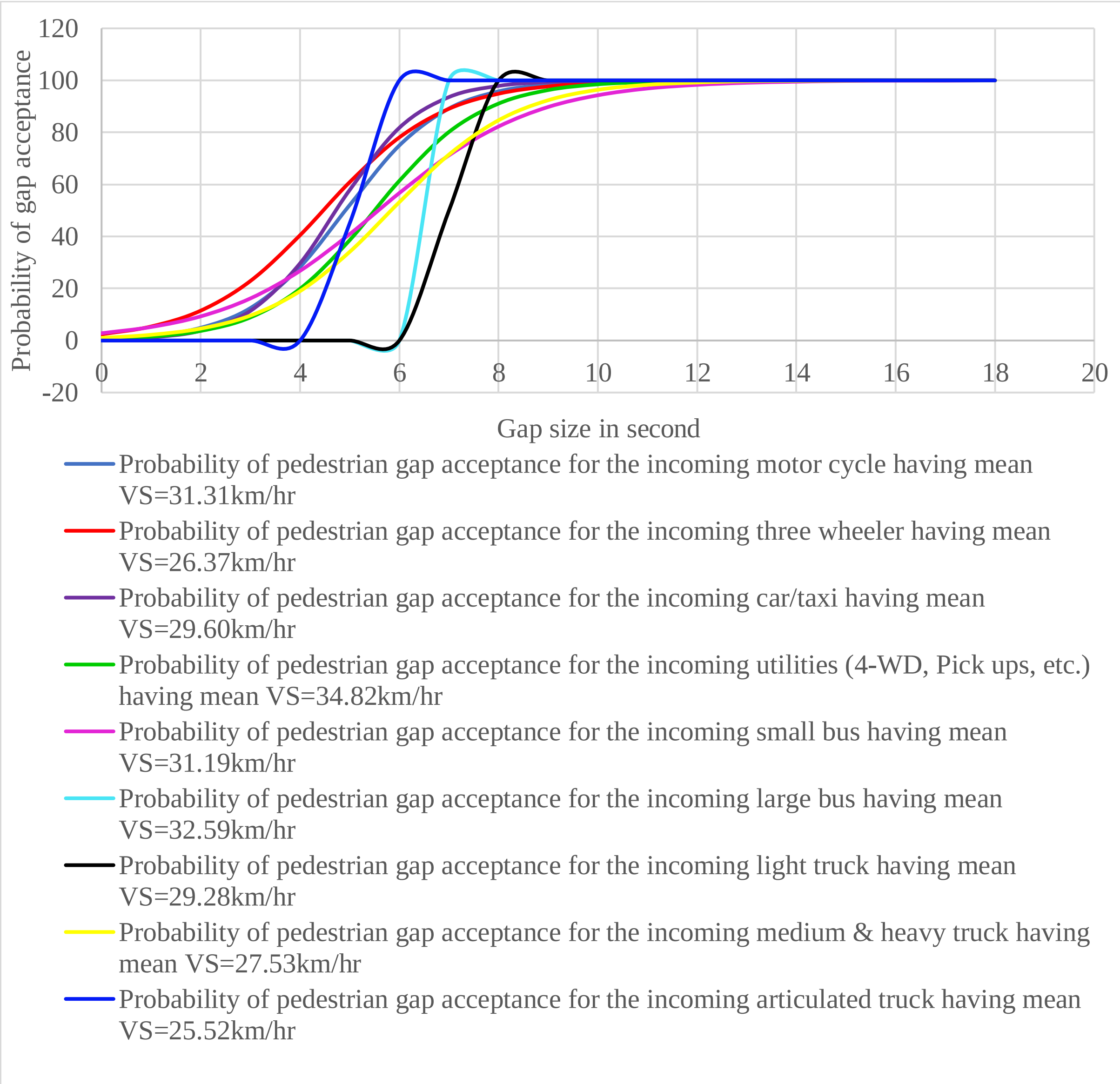


Figure 4. 16 Effect of vehicle type on probability of gap acceptance

Sensitivity of waiting time on probability of gap acceptance

In figure 4.17, it can be observed that the sensitivity of gap acceptance increased with an increase in waiting time. Pedestrians wait for 11-15 seconds to accept a smaller gap than pedestrians wait for less than 5 seconds. It indicates pedestrians may feel impatient with an increase in waiting time. It's dangerous because drivers didn't know the pedestrians lose a patient. This observation was strongly supported by a recent study in China (Zhao et al., 2019). Pedestrians wait for less than 5 seconds were higher safety conscious than pedestrians wait for 11-15 seconds. But, excess waiting time (greater than 16 seconds), the probability that a pedestrian cross the street is falling. This observation were supported by a study in Greek (Yannis et al., 2013), and a study in Malaysia (Alajnaf et al., 2016). Pedestrians wait for less than 5 second were 100% probability of accepting gaps greater than 12 second, whereas, pedestrians wait for 6-10 second were 100% probability of accepting gaps greater than 20 seconds, and gaps greater than 27 seconds and gaps greater than 24 second was 100% probability of acceptance by pedestrians wait for 11-15 second and greater than 16 seconds respectively.

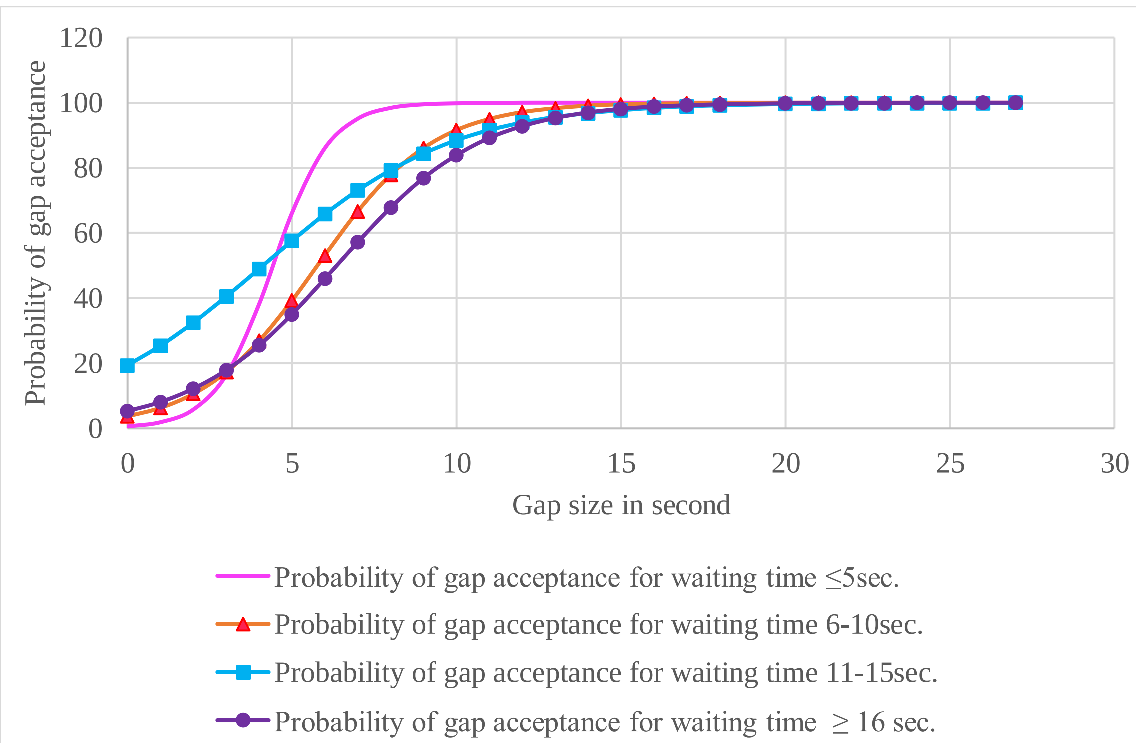


Figure 4. 17 Effect of waiting time on probability of gap acceptance

Sensitivity of Age of pedestrians on probability of gap acceptance

In figure 4.18, it can be observed that initially, the sensitivity of gap acceptance increased for pedestrian age greater than 50, but after a while, there was a higher probability of acceptance for pedestrians age 18-30, which proves young pedestrians can scan the adequate gap than the elders. But, gap acceptance were declined in the age group less than 18 compared with other age groups, which justifies the child's fear of accepting smaller gaps. Elders may have a strong familiarity with the survey site, and they may be perceived that drivers give priority to them. Young aged pedestrian's 100% probability of accepting gaps greater than 14 seconds, whereas, child pedestrians, middle-aged pedestrians, and elder pedestrians were 100% probability of accepting 18 seconds, 16 seconds, and 17 seconds respectively. As ages increased from 18 years old, the probability of accepting gaps with 100% was increased.

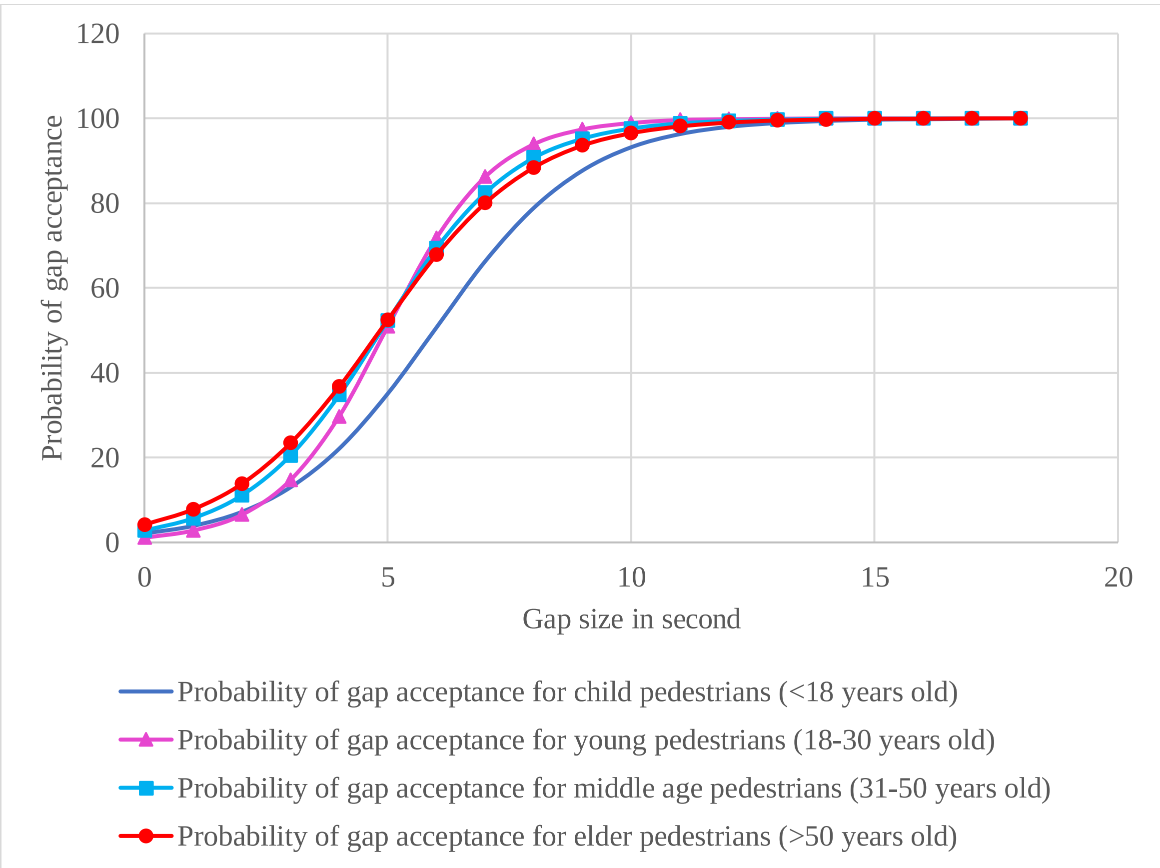


Figure 4. 18 effect of pedestrian age on probability of gap acceptance

Sensitivity of vehicular direction on probability of gap acceptance

Vehicular direction at each site was described in aligning with crosswalks with and without markings except for sites at Amhara martyrs memorial office (have no crosswalk markings). In figure 4.19, it can be observed that the sensitivity of gap acceptance increased at Kuchit market center on the far side, but after a while at Kuchit near side. But, there is a lower probability of accepting the available gap at the Amhara martyrs memorial office. Moreover, the Kuchit market center is a CBD area, resulting in a higher certainty of accepting the available gaps caused by the pedestrian's strong familiarity with the survey site. Also, from descriptive statistics higher vehicular speed was observed at Amhara martyrs memorial office, but the smaller vehicular speed at Kuchit market center, as a result, pedestrians preferred to accept smaller gaps by competing with the incoming vehicles. Each of the sites has a nearly similar probability of gap acceptance by near and far vehicular direction. At Amhara martyr's memorial office, at the far side, there is a decreasing gradient cause for higher vehicular speed and pedestrians' fear of accepting the gap. The effect of crosswalk marking on the probability of gap acceptance results in smaller gap acceptance at all sites, but their effect was negligible. 100 percent probability of gap acceptance with and without crosswalk marking Pedestrians accept gaps greater than 19 seconds at Habesha guest house, gaps greater than 14 seconds at Kuchit market center, gaps greater than 14 seconds at Zenbaba pension, and gaps greater than 11 seconds at Amhara martyrs memorial office with 100 percent probability. At Habesha guest house 100 % probability of gap acceptance with (vehicles move out of the city) and without (vehicles move to the city) crosswalk markings were gaps greater than 18 seconds and 19 seconds respectively. At Kuchit market center 100% probability of gap acceptance with (vehicles move to the taxi station) and without (vehicles move to the busy intersection) crosswalk marking were gaps greater than 13 seconds and 14 seconds respectively. At Zenbaba pension 100% probability of gap acceptance with (vehicles move to the taxi station) and without (vehicles move away from CBD area) crosswalk markings were 12 seconds and 14 seconds respectively. Whereas, at Amhara martyrs memorial near side (vehicles move relatively an upward grade) and far side (vehicles move relatively a downward grade) 100% probability of gap acceptance were 8 seconds and 14 seconds respectively.

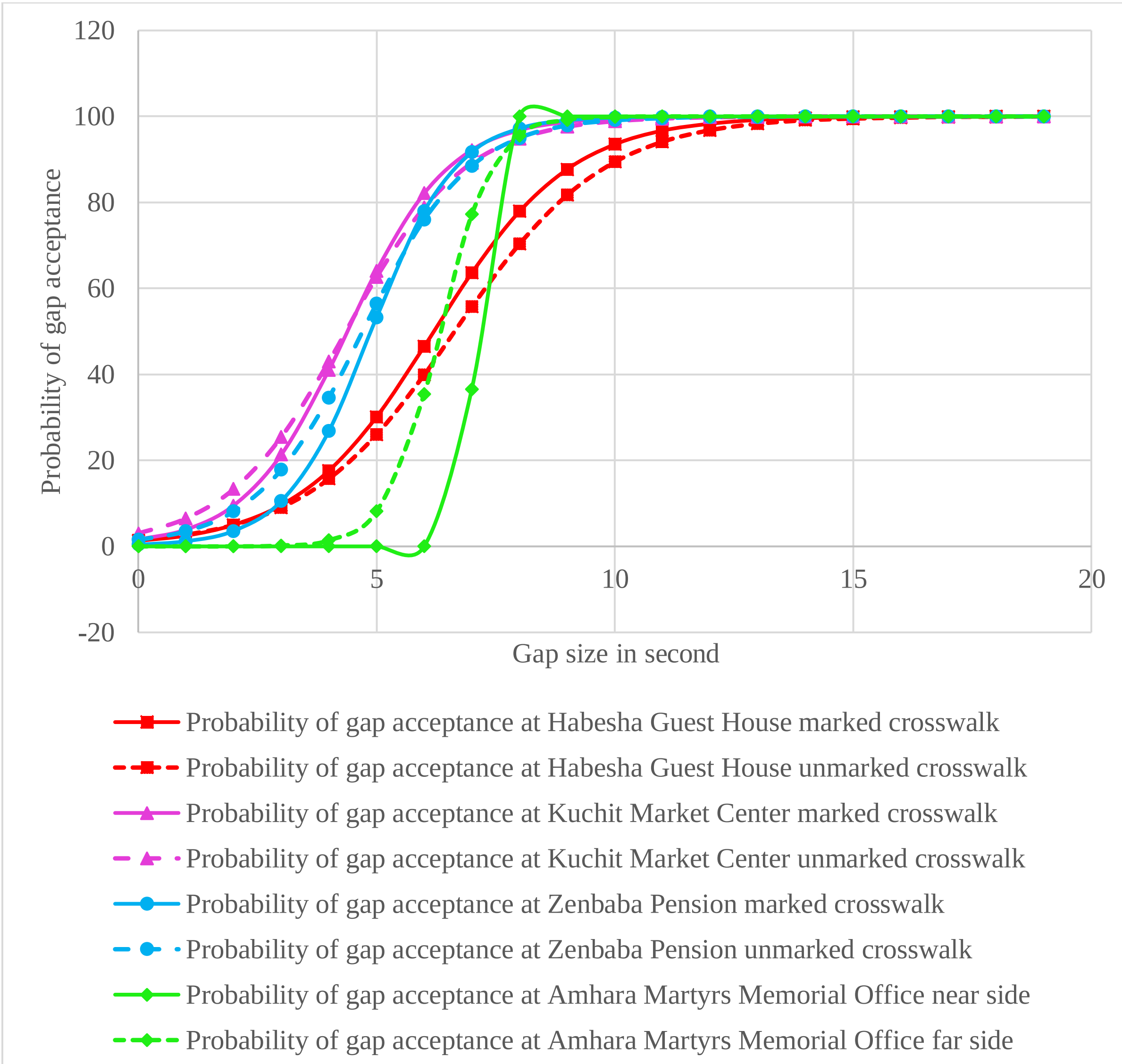


Figure 4. 19 effect of vehicular direction on probability of gap acceptance

4.3.3 Banning of Bajaj

The City transport office was decided for banning Bajaj's on Central Business District (highly loaded road segments). This banning was applied since the end of July, 2019GC. Unfortunately, field data collection was conducted at the beginning of June, 2019GC. To incorporate this, a researcher removed Bajaj from all sites of the extracted data and the significant variables were analyzed in each of the sites caused by the banning of Bajaj. Then after comparison was made, the improvement due to banning at Kuchit market center and Zenbaba pension were understood. For easily understanding of the effect of banning, the researcher preferred to use change in percentage of continuous variables.

Table 4. 18 Banning of Bajaj at Amhara Martyrs Memorial office

Variables	Mean Before Banning	Mean After Banning	% Change
Gap/Lag(sec)	10.58	10.18	3.78
Vehicle travel speed (Km/hr)	42.93	45.03	4.89
Vehicle Arrival rate(veh/sec)	0.19	0.20	5.26
Pedestrian Crossing Speed(m/s)	1.35	1.36	0.74
Waiting time (sec)	6.51	7.25	11.37
Safety margin (sec)	2.07	1.69	18.36
Valid N (listwise)	67	51	23.88

Due to the banning of the Bajaj at Amhara Martyrs memorial office, there is a significant decrease in safety margin by 18.36%. Safety margin was the first significant factor in the size of the gap to be accepted. Previously, the safety margin was higher for smaller vehicles caused by their higher speed. The second factor which brings a significant change due to banning was waiting time which shows an 11.37% increment. Actually, as waiting time increase there is higher safety. Generally, banning at the Kuchit market center and Zenbaba pension by the transport office looks vigilant. But, other improvements like service in shift should also be checked for considering the socio-economic impact of families related to Bajaj. This requires in-depth studying of alternatives, and other geometrical improvements including proper crosswalk markings with visible signposts, or other advanced options like signalization at mid-block should be checked and cost-effectiveness should be applied before banning of Bajaj were applied.

Table 4. 19 Banning of Bajaj at Habesha Gust House

Variables	Mean Before Banning	Mean After Banning	% Change
Gap/Lag(sec)	11.29	11.06	2.04
Vehicle travel speed (Km/hr)	39.02	39.62	1.54
Vehicle Arrival rate(veh/sec)	0.18	0.18	0
Pedestrian Crossing Speed(m/s)	1.59	1.58	0.63
Waiting time (sec)	4.32	3.73	13.66
Safety margin (sec)	4.12	3.95	4.13
Valid N (listwise)	156	115	26.28

Due to banning at Habesha guest house, there is a decreasing waiting time by 13.66%, which is higher change than the Amhara martyrs memorial office. But, the other significant variables were not that much change. As a result, banning at Habesha guest house has no impact. This is evidenced by there is no significant amount of Bajaj at this site, since it is located around the entrance of the city, not on the central district. Compare four sites by using safety margin as a demonstration at Amhara martyrs memorial office there is a decrement by 18.36%, at Habesha gust house there is 4.13% decrement, at Zenbaba pension there is 12.73% increment, and at Kuchit market center there is 75% (more than half) increment in safety margin. In waiting time at Amhara martyrs memorial office 11.37% increment, at Habesha gust house 13.66% decrement, at Zenbaba pension 18.58% decrement, and at Kuchit market center 3.03% increment. When demonstrated in a total number of vehicle decrements at Amhara martyrs memorial office 23.88%, 26.28% at Habesha gust house, 43.2% at Zenbaba pension, and 60.5% (more than half) decrement. From those and other observed criteria's, it is advisable for banning of Bajaj on those of central business district areas like Kuchit and Zenbaba pension. But, it may have a socioeconomic impact, instead, the researcher made recommendations for improvement.

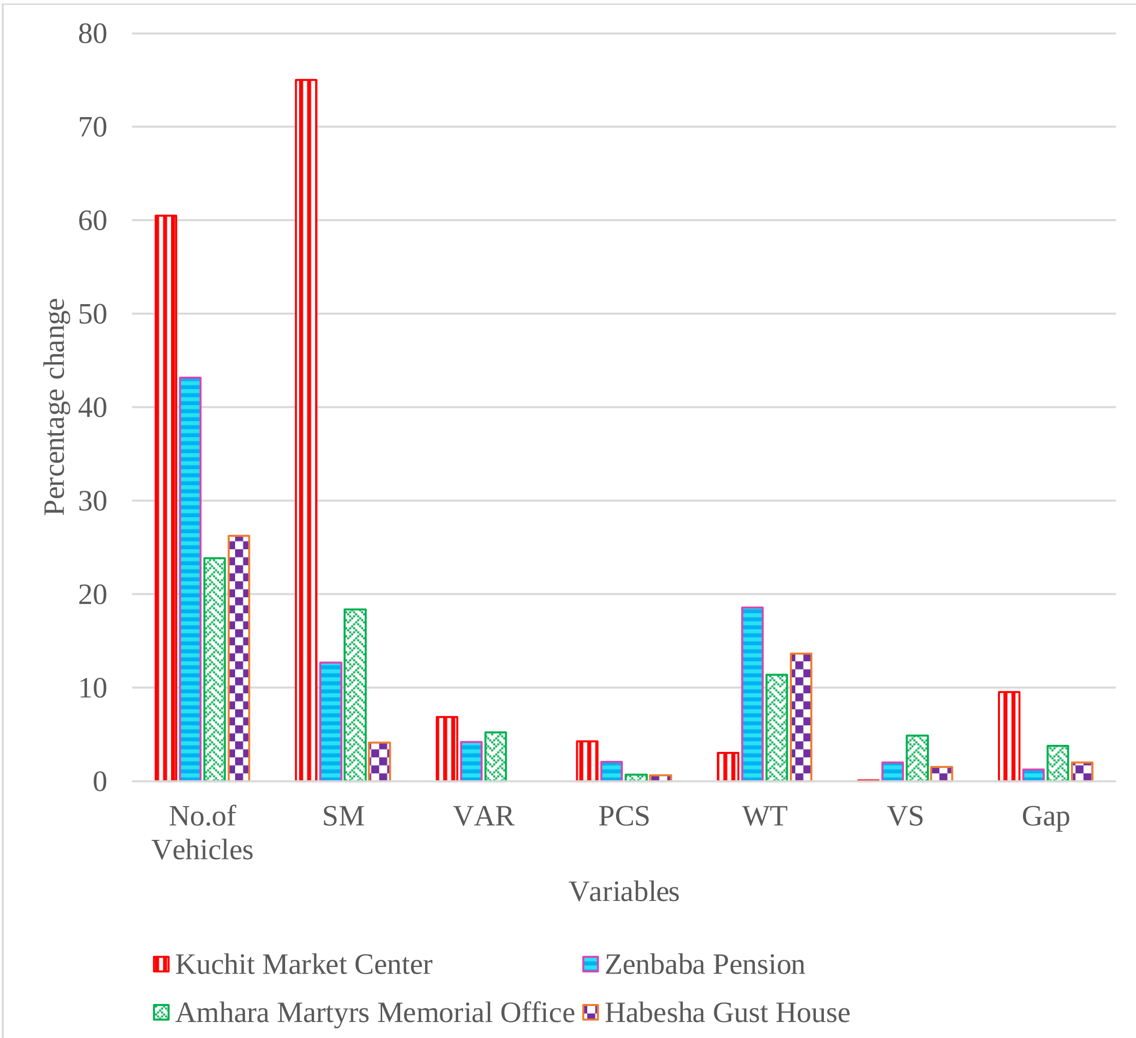


Figure 4. 20 Comparison of continuous data of sites for Banning of Bajaj

The number of vehicles at Zenbaba pension before banning was 176, but after banning the number of vehicles were reduced to 100, which brings a 43.2% decrease in a number of vehicles and results medium effect. Whereas, at Kuchit market center before banning the number of vehicles was 324, but after banning the number were reduced to 128, which brings a 60.5% decrease in a number of vehicles results in a significant change (more than half). In general, banning Bajaj brings significant effect especially on variables like the number of vehicles, vehicle arrival rate, size of gap accepted by pedestrians, and other significant variables obtained in the model.

Table 4. 20 percentage change due to banning of Bajaj at Zenbaba Pension

Variable		Before Banning of Bajaj		After Banning of Bajaj		% Change in Gap size
		% Value	Mean	% Value	Mean	
Pedestrian safety margin [s]		-	1.44	-	1.65	12.73
Vehicle arrival rate [Veh/s]		-	0.25	-	0.24	4.17
Pedestrian crossing speed [m/s]		-	1.40	-	1.43	2.1
Waiting time [s]		-	3.83	-	3.23	18.58
Vehicle speed [km/h]		-	29.56	-	30.17	2.02
Vehicular gap size [s]		-	8.39	-	8.50	1.29
Type of Gap	0=Lag	29.5	8.85	34	8.76	1.03
	1=Gap	70.50	8.20	66	8.36	1.91
Tactic of crossing	0=street	92.6	8.48	93	8.52	0.47
	1=skew	6.8	7.25	7	8.29	12.55
Pedestrian waiting place	0=pavement	59.1	7.99	52	8.10	1.36
	1= other than pavement	10.8	9.42	13	9.54	1.26
	2=not required	30.1	8.81	35	8.71	1.15
Vehicular travel lane	near = 0	56.8	7.67	56	7.57	1.32
	far = 1	43.2	9.34	44	9.68	3.51

Table 4. 21 percentage change due to banning of Bajaj at Kuchit Market Center

Variable		Before Banning of Bajaj		After Banning of Bajaj		% Change in Gap size
		% Value	Mean	% Value	Mean	
Pedestrian safety margin [s]		-	0.3	-	1.2	75.00
Vehicle arrival rate [Veh/s]		-	0.29	-	0.27	6.90
Pedestrian crossing speed [m/s]		-	1.57	-	1.64	4.27
Waiting time [s]		-	3.52	-	3.63	3.03
Vehicle speed [km/h]		-	23.98	-	24	0.08
Vehicular gap size [s]		-	6.90	-	7.63	9.57
Type of gap	0=Lag	26.9	7.34	28.9	8.08	9.16
	1=Gap	73.10	6.73	71.10	7.43	9.42
Tactic of crossing	0=street	75	6.56	78.9	7.34	10.63
	1=skew	25	7.93	21.1	8.74	9.27
Pedestrian waiting place	0=pavement	58.3	6.49	56.3	7.22	10.11
	1= other than pavement	16	7.77	16.4	8.38	7.28
	2=not required	25.7	7.29	27.3	8.03	9.22
Vehicular travel lane	near = 0	58	6.37	50	6.94	8.21
	far = 1	42	7.63	50	8.33	8.40

4.4 Pedestrian Attitudinal Survey Analysis

A descriptive analysis was the first step applied for the exploration of the human factors of data collected from the questionnaire and factor analysis was presented.

4.4.1 Descriptive analysis

Table 4.22 summarizes the demographic proportion of pedestrians participated in the attitudinal survey. Age categories were directly adopted from Amhara police commission for understanding pedestrians' risk-taking and other relevant data's with the accident occurred. The questionnaire was distributed at schools, shopping areas, and community centers for capturing the representative pedestrian in the city. Males and age categories from 18-30 highly participated.

Table 4. 22 Demographic distribution of pedestrians participated in attitudinal survey

Sex	Frequency	Percent
Male	326	65
Female	172	35
Total	498	100.0
Age Category		
Less than 18	107	21
18-30	207	42
31-50	149	30
Greater than or equal 51	35	7
Total	498	100.0

As described in table 4.23, 79% of pedestrians use crosswalks to cross the main road. So, modeling a pedestrian's gap acceptance at mid-block crosswalk locations was realistic. Some pedestrians preferred to cross the road at any convenient locations to reach their destination quickly and due to no give way behavior of drivers at crosswalk areas. This reason was observed in the video graphic survey. From videography, 99 % of drivers did not stop their vehicles at crosswalks for giving priority to pedestrians. This is an indication for the improvement of crosswalks for giving priority to pedestrians.

Table 4. 23 Mostly preferred place for crossing the main road

Mostly used place for crossing the road	Frequency	Percent	Cumulative Percent
Pedestrian Crosswalks	393	78.9	78.9
Any convenient place	105	21.1	100.0
Total	498	100.0	

Reasons for pedestrian respondents for using crosswalks are due to safe from a traffic accident and to be legal. But, some of the respondents preferred for using any place of the road to cross the main road are due to the non-yield of drivers at crosswalk and to reach their destination quickly.

Table 4. 24 Pedestrian place of crossing the road and their reasons

Description		Frequency	Percent	Cumulative Percent
As a pedestrian, which place do you use for crossing the road	Pedestrian crosswalks	393	79	79
	Any convenient place	105	21	100
Reason for choosing crosswalks to cross the road	Safe from traffic accident	252	33	33
	Convenient to cross the road	124	16	50
	Drivers yield place for pedestrians	122	16	66
	Presence of traffic police	18	2	68
	To be legal	213	28	96
	Other pedestrians cross the road at crosswalks	9	1	98
	To save time	12	2	99
	Any other reason for preferring the crosswalk	7	1	100
Reason for crossing the road at any convenient place	To reach my destination quickly	78	36	36
	I am good enough to cross the road between oncoming vehicles	3	1	38
	Drivers do not stop their vehicles for pedestrians at crosswalks	29	13	51

	crosswalks are not sufficient	14	7	58
	Absence of traffic police	20	9	67
	Drivers do not yield to pedestrians at crosswalks	44	20	87
	Other pedestrians cross the road outside crosswalks	12	6	93
	Any other reason for cross at any place	15	7	100

Table 4.25 summarizes the pedestrian's opinion on drivers and crosswalks. Most pedestrians (62%) responded that crossing the main roads of the city is difficult. Also, Pedestrian crosswalk markings are not visible (73% of the respondents). Also, signposts at crosswalk areas are not visible even for pedestrians (58% of the respondents). Most of the respondents (above 70%) agreed that drivers in Bahirdar city are not yielding to pedestrians, they are careless and aggressive and cause for accident most of the time.

Table 4. 25 Distribution of pedestrian's opinion on drivers and crosswalks

As a pedestrian, how much would you agree with each one of the following statements	Strongly Disagree (%)	Disagree (%)	Neither disagree nor agree (%)	Agree (%)	Strongly Agree (%)
Crossing main road is difficult in the city of Bahirdar	9	24	5	44	18
Crossing the main road outside pedestrian crosswalks can save time	36	28	6	24	7
Crossing roads outside pedestrian crosswalk locations increases the risk of accident	3	3	1	38	55
Distance between crosswalks is long	11	30	19	28	12
Pedestrian Crosswalks have not enough width	12	35	11	32	11
Pedestrian crosswalks are inconvenient	13	35	9	32	11
Pedestrian crosswalk markings are not visible	4	16	6	49	24
Sign posts for pedestrian yielding are not visible	6	22	13	39	19
Drivers are not yield to pedestrians at pedestrian crosswalks	4	7	5	45	40
Drivers are aggressive and carless	5	12	11	39	34

Drivers stop their vehicles at pedestrian crosswalks	8	17	12	40	23
When there is an accident, it is the driver's fault most of the time	5	18	17	38	22
During crossing the road, I am more careful than other pedestrians	3	9	6	49	34
During crossing the road, I am faster than other pedestrians	7	18	6	45	24

Table 4.26 summarizes pedestrian self-assessment using attitude, perception and risk takings while crossing the road. Most of the respondents evaluate themselves as, most pedestrians cross the road after checking the adequacy of vehicular gaps, crossing the road with paying attention to oncoming vehicles, make few road crossings for a number of conflicts with vehicles, and give priority for drivers. Some of the pedestrians responded as their visibility can be obstructed by parked vehicles, buildings and trees to see the oncoming vehicles. Furthermore, most pedestrians rarely cross the road in a rolling manner and crossing the road outside crosswalks (even if there are convenient places to cross).

Table 4. 26 Distribution of pedestrian self-assessment

As a pedestrian, how often do the following statements	Never (%)	Rarely (%)	Sometimes (%)	Often (%)	Always (%)
I cross roads diagonally	22	23	42	10	2
I cross the road after checking whether there is an adequate gap between oncoming vehicles	3	5	11	29	52
I cross the road with paying attention to oncoming vehicles	6	7	11	32	44
I cross the road in a rolling manner between vehicles to save time	44	21	26	8	2
During crossing the road parking vehicles, buildings and trees obstruct my visibility of oncoming vehicles	21	14	39	20	6
I cross the road other than pedestrian crosswalks which is convenient for me	22	27	35	11	4
I cross while taking on my cell phone or listening music's	51	18	24	4	2
I try to make as few road crossings as possible	10	16	23	40	12
I let a car go by, even if I have right-of-way	9	8	23	35	25

4.4.2 Principal component analysis (PCA)

In this research, both qualitative and quantitative analysis using SPSS-20 software were used. For the attitudinal data, both descriptive and Factor analysis was used. Factor analysis is applied to reduce the number of problems related to crosswalks into a smaller number of factors.

Factor analysis: it was used to reduce the number of variables to explain and interpret results, and to prepare for easy of understanding for policymakers or any concerns. This analysis was accomplished into two steps; factor extraction (making a choice about the type of model as well the number of items to extract) and factor rotation (achieving a simple structure to improve interpretability) (Papadimitriou et al., 2016, 2017). The adequacy of the sample size is based on the ratio of 10 respondents to 1 statement to be rated. Kaiser-Mayer –Olkin can measure the adequacy of data for the application of factor analysis. For this particular thesis, it is possible to apply factor analysis, because KMO and Bartlett's value was less than 0.8 or significant was less than 0.05, as shown in table 4.27. Bartlett's' test of sphericity was used to check the correlation between items and the result shows the presence of at least one significant correlation between items. The test to be evaluated was:

Ho: There is no any significant correlation between items

Ha: There is at least one significant correlation between items

As a result, Sig. value less than 0.05, the alternative hypothesis was accepted, and factor analysis can be applied.

Table 4. 27 Model fitting test for applying factor analysis

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.715
Bartlett's Test of Sphericity	Approx. Chi-Square	861.908
	df	91
	Sig.	0.000

Principal components analysis was used and was aimed to replicate the correlation matrix using a set of components that are fewer in number and linear combinations with the original sets of items. A PCA was initially implemented on 14 questions of the survey. Table 4.28 was a description of a percentage of questions to be expressed after the application of factor analysis. For example, the question code (Q31) was initially 100 % as if it directly used and 54.7% of its variability was expressed by its factor to be grouped.

Table 4. 28 Communalities of variables

Communalities		
Question code	Initial	Extraction
Q31	1.000	0.547
Q32	1.000	0.716
Q33	1.000	0.852
Q34	1.000	0.560
Q35	1.000	0.688
Q36	1.000	0.679
Q37	1.000	0.588
Q38	1.000	0.585
Q39	1.000	0.629
Q310	1.000	0.632
Q311	1.000	0.377
Q312	1.000	0.634
Q313	1.000	0.524
Q314	1.000	0.623
Extraction Method: Principal Component Analysis.		

The solution suggested that there are 6 components which can explain 61.672% (shown in table 4.29) of the total variance. The output of the component matrix can be interpreted as the correlation of each item with the components. The square of each loading in the component matrix represents the proportion or percent of variance explained by a particular component. If we keep summing up the squared of the loadings across components cumulatively, we will find that it sums to 1 or 100%. This is known as communality, and in principal component analysis, the communality for each item is equal to the total variance. Communality explains how much the variance of the item is explained by the new factors. It is better to consider communality greater than 0.3 and in this thesis communality greater than 0.3 were used. If we sum up squared loading down the items, give you the Eigenvalues. The resulted communality of the data is shown in table 4.29.

Table 4. 29 Total variance explained by components

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.871	20.507	20.507	2.871	20.507	20.507
2	1.433	10.234	30.740	1.433	10.234	30.740
3	1.247	8.909	39.649	1.247	8.909	39.649
4	1.044	7.454	47.104	1.044	7.454	47.104
5	1.023	7.308	54.412	1.023	7.308	54.412
6	1.016	7.260	61.672	1.016	7.260	61.672
7	0.921	6.575	68.248			
8	0.798	5.702	73.950			
9	0.754	5.385	79.335			
10	0.741	5.294	84.628			
11	0.669	4.781	89.409			
12	0.618	4.417	93.827			
13	0.494	3.526	97.352			
14	0.371	2.648	100.000			
Extraction Method: Principal Component Analysis.						

The extraction method will be good enough if it is based on an Eigenvalue greater than 1. In this thesis Eigenvalue greater than 1 was used. Eigenvalues represent the total amount of variance that can be explained by a given principal component. Eigenvalue greater than zero, then it is a good sign. Eigenvalues are also the sum of squared component loadings across all items for each component. Eigenvector represents a weight for each Eigenvalue. The Eigenvectors times the square root of the Eigenvalue gives the component loadings which can be interpreted as the correlation of each item with the principal component. The following scree plot suggests that 6 components can explain 61.672% variance of 14 original components, also from the plot the data can be grouped up to three components. But, to increase the variability it is better to use six factors for further analysis.

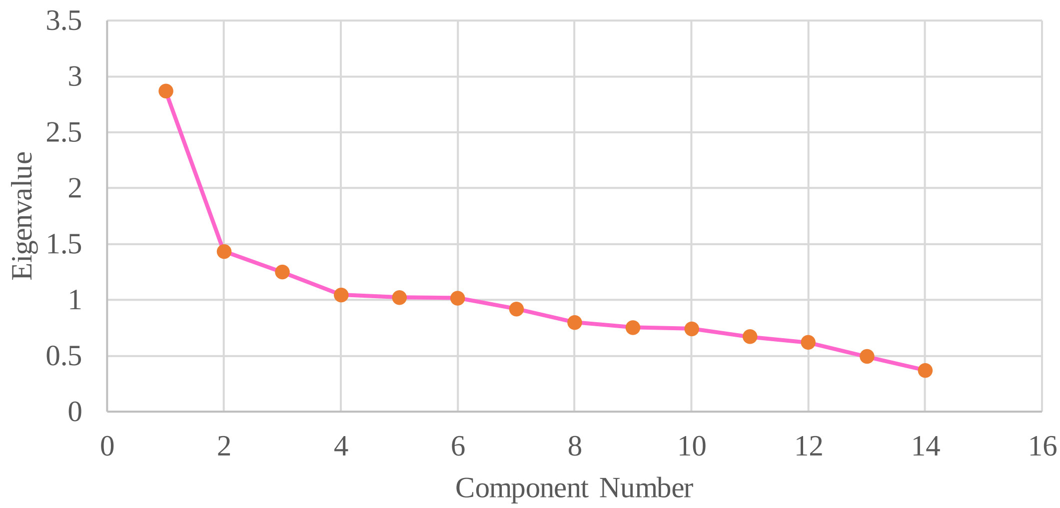


Figure 4. 21 Scree Plot

In factor rotation step, if there is an assumption of less correlation between components (refer correlation matrix in the appendices), then orthogonal rotation especially Varimax rotation is the most efficient and recommended to be used. In this thesis, Varimax rotation was used in the rotation step. After factors were extracted, the representative name for the extracted factor was given.

Table 4. 30 Rotated Component matrix

Rotated Component Matrix[a]						
Question code	Component					
	1	2	3	4	5	6
Q31		0.583				
Q32					0.836	
Q33						0.907
Q34					0.463	
Q35		0.794				
Q36		0.755				
Q37			0.719			
Q38			0.683			
Q39	0.557					
Q310	0.706					
Q311	0.540					
Q312	0.697					
Q313				0.709		

Q314	0.771
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.	
a. Rotation converged in 9 iterations.	

Table 4.31 was the designation of a name for the rotating component. It is applied for a better understanding of the main influential factors responded by residents of the city. 14 statements were reduced to 6 groups of statements used for further analysis.

Table 4. 31 Naming of the extracted factors

Question code in the analysis	Question code description in the questionnaire	New question Code designation used in the analysis	Group name after rotation by Principal Component Analysis in SPSS
Q39	Drivers are not yield to pedestrians at crosswalks	Q315	Illegal behaviour of drivers
Q310	Drivers are aggressive and carless		
Q311	Drivers stop their vehicles at crosswalks		
Q312	When there is an accident, it is drivers' fault most of the time		
Q31	Crossing the main road is difficult in the city of Bahirdar	Q316	crosswalks inconvenience and road crossing difficulty
Q35	Crosswalks have not enough width		
Q36	Crosswalks are inconvenient		
Q37	Crosswalk markings are invisible	Q317	crosswalk markings and sign post invisibility
Q38	Sign posts at crosswalks are invisible		
Q313	During crossing the road, I am more careful than other pedestrians	Q318	self-assessment during crossing the road
Q314	During crossing the road, I am faster than other pedestrians		
Q32	Crossing the main road outside crosswalks can save time	Q319	Lengthy spacing of crosswalks and time saving by crossing outside crosswalks
Q34	Distance between crosswalks is long		
Q33	Crossing the main road outside crosswalks increases the risk of accident	Q33	Crossing the main road outside crosswalks increases the risk of accident

Non-parametric tests were used to check the identified factors. Mann-Whitney U test (for two independent samples) and the Kruskal-Wallis test (for more than two independent samples) were applied. These tests were used because the data was collected by the rating of the questionnaire by Likert scale which does not necessarily require the normality of the variables.

a. Comparison by gender group

The comparison of six factors on males and females using non-parametric tests; (Mann-Whitney U test) at 0.05 significance level, and there is a significant difference between males and females by crosswalk and signpost invisibility. As a result, their needs further study for the understanding of at which sex should crosswalk and signpost invisibility were a higher impact. Moreover, it can be concluded that the five identified components were equally affected by males and females.

Table 4. 32 comparison of factors between genders

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Crossing roads outside crosswalk location increases the risk of accident is the same across categories of Sex.	Independent-Samples Mann-Whitney U Test	.364	Retain the null hypothesis.
2	The distribution of Illegal behavior of drivers is the same across categories of Sex.	Independent-Samples Mann-Whitney U Test	.408	Retain the null hypothesis.
3	The distribution of crosswalks inconvenience and road crossing difficulty is the same across categories of Sex.	Independent-Samples Mann-Whitney U Test	.143	Retain the null hypothesis.
4	The distribution of crosswalk markings and sign post invisibility is the same across categories of Sex.	Independent-Samples Mann-Whitney U Test	.000	Reject the null hypothesis.
5	The distribution of self assessment during crossing the road is the same across categories of Sex.	Independent-Samples Mann-Whitney U Test	.294	Retain the null hypothesis.
6	The distribution of Lengthy spacing of crosswalks and time saving by crossing outside crosswalks is the same across categories of Sex.	Independent-Samples Mann-Whitney U Test	.941	Retain the null hypothesis.

Nonparametric test results in crosswalk markings and signpost invisibility impact on male and females. Thus, the rank of males was 269.53 whereas 211.54 for females, which justifies that males were highly understanding of crosswalk and signpost invisibility.

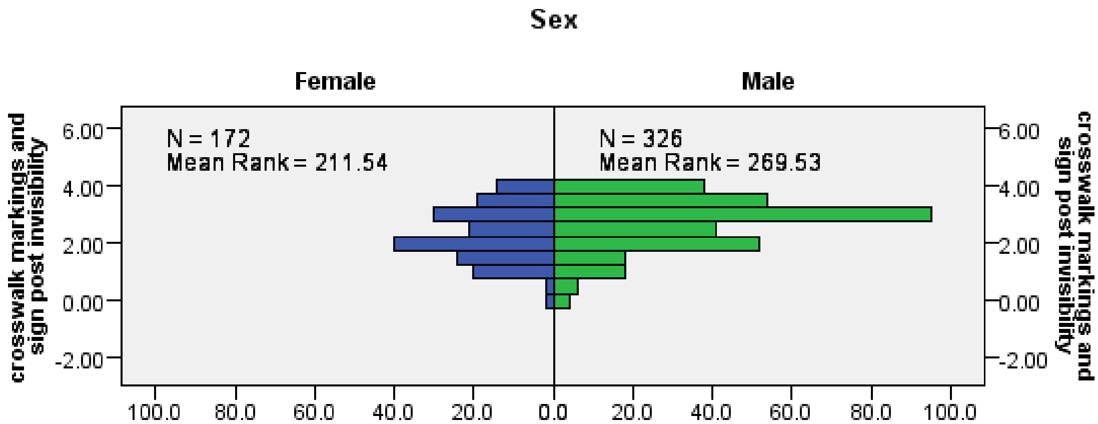


Figure 4. 22 Rank of male and female for crosswalk markings and sign post invisibility

For better understandings of male and female response on each of the groups were summarized in table 4.33. Higher ranks were observed in crosswalks and signpost invisibility (269.53 responded by males), crossing roads outside the designated crosswalks increase risk of accident (256.62 responded by females), and so on.

Table 4. 33 Ranks of factors along with male and female categories

Question code	Rank	
	Male	Female
Q33	245.74	256.62
Q315	253.36	242.19
Q316	256.33	236.56
Q317	269.53	211.54
Q318	254.30	240.40
Q319	246.16	250.15

b. Between the age group

The comparison of six factors impacts each age category using a non-parametric test; (Independent-Sample Kruskal-Wallis test) at 0.05 significance level, and there is a different impact on age categories due to illegal drivers. It can be concluded that the five identified components were equally affected on all age categories, but the different impacts on age categories by illegal behaviors of drivers, as presented in table 4.34. As a result, further study was needed for understanding which age category was highly affected by illegal behavior of drivers.

Table 4. 34 Comparison of factors between age categories of respondents

Hypothesis Test Summary

	Null Hypothesis	Test	Sig.	Decision
1	The distribution of Crossing roads outside crosswalk location increases the risk of accident is the same across categories of Age Category.	Independent-Samples Kruskal-Wallis Test	.725	Retain the null hypothesis.
2	The distribution of Illegal behavior of drivers is the same across categories of Age Category.	Independent-Samples Kruskal-Wallis Test	.005	Reject the null hypothesis.
3	The distribution of crosswalks inconvenience and road crossing difficulty is the same across categories of Age Category.	Independent-Samples Kruskal-Wallis Test	.388	Retain the null hypothesis.
4	The distribution of crosswalk markings and sign post invisibility is the same across categories of Age Category.	Independent-Samples Kruskal-Wallis Test	.131	Retain the null hypothesis.
5	The distribution of self assessment during crossing the road is the same across categories of Age Category.	Independent-Samples Kruskal-Wallis Test	.053	Retain the null hypothesis.
6	The distribution of Lengthy spacing of crosswalks and time saving by crossing outside crosswalks is the same across categories of Age Category.	Independent-Samples Kruskal-Wallis Test	.857	Retain the null hypothesis.

Nonparametric test results in the impact of illegal behavior of drivers on each age category. Thus, the rank of the age group from 31-50 (278.2) was higher than other age groups, which justifies that middle-aged pedestrians were highly understanding of illegal behavior of drivers.

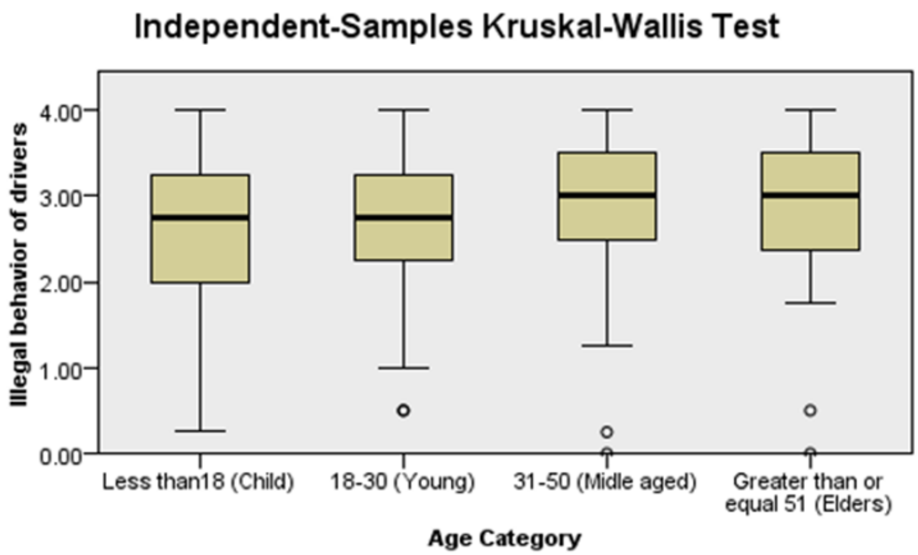


Figure 4. 23 Rank of age category for illegal behavior of drivers

For better understanding, each age group ranked for the age category of respondents are shown in table 4.35. The higher response was observed on illegal behavior of drivers, crosswalk inconvenience, and crosswalk and signpost invisibility.

Table 4. 35 Rank of factors along each age category

Age category	Question code	Rank
<18	Q33	254.41
18-30		250.21
31-50		250.39
>50		226.51
<18	Q315	217.36
18-30		241.61
31-50		278.2
>50		272.24
<18	Q316	248.78
18-30		239.21

31-50		257.35
>50		279.11
<18	Q317	241.78
18-30		236.97
31-50		271.79
>50		252.49
<18	Q318	217.63
18-30		263.01
31-50		250.64
>50		262.2
<18	Q319	245.2
18-30		255.81
31-50		246.29
>50		239.01

Mean score analysis: was done by averaging the rating of statements of Likert scale (5-strongly agree through 1-strongly disagree) in the identifications of main problems after the response of pedestrians on crosswalks and drivers. The mean score of the Likert scale of the questionnaire rating was used to determine the degree of the respondent's agreement on factors defined. Mean scores greater than 2.5 (shown in figure 4.24) generally have a significant effect, and the following points were summarized:

- Most pedestrians responded that crosswalk markings and signposts are invisible
- Most pedestrians responded that drivers are illegal (they are careless and aggressive, not yield to pedestrians, and cause traffic accidents).
- Most pedestrians assess themselves as they are careful and faster while crossing the main road
- Most pedestrians responded that crossing the road outside crosswalk areas increases the risk of an accident.

Furthermore, a study on the opinion of pedestrians on derivers using attitudinal survey was strongly supported by video graphic survey. From videography, 99 % of drivers did not stop their vehicles at selected crosswalks for giving priority to crossing pedestrians. Instead, the pedestrian give way to the motor vehicle. Also, during the filed survey the researcher understands and observes crosswalk and signpost invisibility. A smaller number of respondents were observed on the lengthy spacing between crosswalks, time savings by crossing outside crosswalks, and crosswalks inconvenience and road crossing difficulty. Pedestrians responded that crossing outside designated crosswalks increases the risk of an accident. But, their no give way behavior of drivers, so the government should do the improvement to give priority to crossing pedestrians.

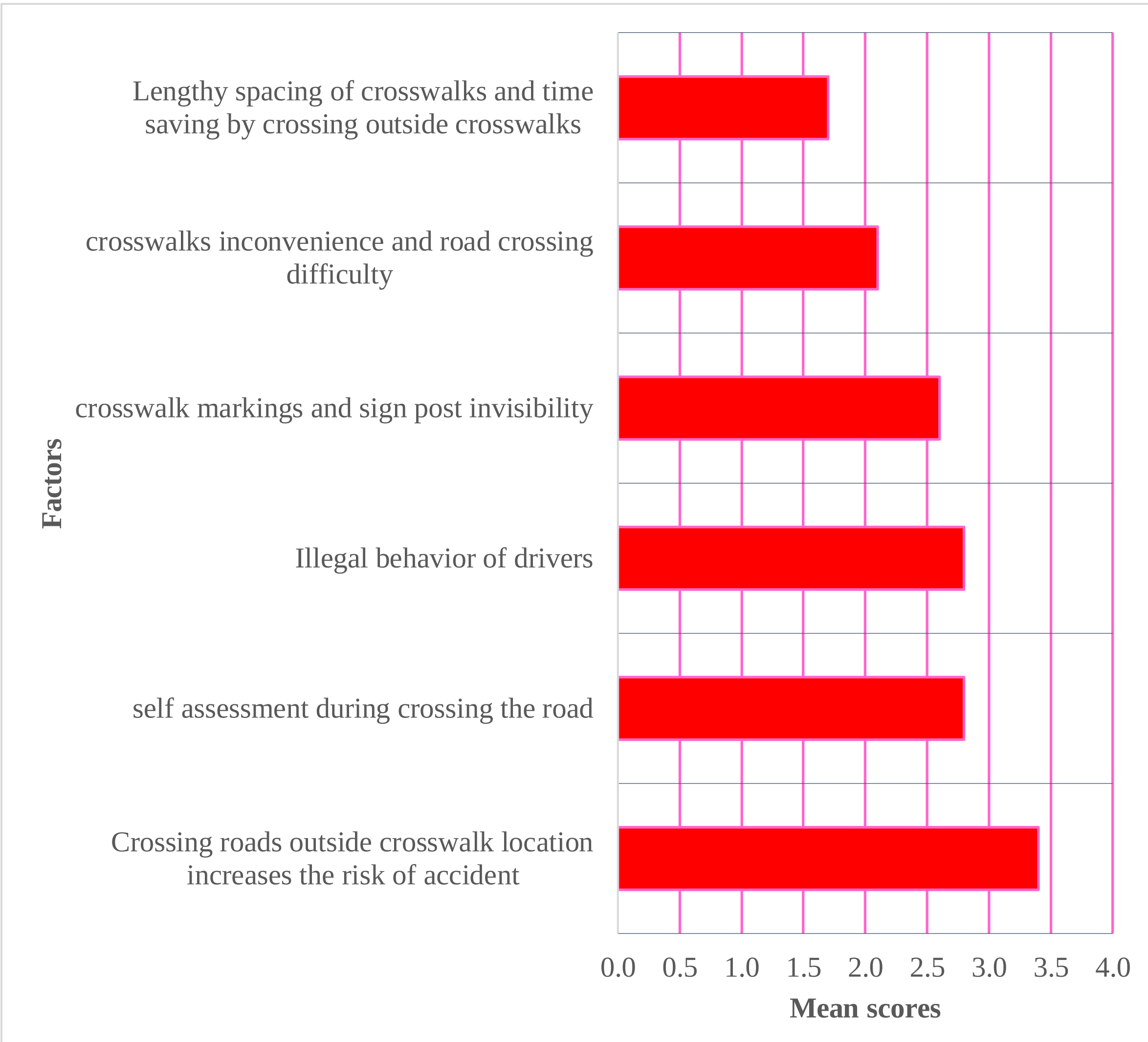


Figure 4. 24 Mean scores of factors

For showing deviation in each of the factors with their respective mean scores, table 4.36 was summarized. All factors have a minimum deviation from the mean.

Table 4. 36 Mean score and standard deviation

Descriptive Statistics		
Factors	Mean	Std. Deviation
	Statistic	Statistic
Crossing roads outside crosswalk location increases the risk of accident	3.4	0.901
self-assessment during crossing the road	2.8	0.86
Illegal behaviour of drivers	2.8	0.788
crosswalk markings and sign post invisibility	2.6	0.939
crosswalks inconvenience and road crossing difficulty	2.1	0.941
Lengthy spacing of crosswalks and time saving by crossing outside crosswalks	1.7	0.977
Valid N (listwise)	498	

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

After capturing the necessary data and analyzing the appropriate method, the following conclusions are made. This study explored the pedestrian gap acceptance at mid-bock locations with detail attitudinal surveys on factors related to crosswalks. Gap acceptance and choice model were conducted at four mid–block sites, whereas the attitudinal survey was conducted using questionnaire data on the residents of Bahir Dar City.

Using statistical analysis, critical vehicular gap size accepted by pedestrians were determined in the individual site and for the combined site data. From the statistical analysis, the critical gaps accepted by the pedestrians were 6.8sec, 6.5sec, 4.8sec, and 4.4sec at Amhara martyrs memorial office, Habesha guest house, Zenbaba pension, and Kuchit market center respectively. Whereas, for the combined site data the critical gap accepted by the pedestrians was 5sec. And also, for the 85% gap accepted by pedestrians the statistical analysis result for Amhara martyrs memorial office, Habesha guest house, Zenbaba pension, and Kuchit market center were 7.6sec, 9.1sec, 6.5sec, and 6.4sec respectively. Whereas, the combined site data gives 7.2sec. As observed from the analysis, the crossing speed for 85% of the pedestrians was found to be 1.58m/s, 2m/s, 1.73m/s, and 1.98m/s at Amhara martyrs memorial office, Habesha guest house, Zenbaba pension, and Kuchit market center. Whereas, for the combined site data speed of 1.87m/s were observed. The analysis made using one way ANOVA declares that, the crossing markings provided at the study sites have no significant effect on gap acceptance. MLR model at each site results that, multiple variables play a significant role in the gap accepted by the pedestrians, amongst which, too many of the variables were found to take part in the Kuchit market center. This is attributed to the fact that, most of the survey participants in this area have a strong familiarity with the survey site, are particularly non-compliant and often risk-taking, and the site is marked as CBD area. While minimum variables contribute to the gap accepted by pedestrians at Amhara martyrs memorial office. And this is found to be because the incoming vehicles have a considerably higher speed than the other survey sites which causes the pedestrians to develop fear and reduce their risk-taking behaviors.

For analysis of combined site data using the MLR model, 27 contributing variables were incorporated and from those 14 variables were found to have a significant effect on the size of gap acceptance with 83.7% the gap acceptance explained by the significant variables. From those significant factors, safety margin and vehicular arrival rate have a significantly higher effect on the size of gap acceptance. Waiting time, pedestrian crossing speed, type of gap, pedestrian crossing tactics, pedestrian waiting place, and pedestrian path change condition have a medium effect on the size of gap acceptance. Whereas, rolling behavior, vehicular travel lane, vehicular speed, driver yield behavior, stage of crossing and number of observations before crossing were having a low effect on the size of gap acceptance. By conducting elasticity analysis on significant variables, the safety margin has 16.25 times the effect of a number of observations before crossing on the size of gap acceptance.

For analysis of combined site data using the BL-regression model, 19 contributing variables were taken and from those 9 variables have a significant effect on the probability of gap acceptance with 68.1% accuracy. From those significant factors, the Pedestrian waiting place, vehicular travel lane, crossing initiation, and gap size have a significantly higher effect on crossing choice. Vehicular direction and pedestrian age have a medium effect on crossing choice. Whereas, vehicle type, waiting time for obtaining adequate vehicular gap and vehicle speed have a low effect on crossing choice. By conducting the elasticity analysis of significant variables, the pedestrian waiting place has 74.8 times the effect of vehicle speed on the probability of gap acceptance.

The sensitivity analysis of significant variables on the probability of gap acceptance indicated the following key point. Those pedestrians who wait at the pavement have a higher probability of gap acceptance than those waiting at the other places. For a gap size higher than 5seconds, pedestrians initiated from the median have a higher probability of acceptance than those initiated from the curb; while for a gap size less than 5 seconds, pedestrians initiated from the curb have a higher probability of acceptance. When we come to vehicle type, pedestrians' probability of gap acceptance is higher for the incoming smaller vehicles than the larger ones without considering the incoming vehicular speed. There is a higher probability of accepting gaps less than 4 seconds by pedestrians who wait for 11-15 seconds than other pedestrians who wait for other time intervals. While for age category, elders have a higher probability of accepting gaps less than 5 seconds than other ages. But, youngsters have a higher probability of accepting gaps greater than 5 seconds.

Finally, from the attitudinal survey, most pedestrians responded that their preference to cross the road is highly suited to crosswalk locations. They also added that, even though they have good attitudes on crosswalks, illegal behavior of drivers (like non-yield, aggressive and careless behaviors, and cause for the accident) were the main challenge at crosswalks locations, which forces them to cross at any place of the road. They also argued that crossing roads outside crosswalk locations can increase the risk of an accident. Besides, crosswalk markings and signposts were invisible. Moreover, pedestrians assess themselves as they try to overcome such problems by increasing their crossing speed with high care while crossing the road.

5.2. Recommendations

This study made interesting findings on pedestrian gap acceptance at mid-block crosswalk locations of main roads in Bahir Dar city. The findings of this research can be applied in other cities of the countries having a similar geometrical configuration with the study site. The findings also used simulation models to develop more precise and reliable models. It was found in this study that generally pedestrians exhibited unsafe vehicular gap acceptance and were ignored in the traffic system. In connection with these findings, multidisciplinary interventions were required with having the following recommendations:

- **To transport office**: transport office should improve mobility and safety of pedestrians by controlling and regulating speed limits of vehicles at crosswalk locations particularly at Amhara martyrs memorial office and Habesha guest house, impose fines on aggressive drivers, improving pedestrian skills on the maneuvering of conflicting vehicles, flourish adequate driver training,
- **To urban and transport planners**: planners should consider a significant pedestrian desire line, apply angled median opening for increasing pedestrians' visibility of the incoming conflicting vehicle, an extension of the curb for minimizing of crosswalk length, and also incorporating pedestrian gap acceptance behavior during pedestrian crossing facility design through local study.
- **To traffic engineers**: traffic engineers should understand that crosswalk marking alone did not improve the safety of pedestrians through gap acceptance. As a result, improving the studied crosswalks using ground-mounted sign, a word on pavement markings, yield line before crosswalk location, traffic signal, and overpass foot-bridge with detail cost-effectiveness. As an indication, at Kuchit market center their needs a pedestrian foot-bridge for reducing interruption of traffic flow, and at Amhara martyrs memorial office and Habesha guest house their needs curb extension with an angled median. But, at all studied crosswalk sites, ground-mounted sign, and a word on the pavement with advanced yield line should be provided. Crosswalk warrant required in each of the survey sites was done using

the O'Flaherty crosswalk warranting technique and resulted that all sites require signal crosswalk.

The researcher also recommends future research on:

- Pedestrian gap acceptance for with median versus without median
- Pedestrian gap acceptance for single lane versus multilane
- Pedestrian gap acceptance using incoming vehicle distance from waiting pedestrian
- Probability of give way by motorists for the waiting pedestrians
- Pedestrians gap acceptance for detail age categories and their arrival rate
- Pedestrian gap acceptance for with crosswalk versus without a crosswalk
- Pedestrian gap acceptance at intersection crosswalk
- Motorist belief and attitude towards the pedestrian-drivers interaction at crosswalk locations

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APPENDIX

Appendix 1 –Passenger Car Unit

Vehicle type	PCU	Source
Bajaj	0.4	(Authority, 2002)
Bus	2.5	(Tamene, 2016)
Car	1	(Authority, 2002)
Truck	2.5	(Tamene, 2016)
Motorcycle	0.25	(Authority, 2002)
Fara motor	0.45	(Authority, 2002)
Bicycle	0.2	(Authority, 2002)
Animal Drawn cart	0.7	(Authority, 2002)

Appendix 2 – Vehicle and Pedestrian count

Vehicle count at Habesha Guest House

a) To Gondar Outlet Vehicle Count

Time	Bajaj	Bus	Car	Truck	Motorcycle	Fara motor	Bicycle	Animal Drawn cart	Passenger car	Hourly Volume		Peak hour volume
07:00:00 to 07:15:00	59	84	46	6	9	0	13	0	299.45	1004.7	1005	1015
07:15:00 to 07:30:00	40	63	35	3	17	3	4	0	222.4	985	985	
07:30:00 to 07:45:00	36	50	44	11	11	0	16	1	217.55	993.6	994	
07:45:00 to 8:00:00	43	75	32	9	12	2	4	2	265.3	1015	1015	
08:00:00 to 08:15:00	48	76	41	9	7	6	6	2	279.75	916	916	
08:15:00 to 08:30:00	37	68	26	6	9	3	8	0	231	882.45	883	
08:30:00 to 08:45:00	35	59	42	12	14	1	4	1	238.95	859	859	
08:45:00 to 09:00:00	35	41	29	7	9	1	3	0	166.3	806.85	807	
09:00:00 to 09:15:00	35	63	47	8	8	4	9	3	246.2	820.6	821	
09:15:00 to 09:30:00	42	53	27	10	5	2	3	5	207.55			
09:30:00 to 09:45:00	38	46	22	12	10	2	6	0	186.8			
09:45:00 to 10:00:00	22	46	21	13	3	2	2	1	180.05			

b) To Bahirdar Vehicle Count

Time	Bajaj	Bus	Car	Truck	Motorcycle	Fara motor	Bicycle	Animal Drawn cart	Passenger car	Hourly Volume		Peak hour volume
07:00:00 to 07:15:00	55	81	80	15	13	4	13	0	349.65	1239.8	1240	1240
07:15:00 to 07:30:00	65	75	48	13	13	2	18	0	301.75	1202.4	1203	
07:30:00 to 07:45:00	60	71	49	13	12	3	13	0	289.95	1183.05	1184	
07:45:00 to 8:00:00	52	78	53	8	13	2	10	5	298.45	1144.55	1145	
08:00:00 to 08:15:00	47	77	43	21	9	2	8	1	312.25	1059.3	1060	
08:15:00 to 08:30:00	48	75	36	14	8	2	9	0	282.4	1028.6	1029	
08:30:00 to 08:45:00	46	65	48	7	5	0	12	2	251.45	976.6	977	
08:45:00 to 09:00:00	39	49	31	14	7	5	8	5	213.2	955.9	956	
09:00:00 to 09:15:00	52	72	36	14	13	2	7	6	281.55	954.15	955	
09:15:00 to 09:30:00	34	54	43	13	14	4	5	0	230.4			
09:30:00 to 09:45:00	46	61	32	9	12	3	5	0	230.75			
09:45:00 to 10:00:00	36	54	31	11	5	2	7	0	211.45			

Vehicle count at Amhara Martyrs Memorial office

a) To Gondar Outlet Vehicle Count

Time	Bajaj	Bus	Car	Truck	Motorcycle	Fara motor	Bicycle	Animal Drawn cart	Passenger car	Hourly Volume		Peak hour volume
07:00:00 to 07:15:00	48	78	51	5	8	5	14	1	285.45	1151.1	1152	1208
07:15:00 to 07:30:00	57	62	59	5	15	5	17	3	260.8	1183.8	1184	
07:30:00 to 07:45:00	64	75	54	9	17	4	16	4	301.65	1204.65	1205	
07:45:00 to 8:00:00	64	68	64	13	22	4	5	4	303.2	1207.05	1208	
08:00:00 to 08:15:00	74	64	80	15	16	11	7	1	318.15	1151.55	1152	
08:15:00 to 08:30:00	69	65	54	10	18	7	7	5	281.65	1106.5	1107	
08:30:00 to 08:45:00	72	66	59	16	20	7	5	3	304.05	1129.85	1130	
08:45:00 to 09:00:00	57	45	60	18	15	5	7	0	247.7	1102.4	1103	
09:00:00 to 09:15:00	66	62	63	8	11	7	7	2	273.1	1122.7	1123	
09:15:00 to 09:30:00	70	64	60	18	8	6	5	9	305			
09:30:00 to 09:45:00	71	55	62	16	12	6	8	2	276.6			
09:45:00 to 10:00:00	66	55	54	16	20	2	7	4	268			

b) To Bahirdar Vehicle Count

Time	Bajaj	Bus	Car	Truck	Motorcycle	Fara motor	Bicycle	Animal Drawn cart	Passenger car	Hourly Volume		Peak hour volume
07:00:00 to 07:15:00	100	90	102	20	25	7	29	5	435.7	1773	1773	1773
07:15:00 to 07:30:00	105	105	130	12	32	6	21	0	479.4	1767.3	1768	
07:30:00 to 07:45:00	97	83	131	17	39	7	25	1	438.4	1720.2	1721	
07:45:00 to 8:00:00	92	78	124	20	36	5	12	0	419.45	1623.5	1624	
08:00:00 to 08:15:00	86	88	108	22	23	5	16	2	430	1512.1	1513	
08:15:00 to 08:30:00	82	93	95	24	22	6	12	2	432.3	1363.9	1364	
08:30:00 to 08:45:00	75	72	76	15	17	14	14	7	341.75	1244.9	1245	
08:45:00 to 09:00:00	72	64	67	16	16	4	11	6	308	1177.6	1178	
09:00:00 to 09:15:00	62	49	72	21	20	5	7	2	281.85	1162.4	1163	
09:15:00 to 09:30:00	64	63	69	19	22	6	10	5	313.3			
09:30:00 to 09:45:00	69	56	55	18	16	4	5	0	274.4			
09:45:00 to 10:00:00	65	60	69	14	23	6	15	2	292.85			

Vehicle count at Zenbaba Pension

a) To Gamby Square Vehicle Count

Time	Bajaj	Bus	Car	Truck	Motorcycle	Fara motor	Bicycle	Animal Drawn cart	Passenger car	Hourly Volume		Peak hour volume
07:00:00 to 07:15:00	67	96	25	2	4	3	22	0	303.55	1309.5	1310	1532
07:15:00 to 07:30:00	104	86	27	2	15	5	18	0	298.2	1368.6	1369	
07:30:00 to 07:45:00	116	110	45	5	18	3	10	0	386.75	1464.3	1465	
07:45:00 to 8:00:00	109	91	34	3	11	2	20	1	320.95	1493.9	1494	
08:00:00 to 08:15:00	102	102	50	4	12	1	17	0	362.65	1531.4	1532	
08:15:00 to 08:30:00	104	120	38	3	10	3	15	0	393.95	1505.8	1506	
08:30:00 to 08:45:00	115	120	46	5	16	4	23	2	416.3	1481.3	1482	
08:45:00 to 09:00:00	107	105	32	3	18	7	16	4	358.45	1447.6	1448	
09:00:00 to 09:15:00	109	91	49	3	18	3	18	0	337.05	1500.1	1501	
09:15:00 to 09:30:00	126	106	38	3	16	3	9	2	369.45			
09:30:00 to 09:45:00	108	109	50	1	26	10	17	0	382.6			
09:45:00 to 10:00:00	102	119	57	2	21	5	16	0	411			

b) To St. George Square Vehicle Count

Time	Bajaj	Bus	Car	Truck	Motorcycle	Fara motor	Bicycle	Animal Drawn cart	Passenger car	Hourly Volume		Peak hour volume
07:00:00 to 07:15:00	84	72	10	1	6	0	8	1	229.9	1155.45	1156	1408
07:15:00 to 07:30:00	111	88	20	0	2	2	20	1	290.5	1258.25	1259	
07:30:00 to 07:45:00	105	87	30	4	10	3	19	1	307.85	1290.3	1291	
07:45:00 to 8:00:00	137	94	28	1	7	5	11	1	327.2	1352.05	1353	
08:00:00 to 08:15:00	148	95	25	0	5	13	16	1	332.7	1377.8	1378	
08:15:00 to 08:30:00	123	86	40	5	7	4	8	1	322.55	1391.1	1392	
08:30:00 to 08:45:00	150	101	44	2	6	8	8	2	369.6	1407.55	1408	
08:45:00 to 09:00:00	155	97	31	3	4	15	11	0	352.95	1377.35	1378	
09:00:00 to 09:15:00	156	88	53	1	11	3	13	2	346	1396.5	1397	
09:15:00 to 09:30:00	140	84	59	2	14	2	16	2	339			
09:30:00 to 09:45:00	151	87	41	5	12	4	16	0	339.4			
09:45:00 to 10:00:00	165	97	46	3	27	3	10	0	372.1			

Vehicle count at Kuchit market Center

a) To Aziwa Hotel

Time	Bajaj	Bus	Car	Truck	Motorcycle	Fara motor	Bicycle	Animal Drawn cart	Passenger car	Hourly Volume		Peak hour volume
07:00:00 to 07:15:00	183	33	22	13	8	4	19	10	224.8	904.85	905	1080
07:15:00 to 07:30:00	167	41	38	10	4	4	17	8	244.1	921.05	922	
07:30:00 to 07:45:00	171	27	45	7	12	5	24	6	212.65	971.55	972	
07:45:00 to 8:00:00	167	35	20	14	12	4	18	8	223.3	982.95	983	
08:00:00 to 08:15:00	195	33	36	14	5	3	17	5	241	1028.7	1029	
08:15:00 to 08:30:00	188	48	38	18	13	13	19	5	294.6	1079.6	1080	
08:30:00 to 08:45:00	165	34	39	8	16	3	19	7	224.05	996.8	997	
08:45:00 to 09:00:00	167	43	45	13	10	7	23	10	269.05	1045.7	1046	
09:00:00 to 09:15:00	182	44	45	20	20	2	13	8	291.9	1047.1	1048	
09:15:00 to 09:30:00	175	24	33	13	17	7	20	7	211.8			
09:30:00 to 09:45:00	209	37	48	13	11	13	14	7	272.9			
09:45:00 to 10:00:00	219	34	44	13	14	8	19	15	270.5			

b) To Gamby square Vehicle Count

Time	Bajaj	Bus	Car	Truck	Motorcycle	Fara motor	Bicycle	Animal Drawn cart	Passenger car	Hourly Volume		Peak hour volume
07:00:00 to 07:15:00	175	50	42	17	14	0	23	11	295.3	1090.95	1091	1091
07:15:00 to 07:30:00	187	49	52	13	10	7	14	15	300.75	1081.3	1082	
07:30:00 to 07:45:00	182	40	53	7	18	11	26	5	261.45	1014.8	1015	
07:45:00 to 8:00:00	175	35	47	6	17	4	22	5	233.45	993.45	994	
08:00:00 to 08:15:00	207	38	63	12	11	6	19	8	285.65	1034.3	1035	
08:15:00 to 08:30:00	155	38	35	9	17	4	23	13	234.25	996.25	997	
08:30:00 to 08:45:00	177	21	58	16	21	7	17	10	240.1	1012.4	1013	
08:45:00 to 09:00:00	197	33	63	14	13	9	21	5	274.3	959.5	960	
09:00:00 to 09:15:00	192	29	57	11	14	4	18	7	247.6	977.15	978	
09:15:00 to 09:30:00	172	31	45	18	16	6	23	4	250.4			
09:30:00 to 09:45:00	139	21	44	8	16	8	13	7	187.2			
09:45:00 to 10:00:00	216	43	63	8	14	9	13	7	291.95			

a) Pedestrian count at Habesha Guest House crosswalk location

Time	No. of Pedestrians	hourly volume	Peak hour volume
07:00:00 to 07:15:00	13	67	84
07:15:00 to 07:30:00	20	77	
07:30:00 to 07:45:00	19	81	
07:45:00 to 8:00:00	15	74	
08:00:00 to 08:15:00	23	84	
08:15:00 to 08:30:00	24	72	
08:30:00 to 08:45:00	12	74	
08:45:00 to 09:00:00	25	72	
09:00:00 to 09:15:00	11	67	
09:15:00 to 09:30:00	26		
09:30:00 to 09:45:00	10		
09:45:00 to 10:00:00	20		

b) Pedestrian count at Amhara Martyrs Memorial crosswalk locations

Time	No. of Pedestrians	hourly volume	Peak hour volume
07:00:00 to 07:15:00	15	70	108
07:15:00 to 07:30:00	14	90	
07:30:00 to 07:45:00	20	106	
07:45:00 to 8:00:00	21	104	
08:00:00 to 08:15:00	35	108	
08:15:00 to 08:30:00	30	89	
08:30:00 to 08:45:00	18	74	
08:45:00 to 09:00:00	25	69	
09:00:00 to 09:15:00	16	60	
09:15:00 to 09:30:00	15		
09:30:00 to 09:45:00	13		
09:45:00 to 10:00:00	16		

c) **Pedestrian count at Zenbaba Pension crosswalk locations**

Time	No. of Pedestrians	hourly volume	Peak hour volume
07:00:00 to 07:15:00	57	204	251
07:15:00 to 07:30:00	44	189	
07:30:00 to 07:45:00	52	186	
07:45:00 to 8:00:00	51	205	
08:00:00 to 08:15:00	42	217	
08:15:00 to 08:30:00	41	245	
08:30:00 to 08:45:00	71	251	
08:45:00 to 09:00:00	63	244	
09:00:00 to 09:15:00	70	239	
09:15:00 to 09:30:00	47		
09:30:00 to 09:45:00	64		
09:45:00 to 10:00:00	58		

d) **Pedestrian count at Kuchit Market Center crosswalk location**

Time	No. of Pedestrians	hourly volume	Peak hour volume
07:00:00 to 07:15:00	207	766	797
07:15:00 to 07:30:00	204	664	
07:30:00 to 07:45:00	170	647	
07:45:00 to 8:00:00	185	681	
08:00:00 to 08:15:00	105	712	
08:15:00 to 08:30:00	187	782	
08:30:00 to 08:45:00	204	797	
08:45:00 to 09:00:00	216	775	
09:00:00 to 09:15:00	175	763	
09:15:00 to 09:30:00	202		
09:30:00 to 09:45:00	182		
09:45:00 to 10:00:00	204		

Appendix 3 –Descriptive statistics of variables used in the gap acceptance model framework at each site

a) Descriptive statistics at Habesha Guest House crosswalk location

Variable		% of value	Mean	Standard deviation
Pedestrian safety margin [s]		-	4.12	5.871
Vehicle arrival rate [Veh/s]		-	0.1828	0.09273
Pedestrian crossing speed [m/s]		-	1.5858	0.50759
Waiting time [s]		-	4.32	7.741
Vehicle speed [km/h]		-	39.0225	11.88529
Stage of crossing		-	0.01	0.113
Vehicular gap size [s]		-	11.2885	6.26615
Number of observations before crossing		-	1	0
Number of observations during crossing		-	0.58	0.623
Frequency of Attempt		-	0	0
Frequency of step backward		-	0	0
Type of Gap [s]	0=Lag	39.7	10.4194	6.68874
	1=Gap	60.3	11.8617	5.93803
Tactic of crossing [s]	0=street	67.3	11.0476	6.37963
	1=skew	32.7	11.7843	6.05744
Pedestrian path change condition [s]	0=yes	30.8	11.7292	6.19451
	1=no	69.2	11.0926	6.31648
Pedestrian waiting place [s]	0=pavement	39.7	11.1613	5.94839
	1= other than pavement	21.8	12.7059	5.96723
	2=not required	38.5	10.6167	6.7097
Vehicular travel lane [s]	near = 0	59	11.087	5.8959
	far = 1	41	11.5781	6.80057
Driver yield behaviour [s]	0=yes	0	-	-
	1=no	100	11.2885	6.26615
Vehicular direction [s]	East=0	0	-	-
	West=1	0	-	-
	North=2	48.7	12	6.354
	South=3	51.3	10.6125	6.14486
Pedestrian gender [s]	male = 0	49.4	10.6364	6.19191
	female = 1	41.7	12.1231	6.56817

	Both = 2	9	11	5.05356
Pedestrian age [s]	child (<18) = 0	5.1	12.5	6.18755
	young (18-30) = 1	49.4	10.7273	6.21254
	middle (31-50) = 2	41.7	11.9077	6.49693
	elders (>50) = 3	3.8	10.1667	4.79236
Pedestrian platoon size [s]	single = 0	79.5	11.2581	6.22592
	two = 1	16	11.48	6.70274
	three or more = 2	4.5	11.1429	6.30948
Pedestrian speed change behaviour [s]	yes = 0	17.9	8.2857	5.14859
	no = 1	82.1	11.9453	6.31373
Pedestrian usage of cell phone [s]	yes = 0	1.3	10.5	4.94975
	no = 1	98.7	11.2987	6.29361
Pedestrian rolling behaviour condition [s]	yes = 0	18.6	10.8276	6.26822
	no = 1	81.4	11.3937	6.28573
Pedestrian baggage effect [s]	Yes=0	3.8	11.6667	6.43946
	No=1	96.2	11.2733	6.28079
Pedestrian Crossing direction [s]	East = 0	46.8	11.2329	6.7485
	West = 1	53.2	11.3373	5.85032
	North = 2	0	-	-
	South =3	0	-	-
Type of vehicle [s]	Motor cycle = 0	7.1	9	3.84708
	Three-wheeler = 1	26.3	11.9268	6.55893
	car/ taxi = 2	7.7	7.9167	1.78164
	Utilities =3	15.4	11.75	6.13082
	Small bus =4	32.1	11.34	6.77815
	Large bus =5	3.8	15	6.09918
	Light truck =6	0	-	-
	Medium & heavy truck =7	5.1	12	7.70899
	Articulated truck =8	2.6	10.75	7.32006
	Others (Loader, Grader, etc.) =9	0	-	-
Crossing initiation [s]	Curb = 0	49.4	10.8831	6.20478
	Median = 1	50.6	11.6835	6.33983

b) Descriptive statistics at Amhara Martyrs Memorial crosswalk locations

Variable		% of value	Mean	Standard deviation
Pedestrian safety margin [s]		-	2.07	4.318
Vehicle arrival rate [Veh/s]		-	0.1866	0.10688
Pedestrian crossing speed [m/s]		-	1.3546	0.28581
Waiting time [s]		-	6.51	10.856
Vehicle speed [km/h]		-	42.9343	15.43076
Stage of crossing		-	0.19	0.584
Vehicular gap size [s]		-	10.5821	4.68443
Number of observations before crossing		-	0.99	0.213
Number of observations during crossing		-	0.94	0.795
Frequency of Attempt		-	0	0
Frequency of step backward		-	0	0
Type of Gap [s]	0=Lag	52.2	10.6857	5.60867
	1=Gap	47.8	10.4688	3.49178
Tactic of crossing [s]	0=street	58.2	10.8205	4.6953
	1=skew	41.8	10.25	4.73462
Pedestrian path change condition [s]	0=yes	40.3	10.2593	4.71978
	1=no	59.7	10.8	4.70788
Pedestrian waiting place [s]	0=pavement	37.3	11.32	3.82666
	1= other than pavement	32.8	9.4545	4.03234
	2=not required	29.9	10.9	6.12072
Vehicular travel lane [s]	near = 0	61.2	9.6585	4.14494
	far = 1	38.8	12.0385	5.18059
Driver yield behaviour [s]	0=yes	0	-	-
	1=no	100	10.5821	4.68443
Vehicular direction [s]	East=0	0	-	-
	West=1	0	-	-
	North=2	43.3	12.5172	5.7422
	South=3	56.7	9.1053	3.00261
Pedestrian gender [s]	male = 0	86.6	10.4483	4.34952
	female = 1	10.4	12.2857	7.5214
	Both = 2	3	8.5	0.70711
Pedestrian age [s]	child (<18) = 0	7.5	13.6	5.81378
	young (18-30) = 1	59.7	10.25	4.82913
	middle (31-50) = 2	28.4	10.5789	4.33738
	elders (>50) = 3	4.5	10	2.64575
Pedestrian platoon size [s]	single = 0	74.6	11.02	5.14083
	two = 1	22.4	9.8	2.42605
	three or more = 2	3	5.5	0.70711

Pedestrian speed change behaviour [s]	yes = 0	34.3	8.3478	2.70704
	no = 1	65.7	11.75	5.08589
Pedestrian usage of cell phone [s]	yes = 0	4.5	9.6667	3.78594
	no = 1	95.5	10.625	4.74258
Pedestrian rolling behaviour condition	yes = 0	56.7	10.7105	4.02632
	no = 1	43.3	10.4138	5.50011
Pedestrian baggage effect [s]	Yes=0	13.4	10.6667	3.53553
	No=1	86.6	10.569	4.86344
Pedestrian Crossing direction [s]	East = 0	28.4	11.4737	5.55146
	West = 1	71.6	10.2292	4.30852
	North = 2	0	-	-
	South =3	0	-	-
Type of vehicle [s]	Motor cycle = 0	0	-	-
	Three-wheeler = 1	23.9	11.875	5.69064
	car/ taxi = 2	14.9	10.9	4.88649
	Utilities =3	25.4	10.2353	3.43747
	Small bus =4	17.9	8.5	2.15322
	Large bus =5	7.5	8.6	2.96648
	Light truck =6	1.5	12	0
	Medium & heavy truck =7	7.5	14.2	8.61394
	Articulated truck =8	1.5	8	0
	Others (Loader, Grader, etc.) =9	0	-	-
Crossing initiation [s]	Curb = 0	47.8	11.625	5.36265
	Median = 1	52.2	9.6286	3.79695

c) Descriptive statistics at Zenbaba Pension crosswalk locations

Variable		% of value	Mean	Standard deviation
Pedestrian safety margin [s]		-	1.47	4.487
Vehicle arrival rate [Veh/s]		-	0.2447	0.12066
Pedestrian crossing speed [m/s]		-	1.4035	0.36812
Waiting time [s]		-	3.87	5.626
Vehicle speed [km/h]		-	29.5847	8.79906
Stage of crossing		-	0.1	0.335
Vehicular gap size [s]		-	8.4655	4.59284
Number of observations before crossing		-	1	0.108
Number of observations during crossing		-	0.76	0.671
Frequency of Attempt		-	0.01	0.107
Frequency of step backward		-	0.02	0.15
Type of Gap [s]	0=Lag	29.9	8.8462	3.90768

	1=Gap	70.1	8.3033	4.86154
Tactic of crossing [s]	0=street	93.1	8.5092	4.58576
	1=skew	6.9	7.8182	4.8748
Pedestrian path change condition [s]	0=yes	4.6	7.875	5.84166
	1=no	95.4	8.494	4.54439
Pedestrian waiting place [s]	0=pavement	58.6	8.1078	4.70287
	1= other than pavement	10.9	9.4211	5.75727
	2=not required	30.5	8.8113	3.87823
Vehicular travel lane [s]	near = 0	56.9	7.7374	4.51208
	far = 1	43.1	9.4267	4.55054
Driver yield behaviour [s]	0=yes	0.6	7	0
	1=no	99.4	8.474	4.60481
Vehicular direction [s]	East=0	0	-	-
	West=1	0	-	-
	North=2	50	8.9195	5.27658
	South=3	50	8.0115	3.76488
Pedestrian gender [s]	male = 0	61.5	8.2991	4.45992
	female = 1	25.9	9.4	5.38263
	Both = 2	12.6	7.3636	3.06354
Pedestrian age [s]	child (<18) = 0	20.7	9.0556	4.10536
	young (18-30) = 1	29.9	8.0769	4.36495
	middle (31-50) = 2	36.8	8.4688	5.15157
	elders (>50) = 3	12.6	8.4091	4.33874
Pedestrian platoon size [s]	single = 0	60.3	8.5429	5.03646
	two = 1	31	8.6296	4.12675
	three or more = 2	8.6	7.3333	2.49762
Pedestrian speed change behaviour [s]	yes = 0	7.5	6.1538	1.95133
	no = 1	92.5	8.6522	4.69609
Pedestrian usage of cell phone [s]	yes = 0	1.7	6.6667	1.1547
	no = 1	98.3	8.4971	4.62522
Pedestrian rolling behaviour [s]	yes = 0	28.2	7.7959	4.79574
	no = 1	71.8	8.728	4.50336
Pedestrian baggage effect [s]	Yes=0	16.1	8.6071	4.19293
	No=1	83.9	8.4384	4.6786
Pedestrian Crossing direction [s]	East = 0	35.1	8.9016	5.23674
	West = 1	64.9	8.2301	4.21097
	North = 2	0	-	-
	South =3	0	-	-
Type of vehicle [s]	Motor cycle = 0	2.9	11	6.78233
	Three-wheeler = 1	43.7	8.25	4.4456
	car/ taxi = 2	5.2	6.1111	2.31541
	Utilities =3	4	8	3.82971

	Small bus =4	40.8	8.493	4.55404
	Large bus =5	1.7	16	7.93725
	Light truck =6	0.6	10	0
	Medium & heavy truck =7	1.1	9.5	3.53553
	Articulated truck =8	0	-	-
	Others (Loader, Grader, etc.) =9	0	-	-
Crossing initiation [s]	Curb = 0	50	8.7816	4.614
	Median = 1	50	8.1494	4.5763

d) Descriptive statistics at Kuchit Market Center crosswalk location

Variable		% of value	Mean	Standard deviation
Pedestrian safety margin [s]		-	0.3	3.352
Vehicle arrival rate [Veh/s]		-	0.2846	0.13094
Pedestrian crossing speed [m/s]		-	1.5689	0.46322
Waiting time [s]		-	3.54	4.65
Vehicle speed [km/h]		-	23.9746	6.80183
Stage of crossing		-	0.07	0.258
Vehicular gap size [s]		-	6.7864	3.64592
Number of observations before crossing		-	1	0
Number of observations during crossing		-	0.52	0.525
Frequency of Attempt		-	0	0
Frequency of step backward		-	0	0
Type of Gap [s]	0=Lag	26.9	7.3448	3.85441
	1=Gap	73.1	6.5805	3.55233
Tactic of crossing [s]	0=street	75.2	6.5556	3.22695
	1=skew	24.8	7.4875	4.64974
Pedestrian path change condition [s]	0=yes	25.1	7.5432	4.64771
	1=no	74.9	6.5331	3.21449
Pedestrian waiting place [s]	0=pavement	58.2	6.2926	3.52448
	1= other than pavement	16.1	7.7692	3.41631
	2=not required	25.7	7.2892	3.89662
Vehicular travel lane [s]	near = 0	57.9	6.1711	3.29101
	far = 1	42.1	7.6324	3.94182
Driver yield behaviour [s]	0=yes	1.5	7.2	3.03315
	1=no	98.5	6.7799	3.65836
Vehicular direction [s]	East=0	0	-	-
	West=1	0	-	-
	North=2	49.2	6.5346	3.62966

	South=3	50.8	7.0305	3.65611
Pedestrian gender [s]	male = 0	54.2	6.6571	3.09191
	female = 1	24.1	6.6026	3.94554
	Both = 2	21.7	7.3143	4.49329
Pedestrian age [s]	child (<18) = 0	1.2	4.5	1
	young (18-30) = 1	43	7.223	3.89545
	middle (31-50) = 2	45.5	6.4762	3.41097
	elders (>50) = 3	10.2	6.6061	3.63094
Pedestrian platoon size [s]	single = 0	47.7	6.2013	3.04944
	two = 1	27.9	7.1889	3.94312
	three or more = 2	24.5	7.4684	4.19045
Pedestrian speed change behaviour [s]	yes = 0	9.9	4.5625	1.86543
	no = 1	90.1	7.0309	3.71238
Pedestrian usage of cell phone [s]	yes = 0	1.9	8.5	4.50555
	no = 1	98.1	6.7539	3.62865
Pedestrian rolling behaviour condition [s]	yes = 0	31	5.31	2.6994
	no = 1	69	7.4484	3.82215
Pedestrian baggage effect [s]	Yes=0	9.6	6.2258	3.51861
	No=1	90.4	6.8459	3.65997
Pedestrian Crossing direction [s]	East = 0	49.8	6.8882	3.62456
	West = 1	50.2	6.6852	3.67546
	North = 2	0	-	-
	South =3	0	-	-
Type of vehicle [s]	Motor cycle = 0	5.6	6.3889	1.78684
	Three-wheeler = 1	60.4	6.2308	3.1839
	car/ taxi = 2	7.7	7.72	3.91067
	Utilities =3	6.5	7.5714	3.55769
	Small bus =4	12.4	7.925	5.12604
	Large bus =5	0.9	14.3333	4.16333
	Light truck =6	0.6	7	0
	Medium & heavy truck =7	4.6	5.9333	3.23964
	Articulated truck =8	1.2	11.75	0.95743
	Others (Loader, Grader, etc.) =9	0	-	-
Crossing initiation [s]	Curb = 0	52.3	6.7692	3.60555
	Median = 1	47.7	6.8052	3.7014

Appendix 4–Functions of significant variables on crossing choice

Significant variable	Categories of the variable	Utility function obtained from BL-regression
Pedestrian waiting place	Wait at the Pavement	U=-3.368+0.726*G
	Wait other than the pavement	U=-5.547+0.96*G
Vehicular travel lane	Near lane to waiting pedestrian	U=-3.224+0.745*G
	Far lane to waiting pedestrian	U=-5.038+0.9*G
Pedestrian crossing initiation	Crossing initiates from Curb	U=-3.39+0.681*G
	Crossing initiates from Median	U=-4.373+0.882*G
Incoming vehicle type	Motorcycle	U=-4.985+1.014*G
	Three wheeler	U=-3.701+0.829*G
	Car/taxi	U=-5.592+1.182*G
	Utilities	U=-5.114+0.93*G
	Small bus	U=-3.548+0.636*G
	Large bus	U=-201.097+30.952*G
	Light truck	U=-62.812+8.973*G
	Medium & Heavy truck	U=-4.604+0.789*G
	Articulated truck	U=-84.795+16.92*G
Pedestrian's waiting time	Waiting time ≤5sec.	U=-5.085+1.151*G
	Waiting time : 6-10sec.	U=-3.26+0.565*G
	Waiting time: 11-15sec.	U=-1.423+0.346*G
	Waiting time ≥ 16 sec.	U=-2.886+0.454*G
Pedestrian's age	Child (<18)	U=-3.84+0.645*G
	Young(18-30)	U=-4.454+0.898*G
	Middle age (31-50)	U=-3.536+0.726*G
	Elders (≥51)	U=-3.119+0.644*G
Vehicular moving direction	Marked crosswalks at Habesha Guest House	U=-4.348+0.701*G
	Unmarked Crosswalk at Habesha Guest House	U=-4.225+0.636*G
	Marked crosswalks at Kuchit Market Center	U=-4.139+0.944*G
	Unmarked Crosswalk at Kuchit Market Center	U=-3.471+0.797*G
	Marked crosswalks at Zenbaba Pension	U=-5.55+1.136*G
	Unmarked Crosswalk at Zenbaba Pension	U=-4.213+0.894*G
	Near side at Amhara Martyrs Memorial Office	U=-116.427+16.554*G
	Far side at Amhara Martyrs Memorial Office	U=-11.553+1.825*G
Where; G-is vehicular gap size in second , and U-is the utility function obtained from BL-regression		

Appendix 5 –Sample data's used for modeling

Sample data's of significant variables used for gap acceptance model

Ped.no.	Gap/Lag (sec)	Vehicle travel speed (Km/hr) (VS)	Vehicle Arrival rate (veh/sec) (VAR)	Vehicluar Travel Lane (VTL)	Driver Yield Behavior (DYB)	Pedestrian Crossing Speed (PCS)	Waiting time (sec) (WT)	Safety margin (sec) (SM)	pedestrian path change condition (PPcc)	stage of crossing (SOC)	pedestrian rolling behavior (Rbeh)	Tactic of crossings (PCT)	Pedestrian Waiting place (PWP)	no.of observation before crossing (NOBC)	Type of Gap (TOG)
1	5	31.02	0.2	0	1	2.10	0	0	0	0	0	1	2	1	0
2	6	67.20	0.16	0	1	1.34	0	-2	0	0	1	1	2	1	0
3	14	33.60	0.02	1	1	1.12	0	5	0	0	0	1	2	1	0
4	8	33.60	0.13	1	1	1.75	0	2	0	0	0	1	2	1	0
5	11	57.60	0.09	0	1	1.29	0	3	0	0	1	1	2	1	0
6	7	57.60	0.14	0	1	1.17	0	-2	0	0	1	1	2	1	0
7	24	36.65	0.02	1	1	0.93	0	13	0	0	1	1	2	1	0
8	17	57.60	0.06	0	1	1.20	0	8	1	0	1	0	2	2	0
9	14	20.16	0.07	1	1	1.03	0	4	1	0	1	0	0	1	0
10	7	57.60	0.15	0	1	1.11	7	-3	1	0	1	0	1	0	0
11	13	36.65	0.08	0	1	1.11	0	3	1	0	1	0	1	1	0
12	23	36.65	0.04	1	1	1.37	0	16	0	0	1	1	1	1	0
13	7	80.64	0.14	0	1	1.58	2	-1	1	0	1	0	1	1	0
14	7	23.72	0.14	0	1	1.98	0	2	0	0	1	1	1	1	0
15	8	28.80	0.13	1	1	1.61	0	1	1	0	0	0	0	1	0
16	4	44.80	0.23	0	1	2.34	0	0	0	0	1	1	1	1	0
17	12	60.18	0.08	0	1	1.01	0	2	0	0	0	1	1	1	0
18	6	44.80	0.15	0	1	1.54	0	0	1	0	1	0	0	1	0
19	17	31.02	0.06	1	1	1.51	2	8	1	0	0	0	0	1	0
20	12	67.20	0.08	0	1	0.99	0	2	1	1	0	0	2	1	0
21	13	33.60	0.08	1	1	1.32	0	5	1	0	1	0	2	1	0
22	10	24.89	0.1	0	1	1.27	0	2	1	0	0	0	2	1	0

Sample data's of significant variables used for crossing choice model

Ped.no.	Ped. Decision	Gap/ Lag(sec)	Vehicle type (VT)	Vehicle travel speed(Km/hr) (VS)	Vehicle direction (VD)	Vehicluar Travel Lane (VTL)	Pedestrian Age (Age)	Waiting time (sec) (WT)	Pedestrian Waiting place (PWP)	Crossing initiation (CRI)
1	0	4	2	44.8	2	0	1	4	1	0
2	0	5	1	40.32	3	1	1	22	1	1
3	0	5	0	40.32	3	1	1	31	1	1
4	0	8	1	44.8	3	1	0	8	0	0
5	0	4	5	57.6	3	0	2	8	1	1
6	0	4	4	43.83	3	1	2	11	1	1
7	0	3	1	31.5	2	0	1	7	0	0
8	0	3	1	36.65	3	0	1	3	0	1
9	1	9	2	36.32	3	1	1	2	1	1
10	1	14	7	40.32	3	0	1	4	0	1
11	1	9	5	14.5	2	1	1	26	0	0
12	1	6	2	42	3	1	1	1	1	1
13	1	8	4	54.49	3	0	2	4	1	1
14	1	14	3	44.8	2	1	2	4	0	0
15	1	13	2	36.65	2	0	0	9	1	1
16	1	10	3	31.02	3	0	1	9	0	1
17	1	11	3	44.31	2	1	1	7	0	0
18	1	7	5	50.4	3	1	2	20	1	1
19	1	12	2	80.64	3	1	0	15	0	0
20	1	12	3	36.65	2	1	1	6	0	0
21	1	9	4	50.4	3	0	1	50	0	1
22	1	13	1	44.8	3	0	1	9	0	1
23	1	7	1	44.8	3	0	1	20	0	0
24	1	23	2	44.8	2	1	0	4	0	1
25	1	9	4	36.65	3	0	3	3	1	1
26	1	14	2	40.32	2	1	2	5	0	0
27	1	9	5	57.6	3	0	2	23	1	1
28	1	12	2	80.64	3	1	1	12	0	0
29	1	13	1	28.8	2	1	1	17	0	0
30	1	8	1	42	3	0	1	9	1	1
31	1	44	1	30.13	2	1	1	11	0	0
32	1	15	7	50.4	3	1	2	13	1	1
33	1	12	6	43.83	3	0	1	7	1	1
34	1	8	8	57.6	3	0	3	49	0	0
35	1	8	4	23.72	2	1	2	10	1	1
36	1	15	1	23.86	2	0	2	9	0	0
37	0	2	7	29.17	2	1	2	0	0	0
38	0	1	1	29.17	3	1	2	0	0	1
39	0	4	1	34.02	3	1	2	0	0	0
40	0	4	0	20.42	2	1	1	0	0	0

Appendix 6 –Questionnaire

a) Cover page of the Questionnaire

በባህርዳር ከተማ ዉስጥ ስላሉ የእግረኛ ማቋረጫ በታዎች የፅሑፍ መጠይቅ

በቅድሚያ ጊዜዎትን ሰዉተዉ መጠይቁን ለመሙላት ስለተባበሩኝ ለማመስገን እወዳለሁ።

ስሜ አበበ ሰዉነት ይባላል። በደብረታቦር ዩኒቨርሲቲ በሲቪል ምህድስና ትምህርት ክፍል መምህር እና በባህርዳር ዩኒቨርሲቲ የ 2ኛ ዲግሪ የመንገድ እና ትራንስፖርት ተማሪ ነኝ። በአሁኑ ሠዓት በባህዳር ከተማ ዉስጥ የእግረኛ ማቋረጫ በታዎች ላይ ስላሉ ችግሮች የመመረቂያ ጥናት በመስራት ላይ እገኛለሁ።

እያንዳንዱን ጥያቄ በጥሞና ካነበቡ በሁዋላ የርስዎን ሀሣብ ወይም እምነት ያንፀባርቃል የሚሉትን አንድ ምርጫ ከተሰጡት አማራጮች መካከል ከጎን ባለዉ የሳጥን ምልክት ዉስጥ የ" √" ምልክት በማድረግ ምርጫዎን ያመላክቱ።

ለያንዳንዱ ጥያቄ ትክክል ወይም ስህተት መልስ የለም። የራሴን ሀሳብ ወይም እምነት ያንፀባርቃል የሚሉት ምርጫ ነዉ ትክክለኛ መልሱ።

የርስዎ መልስ እግረኛ ላይ የሚደርሱ የትራፊክ አደጋ ለመቀነስ መፍትሄ ለማምጣት አስተዋፅኦ ስላለዉ ከፍተኛ ጥንቃቄ ያድርጉ።

በመጠይቁ ላይ ስም መፃፍ አያስፈልግም።

b) Demography and crossing preference of pedestrians

እባክዎን በምርጫዎ ጎን ባሉ የሳጥን ምልክት ዉስጥ የ "√" ምልክት ያድርጉ።

ክፍል-1 ፡ የግለሰቡ የግል መረጃ

1. ፆታ ወንድ ☐ ሴት ☐
2. የእድሜ ክልል <18 ☐ 18-30 ☐ 31-50 ☐ >51 ☐

ክፍል-2፡ አዉራ መንገድን ለማቋረጥ ስለሚመርጡት ቦታ እና ምክንያትዎ

3. አብዛኛዉን ጊዜ መንገድ ለማቋረጥ የትኛዉን ቦታ ይጠቀማሉ?
   ሀ. የእግረኛ ማቋረጫ ቦታዎችን ☐
   ለ. በማንኛዉም የተመቸኝ ቦታ ☐
4. ከላይ በጥያቄ ቁጥር 3 ለቀረበልዎ ጥያቄ መልስዎ "ሀ" ከሆነ ለምን የእግረኛ ማቋረጫ ቦታዎችን ተጠቀሙ? **[ከአንድ ምርጫ በላይ መምረጥ ይቻላል]**
   ሀ. ለአደጋ ስለማያጋልጡ ☐
   ለ. ለማቋረጥ ምቹ ስለሆኑ ☐
   ሐ. አሽከርካሪዎች ለእግረኛ ቅድሚያ ስለሚሰጡ ☐
   መ. ትራፊክ ፖሊስ በቦታዉ ስለሚኖር ☐
   ሰ. ህጋዊ ለመሆን ☐
   ረ. ሌሎች እግረኞች ስለሚያደርጉት ☐
   ሸ. ጊዜ ለመቆጠብ ☐

   ሌላ ምክንያት ካለዎት____

5. ከላይ በጥያቄ ቁጥር 3 ለቀረበልዎ ጥያቄ መልስዎ "ለ" ከሆነ ለምን በማንኛዉም የተመቸዎ ቦታ መንገድ ያቋርጣሉ? **[ከአንድ ምርጫ በላይ መምረጥ ይቻላል]**
   ሀ. የምፈልገዉ ቦታ ቶሎ ለመድረስ ☐
   ለ. በተሽከርካሪዎች መካከል ለማለፍ ጎበዝ ስለሆንኩ ☐
   ሐ. አሽከርካሪዎች በእግረኛ ማቋረጫዎች ላይ መኪናቸዉን ስለሚያቆሙ ☐
   መ. የእግረኛ ማቋረጫ ቦታዎች ስፋታቸዉ በቂ ባለመሆናቸዉ ☐
   ሰ. ትራፊክ ፖሊስ በቦታዉ ስለማይኖር ☐
   ረ. የእግረኛ ማቋረጫ ቦታዎች ላይ አሽከርካሪዎች ለእግረኛ ቅድሚያ ስለማይሰጡ ☐
   ሸ. ሌሎች እግረኞች ስለሚያደርጉት ☐
   ሌላ ምክንያት ካለዎት____

c) Pedestrians agreement on statements

ክፍል-3፡ የሚከተሉት ሀሳቦች ላይ ምን ያህል ይስማማሉ

ተ/ቁ	ሀሳቦች	በፍፁም አልስማማም	አልስማማም	አስተያየት የለኝም	እስማማለሁ	በጣም እስማማለሁ
1	በባህርዳር ከተማ ዉስጥ ባሉ አዉራ መንገዶች ላይ በሚገኙ የእግረኛ ማቋረጫ ቦታዎች ላይ መንገድ ማቋረጥ አስቸጋሪ ነዉ	☐	☐	☐	☐	☐
2	ከእግረኛ ማቋረጫ ቦታዎች ዉጭ መንገድ ማቋረጥ ጊዜ ይቆጥባል	☐	☐	☐	☐	☐
3	ከእግረኛ ማቋረጫ ቦታዎች ዉጭ መንገድን ማቋረጥ ለአደጋ የመጋለጥን እድል ይጨምራል	☐	☐	☐	☐	☐
4	በእግረኛ ማቋረጫ ቦታዎች መካከል ያለዉ ርቀት ረጅም ነዉ	☐	☐	☐	☐	☐
5	የእግረኛ ማቋረጫ ቦታዎች ስፋታቸዉ በቂ አይደለም	☐	☐	☐	☐	☐
6	የእግረኛ ማቋረጫ ቦታዎች ምቹ አይደሉም	☐	☐	☐	☐	☐
7	የተቀቡ የእግረኛ ማቋረጫ ቦታዎች (ዜብራዎች) ቀለማቸዉ አይታይም	☐	☐	☐	☐	☐
8	ለእግረኛ ቅድሚያ የሚያሰጡ ምልክቶች የተቀመጡበት ቦታ ለእይታ የተጋረዱ ናቸዉ	☐	☐	☐	☐	☐
9	የእግረኛ ማቋረጫ ቦታዎች ላይ አሽከርካሪዎች ለእግረኛ ቅድሚያ አይሰጡም	☐	☐	☐	☐	☐
10	አሽከርካሪዎች ዝንጉ እና እግረኛን የማያከብሩ ናቸዉ	☐	☐	☐	☐	☐
11	አሽከርካሪዎች የእግረኛ ማቋረጫ ቦታዎች ላይ መኪናቸዉን ያቆማሉ	☐	☐	☐	☐	☐
12	አብዛኛዉን ጊዜ አደጋ የሚደርሰዉ በአሽከርካሪዎች ጥፋት ነዉ	☐	☐	☐	☐	☐
13	መንገድ ሳቋርጥ ጠንቃቃ ነኝ	☐	☐	☐	☐	☐
14	መንገድ ሳቋርጥ ፈጣን ነኝ	☐	☐	☐	☐	☐

d) How much of pedestrians doing the statements

ክፍል-4፡ የሚከተሉት ሀሳቦችን ምን ያህል ጊዜ ደጋግመዉ አድርገዋቸዋል

ተ/ቁ	ሀሳቦች	በፍፁም	በጣም አልፎ አልፎ	አንዳንድ ጊዜ	በአብዛኛዉ	ሁልጊዜ
1	መንገድ በሰያፍ (ዲያጎናል) አቋርጣለሁ	☐	☐	☐	☐	☐
2	መንገድ ከማቋረጤ በፊት በመኪኖች መካከል ያለዉን ክፍተት ለማቋረጥ በቂ መሆኑን አረጋግጣለሁ	☐	☐	☐	☐	☐
3	መንገድ በማቋርጥበት ጊዜ ሙሉ ትኩረት ለተሽከርካሪ እሰጣለሁ	☐	☐	☐	☐	☐
4	ጊዜ ለመቆጠብ ብየ በተሽከርካሪዎች መካከል እየተሽሎከሎኩ (በዚግዛግ) መንገድ አቋርጣለሁ	☐	☐	☐	☐	☐
5	መንገድ በማቋርጥበት ጊዜ የቆሙ መኪኖች፣ዛፎች፣ህንፃዎች ተሽከርካሪ እንዳላይ ይጋርዱኛል	☐	☐	☐	☐	☐
6	ከእግረኛ ማቋረጫዎች ዉጪ በማንኛዉም ቦታ መንገድ አቋርጣለሁ	☐	☐	☐	☐	☐
7	መንገድ በማቋርጥበት ጊዜ ስልክ አወራለሁ ወይም በስልኬ ሙዚቃ አዳምጣለሁ	☐	☐	☐	☐	☐
8	መንገድን ብዙ ቦታ ላለማቋረጥ እሞክራለሁ	☐	☐	☐	☐	☐
9	የእግረኛ ማቋረጫ ቦታዎች ለእግረኛ ቅድሚያ የሚያሰጡ ቢሆኑም ተሽከርካሪ እንዲያልፍ ቅድሚያ እሰጣለሁ	☐	☐	☐	☐	☐

……………………………………… ***ስለትብብርዎ በድጋሜ አመሰግናለሁ*** !!!………………………………………

Appendix 7 – Recommended crosswalk treatment at each location using O'Flaherty, 2018 crosswalk warrant