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JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

HIGHWAY ENGINEERING

Analyzing and Identifying Characteristics of High Risk Intersections for Pedestrians and Its Countermeasures: A Case of Dire Dawa City

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Highway Engineering

BY

Ali Shukur

December 2018

Jimma, Ethiopia

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By:

Ali Shukur

Main Advisor: Prof. Emer T. Quezon, P.Eng

Co-Advisor: Eng. Desalegn Ayele (MSc)

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DECLARATION

I, the undersigned, declare that this thesis entitled: **"Analyzing and Identifying Characteristics of High Risk Intersections for Pedestrians and Its Countermeasures: A Case of Dire Dawa City.**" is my original work, and has not been presented by any other person for an award of a degree in this or any other University, and all sources of material used for these have been duly acknowledged.

Candidate:

Ali Shukur	____________	____________
	Signature	Date

Approved By Board of Examiners

Prof. Dr.-Ing. Alemayehu Gebisa	____________	____________
External Examiner	Signature	Date
Engr. Tarekegn Kumela	____________	____________
Internal Examiner	Signature	Date
Engr. Teyba Wedajo	____________	____________
Chairman	Signature	Date
Prof. Emer T. Quezon	____________	____________
Advisor	Signature	Date
Engr. Desalegn Ayele	____________	____________
Co- Advisor	Signature	Date

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ABSTRACT

Pedestrian accidents are a serious and growing problem in the world, especially in the cities of low-income and middle-income countries. Dire Dawa City, one of the federal states in East Ethiopia has a high frequency of pedestrian injuries. Thus, the primary goal of the study was to identify high risk intersections, relationships between pedestrian crashes and the environments in terms of intersection and traffic characteristics. Three year (2013/14 to 2015/16) pedestrian crash data from police records of Dire Dawa Administration Police Commission has been used in for the analysis. From the study, the total number of pedestrian Crashes reported at Dire Dawa intersections were 165. From this, 13 were fatal, 54 were serious injury and 98 were minor injury. Both probability sampling and random sampling techniques were applied. Based on the results of this research using priority value method, there were nine selected intersections from the 24 sample intersections selected. To identify how specific roadway intersection characteristics are associated with pedestrian crashes, this study conducted pedestrian crash frequency analysis on the basis of negative binomial (NB) model. The analysis compared the association of the number of pedestrian crash with intersection characteristics. In the analysis, sixteen variables was considered for use in the statistical model of the number of pedestrian crashes at each study intersection. The result of negative binomial regression indicated that motorized traffic volume, pedestrian crossing volume, presence of school and alcohol bar within 300m radius, availability of an intersection at near offices and commercial areas, presence of stop or yield control and width of minor road were positively associated with the number of pedestrian crashes. Therefore, these identified factors found out which are associated with an increase in the number of pedestrian crashes. Based on the findings, it was suggested countermeasures such as provision of sidewalks, pedestrian crosswalk markings, pedestrian refuge island and regular crosswalks maintenance.

***Keywords**: Countermeasures, Pedestrian Crashes, High Risk Intersections, Intersection Characteristics, Negative Binomial (NB) model, priority value.*

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ACRONYMS

ADT	Average Daily Traffic
AVEI	Average yearly Traffic Entering at Intersection
CSA	Central Statistical Agency
CRF	Crash Reduction Factor
EB	Empirical Bayes
ERA	Ethiopian Road Authority
FHA	Federal Highway Administration
GPS	Global Positioning System
HRL	Hotspot Road Location
IRR	Incidence Rate Ratio
MUTCD	Manual on Uniform Traffic Control Devices
WHO	World Health Organization
PCE	Passenger Car Equivalent
PDO	Property Damage Only
RTAs	Road Traffic Accidents
RMEV	Rate per Each Million Entering Vehicles
RTM	Regression-to-Mean
SPF	Safety Performance Function
SPSS	Statistical Package for the Social Sciences
TB	Tuberculosis

CHAPTER ONE

INTRODUCTION

1.1 Background

Road traffic accident is a major but neglected public health challenge. The World report on road traffic accident prevention has indicated that worldwide, an estimated 1.2 million people died in road traffic accident each year and as many as 50 million are being injured [1]. Current and projected trends in motorization indicated that the problem of Road traffic accident will get worse, leading to a global public health crisis. It has been indicated that, accordingly, by 2020 traffic accident is expected to be the third major killer after HIV/AIDS and TB [2]. Due to its perception as a 'disease of development', road traffic accidents and related injuries tend to be under recognized as major health problems in developing countries.

Pedestrian accidents are a serious and growing problem in the world, especially in the cities of developing countries. According to WHO report, over 90% of the world's fatalities on the roads occurred in low-income and middle-income countries, which have only 48% of the world's registered vehicles [1]. For example, an estimated total of 227, 835 pedestrians died in low-income countries, as opposed to 161,501 in middle-income countries and 22,500 in high income countries each year [3].

The severity of road traffic crashes is also likely to be much greater in Africa than anywhere else, because many vulnerable road users are involved, poor reporting system, lack of pre-hospital and hospital emergency care after accidents makes the outcome of car accidents in Africa the worst [4]. The African Region has the highest proportion of pedestrian and cyclist deaths at 43% of all road traffic deaths [50].

Again WHO report also shows that Ethiopia is one of the ten countries with highest number of deaths by traffic accidents [1]. Some study shows that according to federal police commission report, the death rate due to car accident is significantly increasing among pedestrians and passengers from time to time in Ethiopia [5]. A total of 25,110 accidents and 3,415 fatalities were recorded in Addis Ababa during 2000-2009 [6].

From 2003/4-2007/8, on average, about 56 percent of the road traffic accident fatalities are pedestrians, 36 percent are passengers, and only 8 percent are drivers. The figure of pedestrian fatalities rises in built-up areas. For example in the city of Addis Ababa, pedestrian fatalities are about 90 per cent of the total road accident fatalities in the city [7]. The WHO report supports this reality, because it shows that pedestrian accounts the highest percentage (55%) in Traffic accidents.

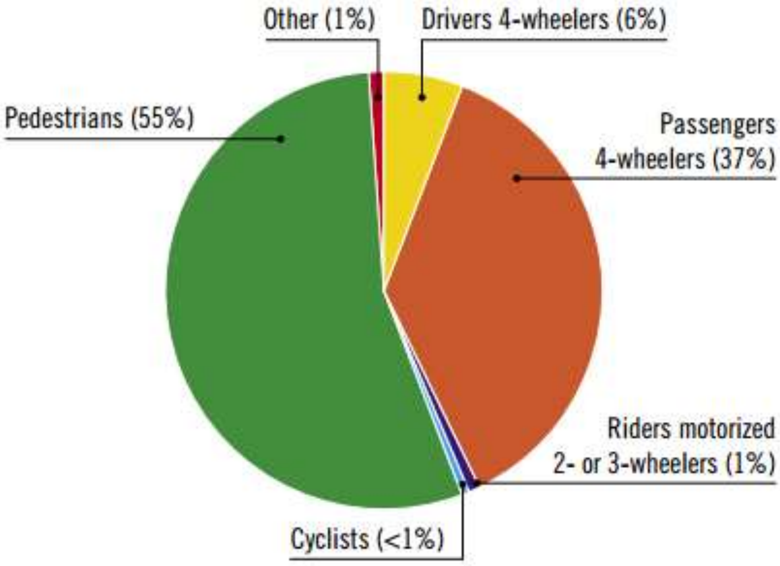


Figure 1.1 Deaths by road user category [1]

Another literature stated that between 2000 and 2020, deaths are expected to increase by as much as 80% in low income and middle-income countries, without increased efforts and new initiatives to improve traffic safety. The majority of such deaths are currently among “vulnerable road users” – pedestrians, pedal cyclists and motorcyclists [2].

Dire Dawa city is one of cities in which pedestrian crashes are a major problem. A report from traffic Police office of Dire Dawa city indicated that in 2005, there were a total 217 RTAs and in 2009 the total number RTAs increased to 322 [8]. In 2010, it is reported that 315 traffic accidents were occurred in Dire Dawa and 137 were pedestrian accidents (15 fatalities, 57 serious injuries and 65 minor injuries).

Therefore, this research has focused on identifying high risk road intersections, possible intervention and analysis of the pedestrian crash at intersections in Dire Dawa city. The results of this study have been used to provide appropriate recommendation of theoretical and practical techniques to reduce the problems related to pedestrian safety at intersections in Dire Dawa city.

1.2 Statement of the problem

Transportation network is meant to accommodate a variety of transportation modes and hence the experience varies for the users of each mode such as an automobile, cyclist, transit rider, and pedestrian having a very different experience traveling along the same corridor. Often, the physical characteristics of the system that make travel easier or more enjoyable for one mode may produce challenges or increase risk for users of another mode. These heightened risks are most common at intersections and are especially relevant for users of active transportation modes, such as pedestrians.

More often, pedestrian crashes are one of the major road safety problems in the world, especially developing countries, representing about 40% of total fatal crashes in low income countries and many pedestrian crashes in these countries occur at unsignalized intersections [42]. Most countries in Africa have insufficient policies and strategies to protect vulnerable road users. As a result some studies depicted that the African Region has the highest proportion of pedestrian and cyclist deaths at 43% of all road traffic deaths [51]. As Ethiopia is one of the developing countries, pedestrians account for 55% of fatal crashes per annum [1].

Dire Dawa city is one of cities in which pedestrian crashes are a major problem in Ethiopia. A report from traffic Police office of Dire Dawa city indicated that in 2005, there were a total 217 traffic accidents and in 2009 the total number traffic accidents increased to 322 [8]. In 2010, it is reported that 315 traffic accidents were occurred in Dire Dawa and 137 were pedestrian accidents (15 fatalities, 57 serious injuries and 65 minor injuries). Such accidents give pain, grief and suffering to the victims as well as those who care for the victims. Further, it is generally not possible to implement all remedial measures identified due to so many limitations. Therefore, there is an urgent need to assess and investigate the number of pedestrian accidents, understand the relationships between intersection characteristics and pedestrian crashes, and implement road safety methods at high risk intersections in the road network.

This research adopted a structured approach to identify and rank the high risk intersections so that depending on the priority, these intersections can be treated. Further, statistical analysis was employed to investigate the relationship between intersection characteristics and pedestrian crashes. It is for this reason that this research study has aimed to analyze and identify pedestrian high risk road intersections and their characteristic, possible intervention and analysis of the pedestrian crash at intersections in Dire Dawa city.

1.3 Research questions

The research questions that the study sought to answer were as follows:

1. Which intersections have the highest risk pedestrian crashes that are always occurring in Dire Dawa city?
2. What are the characteristics of pedestrian crashes which make the intersections vulnerable of accidents most of the time?
3. What possible treatments or remedies can be recommended to improve pedestrian safety, especially at the high risk intersections?

By answering these questions, this research has identified key characteristics of the intersections that may contribute to or detract from pedestrian safety at intersections, and provided recommendations for intersection improvements based on the analysis.

1.4 Objectives

1.4.1 General objective

The general objective of this research was to analyze and identify characteristics of high-risk intersections for pedestrians in Dire Dawa city.

1.4.2 Specific objectives

The specific objectives of this research were:

- To analyze and rank high risk intersections based on pedestrian crash data at intersections in Dire Dawa city.
- To identify and discuss the relationship between intersection characteristics and pedestrian crashes so that contributing factors can be examined.
- To recommend appropriate treatments on the existing intersections to improve safety for pedestrians.

1.5 Scope of the study

The study is confined to one of the major cities of Ethiopia, Dire Dawa City. The research considered three years (2013/14-2015/16) of pedestrian crashes and with detailed review of all police reports to obtain additional details. The study focused on identifying and characterizing high risk intersections using major pedestrian safety parameters in Dire Dawa including appropriate recommendations in order to treat the intersections.

1.6 Significance of the study

This study was mainly concerned with the identification of high risk intersections and their characteristics in Dire Dawa city. Therefore, the findings obtained from the study helps to gain information and knowledge to prioritize intersections to treat high risk intersections based the available budget. The study may also have some paramount importance to the government and authorities at the future to prepare pedestrian safety action plan. The study will be used as a bench mark information to those researchers who want to conduct future detailed studies on pedestrian safety issues. Finally, it will also help to carry out further research to refine the conceptual and methodology of the present study.

1.7 Limitations of the study

This study has several limitations. The socio-demographic characteristics of the location of injury (average income, age of the population), and of the injured pedestrian (age, income, etc.) were not addressed. It was focused on the contribution of the built-environment and intersection characteristics. Also, the identification of pedestrian high-risk intersections was using crash frequency, as data scarcity limited to use more sophisticated methods for high-risk intersection identification.

1.8 Organization of the Thesis

The thesis is organized in five chapters as follow:

Chapter 1: Presents the background of the study, statement of the problem, questions and objectives of the study, significance of the study, the study area, scope of the study, limitation of the study and to the end organization of the thesis followed.

Chapter 2: Describes previous research studies regarding intersection characteristics, pedestrian safety, review of statistical analysis and high risk intersection identification to undertake countermeasures.

Chapter 3: Discusses the sources and procedure of data collection, study variables and analysis methodology used in this study.

Chapter 4: Presents and discusses analysis and results of the analysis and Probable countermeasures.

Chapter 5: Presents the conclusions and recommendations of the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Definitions of Key Concepts

High-risk intersections: As defined by NZ High-risk intersections guide, high-risk intersections are intersections with a higher than normal risk that people will die or be seriously injured in the future [53]. Another definition of high risk road location is that abnormal concentration of crashes in some particular road section within the route or location of a road where traffic accidents often take place. High risk road locations are also called Hazardous Road Locations (HRLs) or Accident Prone Location or Black Spots [41]. This is because of road crashes are normally clustered in some specific sites. In this thesis, the flemish government definition is used for the high risk intersections as "intersections where its priority value (P) equals 15 or more" [66].

Vulnerable road users: road users most at risk in traffic, such as pedestrians, cyclists and public transport passengers. Children, older people and disabled people may also be included in this category [56].

Pedestrian: The term "pedestrian" refers to people travelling outside of a motorized vehicle but who are not pedal cyclists. Pedestrians, quite naturally, are made up of all ages and abilities of people (e.g., children, older adults, persons with disabilities, persons with visual or hearing challenges, as well as those using assistive devices, skateboards, longboards, rollerblades and Segways) [23]. MUTCD also defined pedestrian as "a person on foot, in a wheelchair, on skates, or on a skateboard" [57].

Pedestrian Facilities: a general term denoting improvements and provisions made to accommodate or encourage walking [57]. Another literature stated that pedestrian facilities consist of sidewalks, curb ramps, marked crosswalks, transit stop treatments, roadway lighting improvements, and street furniture [44].

Intersection/ Junction: An intersection is a crossing or meeting of two or more roads, at grade. An intersection may be controlled by a traffic signal, stop signs or yield signs, or it may be uncontrolled. Where two or more roads meet or cross, the intersection may be "controlled" by a traffic circle or rotary [40]. ERA define a junction, or intersection, as the general area where two or more roads join. ERA also categorized junction as T-Junctions, Cross-Junctions, Roundabouts and Grade Separation Junctions [59].

Roundabout: As defined by the MUTCD, roundabouts are circular intersections with yield control at entry, permitting a vehicle on the circulatory roadway to proceed, and deflecting the approaching vehicle counter-clockwise around a central island [56]. A roundabout is a one-way circulatory system around a central island, entry to which is controlled by markings and signs. Priority is given to traffic already in the roundabout. Roundabouts provide high capacity and minimal delay. Roundabouts have a good safety record [59].

Major and Minor Street: MUTCD has defined the major street as the street normally carrying the higher volume of vehicular traffic while minor street is the street carrying the lower volume of vehicular traffic [56].

Traffic Island: As defined by MUTCD, island is a defined area between traffic lanes for control of vehicular movements, for toll collection, or for pedestrian refuge. It includes all end protection and approach treatments. Within an intersection area, a median or an outer separation is considered to be an island[56]. According to definition of ERA, a traffic island is a defined area between traffic lanes for the control of vehicle movements and which may also be used as a pedestrian refuge. Traffic islands may take the form of an area delineated by barrier curbs or a pavement area marked by paint or a combination of these. ERA stated that traffic islands may be included in the design of junctions for one or more of the following purposes [59]:

- Separation of conflicts
- Control of angle of conflict
- Reduction of excessive pavement areas
- Regulation of traffic and indication of proper use of junction
- Arrangements to favor a predominant turning movement
- Protection of pedestrians
- Protection and storage of turning and crossing vehicles
- Location of traffic signs

Crash/accident: A crash is a rare, random, multifactor event preceded by a situation in which one or more persons failed to copewith their environment. The term ‘accident’ is sometimes still used and these terms are interchangeable [58].

Crash severity: The most severely injured casualty occurring as a result of a crash [58].

Fatal: A death occurring as the result of injuries sustained in a road crash within 30 days of the crash [58].

Serious: Injury (fracture, concussion, severe cuts or other injury) requiring medical treatment or removal to and retention in hospital [58].

Minor: Injury which is not 'serious' but requires first aid, or which causes discomfort or pain to the person injured.

Non-injury: Property damage only (PDO) [58].

Crash Frequency: is defined as the number of crashes occurring within a specific jurisdiction, on a roadway segment, or at an intersection [60]. The above literature stated that multiple crashes occurring at the same location over a period of time may be an indication of a safety issue and should be investigated and addressed appropriately. This is referred to as "clustering". Crashes can be clustered by route, specific location on that route, or by intersection [60].

Crash rate: Crash rate analysis of the relative safety of a segment or intersection takes into account exposure data. The crash rate is calculated to determine relative safety compared to other similar roadways, segments, or intersections. Crash rate analysis typically uses exposure data in the form of traffic volumes or roadway mileage [60].

2.2 Pedestrian Safety and Intersections

Pedestrian safety at intersection is a serious matter of concern for the traffic and road safety engineers, researchers and organizations. Enormous statistics and literatures are available related to this region. After studying several literatures, some significant points have been acknowledged that are cited here concisely.

Representing conflict points in the road network, intersections have received and should continue to receive considerable attention. Intersections continue to represent crash-prone locations on a transportation network. When approaching intersections, drivers are confronted with a complex driving task that includes observing and responding to traffic control devices, reacting to these devices by stopping, reducing speed (or proceeding without delay), executing turns, observing and reacting to pedestrians and cyclists and avoiding conflicts with other vehicles.

Globally, road traffic crashes are a leading cause of death among young people, and the main cause of death among those aged 15–29 years [50].

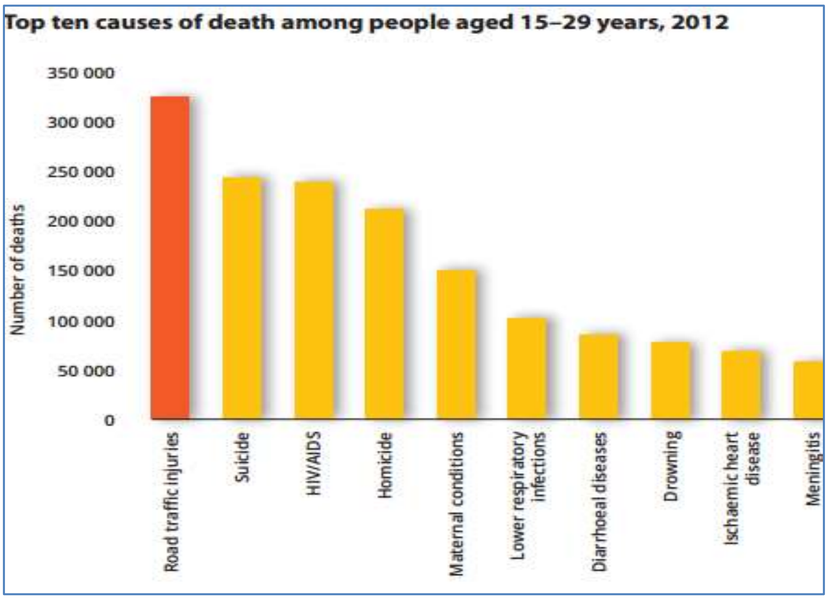


Figure 2.1: Top ten causes of death among people aged 15-29 [50]

A literature stated that between 2000 and 2020, deaths are expected to increase by as much as 80% in low income and middle-income countries, without increased efforts and new initiatives to improve traffic safety. The majority of such deaths are currently among “vulnerable road users” – pedestrians, pedal cyclists and motorcyclists [2].

Studies have shown that children under the age of 10 are not yet capable of crossing a roadway intersection alone. Young children have not fully developed an awareness of the direction of sound (e.g., an approaching car), peripheral vision, focus and concentration levels, or proper judgment of a car’s speed and distance until after the age of ten [12].

Pedestrians killed in traffic crashes account for nearly 12 percent of all traffic fatalities and 59,000 injuries each year [14]. Automobiles alone cannot be blamed for pedestrian and cyclist fatalities. Research has shown that both motorists and cyclists/pedestrians are frequently observed committing “road-rule violations” at intersections leading to an increase in safety risks [15]. Additionally, there are two vulnerable populations when it comes to pedestrian crashes; the young (ages 18 and under) and the elderly (ages 65+). Pedestrians in these two groups alone account for over 26% of traffic crash fatalities [16]. Children are especially vulnerable because they are often “exposed to traffic conditions that exceed their developmental and sensory abilities and their parents often overestimate their abilities” [17]. A recent study reported that one of the top reasons parents do not let their children walk to school is concerns about traffic [17]. The evidence shows that walking can be dangerous forms of transportation, as the user is more vulnerable than someone traveling in a motor vehicle. The question then becomes, what factors make the environment more dangerous for pedestrians?

About one-third of fatal collisions with pedestrians are the result of pedestrians disobeying intersection traffic control or making dangerous judgments in attempting to cross a street**.** Collisions with pedestrians occur far more often with turning vehicles than with straight-through traffic. Left-turning vehicles are more often involved in pedestrian accidents than right-turning vehicles, partly because drivers are not able to see pedestrians to the left as well [13]. Pedestrians involved in crashes are more likely to be killed as vehicle speed increases. The fatality rate for a pedestrian hit by a car at 20 mph is five per- cent. The fatality rate rises to 80 percent when vehicle speed is increased to 40 mph [13].

U.S. national statistics of FHWA has shown that about 79% of total fatalities occurred in non-intersection points and 21% at intersections, where about half of all injury crashes occurred at intersections in 2007. Among the intersection fatalities 39% occurred in rural intersections and 61% in urban intersections. On average a pedestrian is killed in a traffic crash every 111 minutes in U.S. [12].

The highest road traffic death rates are still in the African Region. The African Region have the highest proportion of pedestrian and cyclist deaths at 43% of all road traffic deaths [50].

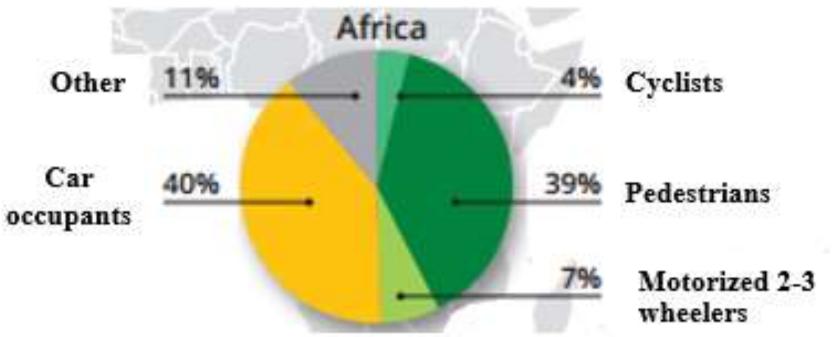


Figure 2.2: Road traffic fatality rates by type of Road user [50].

Pedestrian crashes in Ethiopia is also very serious. The figure of pedestrian fatalities rises in built-up areas. For example in the city of Addis Ababa, pedestrian fatalities are about 90 per cent of the total road accident fatalities in the city [7]. In some other literatures, pedestrian injury crashes represent nearly 85% of the total injury crashes in Addis Ababa [47, 48]. Another study shows that pedestrian injuries at intersections are more severe than midblock crashes in Addis Ababa [49].

2.3 Factors Influencing Pedestrian Crashes

A problem with much of the research on pedestrian safety is the lack of an index of exposure. That is, there is no control for the amount of pedestrian and vehicle traffic. For example, some age groups may have more crashes because there are more of them walking in locations with high levels of vehicle traffic. A "dangerous" intersection may have a high collision frequency because there are large numbers of pedestrians and vehicles there [23].

According to [9], factors affecting crashes, including bicycle and pedestrian crashes, can generally be classified into two broad categories:

1. Social and behavioral characteristics of the individuals involved in a crash;
2. Environmental/urban form characteristics of the setting (e.g., road design, traffic speed, volume and mode share, physical and land use characteristics, etc.).

In this study, the primarily focus will be on some of the second group of factors related to pedestrian crashes.

2.3.1 Impact of Design and Built Environment

Detailed data are required to assess the characteristics of the built environment that contribute to or prevent pedestrian collisions. A review of the existing literature suggests certain elements (e.g., crosswalks), which have been previously studied and provided a direction about what data should be collected for the analysis.

In 2006, the Federal Highway Administration **(**FHWA**)** released a publication entitled "Pedestrian and Bicyclist Intersection Safety Indices" to help transportation engineers and planners develop safety indices for ranking intersection and street approaches [11]. The FHWA divided the variables into two groups: pedestrian site variables and bicycle study site variables [11]. The variables are listed below:

Federal Highway Administration (FHWA) List of Pedestrian Study Site Variables [11]

- Traffic control (presence and type)
- Traffic speed
- Traffic volumes
- Number of intersection legs
- One way or two way
- Number of lanes
- Crossing width
- Pedestrian signals (presence and type)
- Pedestrian-related signs
- Right-turn curb radii
- On-street parking
- Right turn on red allowance
- Street lighting
- Surrounding development type

- Crosswalks (presence and type)
- Median islands (presence and type)

Another study conducted by [10] analyzed pedestrian crash risk at 81 intersections in Alameda County, California. Over 30 variables were considered for developing a statistical model. The statistically significant variables are listed in Table 2.1. The final pedestrian crash model found the presence of a median, number of right-turn-only lanes, number of non-residential driveways, and number of commercial properties to affect pedestrian safety.

Table 2.1: Variables Affecting Pedestrian Safety Identified by [10]

• Type of traffic control	• Curbs radius
• Crossing distance	• Number left/right only lanes
• Median	• Right turn islands
• Number of travel lanes	• Surrounding land use types
• Number of non-residence driveways	• Number of bus stops

Other literatures have shown that a number of key characteristics play a significant role in increasing the risk a pedestrian or cyclist faces at any given intersection. They include:

- Traffic volume [18-21]
- Land-use mix [18, 21, 22]
- Dedicated right turn lanes [21]
- Presence of non-residential driveways within 50 feet of an intersection [21]
- Percent of residents under age 18 living within a ¼ mile of the intersection [21]
- Intersection width and number of through lanes [20] and
- Signal cycle time [20]

Although research has shown that there are specific components that can make some intersections more dangerous than others, a majority of cities and regions are still using a simplistic pedestrian infrastructure approach to improving pedestrian safety, rather than addressing intersection characteristics more holistically. For example the United Kingdom Department of Transport recently created a management strategy to help minimize pedestrian risks, it includes: reducing traffic speeds and volumes; providing intersection treatments, traffic management, and hazard site treatments; improving carriageways (sidewalks); and converting footpaths to shared-use cycle paths [20]. Of these strategies, only traffic volumes have been shown to significantly impact pedestrian safety. This business-as-usual approach to planning may have long term consequences when it comes to the safety of active mode users.

2.4 Method of Analysis to Identify and Rank Intersections

Identification of locations for safety improvement is the starting point of all the processes. The process is sometimes known as black spot identification or hazardous identification location. Generally black spot are termed to define the location where many accidents have occurred and risk (severe, major, and minor) is involved in that accident.

There are different and several ways to analyze, identify and rank high risk and hazardous locations such as roadway segments and intersections. The criteria to select high risk road locations, for individual sites, three causality accidents should be occurring in any one year period or three should occur in a three year period, four in a four year period and so on. Severity index, accident weighted points etc methods are also used to determine high risk road locations. In traditional identification of high risk road locations, methodologies are developed based on the total number of accidents that occurred in a particular location.

As noted by [35] crash frequency and severity are commonly used to measure safety performance. Many studies, for example [43] has used data like accidents frequency, average daily traffic, segment length, and accidents severity to classify hazardious road locations. Then, the locations were classified individually in three categories: frequency, accident rate, and severity. The studies like [43] assigned a weight 400 to a fatality, 60 to a major injury, 4 to a minor injury and 1 to property damage only to calculate a severity level. The frequencies of the categories by intersections or segments were sorted individually in descending order and the values were added in other to determine the final ranking. Other study used all injury, incapacitating injury and fatal crashes to evaluate the effectiveness of roundabout conversions [36].

A crash prediction model will typically use crash frequency as the dependent variable [31, 32]. In many literatures numerous “refined” measures of intersection safety performance have been used, including the deviation from an average or expected number of crashes [35]; accident or crash rates [30, 33], conflict rates [37, 38], and the number of “primary” and “secondary” conflicts [34].

Most of the studies are based on two methods of assessment (i.e. statistical modeling and micro-simulation) and used either accident or conflict data as the main element of the research. Some studies discussed several methods that were used to analyze accidents in segments and intersections [39]. For example, the method of accident frequency summarizes the number of accidents by location. This is a simple method because additional information is not required, but has the disadvantage that does not consider the level of exposure and severity. It can be applied initially in order to obtain an initial screening of the data follow by other type of analysis.

The method of accidents rate at intersections is function of the quantity of accidents and the average daily traffic volume that enters to an intersection (crash rate). The crash rate is defined as the ratio of the total number of crashes occurring during a given study period to the total number of vehicles entering the intersection during that period. For example, to determine the rate per each million entering vehicles (RMEV) when analyzing intersections, the following formula is used:

$$RMEV = \frac{A \times 1{,}000{,}000}{V} \qquad \text{(1)}$$

Where:

A = total number of accidents per year in the studied place

V = average yearly traffic entering at intersection (AVEI x 365 = (ADT1 + ADT2) x 365)

ADT1 = ADT in major street and ADT2 = ADT in minor street.

This method gives priority to locations with high frequency of accidents in relation to volume; nevertheless it tends to give priority to locations with few accidents and low volume. The combination of different methods of accidents analysis decreases their deficiencies. For example, the rate-frequency method is a combination of the accidents rate method and the frequency method. The steps include a frequency ranking to identify the intersections with higher frequency followed by a ranking of accident rate. The results of combining these methods reduce their deficiencies; however the severity of accidents is not being considered.

The accidents severity method uses monetary losses according to the severity level implied by the crash event. It assigns weights to the different accidents categories classified as fatality, injury and property damage only. This method helps to identify places with serious accidents and fatalities; nevertheless, places with a single fatality have more weight than places with many property damage only accidents.

Some studies stated that severity is used because it is more important to find countermeasures at sites with serious accidents than at sites with not so serious accidents [54]. The above literature stated that first the relevance of the severity value has to be checked. Is it based on few or many accidents? The relevance is greater, of course, if the severity is based on many accidents.

The severity value for road section number:

$$S_j = I_{f,j} \times 9 + I_{b,j} \times 3 + I_{d,j} \times 1 \quad \text{.......... (2)}$$

or more clearly:

Severity = number of fatalities (f)*9 + number of injured persons (b)*3 + number of damaged vehicles (d)*1

This value can be divided by a suitable value. One such value could be the number of accidents. The relevant severity value is then:

$$Q_j = S_j / A_j \quad \text{.......... (3)}$$

which means severity per accident. The average value is estimated with:

$$Q_{ave} = \frac{\sum_{i=1}^{n} S_i}{\sum_{i=1}^{n} A_i} \quad \text{.......... (4)}$$

And the variance σ^2 is estimated with:

$$\hat{\sigma}^2 = \frac{1}{n-1}\sum_{i=1}^{n} (Q_i - Q_{ave})^2. \quad \text{.......... (5)}$$

The road section is considered to be a black spot, from the severity point of view, if:

$$Q_j > Q_c \quad \text{.......... (6)}$$

where the critical value

$$Qc = Q_{ave} + k_\alpha \sqrt{\hat{\sigma}^2} - 0.5 \quad \text{.......... (7)}$$

k_α is a constant that is chosen for the significance test. It is determined from a normal distribution and selected to give a certain significance level α:

$\alpha = 0,1\%$ gives $k_\alpha = 2.576$

$\alpha = 5\%$ gives $k_\alpha = 1.645$

$\alpha = 10\%$ gives $k_\alpha = 1.282$

If damage only accidents are not collected, severity per accident can still be calculated. The weighting factors 9 for a fatal accident and 3 for a injury accident do not have to be changed.

Besides the above methods, the other method that can be used for the identification of hazardous locations is priority value which is used in Belgium. In Flanders (Belgium), 'dangerous' accident sites or so-called 'black spots' are selected by means of historic accident records. More specifically, each site where in these three years 3 or more injury accidents have occurred, is selected. Then, a combination of weighing values, respectively 1 for each light injury, 3 for each serious injury and 5 for each deadly injury (1:3:5) is used to calculate the priority score for each accident location. Finally, a location is considered to be dangerous when its priority value (P), calculated using the following formula, equals 15 or more [66].

$$P = X + 3*Y + 5*Z$$

Where X = total number of light injuries (minor injury)

Y = total number of serious injuries

Z = total number of deadly injuries (Fatal)

This could be the simplest and clear method to rank a given location and can be used if the three parameters are available.

2.5 Statistical Analysis of Pedestrian Crash

The purpose of statistical model analysis is to identify how specific roadway intersection characteristics are associated with pedestrian crashes. There are many different techniques and methods that can be employed to analyze accident data of a roadway. Traffic crash analysis at intersections is a count data analysis. Crash numbers are nonnegative in nature and the assigned crash frequencies are nonnegative integers, thus, using a count data modeling technique will be the most appropriate.

Some studies like [46] categorized the techniques and methods in to two categories: traditional descriptive analysis and predictive analysis. A traditional descriptive analysis focuses on summarizing, quantifying, and analyzing historical crash data. Methods involved in traditional analysis include before and after studies, crash rate, crash frequency, and equivalent property damage only (PDO) analysis. These methods can be useful in identifying and prioritizing sites that are in need of safety improvements and evaluating safety effectiveness; however, these methods generally neglect to take into consideration regression to the mean (RTM) bias.

Predictive analysis methods include crash modification factors (CMFs), crash reduction factors (CRFs), safety performance functions (SPFs), ordinary least square regression and Poisson estimations, negative binomial (NB) models, Empirical Bayesian (EB) methods, and hierarchical Bayesian methods [46].

A number of statistical approaches, including Poisson regression, negative binomial, zero-inflated Poisson regression, and zero-inflated negative binomial have been used to model count data in many studies [42, 66, 67].

The Poisson regression model constraints the variance and mean to be equal but since accidents are discrete random events, over dispersion is usually a common occurrence. Over dispersion is the condition where greater variability exists between the observed response and predicted value in a dataset than predicted by a statistical model. If over dispersion is present in a dataset, the estimated standard errors and test statistics overall goodness-of-fit will be distorted and adjustments should be made [42, 55] .

The negative binomial (NB) model overcomes the 'mean equal to variance' assumption of the Poisson regression model. Therefore, the negative binomial (NB) model is generally preferable since overdispersion is often present in motor vehicle crash count data [42, 55, 66].

2.6 Countermeasures to Improve Pedestrian Safety

There exists a long and growing list of pedestrian fatality and injury countermeasures. This section will show some major examples of proven and emerging practices.

A study published in the *American Journal of Public Health* found that one of the general engineering principles for better protecting pedestrians involves separation of pedestrians from vehicles through space and time [24]. Countermeasures that separate pedestrians from vehicles, through space or time, or provide other engineering/traffic control safety benefits to pedestrians.

Engineering countermeasures for pedestrians can be classified into broad categories; separation of pedestrians from vehicles through space or time, reducing or eliminating concurrent movements of vehicles and people, reducing crossing distances, increasing the visibility of pedestrians including through better lighting, alerting drivers to the location of crosswalks and reducing vehicle speeds. If a countermeasure can address one of these key areas it will have good chance of playing a positive role in pedestrian safety [23]. At the same time, other measures also exist to support pedestrian safety and these can perform this role in many different ways. One example is through the use of measures that provide good access to safe crossings like the simple use of curb cuts and tactile markings for people who use wheelchairs and people who are visually impaired [Ibid.].

2.6.1 Crosswalk Design

Crosswalk design is a critical component of pedestrian safety. One of the primary goals of crosswalk design is to provide safe places for pedestrians to cross while enabling drivers and pedestrians to make safer decisions while minimizing the likelihood of a crash. Crosswalks are also used by forward-thinking jurisdictions to signal greater priority to pedestrian travel.

The definition of crosswalk generally includes both marked and unmarked crosswalks. Unmarked crosswalks exist at most intersections and drivers must yield to pedestrians in these locations [25]. However, some studies stated that despite the legislative provision that crosswalks exist at every intersection, there are areas where additional devices and markings will improve the safety of the crossing by both drawing driver attention to the crosswalk, reducing vehicle speeds, distances that pedestrians must cross, number of lanes they must cross as well as other features that improve safety and encourage pedestrians to cross at a preferred location [23].

The design of a crosswalk should consider all possible users and take an inclusionary approach. Curb cuts make crosswalks accessible to pedestrians using wheelchairs, scooters, strollers and other walking devices. Furthermore, the alignment of curb cuts with crosswalks enables the pedestrian to face the crosswalk, which is an important signal to approaching drivers [Ibid.].

2.6.2 Intersection Channelization

Intersection channelization is the use of raised islands located in an intersection to obstruct specific traffic movements and physically direct traffic through an intersection. A literature stated that intersection channelization can improve pedestrian crossing safety by reducing crossing distances and providing refuge areas. As a result, it may reduce vehicle pedestrian conflict [23].

2.6.3 Raised Median

A raised median through an intersection, is an elevated median located on the centerline of a two-way roadway through an intersection. The purpose of a raised median through an intersection is to obstruct motor vehicle short-cutting and reduce the crossing distance for pedestrians. It can create a refuge for pedestrians, enabling them to cross one direction of travel at a time, thereby reducing waiting times for gaps when crossing the roadway.

2.6.4 Sidewalk Design

As defined by the Geometric Design Guide for Canadian Roads, a sidewalk is “a travelled way intended for pedestrian use, following an alignment generally parallel to that of the adjacent roadway” [29]. Sidewalks provide pedestrians with a means of travelling within the public right-of-way but separate from vehicles on the road. Research has shown that separating pedestrians from the roadway reduces pedestrian trauma from motor vehicles. Generally, the further that sidewalks are separated from the roadway the better the safety benefits for pedestrians. The US DoT, in their Toolbox of Countermeasures, for pedestrian crashes, has recognized the safety benefits of sidewalks and concluded they provide an 88 percent reduction in pedestrian collisions [26]. A US cross-sectional study of urban streets with and without sidewalks found that pedestrian collisions were more than two times as likely to occur at locations without sidewalks based on equal exposure [28].

Figure 2.3: Separated Sidewalk [23]

The width of a sidewalk depends on the volume and type of road users. Since pedestrians may desire opportunities to pass stopped or slower moving pedestrians and sometimes walk in pairs, it is desirable to have a clear sidewalk width of 1.8 m; however 1.5 m is the minimum design width. Each additional lane of pedestrian travel requires a minimum of approximately 0.7 m of clear sidewalk width [29]. This width is free from any obstructions such as lighting poles, fire hydrants, traffic signs, etc.

In commercial areas where there is a higher volume of pedestrians, sidewalk widths are usually 2.4m. At bus stops, there should be sufficient space to accommodate waiting passengers and also those pedestrians wanting to walk past. This is typically 3.0 m of width [Ibid.]. A special consideration should be given to areas where there are hospitals and assisted care homes, as persons who use wheelchairs need a wider sidewalk. Persons who use wheelchairs need about 1.2 m of clear sidewalk width for unimpeded travel; therefore, typically 2.0 m is used for the full sidewalk width [Ibid.].

2.6.5 Roundabouts

A roundabout is an effective intersection design that involves traffic flowing in a counterclockwise circle around a centre island. Although an old idea, modern roundabouts have been re-gaining their popularity since the 1990s due to their immense safety benefits, the marvelous quality of reduced speeds that this design brings about and their ability to control traffic flows without the use of traffic signals and concomitant reductions in greenhouse gas emissions. Roundabouts significantly reduce road user injuries due to the slower speeds and the lesser conflict points outlined in Figure 2.4. Roundabouts reduce vehicle-pedestrian conflict points from 24 to 8. With such a decrease in possible conflict points, and the average maximum speed in a roundabout much less, they have proven to greatly decrease the severity and likelihood of an injury collision [23].

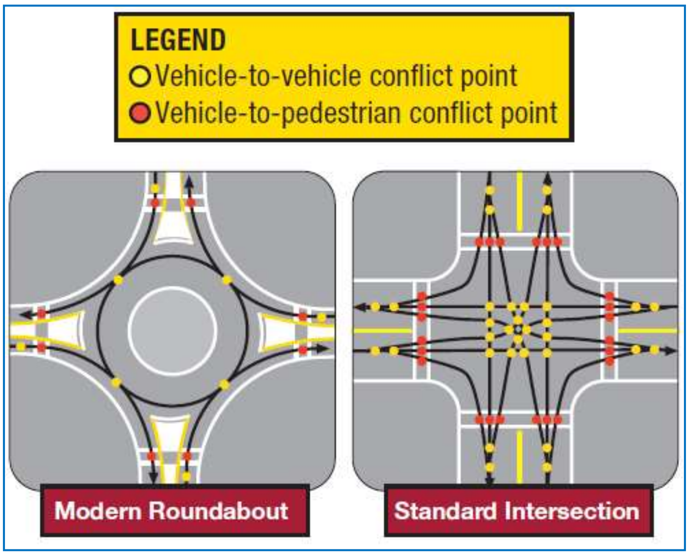


Figure 2.4: Vehicle-vehicle and vehicle-pedestrian conflict points [Ibid.]

There are three reasons why pedestrians are safer at roundabouts: Pedestrian crossing distances are often shorter because extra lanes are not needed on an approach, and where splitter islands are present the crossing is done in two-stages; pedestrians only have to look in one direction for oncoming traffic; lower vehicle speeds -roundabouts are designed to reduce vehicle speeds by up to 85 percent, thus there is more time to make eye contact with a motorist and avoid a crash, and if a crash does occur it will be less severe [23]. Well-designed roundabouts that take into account pedestrian safety consider factors such as the roundabout's cross-distance (typically the more compact the better in order to reduce speeds), the need for the fewest number of lanes, measures that make navigating the roundabout as simple as possible for drivers as well as pedestrians, additional speed reduction measures if necessary and the use of pedestrian crossing features such as use of a median, good lighting and many other general crosswalk features [23].

2.6.6 Protected Left-Turn Phasing

According to [23] some jurisdictions in Canada have increased the number of intersections with protected left-turn phasing and those where drivers are prohibited from turning right on a red light. This is because most intersections make it difficult for drivers to make safe turning choices. To reduce the potential for conflicts, protected left-turn phases can be included into a signal sequences. In this scenario, the pedestrian is held at the curb by a "Do Not Walk" phase and through traffic is held by a red light. The driver is able to make a turn without conflicting with pedestrians.

Figure 2.5: Protected Left-Turn Phasing [23]

2.6.7 Pedestrian Overpasses and Underpasses

In some situations, it may be clear that a traditional crosswalk is not an option because the roadway to be crossed is unsafe. It may be because of higher speeds or it may be that many people cross at a particular location that is unsafe for any number of different reasons. Underpasses or overpasses are commonly used where there are high volumes of traffic at high speeds and where pedestrians would be especially vulnerable. Common locations include near schools, universities, parks, shopping areas, recreation facilities, multi-use paths, or any long stretch of higher speed road without alternate locations for pedestrians to cross. Moreover, to be most effective these overpasses (or underpasses) should be accessible so ramps or even an elevator may need to be included in the design. In addition, underpasses should be well lit at night and consider what can be done to prevent other types of safety issues from arising such as crimes involving assault. Also, if crossings appear to be an inconvenience they will be not be used [26]. A Japanese study of 31 overpasses in urban areas found that the number of pedestrian collisions decreased 91 percent within 100 meters of an overpass [27].

Figure 2.6: Pedestrian Overpass [23]

2.6.8 Parking Restrictions and Bus Stop Placement

In many cases, pedestrian trauma occurs because there are parked vehicles obstructing drivers' views as they approach an intersection or marked crosswalk. Parked vehicles also hinder a pedestrian's ability to see oncoming traffic from the safety of the curb. To reduce the potential for collisions, parking has to be prohibited near intersections and crosswalks and moved bus stops from these same locations [23]. Ideally, fencing is in place to deter people from crossing near the bus stop location and instead guides them to the safest crossing location.

2.6.9 Other Potential Countermeasures

As stated by [23], the following Countermeasures can also be used to improve pedestrian safety:

Signs and Signals:

- At intersections install signs warning drivers to watch for pedestrians and signs to prompt pedestrians to watch for turning vehicles.
- At intersections install signs indicating "YIELD TO PEDESTRIANS" or "STOP HERE FOR PEDESTRIANS".
- Place placards at signalized crosswalks with instructions on how to use pedestrian-activated signals and the meaning of pedestrian signal indications where there are frequent pedestrian violations.

- Introduce innovative applications such as the "HAWK" pedestrian signals and voice messages indicating when it is safe to cross. Install count-down pedestrian signals.
- Use Rectangular Rapid Flash Beacons particularly in multi-lane crosswalks.

Pavement Markings:

- Install advance stop bar markings at least 15 meters in advance intersections.
- Install markings warning pedestrians of turning vehicles.
- Install within-pavement flashing lights at appropriate locations.
- Limit the use of markings for crosswalks to roads with an ADT of less than 12,000 vehicles.
- Maintain crosswalk markings to ensure high visibility.

Volume control measures:

- Direction closure; diverter, full closure, intersection channelization, raised median through an intersection, right-in /right-out island.

2.7 Literature Review Summary

The literatures reviewed have helped in understanding problems of pedestrian safety at intersections. There are different methods to sustain the safety of roads users. Among all the methods, one of them is the identification of hazardous locations i.e. sections of the road with the highest concentration of traffic crashes.

There are different approaches for identification the method to be used depending on different factors. Some of these are availability of data for the analysis, which is to mean the way they are recorded and manuals developed with standards or specifications with guidelines. The methods are explained and some of the criteria's used by different authors are cited. First and for all there is no integrated crash, road and traffic data in Ethiopia (specifically in Dire Dawa). Because of this, it cannot be used more sophisticated methods for high-risk intersection identification. Therefore, Flemish government analysis method is used to rank and identify intersections which are vulnerable for pedestrian in the study area by computing priority value.

Studies which dealt with roadway characteristics and intersection design have helped to understand and possibly look for more variables related to the design of the intersections which could explain pedestrian crashes. The different factors which can be used in the analyze pedestrian crash such as traffic volumes, intersection characteristics and other built environment have been studied and this has helped in deciding on what data needed to be collected as part of the different variables to be used in the analysis of pedestrian crashes in Dire Dawa city.

Different methods used by different researchers have been looked at to investigate the association between intersection characteristics and pedestrian crashes, which gave an idea on the advantages and disadvantages of specific analysis methods. It was seen that a majority of researchers preferred the use of a negative binomial regression model for statistical analysis because of its advantages over a Poisson regression. Both, Poisson regression and negative binomial regression though best suited for count data, the assumption that the mean and variance are equal in a Poisson regression could lead to bias and underestimation of coefficients. This could be eliminated with the use of a negative binomial regression. Finally, the literature review have also helped to understand the different countermeasures that can be used in reducing pedestrian crashes.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study Area

Dire Dawa city is one of the largest cities in the eastern parts of Ethiopia located in the Eastern part of the country within the General boundaries of $9^0$20' north, latitude and $42^0$09' east, longitudes. It is bordered by the shinile zone of the Somali National Regional State on the Northwest and Northeast, and by the Eastern Harargie zone of the Oromia Regional State on the South, Southeast, and East. The city is located 515 km away from Addis Ababa in the eastern parts of Ethiopia, on the Dechatu River, at the foot of a ring of cliffs that has been described as "somewhat like a cluster of tea-leaves in the bottom of a slop-basin." [8, 51].

Dire Dawa was founded in 1902 by French railway contractors after the Addis Ababa Railway reached the area. This led to Dire Dawa becoming an important centre of trade between the port of Djibouti and the capital city, Addis Ababa. Based on the (2008 G.E) census conducted by the central statistical agency of Ethiopia (CSA) Dire Dawa has a total population of 453,000.From this 49% are female and 51% are male [51]. The city has many industrial and market center. It seems due to this reasons that there is a high inflow of vehicle, which coupled with fast population growth rate that exaggerated the problem of road traffic accident in the city [8].

The total road network of Dire Dawa is 357.75 Km which is covered with different type of road surfaces. Of the total networks, 14.94km is primary road, 22.41km is secondary road, 76.02 km is collector road and 76.02 is local road. Again the road network is covered with different types of materials. 13.38% is Asphalt 47.85Km, 22.45% is Coble Stone, 12.13% is Gravel, 49.45% Compacted Earth, 2.59% is Large Block Stone [51].

Amazingly, the road network with pedestrian walkways (sidewalk) is 49.18Km. From the total walkways, 19.2Km is Asphalt, 28.07Km is Coble Stone and 2.14 is Clay Tile [51].

Figure 3.1: Location of Study Area (Google maps, 2017)

3.2 Study period

The study period of this research was conducted from March 2017 to May 2018.

3.3 Study design

The research study was conducted by using analytical methods. Qualitative and quantitative studies were employed in this study area. Quantitative study was used to describe the numerical aspects of the research findings. Qualitative study was used for qualitative evaluations of the characteristics of the high-risk intersections.This include an evaluation of the relationship between accident frequency and intersection characteristics and built environment measures.

The physical parameters used to characterize the intersections were pedestrian volume in pedestrian per hour, vehicular volume in vehicle per hour, the number of lanes of approaching street and the existence of raised medians. There are also other parameters used in describing intersections related with pedestrian facility like presence of crosswalk and sidewalk. The collected characteristics of intersections and pedestrian crash analysis have been used to characterize the identified high risk intersections and to recommend the appropriate treatments to improve the pedestrian safety.

3.4 Population

The research assesses characteristics of high risk intersections in an attempt to mitigate pedestrian crashes in Dire Dawa city. Thus, the population under investigation in this study were the intersections that are found in in Dire Dawa city.

3.5 Sample size

The sample size calculations rely on three variables [63, 64]:

- **Coefficient of variation (Cv.):-** a relative measure of variability, defined as the standard deviation divided by the mean. The c.v. can be estimated if raw data is available but mimimum value (0.1) is used in this research.
- **Z-statistic (Z):-** a function of the desired confidence level (e.g., 99 percent confidence level) for the sample mean. In this research, 99 percent confidence level is used (i.e z value of 2.575).
- **Relative permitted error (d)**:- is expressed as a percentage of the sample mean, and is typically based upon the use of the data. The most commonly used error levels are between 5 and 10 percent, but 5 percent is used in this paper.

Therefore, the sample size is calculated based on the following formula [64]:

$$n = \frac{(z)^2 \times (Cv)^2}{d^2}$$

Where n = number of sample size

Cv = relative measure of variability = 0.1 low variance

d = acceptable margin of error for proportion (desired precision rate), usually

d = acceptable margin of error for proportion (desired precision rate) = 0.05 is used

z = 2.575, which means a 99% confidence interval

$$n = \frac{(2.575)^2 * (0.1)^2}{(0.05)^2} = 26.52 = 27$$

3.6 Sampling Procedure

The selection of samples for high risk location analysis was based on a probability sampling (i.e. Convenience sampling) technique. This sampling technique is widely used in developing countries where accurate data is available in specific locations [64]. Again, convenience sampling is advantageous in terms of saving time and cost, and its applicability to a large road network population. For Flemish government analysis method, the intersections which have three or more injury accidents in the last three years should be selected. Hence, 24 intersections are selected and used for the identification high risk junctions.

Three additional intersections were selected by simple random sampling (lottery method) for statistical analysis based on the sample size (n = 27) computed in the previous section. Therefore, 27 intersections were used for the purpose of statistical analysis.

3.7 Study variables

Dependent variable: The dependent variable of this research is the High Risk Intersections for Pedestrians and number of total pedestrian crashes at intersections of Dire Dawa city.
Independent variables: The independent variables for this research are:

- **Roadway and Traffic Variables:** Motorized traffic volume, pedestrian volume, number of lanes, width of road, intersection configuration, presence of raised median on major road, availability of sidewalk, availability of marked crosswalk.
- **Spatial Characteristics:** Presence of schools within 300m radius of intersection, availability of an alcohol bar 300m radius of intersection, availability of an intersection at office and/or commercial areas.

3.8 Software and instruments

The following instruments and software have been used for this study:

- Meter tape, photos taken, MS word, Excel and SPSS to analyze accident data and display research data, has been used in this study.

3.9 Data collection procedure

Quantitative and qualitative data has been utilized based on the necessary input parameters for the analysis. Consequently, the research work consisted the relevant data collection from the primary and secondary sources.

3.9.1 Primary data collection

Primary data collection has consisted of site observation and traffic volume (both vehicles and pedestrians). To get accurate result in traffic count, it is important to count at least for 7 days but due to time constraint the count was done only for four days from September 13-16, 2017 during the two peak hours in the morning (7:30 AM.-9:30 AM) for the identified junctions, in the midday (11:00 AM-1:00 PM), while for some intersections and in the evening (5:00 PM.-7:00 PM) for some other intersections.

3.9.1.1 Field Observation

A field measurement has been done to gather data on the geometrical features of intersection for the description of the intersections. During field measurement, width of traffic lanes, crosswalks, a number of lanes, street side elements, median, land use data and the method of treating has been collected on each approach for the intersections.

The width of traffic lane and median measurement were done manually using tape meter; the same method is used for the intersection. The rest of the data were collected by visual observation. The collected data are used for the analysis performed in chapter four.

3.9.1.2 Vehicle volume

Data related to vehicle volume were obtained directly using manual traffic volume counts. Field survey of traffic data were conducted in four days (Wednesday, Thursday, Friday, Saturday) for two hours at 15 minutes interval. The vehicles have been counted in category as two wheel (Cycle and Motorcycle), three wheel or Bajaj, cars and taxi, 4WD, minibus taxi, Mid-Bus and standard Bus, Light, Medium and Heavy commercial or truck vehicles. The four days average vehicle volume along major and minor roads was combined to estimate the total number of vehicle volume at an intersection. The raw data of traffic volume for each intersection is summarized in Appendix B.

3.9.1.3 Passenger Car Equivalent

A Passenger Car Equivalent is a measure of the impact that a mode of transport has on traffic variables (such as headway, speed, density) compared to a single standard passenger car. This is also known as passenger car unit.

Literatures show that there are many methods to estimate PCE. Among the methods that have been employed in different studies to calculate PCE values, the headway ratio method was selected for this research; this is the most commonly used method for calculating PCE values at intersections. Headway is the time separation of vehicles in the traffic stream and is usually measured in fraction of a second. Headways are measured between successive vehicles; time gap are measured from the rear of one vehicle to the front of the next [61].

PCE by headway ratio method: $\mathrm{PCE} = \frac{h_i}{h_c}$

Where: PCE_i = Passenger Car Equivalent of vehicle type i

h_i = headway of i-th vehicle

h_c = headway of passenger car

The headway method requires measurements of time headway data. Therefore, time headway data was collected at major approach of Shel intersection as this junction has high traffic volume, good mix of different vehicle types and no parking allowed on the intersection major approach. The data was collected for 15 minutes during peak traffic conditions. Data were collected under dry and sunny weather conditions and during the morning. For vehicles in the queue, headways were measured between successive vehicles; time gap were measured from the rear of one vehicle to the front of the next. During headway data collection, there was no sufficient data regarding cycles and motorcycles at the selected intersection. Therefore, the PCE value recommended by some literature have been used [63]. The collected data at Shel Intersection are listed in Table B2 under Appendix B. The following table shows the computed PCE value of each vehicle.

Table 3.1: Computed PCE value of each vehicle

Vehicle Type	Cycle	Motor Cycle	Bajaj	4-WD	Mini Bus	Medium Bus	Std. Bus	Medium Trucks	Large Trucks
PCE	0.3	0.4	1	1	1.25	1.5	2.2	2.3	2.5

3.9.1.4 Pedestrian volume

Pedestrian counts has a vital importance to evaluate sidewalk and crosswalk needs. Pedestrian counts can be taken at intersection crosswalks, midblock crossings, or along sidewalks. The pedestrian counts for this study was taken at intersections' crosswalks and manual count procedure have been used to get pedestrian volume of each intersection. The count is basically done using pen and paper by standing at a side of the sidewalk and counting every pedestrian that passes in each direction.

Between two and four observers have been allocated per intersection depending on a rough estimate of pedestrian activity at each intersection. Observations were made on weekday Wednesday, Thursday and Friday and on one Saturday for each location. These days were assumed to have the most consistent pedestrian travel patterns from week to week. The observation period was the same with vehicle count time.

In this study, pedestrian counting was taken when they crossed the intersection on any of the legs, as long as they crossed at least half of the roadway. Even though pedestrian counts along sidewalk segments have importance in planning and prioritization, this study evaluated intersection characteristics related with pedestrian crashes and safety, so it focused on roadway crossings at intersections. If a single pedestrian crossed multiple legs of the intersection, he or she could be counted multiple times. The counts were taken in 15-minute intervals for the two-hour periods, and the counts for each leg were summed to get a total volume. Table B2 of Appendix B shows the hourly volume of Vehicle and pedestrian at intersections.

3.9.2 Secondary data collection

The secondary data used to achieve the objective of the research was the pedestrian crash data. The pedestrian crash data at intersections were obtained from the Dire Dawa city police commission report for the 3-year period between 20213/14 and 2015/16. This thesis focuses on crashes that occurred at or within 50 m of each intersection. The information recorded regarding pedestrian accident were:

- Time, month and year at which the accident happened
- Location at which the crash happened
- Severity of the crash: Fatal injury, Serious injury and Minor injury

As it can be seen in the figure below, the number of police reported accidents varied significantly during the study period in Dire Dawa. Total numbers of police reported accidents experienced an increasing trend from 2013/14 to 2015/16 while total numbers of pedestrian crashes experienced a decline in 2014/15 and increased in 2015/16. Figure 3.2 below illustrates the trend that the total numbers of accident and total pedestrian accidents followed during the study period in Dire Dawa.

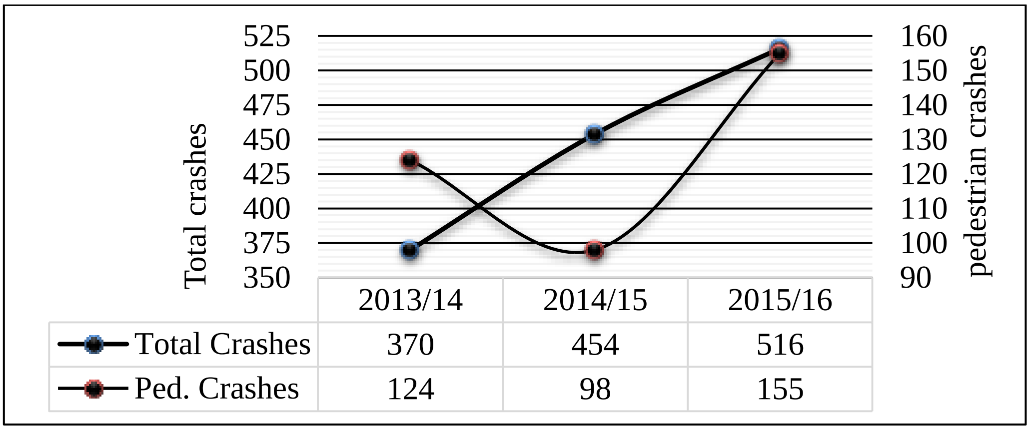


Figure 3.2: Total Traffic Accidents and pedestrian crashes per year in Dire Dawa

In Figure 3.3 below, also indicated the trends of total traffic crashes and total intersection related crashes. In here, the intersection accidents have a decreasing trend during the study period.

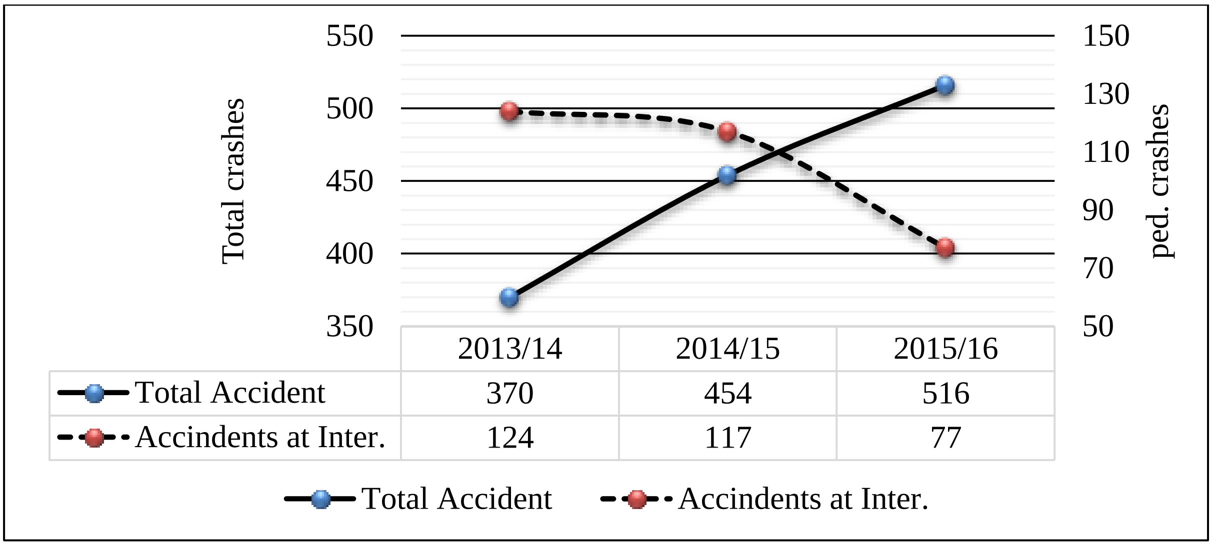


Figure 3.3: Traffic Accidents and intersection crashes at intersections per year in Dire Dawa

In Table 3.2 showed the percentage of pedestrian crashes occurred at intersections in each of study period. Even though the number of pedestrian crashes indicated a decline in 2015/16, the percentage of pedestrian crashes showed an increasing trend with to the total crashes occurred in each year.

Table 3.2: Total Accidents at intersections and intersection-related pedestrian crashes per year in Dire Dawa

Year	**Crashes at Inter.**	**pedestrian Crashes at intersections**	**%age of pedestrian crashes**
2013/14	124	56	**45.16**
2014/15	117	60	**51.28**
2015/16	77	49	**63.64**
Total	**318**	**165**	**51.89**

Pedestrian accident records from September 2013/14 to August 2015/16 have been shown on Appendix A.

3.10 Data processing and analysis

This study was based primarily on pedestrian crash data from Dire Dawa administration police commission. The Pedestrian crash data obtained have been checked and edited manually, then coded and entered into the computer using MS excel and Statistical Package for the Social Sciences (SPSS). The data has been analyzed and presented by graphs and pie charts.

In this research, intersections were ranked according to the Flemish government analysis method. First, each intersection where in the last three years, three or more injury accidents have occurred, have been selected. Then, an intersection was considered to be dangerous when its priority value (P) equals 15 or more. Finally, an intersection was considered to be dangerous when its priority value (P), calculated using the following formula, equals 15 or more [66].

$$P = X + 3*Y + 5*Z$$

Where X = total number of light injuries (minor injury)

Y = total number of serious injuries

Z = total number of deadly injuries (Fatal)

The intersections ranked based on their priority value (P) are presented in chapter 4.

3.10.1 Statistical Regression Analysis

The purpose of statistical model analysis is to identify how specific roadway intersection characteristics are associated with pedestrian crashes. The model identified several key intersection and built environment characteristics related to pedestrian safety.

As crash frequency analysis at intersections is a count data analysis, count data regression analysis approach was generally adopted in the modeling process. It can be observed that crash numbers are nonnegative in nature, and the assigned crash frequencies are nonnegative integers, thus, using a count data modeling technique will be the most appropriate. A number of count data methodologies including Poisson regression, zero-inflated Poisson regression, negative binomial and zero-inflated negative binomial models have been used in many literatures.

Crashes occurring on transport facility locations such as intersections are often approximately Poisson or Negative Binomial (NB) distributed [42], thus requiring the appropriate regression model to relate covariates to crash outcomes. In order to account for the possibility of either underdispersion or overdispersion in the data, a negative binomial (NB) model was often selected and it was analysed by using SPSS. This NB regression model have been used to empirically examine the impacts of geometric, traffic volume (both vehicle and pedestrian) and pedestrian facility-factors on the total number of pedestrian crashes.

3.10.2 Variable Effects in the Analysis

Statistical analysts measure the effect of the independent variable on the dependent variable through the Incidence Rate Ratio (IRR). Therefore, incidence rate ratios (IRR) have been computed to interpret the effect of each significant variable included in the analysis. The IRR represents the change in the dependent variable in terms of a percentage increase or decrease, with the precise percentage determined by the amount the IRR is either above or below 1. If the IRR of an explanatory variable is greater than 1, an increase or factor change in that variable results in an increase in pedestrian crashes at intersections. Conversely, a reduction of pedestrian crashes at intersections corresponds to an IRR that is less than 1.

3.10.3 Software

The data are analyzed using the Statistical Packages for Social Sciences (SPSS) version 25. In addition 0.05 level of significance was used for the model.

3.11 Ethical considerations

In order to attain the purpose of this research work, the community and local officials have been approached politely and addressed through formal letter from the department of Highway engineering, JiT and an official permission have been obtained from Dire Dawa Administration Police Commission Office. The purpose of this study has been explained to the concerned respondents in order to get their permission to give information.

3.12 Data quality assurance

To assure the quality of data, data collection tool which was the checklist used by the police officer during assessment at the scene has been used as a sole source of information. During the data collection procedures, all the collected data have been reviewed and checked for its completeness. In this study, the data has been collected in two ways of data collections from the sources. These are primary source of data collection (the first witness of a fact) and secondary source of data collection (record of an event, books or circumstance). Therefore; the assurance of those data to be highly recognized and those data are true. In order to obtain quality of data, all the system for quality control /assurance of data collection also has to be worked out effectively

CHAPTER FOUR

ANALYSIS, RESULTS AND DISCUSSION

4.1 General Characteristics of Pedestrian Crashes in Dire Dawa City

Road accident records were obtained from Dire Dawa city police commission report for the years 2013/14-2015/16 (2006-2008 E.C). At total of 1340 (excluding PDO) accidents were happened in three years (Table 4.1). From the recorded three year data, there were a total of 377 (51.36%) pedestrians participated in crash.

Table 4.1: Total number of crashes recorded in the study area (2013/14-2015/16).

Accident	**Total crashes per year**			
	2013/14	**2014/15**	**2015/16**	**Total**
Total accidents	370	454	516	**1340**
Total Property Damage only	230	256	248	**734**

Established on the total pedestrian crashes, 54 resulted in fatal crashes, 163 in serious injury crashes and 160 in minor injury crashes as illustrated in Table 4.2 below. On the other hand, it was found out that the occurrence of pedestrian crashes has a fluctuated pattern from year to year as it has been decreased in 2012/13 and 2014/15 as compared to 2011/12 and 2013/14, respectively. But looking at 2015/16 there is an increased both in the number of pedestrian crashes and severity.

Table 4.2: Total number of pedestrian crashes recorded in the study area (2013/14-2015/16).

Year	**Pedestrian Crashes in Dire Dawa Road network**			
	Fatal	**Serious**	**Minor**	**Total**
2013/14	15	53	56	124
2014/15	18	49	31	98
2015/16	21	61	73	155
Total	**54**	**163**	**160**	**377**

When considering the number of crashes at intersections, this three years crash records contain all intersection-related pedestrian accidents reported by traffic police in the administrative city. As table 4.3 shows, 165 pedestrian crashes happened at the intersections which includes 13 fatal, 54 series injury and 98 minor injury accidents. Table 4.3 shows the annual pedestrian crashes at intersection of the city with severity.

Table 4.3: Annual pedestrian crashes at intersection in Dire Dawa

Year	Pedestrian Crash at intersections			
	Fatal	Serious	Minor	Total
2013/14	4	22	30	**56**
2014/15	5	19	36	**60**
2015/16	4	13	32	**49**
Total	**13**	**54**	**98**	**165**

From Table 4.3, it is obvious that, a significant number of pedestrian accidents occurs in Dire Dawa city intersections every year with a large number of resulting casualties. Though percentage of pedestrian accident at intersections showed an increasing trend in 2014/15, it was decreased to 49 in 2015/16.

4.2 Detail Description of Pedestrian Crashes at Intersections in Dire Dawa City

In the next sub-sections, pedestrian crashes occurred at intersections of Dire Dawa were discussed with respect to severity, intersection type, gender, age group, time of the day, day of the week and month of the year.

4.2.1 Pedestrian Crash Severity per year

The following Figure showed the severity of pedestrian crashes (Fatal accident, serious Injury, Minor Injury) of Dire Dawa city for three years. The total number of pedestrian accident was increasing from year to year in type of severity class in Dire Dawa city except the last year (2015/16) in which serious and minor injuries were decreased compared to the previous years. Fig. 4.1 shows pedestrian crash by crash severity.

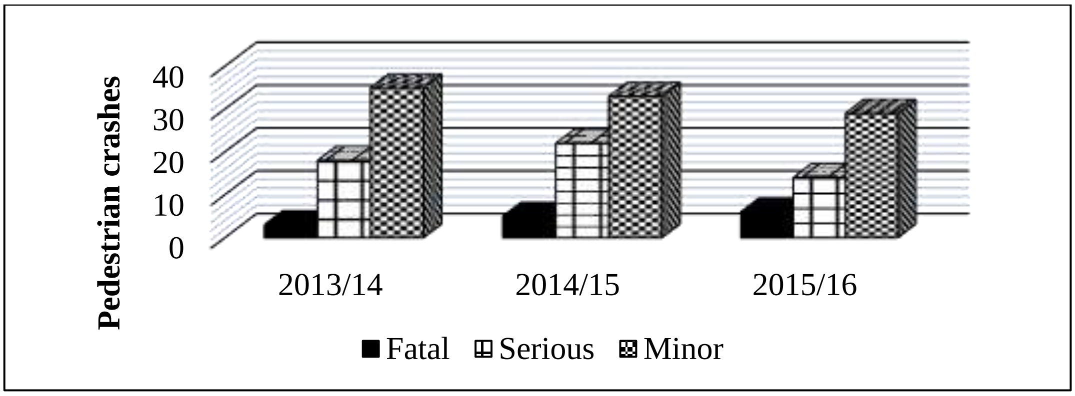
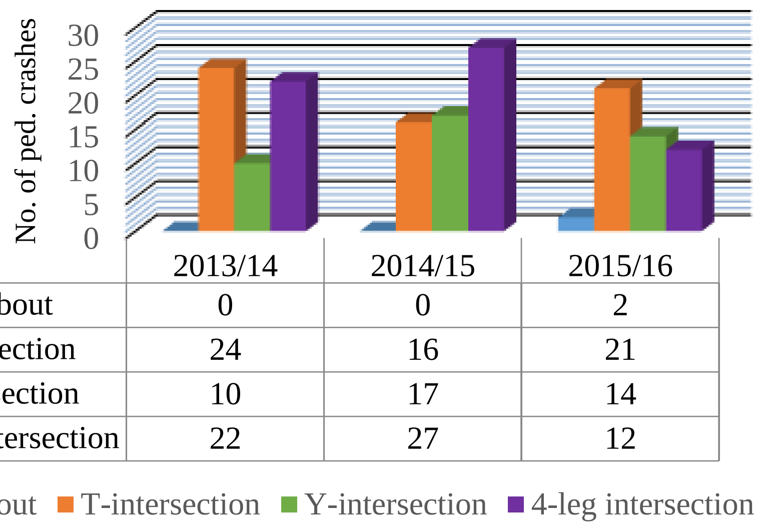


Figure 4.1: Intersection-related Pedestrian Crashes by Severity

4.2.2 Pedestrian Crash By Intersection Type

Figure 4.2 below showed the pedestrian accident distribution within different intersection types. As the table indicates, there was a large number of accidents on T-intersection and 4-leg intersection types. Contrarily, Y-intersections and roundabouts do not have large amounts of accident record. This indicates that, much emphasis must be given at T-junctions and 4-leg intersection to study the causes of the crash and to treat using effective countermeasures.



	2013/14	2014/15	2015/16
Roundabout	0	0	2
T-intersection	24	16	21
Y-intersection	10	17	14
4-leg intersection	22	27	12

Figure 4.2: Pedestrian Crash by Intersection Type

4.2.3 Pedestrian Crash by age group

Figure 4. 3 showed younger people age group of 18-30 years were more likely to be involved in pedestrian crashes than children and adults in Dire Dawa city. The crash for 31-50 age group was highest next to the 18-30 age group.

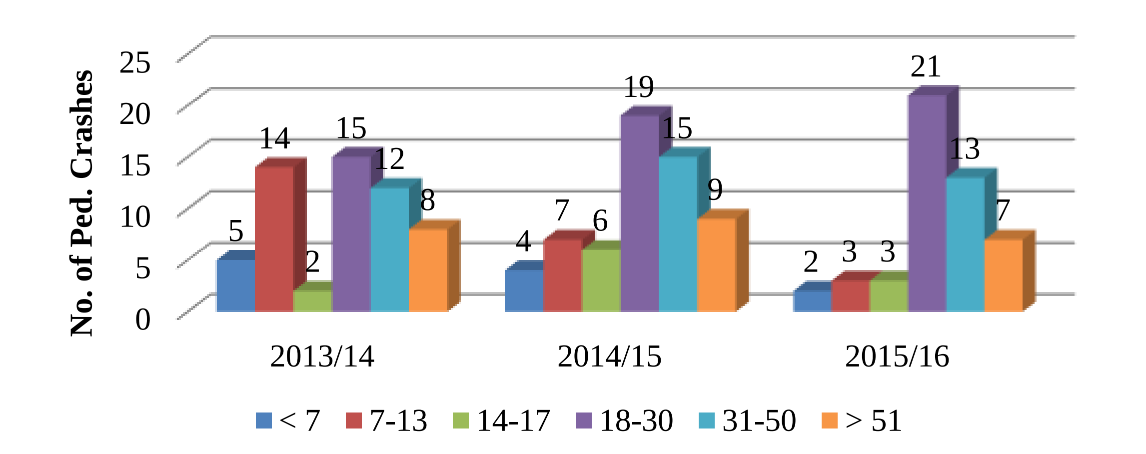


Figure 4.3: pedestrian Crash by Age Group

4.2.4 Pedestrian Crashes by Gender

Males were the dominant participator of crashes involved in the study area having a total of 110(66.67%) crashes (Figure 4.4). Based on the crash severity type on male, there were 10 fatal, 43 serious and 57 minor injuries recorded as illustrated in Table 4.4. The reason behind this is may be that males are the work force of the family and stays out of the house throughout the day, besides also it is the traditional norm in the countryside areas living standard.

Table 4.4 Pedestrian Crashes by gender

Crash Severity	Pedestrian Crashes by gender		
	Male	**Female**	**Total**
Fatal	10	4	**14**
Serious Injury	43	11	**54**
Minor Injury	57	40	**97**
Total	**110**	**55**	**165**

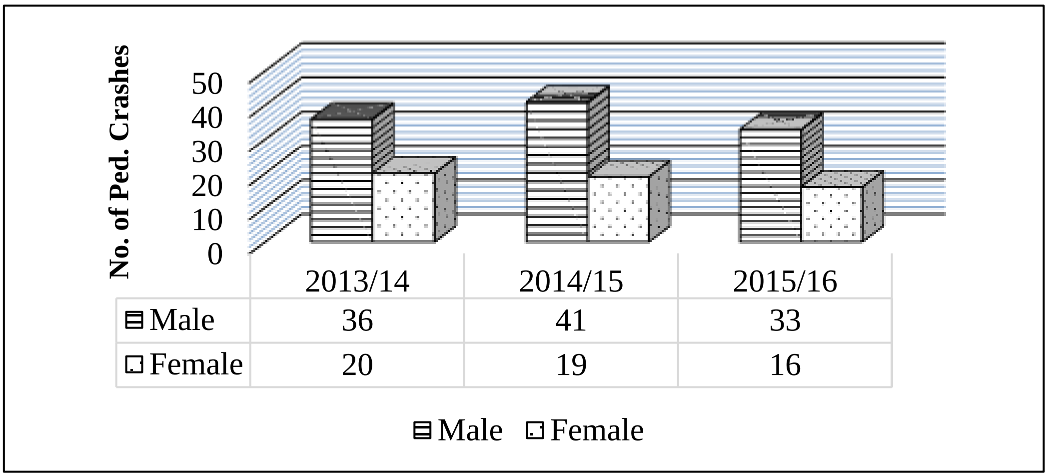


Figure 4.4: Pedestrian Crashes by Gender

4.2.5 Pedestrian Crashes by time the day

The next figure shows, distribution of traffic accident with time difference throughout a day. The chart shows the most critical time for pedestrian accident were happened during day time from 8:00 a.m up to night time 8:00 p.m. with a peak time between 10:00 A.M. and 3:00 P.M.

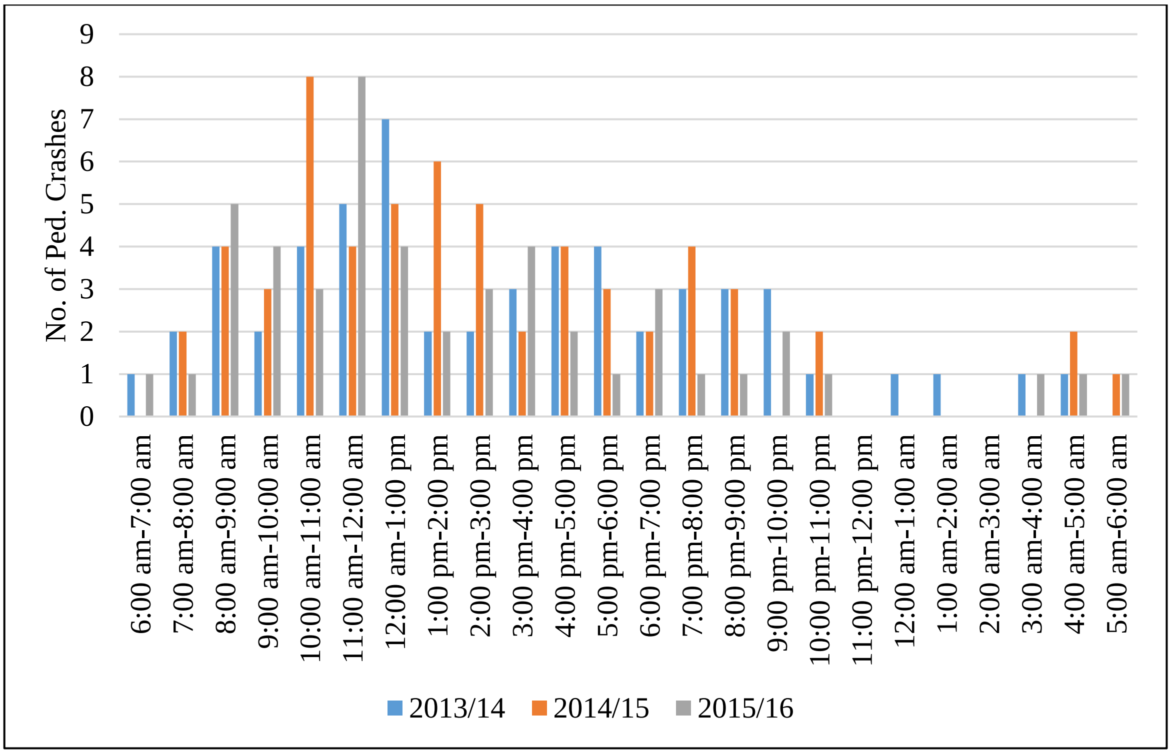


Figure 4.5: pedestrian Crash by Time of the Day

4.2.6 Pedestrian Crashes by day of the weak

Figure 4.6 describes that, there is a slight variation in the occurrence of pedestrian crashes among the days of the week. The following figure depicts the daily variation of accidents showing that there are a greater proportion of pedestrian crash on Wednesday, Thursday and Friday where there are a large number of accidents occurring on Thursday during the study period.

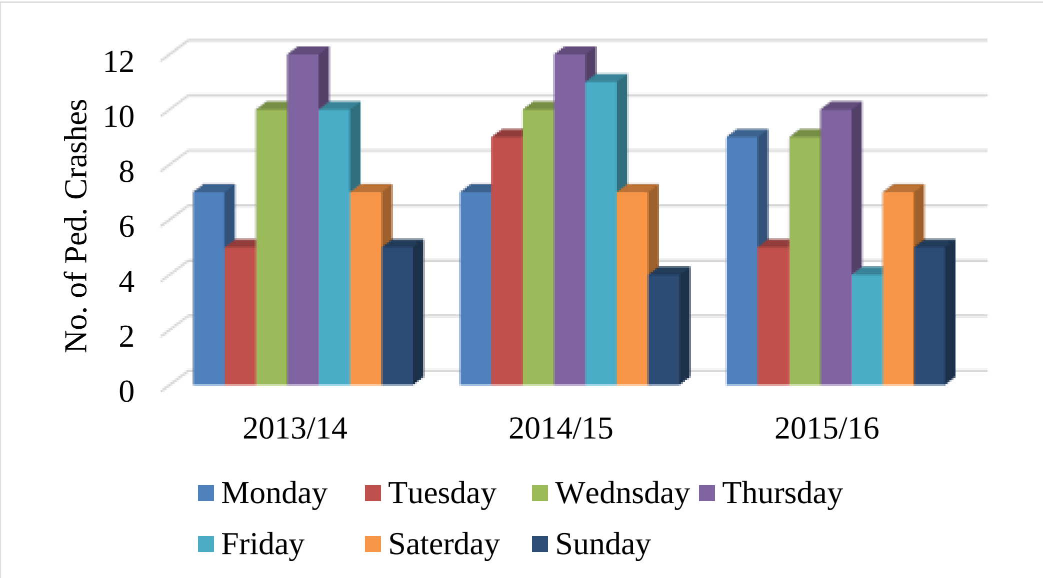


Figure 4.6: Pedestrian Crash by Day of the Week

4.2.7 Pedestrian Crashes by month of the year

The occurrence of pedestrian crashes can vary within the months of a year. The following figure shows that there are a high number of pedestrian accidents on month of September.

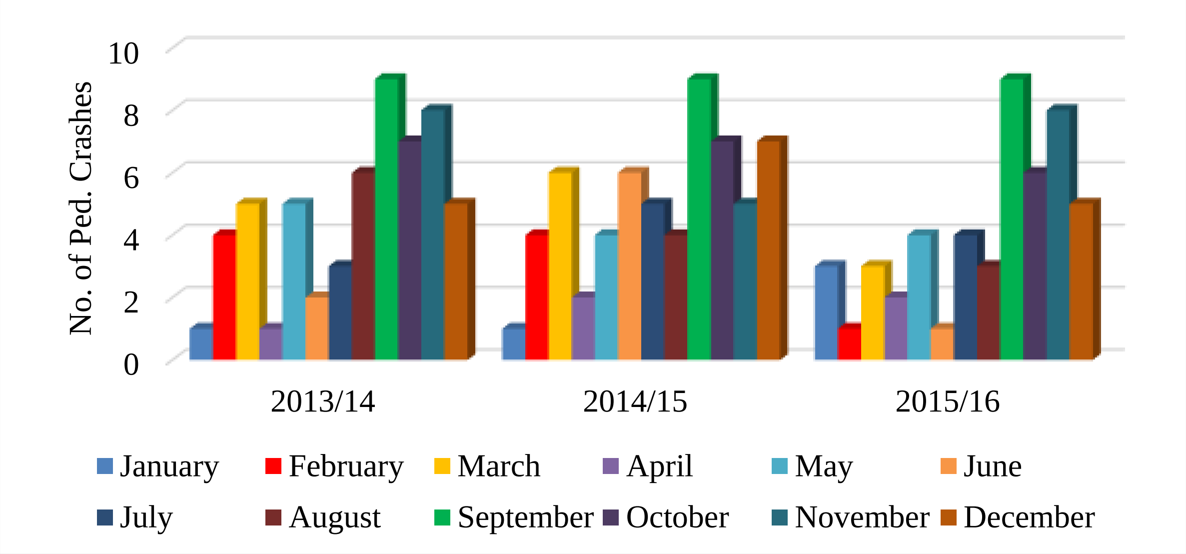


Figure 4.7: Pedestrian Crash by Month of the Year

4.3 Identification of High-Risk Intersections

This section focused on identifying and analyzing intersections with high pedestrian crash frequencies. It provides the analysis and list of pedestrian high crash non-signalized intersections in the Dire Dawa city. Like any other site-specific safety studies, a pedestrian safety study starts with identifying pedestrian high crash locations. The first specific objective of this thesis was to analyze, identify and rank the most dangerous intersections for pedestrians in Dire Dawa city using three years data 2013/14–2015/16 (2006-2008 E.C).

As explained in chapter three, 24 intersections were selected for this study and intersections with priority value of 15 or greater than 15 were identified as high risk intersections. The priority value is determined based on Flemish government’s formula which is

P = X + 3*Y + 5*Z

Where X = total number of light injuries (minor injury)

Y = total number of serious injuries

Z = total number of deadly injuries (Fatal)

It is illustrated in Table 4.5 that the intersections in the study area are listed with respect to priority value. Analyzing Table 4.5 dangerous intersections identified and ranked as a worst intersection in Dire Dawa City in terms of Severity as well as priority value.

Table 4.5: Ranked High-Risk Intersections in DD City

No.	Intersection Name	Intersection Type	Pedestrian Crashes (2013/14 - 2015/16)					
			Fatal (Z)	Serious (Y)	Minor (X)	Total	P	Rank
1	Konel (Bridge)	4-Leg	2	3	4	9	**23**	**1**
2	Seido	4-Leg	1	4	5	10	**22**	**2**
3	Shel	4-Leg	2	2	5	9	**21**	**3**
4	Posta Bet jerba	4-Leg	1	3	5	9	**19**	**4**
5	CBE (Main)	4-Leg	1	3	4	8	**18**	**5**
6	Sabian Madeya	T-Intersection	1	3	3	7	**17**	**6**
7	Taiwan	4-Leg	1	3	2	6	**16**	**7**
8	Meskelegna	4-Leg	1	2	4	7	**15**	**8**
9	Dipo	T-Intersection	1	2	4	7	**15**	**9**
10	MOTB school	Y-intersection	1	1	3	5	11	10
11	Konel (Megala)	4-Leg	0	2	4	6	10	11
12	Orbit	T-Intersection	0	2	4	6	10	12
13	Eshet	4-Leg	0	2	3	5	9	13
14	Ashewa	4-Leg	0	2	3	5	9	14
15	Kazira	4-Leg	0	3	0	3	9	15
16	Fird bet	Y-intersection	0	2	1	3	7	16
17	Dachatu	Y-intersection	0	1	3	4	6	17
18	Number One	4-Leg	0	1	3	4	6	18
19	Alfedli	T-Intersection	0	1	3	4	6	19
20	African-Village	Y-intersection	0	1	2	3	5	20
21	Gende-Kore	T-Intersection	0	1	2	3	5	21
22	Konel-Kefira	T-Intersection	0	0	3	3	3	22
23	DDU megenteya	T-Intersection	0	0	3	3	3	23
24	Mariam	T-Intersection	0	0	3	3	3	24
Total			**12**	**44**	**76**	**132**		

The above table clearly shows that the maximum number of pedestrian crashes in Dire Dawa city during the study period (2013/14 to 2015/16) were occurring repeatedly in 4-leg intersections. The Konel (Bridge) intersection experienced the largest number of pedestrian crashes and was considered to be the first high-risk intersection having p-value of 23. This intersection also registered the highest number of fatal crashes (2) during the study period. The Seido intersection was the second high risk intersection Dire Dawa city having p-value of 22. This intersection registered 1 fatal crash, 4 serious and 5 minor injury during the last three years. This intersection is the second high-risk intersection having p-value of 22. The eight intersections (i.e. Seido, Sabian Madeya, Posta Bet Jerba, Taiwan, CBE-Main, MOTB School, Meskelegna and Dipo) were the second sever intersections next to Shel and Konel-Bridge by having 1 fatal crash. No fatal crashes were registered at some intersections including roundabouts in Dire Dawa city.

Among these 24 intersections, the nine most vulnerable intersections have been selected based on their computed priority value and these high-risk intersections have been highlighted and ranked in the Table 4.5.

4.4 Characteristics of High-risk Intersections

4.4.1 General description of High-risk Intersections

From the data analyzed, the most hazardous intersection identified was Konel-Bridge which is a 4-leg (cross) junction having major and minor streets without raised median. The major road is two way-two lanes of travel and there is a long span bridge in Posta Bet approach within 50m of the intersection. The minor street was with single lane of travel each direction without median. There was no sidewalk except for Posta Bet approach.

The second high risk intersection was Seido which is a 4-leg (cross) junction having a major road with two lanes of travel in each direction divided by a rectangular center median. The median is unpaved and with a vegetation in the center. The minor street was with single lane of travel each direction without median. All the approaches were paved except approach from Goro side which was unpaved. For the sides of the three (paved) approaches there were sidewalks with no barriers. This junction is uncontrolled and sometimes it is controlled by police man at peak time of vehicle and pedestrian movement.

Figure 4.8: pedestrian movement while crossing the Seido Junction
(Source: photo captured by the author)

The third most hazardous intersection in Dire Dawa identified was Shel-Maneharia which is a 4-leg (cross) junction having a major road with single lane of travel in each direction divided by a rectangular center median. The median is unpaved and with a vegetation in the center. The minor street was with single lane of travel each direction without median. All the approaches were paved except approach from Ganda-Kore side which was unpaved. For the sides of the three (paved) approaches there were sidewalks with no barriers. This junction is uncontrolled and sometimes it is controlled by police man at peak time of vehicle and pedestrian movement.

Figure 4.9: Traffic movement at Shel junction
(Source: photos captured by the author)

The Junction behind Post Office (named as Posta Bet Jerba) or in front of Dashen Bank was the fourth high-risk junction. The CBE-Main Junction was the fifth most high risk intersection in Dire Dawa which is a 4-leg (cross) junction having a major road with two lanes of travel in each direction without median. The minor street was with single lane of travel each direction without median. There were sidewalks with no barriers for all approaches. This junction is also uncontrolled.

The sixth high risk intersection was Sabian Madeya which is a T-type junction having a major and minor road with two lanes of travel in each direction divided by a rectangular center median. The median is unpaved and with a vegetation in the center. All the sides (approaches) have sidewalks with no barriers.

Taiwan was the seventh most hazardous intersection which is found in commercial area of Dire Dawa city. It was a 4-leg (cross) junction having a major and minor road with single lane of travel in each direction without raised median. There is no sidewalk in all approaches of the junctions. This junction is uncontrolled and sometimes it is controlled by police man at peak time of vehicle and pedestrian movement.

The 8th high risk intersection was Meskelegna which is a 4-leg (cross) junction having a major and minor roads with two lanes of travel in each direction divided by a rectangular center median. The median is unpaved and with a vegetation in the center. All the sides (approaches) have sidewalks with no barriers.

Dipo junction was 9th high-risk junctions, which is T-type intersection having Minor Street of two-lane two-way directions without raised median. The major street of Dipo Junction was with two-lane of travel in each direction without median around the junction.

Figure 4.10: Dipo Junction
(Source: photo at the right side is captured by the author)

4.4.2 Intersection Characteristic Parameters Used for Statistical Analysis

The physical parameters used to characterize the intersections were pedestrian volume in pedestrian per hour, vehicular volume in vehicle per hour, the number of lanes of approaching street, presence of posted speed and the existence of raised medians. There are also other parameters used in describing intersections related with pedestrian facility like presence of crosswalk and sidewalk. The collected characteristics of intersections and pedestrian crash analysis have been used to analyze the association between the characteristics and pedestrian crashes, and to recommend the appropriate treatments to improve the pedestrian safety at the identified high risk intersections. The table below shows descriptive statistics of used parameters in the model.

Table 4.6 Descriptive Statistics of parameters used in the model

Descriptive Statistics				
Variables	**Min**	**Max**	**Mean**	**Std. Dev**
Pedestrian Crash	1.00	10.00	4.96	2.64
Pedestrian Crossing Volume	650.00	1828.00	1195.26	389.69
Motorized Traffic Volume	350.00	1324.00	786.15	313.68
No. of lane of major road	2.00	4.00	2.67	0.96
No. of lane of minor road	1.00	2.00	1.67	0.48
Width of major road	4.00	12.00	7.12	2.530
Width of minor road	3.00	10.00	6.50	2.160
Intersection Configuration (4-leg = 1, otherwise 3-leg = 0)	.00	1.00	.44	0.51
Presence of Crosswalk on major road = 1, otherwise = 0	.00	1.00	.52	.51
Presence of Crosswalk on minor road = 1, otherwise = 0	.00	1.00	.41	.50
Presence of Sidewalk along major road = 1, otherwise = 0	.00	1.00	.41	.50
Presence of Sidewalk along minor road = 1, otherwise = 0	.00	1.00	.48	.51
Presence of Raised Median along Major road = 1, otherwise = 0	.00	1.00	.52	.51
Presence of Alcohol Bar within 300m Radius = 1, otherwise = 0	.00	1.00	.48	.51
Presence of Stop or Yield Control = 1, otherwise = 0	.00	1.00	.56	.51

Intersection is at office and commercial areas = 1, otherwise = 0	.00	1.00	.59	0.50
Presence of schools within 300m radius of intersection = 1, otherwise = 0	.00	1.00	.44	.51

4.5 Relationship between Intersection Characteristics and Crash Frequencies

In this section, NB regression analyses conducted for all intersections to examine and identify the relationship between intersection characteristics and pedestrian crash frequencies. The statistical analysis employed to identify which, if any, characteristics of the intersections were significantly correlated to crash frequency as the target intersections.

4.5.1 Goodness of fit and Tests of Model Effects

Table 4.7 shows that the results of the NB model fit statistics. As shown in the table, the likelihood-ratio chi-square value for the model was found to be significant. In general, the likelihood-ratio chi-square values for the model found to be significant. The relationship between independent variables (explanatory parameters) and dependent variable (pedestrian crashes) is statistically significant (Wald $\chi^2 = 10.561$, $p < .05$) Thus, the regression model is significant as p-values are indicated in bracket.

Table 4.7: Goodness of fit and Model Effects Results of NB

Likelihood Ratio (LR) Chi-Square	35.095 *(P=0.004)*
Log-Likelihood	-45.480
AIC	126.961
BIC	150.286
Wald Chi-Square	10.561 *(P=0.001)*

4.5.2 Negative Binomial Model Result

The NB model estimation results represented in Table 4.8 indicated that, out of the sixteen estimated parameters, twelve parameters are statistically significant including motorized traffic volume, pedestrian volume, number of lanes along minor road, width of minor road, intersection configuration, presence of raised median on the major road, sidewalk on minor road, marked crosswalk, presence of schools within 300m radius of intersection, presence of stop or yield control, availability of an alcohol bar 300m radius of intersection, if the intersection is located at office and commercial areas. All variables have acceptable signs and magnitudes.

A 4-leg intersection configuration has a statistically significantly (p value of 0.00) lower pedestrian crashes (*IRR=0*.591) than 3-leg intersection configuration, the reference category in the model. Therefor, the reduction of pedestrian crashes is 40.9% compared to intersections with 3-leg intersection.

The availability of marked crosswalk along major (B= -.185, P>0.05, IRR=0.831) and minor road (B= -0.225, P>0.05, IRR=0.799) is negatively associated with pedestrian crashes at intersections. The corresponding reduction of pedestrian crashes is 16.9% and 20.1% compared to intersections without marked crosswalk along major and minor road, respectively.

The presence of raised medians along the major road is negatively associated (B=-.313, P>0.05, IRR=.731) with pedestrian crashes. The corresponding reduction of pedestrian crashes is 26.9% compared to roads with raised medians. Several prior studies, for example [10] [42], have reported that raised medians significantly reduce pedestrian crashes and assist pedestrians to cross roads safely.

Consistent with previous studies, an increase in the vehicle traffic was found to be associated with an increase in crashes. The motorized traffic volume was significant (P>0.05, IRR=1.001) and positively associated (coef. of .001) with pedestrian crashes at intersections. The IRR value indicates that pedestrian injury crashes increase by 1.001 times if the vehicle volume increases by one unit. As previous studies by various authors have found, there is a positive correlation between frequency of pedestrian crashes and traffic volume [10] [42]. These studies also revealed non-linear relationships between pedestrian crashes and traffic volumes.

The pedestrian crossing volume is positively associated (P>0.05, IRR=1.001) with pedestrian crashes. A unit increase in average pedestrian volume is associated with about a 0.1% increase in pedestrian crashes. Hence pedestrian crashes are likely to increase with higher crossing volumes. Pedestrian volumes have also been significant predictors of pedestrian crash in other studies [10] [18] [42].

Table 4.8: NB regression analysis Result

Parameter Estimates			
Parameter	***B***	***Sig.***	***Exp(B)***
(Intercept)	-.832	.005	.435
[4-leg Intersection Configuration=1.00]	-.527	.000	.591
[4-leg Intersection Configuration=.00]	0[a]	.	1
[Availability of Crosswalk on major road=1.00]	-.185	.006	.831
[Availability of Crosswalk on major road=.00]	0[a]	.	1
[Availability of Crosswalk on minor road=1.00]	-.225	.027	.799
[Availability of Crosswalk on minor road=.00]	0[a]	.	1
[Availability of Sidewalk along major road=1.00]	-.278	.000	.758
[Availability of Sidewalk along major road=.00]	0[a]	.	1
[Availability of Sidewalk along minor road=1.00]	-.202	.007	.817
[Availability of Sidewalk along minor road=.00]	0[a]	.	1
[Presence of Raised Median along Major road=1.00]	-.313	.000	.732
[Presence of Raised Median along Major road=.00]	0[a]	.	1
[Presence of Alcohol Bar within 300m Radius=1.00]	.100	.017	1.105
[Presence of Alcohol Bar within 300m Radius=.00]	0[a]	.	1
[Presence of Stop or Yield Control =1.00]	.276	.000	1.317
[Presence of Stop or Yield Control =.00]	0[a]	.	1
[Intersection is at office and commercial areas=1.00]	.474	.000	1.606
[Intersection is at office and commercial areas=.00]	0[a]	.	1
[Presence of School within 300m Radius=1.00]	.352	.001	1.421
[Presence of School within 300m Radius=.00]	0[a]	.	1
Pedestrian Crossing Volume	.001	.000	1.001
Motorized Traffic Volume	.001	.000	1.001
No. of lane of major road	-.019	.490	.981
No. of lane of minor road	-.002	.964	.998
Width of major road	.003	.588	1.003
Width of minor road	.043	.025	1.044
(Negative binomial)	3.453E-8		

The other significant parameter was the presence of sidewalk along major (B= -.278, P>0.05, IRR=0.758) and minor road (B= -0.202, P>0.05, IRR=0.817) which is negatively associated with pedestrian crashes at intersections. The corresponding reduction of pedestrian crashes is 24.2% and 18.3% compared to intersections without sidewalk.

The presence of an alcohol bar in close proximity to an intersection is positively associated (B=.01, P>0.05, IRR=1.105) with pedestrian crashes at intersections. The IRR suggests that the presence of alcohol bar increases pedestrian crashes as much as 10.5% compared to those without an alcohol bar.

Presence of Stop or Yield Control at intersections is positively associated (B=0.276, P>0.05, IRR=1.317) with pedestrian crashes at intersections. An intersection with stop or yield control is associated with 31.7% more pedestrian crashes.

The availability of an intersection at office and commercial area is the other variable which is positively associated (B=.474, P>0.05, IRR=1.606) with pedestrian crashes at intersections. An intersection available around office and commercial area is associated with 60.6% more pedestrian crashes, which indicates a direct relationship with pedestrian crashes as supported by other studies [10]. The presence of schools within a 300m radius of an intersection is positively associated (B=.352, P>0.05, IRR=1.421) with pedestrian crashes at intersections. An intersection near a school is associated with 42.1% more pedestrian crashes.

The last variable significant variable, width of minor road is positively associated (B=.043, P>0.05, IRR=1.044) with pedestrian crashes at intersections. A unit increase in the width of minor road is associated with about a 4.4% increase in pedestrian crashes.

4.6 Possible Countermeasures to Improve Pedestrian Safety At Intersections

The countermeasures section concentrated mainly on pedestrian safety engineering measures which are specifically targeted towards reducing fatal and other injury crashes. This section aims to provide information on the probable effective measures to reduce casualties and severity by particular intersection form and control within the identified intersection characteristics. On the basis of the results and findings, the necessary remedial measures should be provided to be implemented at intersections.

As study stated in [24], modification of the built environment, enforcement of traffic safety laws and pedestrian/driver education are among primary approaches in terms of reducing as well as preventing pedestrian crashes. The above literature also listed highly effective countermeasures including single-lane roundabouts, sidewalks, pedestrian refuge islands and increased intensity of roadway lighting as engineering countermeasures. Modification of the built environment is a widely used approach that can be highly effective. Junction modifications and improvements to visibility are among modifications that may made to improve safety.

Pedestrian education is a popular approach, but with the exception of children, there is a lack of evidence regarding the effectiveness of safety education. Pedestrian and driver education can provide information to roadway users and help motivate a change in specific behaviors to reduce the risk of pedestrian crashes [24, 52].

A literature stated that police enforcement is a primary component in preserving pedestrian right-of-way and maintaining a safe environment for all modes of travel [52]. According to this literature, even though engineering countermeasures are implemented, the failure of motorists and pedestrians to adhere to traffic laws can create an unsafe environment. Therefore, Police enforcement can increase driver awareness of the need to share the roadway and reduce pedestrian-related traffic crashes.

Considering the complexity events associated with pedestrian crash circumstances at intersections, priority must be given to the specific countermeasures and settings with the greatest potential for crash prevention. Some literatures suggested countermeasures related to specific safety problems with particular intersection characteristics. Based on the results from the analysis and findings of this study in Dire Dawa, some possible countermeasures are provided below for the identified and ranked high-risk intersections.

4.6.1 *Countermeasure for Konel-Bridge junction*

There are many pedestrian safety problem visible at the high-risk Konel-Bridge junction. List of possible countermeasures are provided for implementation at the this intersection. The countermeasures listed are specific to the problems related with high pedestrian volume, absence of raised median, absence of sidewalk and number of lane, and were compiled using the pedestrian facility countermeasure found [52, 53]. These are:

- Since unmarked crosswalks at uncontrolled locations are not safe for pedestrians, especially when there are high vehicle and pedestrian movements, standard crosswalk marking should be used for crosswalks with stop-sign-controlled traffic along minor road.

- Maintaining crosswalk markings along major road
- Advanced stop bar and sign "Stop here for pedestrian" can be used [52]
- Channelizing the intersection to provide safe pedestrian crossing

4.6.2 *Countermeasure for Seido junction*

The pedestrian safety problem visible at the high-risk seido intersection related with high vehicle and pedestrian volume, Roadway width and number of lane which may result in high number of crashes. List of possible countermeasures are provided for implementation at the Seido intersection. This list of countermeasures are based on the analysis and the identified characteristics discussed in previous section. The countermeasures listed are specific to the problems related with vehicle and pedestrian volume, Roadway width and number of lane, and were compiled using the pedestrian facility countermeasure found [44, 52, 53]. These are:

- Installing pedestrian barriers
- Installing advanced stop bar
- Installing Pedestrian crossing sign

4.6.3 *Countermeasure for Shel-Maneharia Junction*

There are many pedestrian safety problem visible at the high-risk Konel-Bridge junction. Some of them are related with high motorized traffic along minor road, high pedestrian movement, absence of sidewalk along minor road and narrow lane width of minor street as well as it is uncontrolled intersection. The eastern approach of minor street serves for a movement of high motorized traffic and as a result, this may lead to vehicle-pedestrian collision. List of possible countermeasures are provided and compiled using the countermeasures found in [52], these are:

- Providing sidewalk along eastern approach of minor street.
- Maintaining Marked Crosswalks
- Installing "STOP FOR PEDESTRIAN" or "YIELD FOR PEDESTRIAN" sign

4.6.4 *Countermeasure for the Junction behind Post Office*

Pedestrian safety problems visible at the high-risk Konel-Bridge junction were related with high pedestrian volume, faded crosswalk and presence of alcohol bar with 20m of the intersection as well as it is uncontrolled intersection. List of possible countermeasures are provided for implementation at this intersection. The countermeasures were compiled using the countermeasures found in [44][52]. These are:

- Providing pedestrian crossing island along major road approach

- Provide lighting since it is uncontrolled high risk locations
- Maintaining crosswalk markings of all approaches.
- Installing “STOP FOR PEDESTRIAN” or “YIELD FOR PEDESTRIAN” sign

4.6.5 *Countermeasure for Meskelegna Junction and CBE-Main Junction*

Both intersections are high-risk and having pedestrian safety problems related with high pedestrian movement, narrow sidewalk and located at commercial and office area as well as it is uncontrolled intersection. List of possible countermeasures are provided and compiled using the countermeasures found in [52][53]. These are:

- To prohibit pedestrians from crossing roads with high traffic movement or multiple lanes, pedestrian channelization is recommended.
- Channelizing the intersection to provide safe pedestrian crossing and serving as refuge
- Curb Extensions at eastern approach of major street (only for *CBE-Main Junction*)
- Maintaining Marked Crosswalks
- Provide lighting since it is uncontrolled high risk locations
- Installing “STOP FOR PEDESTRIAN” or “YIELD FOR PEDESTRIAN” sign
- Installing pedestrian barriers (only for *CBE-Main Junction*)

4.6.6 *Countermeasure for Sabian Madeya Junction*

Pedestrian safety problems visible at the Sabian Madeya junction were related with high motorized traffic pedestrian volume, absence of sidewalk and narrow lane width of minor street as well as it is uncontrolled intersection. List of possible countermeasures are provided and compiled using the countermeasures found in [52], these are:

- Providing sidewalk along minor road
- Maintaining Marked Crosswalks
- Provide lighting since it is uncontrolled high risk locations
- Installing “STOP FOR PEDESTRIAN” or “YIELD FOR PEDESTRIAN” sign

4.6.7 *Countermeasure for Taiwan Junction*

This high risk junction is located around commercial area. High pedestrian movement was observed during field observation. narrow sidewalk, absence of marked crosswalk and the intersection being uncontrolled are the main safety problems at this junction. List of possible countermeasures are provided and compiled using the countermeasures found in [52], these are:

- Providing sidewalk along eastern approach of minor street.

- Maintaining Marked Crosswalks
- Installing "STOP FOR PEDESTRIAN" or "YIELD FOR PEDESTRIAN" sign

4.6.8 *Countermeasure for Dipo junction*

There are many pedestrian safety problem visible at Dipo junction which was the last high-risk junction. There are many pedestrian safety problems visible at this intersection. Some of them are related high motorized traffic volume and pedestrian movement, absence of visibility of marked crosswalk, absence of sidewalk along minor road and narrow lane width of minor street. List of possible countermeasures are provided and compiled using the countermeasures found in [52]. These are:

- Maintaining Marked Crosswalks
- Providing sidewalk along major road
- Extending the existing Raised median (since it stoped more than 300m from the junction) towards the intersection for major road. It will serve as refuge for pedestrian.

In general, the following table shows the summary of possible remedies discussed above to be applied for each of the high-risk intersection identified.

Table 4.9: Summary of Countermeasures at high-risk intersections

Category	Countermeasure	Application Location
Roadway and Intersection Design	extending existing raised median	Dipo
	Install refuge island	Posta Bet Jerba, CBE-main, Konel Bridge
Pedestrian Facility Design	Install sidewalks and walkways	Konel-Bridge, Shel (minor road), Taiwan (2-legs),
	Install marked crosswalks	Konel-Bridge (minor road)
	Install barriers	Seido, CBE-Main
	Maintain crosswalk	Konel-Bridge (major road), Posta Bet Jerba, Meskelegna, CBE-Main, Shel, Taiwan, Dipo
	Improve lighting at intersection	Posta Bet Jerba, Meskelegna, CBE-Main
	Curb Extensions	CBE-Main
Pedestrian Signs	Install "Stop For Pedestrian" sign	Seido, Konel-Bridge, Posta Bet Jerba, Meskelegna, CBE-Main, Shel, Taiwan
	Installing advanced stop bar	Seido, Konel-Bridge

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

The study identified and analyzed the pedestrian crashes occurred at intersections with the high-risk intersections based on the data collected from Dire Dawa city police commission report for the years 2013/14-2015/16 (2006-2008 E.C). Based analysis, the results and the discussions, the following conclusions and recommendations are drawn.

5.1 Conclusion

The analysis presented in research addressed many of the characteristics and issues concerning high-risk intersections for pedestrians and identified which characteristics are the most significant resulting in high pedestrian crash frequency. Based on the findings, the following conclusions were drawn:

- From the study, a total of 165 pedestrian crashes were occurred at intersections in the three years. From this, 13 were fatal, 54 were serious injury and 98 were minor injury.
- For the identification of the high-risk intersections, Flemish government analysis method was used and established. Based on the analysis, nine intersections were selected and considered as a high-risk junction of which Konel Bridge, Seido and Shel menaharia were the first three vulnerable crash prone junctions.
- Negative binomial (NB) model was selected and it was analysed by using SPSS to identify how specific roadway intersection characteristics were associated with pedestrian crashes.
- Based on NB statistical analysis, intersection charecteristics that indicated an increased probability of pedestrian crash frequency includes motorized traffic volume, pedestrian volume, width of minor road, intersection configuration, presence of schools within 300m radius of intersection, presence of stop or yield control, availability of an alcohol bar 300m radius of intersection, the availability of intersection around office and commercial areas.
- Although, there were some limitations in the current study, this study provides insights into crash frequency at unsignalized intersections in Dire Dawa city.

5.2 Recommendation

Based on the findings, the countermeasures to be implemented on the identified high-risk intersections are forwarded.

- Crosswalks should be used in combination with other treatments to improve safety. Since unmarked crosswalks at uncontrolled locations are not safe for pedestrians, especially when there are high vehicle and pedestrian movements, standard crosswalk marking should be used for crosswalks in combination with other treatments to improve safety at Konel-Bridge. Refuge islands, raised medians, curb extensions, and lighting are examples. Again, existing raised median should be extended at Dipo Junction.
- Many intersections require maintaining the crosswalk, specifically at Konel-Bridge (major road), Posta Bet Jerba, Meskelegna, CBE-Main, Shel, Taiwan and Dipo junctions.
- Pedestrian crossing island and channelization should be provided at Posta Bet Jerba, CBE-main and Konel Bridge Junctions.
- Pedestrian barriers are highly recommended at seido junction as there was a high movement of pedestrian.
- Advanced stop bar is also recommended at CBE-Main and seido junctions.

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APPENDIXES

Appendix A: Pedestrian Crash Data in DD city

Table A1: Total Pedestrian Crashes at DD Roads including Intersections

Pedestrian Age	Total Pedestrian Crashes at DD Roads including Intersections																		Total
	2013/14 (2006 E.C)						2014/15 (2007 E.C)						2015/16 (2008 E.C)						
	Fatal		Serious		Minor		Fatal		Serious		Minor		Fatal		Serious		Minor		
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	
< 7	0	2	6	1	7	0	1	0	2	0	1	0	1	0	5	0	1	0	**27**
13-Jul	3	0	12	7	4	2	2	0	4	3	2	2	0	0	4	0	3	0	**48**
14-17	0	0	1	1	3	4	1	0	3	2	2	1	0	0	0	0	3	0	**21**
18-30	4	0	6	2	7	11	4	0	12	3	5	3	7	3	13	6	26	11	**123**
31-50	4	2	6	3	9	2	4	2	7	8	6	4	4	3	19	8	19	6	**116**
> 51	0	0	6	2	4	3	3	1	3	2	3	2	2	1	3	3	2	2	**42**
Total	**11**	**4**	**37**	**16**	**34**	**22**	**15**	**3**	**31**	**18**	**19**	**12**	**14**	**7**	**44**	**17**	**54**	**19**	**377**

Table A2: Total Traffic Accident vs Intersection Type

Intersection Type	Total Accident vs Intersection Type									Total
	2006			2007			2008			
	Fatal	Serious	Minor	Fatal	Serious	Minor	Fatal	Serious	Minor	
Y-Inter.	0	5	19	2	8	24	5	6	7	**76**
T-Inter.	2	23	25	4	11	21	0	12	18	**116**
Roundabout	0	0	1	0	0	0	0	1	1	**3**
4-leg Inter.	5	20	23	1	23	22	3	9	15	**121**
Other	1	0	0	1	0	0	0	0	0	**2**
Total	**8**	**48**	**68**	**8**	**42**	**67**	**8**	**28**	**41**	**318**

Table A3: Analysis of Pedestrian Crash at Intersection

1. pedestrian Crash Vs Crash Severity				Total
Crash Severity	2013/14	2014/15	2015/16	
Fatal	3	5	6	14
Serious	18	22	14	54
Minor	35	33	29	97
Total	56	60	49	165

2. pedestrian Crash Vs Gender				Total
Gender	2013/14	2014/15	2015/16	
Male	36	41	33	110
Female	20	19	16	55
Total	56	60	49	165

3. pedestrian Crash Vs Age Group				Total
Age Group	2013/14	2014/15	2015/16	
< 7	5	4	2	11
7-13	14	7	3	24
14-17	2	6	3	11
18-30	15	19	21	55
31-50	12	15	13	40
> 51	8	9	7	24
Total	56	60	49	165

4. pedestrian Crash by Time of the Day				Total
Time	2013/14	2014/15	2015/16	
6:00 am-7:00 am	1	0	1	2
7:00 am-8:00 am	2	2	1	5
8:00 am-9:00 am	4	4	5	13
9:00 am-10:00 am	2	3	4	9
10:00 am-11:00 am	4	8	3	15
11:00 am-12:00 am	5	4	8	17
12:00 am-1:00 pm	7	5	4	16
1:00 pm-2:00 pm	2	6	2	10
2:00 pm-3:00 pm	2	5	3	10
3:00 pm-4:00 pm	3	2	4	9
4:00 pm-5:00 pm	4	4	2	10

5:00 pm-6:00 pm	4	3	1	**8**
6:00 pm-7:00 pm	2	2	3	**7**
7:00 pm-8:00 pm	3	4	1	**8**
8:00 pm-9:00 pm	3	3	1	**7**
9:00 pm-10:00 pm	3	0	2	**5**
10:00 pm-11:00 pm	1	2	1	**4**
11:00 pm-12:00 pm	0	0	0	**0**
12:00 am-1:00 am	1	0	0	**1**
1:00 am-2:00 am	1	0	0	**1**
2:00 am-3:00 am	0	0	0	**0**
3:00 am-4:00 am	1	0	1	**2**
4:00 am-5:00 am	1	2	1	**4**
5:00 am-6:00 am	0	1	1	**2**
Total	**56**	**60**	**49**	**165**

5. pedestrian Crash by Day of the Week				Total
Day	**2013/14**	**2014/15**	**2015/16**	
Monday	7	7	9	**23**
Tuesday	5	9	5	**19**
Wednesday	10	10	9	**29**
Thursday	12	12	10	**34**
Friday	10	11	4	**25**
Saturday	7	7	7	**21**
Sunday	5	4	5	**14**
Total	**56**	**60**	**49**	**165**

4. pedestrian Crash by Month of the Year				Total
Month	**2013/14**	**2014/15**	**2015/16**	
January	1	1	3	**5**
February	4	4	1	**9**
March	5	6	3	**14**
April	1	2	2	**5**
May	5	4	4	**13**
June	2	6	1	**9**
July	3	5	4	**12**
August	6	4	3	**13**
September	9	9	9	**27**
October	7	7	6	**20**
November	8	5	8	**21**
December	5	7	5	**17**

Total	**56**	**60**	**49**	**165**

6. pedestrian Crash by Intersection Type				**Total**
Intersection Type	**2013/14**	**2014/15**	**2015/16**	
Roundabout	0	0	2	**2**
T-intersection	24	16	21	**61**
Y-intersection	10	17	14	**41**
4-leg intersection	22	27	12	**61**
Total	**56**	**60**	**49**	**165**

Appendix B: Traffic Volume Data of DD city Road

Table B1: Motorized and pedestrian Volume

No.	Easting and Northing Coordinates*	Intersection Name	Traffic Volume	
			Veh. Vol.	Ped. Vol.
1	(813152.80, 1061678.73)	African-Village	900	526
2	(810986.45, 1063033.65)	Alfedli	999	835
3	(815068.74, 1062357.31)	Ashewa	1057	658
4	(814119.95, 1061660.00)	CBE (Main)	1700	1160
5	(814251.59, 1061650.36)	Dachatu	1018	619
6	(811567.85, 1063653.81)	DDU megenteya	871	490
7	(813838.03, 1061146.86)	Dil chora	748	415
8	(813049.99, 1061983.22)	Dipo	1680	1116
9	(811851.66, 1063563.69)	Eshet	1080	804
10	(814284.88, 1062691.82)	Fird bet	973	550
11	(813645.65, 1060974.62)	Gende-Kore	898	514
12	(813986.09, 1061567.22)	Kazira	979	575
13	(814404.70, 1061494.36	Konel (Bridge)	1808	1294
14	(814625.23, 1061461.25)	Konel (Megala)	1246	772
15	(814780.55, 1061431.10)	Konel-Kefira	850	460
16	(814462.47, 1062345.28)	Mariam	823	439
17	(812546.35, 1063309.54)	Meskelegna	1704	1108
18	(814098.72, 1061891.71)	Midirbabur	725	395
19	(815229.36, 1063033.12)	MOTB school	1108	697
20	(814549.25, 1062205.80)	Number One	991	803
21	(813989.41, 1062878.39)	Orbit	1150	724
22	(814171.35, 1061790.52)	Posta Bet jerba	1760	1184
23	(812306.89, 1062569.58)	Sabian Madeya	1696	1140
24	(811245.44, 1063766.13)	Sebategna	650	350
25	(811594.43, 1062816.15)	Seido	1828	1324
26	(813899.14, 1060931.85)	Shel	1780	1264
27	(814851.29, 1061833.87)	Taiwan	1250	1010

* The coordinates indicate the easting and Northing of center of intersections (Google Earth, 2018)

Table B2: PCE value Analysis

Vehicle Number	Car and Taxi	Bajaj	4-WD	Mini Bus	Medium Bus	Std. Bus	Medium Trucks	Large Trucks
1	4.1	2.5	4.6	4.7	5.3	-	7.9	8.9
2	7.2	4.4	4.2	5.2	4.1	-	8.9	9.9
3	2.7	4.0	4.6	4.8	4.7	-	7.8	8.8
4	2.6	4.1	4.3	4.6	3.8	8.2	9.1	9.7
5	3.7	3.1	4.6	5	4.7	7.5	9.3	8.7
6	1.9	2.1	4.2	4.8	4.6	-	8.1	9.1
7	3.1	3.3	4.3	4.8	4.8	-	7.9	7.6
8	4.1	3.4	4.1	5.3	6.0	-	7.6	7.6
9	3.6	3.2	4.7	4.9	4.9	5.6	6.6	7.6
10	4.6	3.6	3.8	5.3	4.5	5.7	8.2	8.2
11	5.8	3.4	4.7	3.6	5.7	8.3	10.6	10.6
12	5.4	4.2	4.6	4.9	5.8	9.4	9.7	9.7
13	4.5	3.9	4.2	4.2	5.6	7.7	9.1	9.1
14	3.6	4.3	3.7	5.7	6.0	7.2	10.1	10.1
15	3.2	2.9	4.2	5.4	5.8	8.2	11.3	11.3
16	3.3	4.1	3.8	3.9	6.6	8.7	9.2	10.2
17	3.6	4.3	4.8	4.6	6.3	8.6	8.3	8.3
18	3.1	3.2	4.6	3.9	6.7	-	6.9	8.3
19	2.9	4.2	4.7	4.2	5.2	-	8.3	6.8
20	3.5	2.8	4.9	3.9	5.4	-	8.3	8.2
21	3.6	2.2	4.2	5.3	4.7	9.1	8.6	7.9
22	3.7	3.2	4.5	5.2	5.2	9.8	8.8	10.3
23	2.8	3.3	4.6	4.8	5.8	10.5	7.9	9.4
24	4.2	3.2	3.2	4.9	5.8	-	8.5	10.0
25	4.6	3.1	4.2	5.3	5.6	-	8.2	9.7
26	3.8	3	2.8	5.1	5.7	-	9.4	10.9
27	4.3	3.6	2.2	4.2	5.9	8.3	8.3	9.8
28	4.1	3.2	3.2	5.3	5.6	8.5	9.3	10.8
29	3.9	3.3	3.3	5.8	4.8	9.4	9.4	10.9
30	2.5	3.2	3.2	4.9	5.9	8.7	7.7	9.9
Average h	3.80	3.41	4.10	4.82	5.38	8.29	8.64	9.26
PCU	1.00	0.90	1.08	1.27	1.42	2.18	2.27	2.44
Used PCE	**1.0**	**1.0**	**1.0**	**1.25**	**1.5**	**2.2**	**2.3**	**2.5**

Appendix C: Statistical model Variables and Outputs

Appendix C1: Statistical model Variables

Table C1: Statistical model Variables

1. Roadway and Traffic Variables

1.1 Continuous Variables

- Motorized traffic volume
- Pedestrian volume
- Number of lanes along major road
- Number of lanes along minor road
- Width of major road
- Width of minor road

1.2 Indicator Variables

- Intersection configuration (4-leg = 1, otherwise 3-leg = 0)
- Presence of raised median on the major road = 1, otherwise = 0
- Availability of sidewalk on major road = 1, otherwise = 0
- Availability of sidewalk on minor road = 1, otherwise = 0
- Availability of marked crosswalk on major road = 1, otherwise = 0
- Availability of marked crosswalk on minor road = 1, otherwise = 0

2. Spatial Characteristics

1.1 Indicator Variables

- Presence of schools within 300m radius of intersection = 1, otherwise = 0
- Availability of an alcohol bar 300m radius of intersection = 1, otherwise = 0
- If the intersection is located at office and commercial areas = 1, otherwise = 0

Appendix C2: Statistical Model Outputs (Generalized Linear Models)

Table C2: Statistical Model Outputs

Model Information

Dependent Variable	Pedestrian Crash
Probability Distribution	Negative binomial (MLE)
Link Function	Log

Categorical Variable Information

			N	Percent
Factor	4-leg Intersection Configuration	Yes	12	44.4%
		No	15	55.6%
		Total	27	100.0%
	Presence of Crosswalk on major road	Yes	14	51.9%
		No	13	48.1%
		Total	27	100.0%
	Presence of Crosswalk on minor road	Yes	11	40.7%
		No	16	59.3%
		Total	27	100.0%
	Presence of Sidewalk along major road	Yes	11	40.7%
		No	16	59.3%
		Total	27	100.0%
	Presence of Sidewalk along minor road	Yes	13	48.1%
		No	14	51.9%
		Total	27	100.0%
	Presence of Raised Median along Major road	Yes	14	51.9%
		No	13	48.1%
		Total	27	100.0%
	Presence of Alcohol Bar within 300m Radius	Yes	13	48.1%
		No	14	51.9%
		Total	27	100.0%
	Presence of Stop or Yield Control	Yes	15	55.6%
		No	12	44.4%
		Total	27	100.0%
	Intersection is at office and commercial areas	Yes	16	59.3%
		No	11	40.7%
		Total	27	100.0%
	Presence of School within 300m Radius	Yes	12	44.4%
		No	15	55.6%

Total	27	100.0%

Continuous Variable Information

		N	Min	Max	Mean	Std. Dev
Dependent Variable	Pedestrian Crash	27	1.00	10.00	5.0000	2.60177
Covariate	Pedestrian Crossing Volume	27	650.00	1828.00	1195.2593	389.69323
	Motorized Traffic Volume	27	350.00	1324.00	786.1481	313.68256
	No. of lane of major road	27	2.00	4.00	2.6667	.96077
	No. of lane of minor road	27	1.00	2.00	1.6667	.48038
	Width of major road	27	4.00	12.00	7.1167	2.53464
	Width of minor road	27	3.00	10.00	6.5019	2.16237

Goodness of Fit[a]

	Value	df	Value/df
Deviance	1.128	9	.125
Scaled Deviance	1.128	9	
Pearson Chi-Square	1.058	9	.118
Scaled Pearson Chi-Square	1.058	9	
Log Likelihood[b]	-45.480		
Akaike's Information Criterion (AIC)	126.961		
Finite Sample Corrected AIC (AICC)	212.461		
Bayesian Information Criterion (BIC)	150.286		
Consistent AIC (CAIC)	168.286		

Omnibus Test[a]

Likelihood Ratio Chi-Square	df	Sig.
35.095	16	.004

Tests of Model Effects

Source	Type III		
	Wald Chi-Square	df	Sig.
(Intercept)	10.561	1	.001
4-leg Intersection Configuration	91.046	1	.000
Presence of Crosswalk on major road	7.560	1	.006
Presence of Crosswalk on minor road	4.898	1	.027
Presence of Sidewalk along major road	22.461	1	.000
Presence of Sidewalk along minor road	7.371	1	.007
Presence of Raised Median along Major road	22.535	1	.000
Presence of Alcohol Bar within 300m Radius	5.666	1	.017
Presence of Stop or Yield Control	22.300	1	.000
Intersection is at office and commercial areas	28.310	1	.000
Presence of School within 300m Radius	11.965	1	.001
Pedestrian Crossing Volume	23.856	1	.000
Motorized Traffic Volume	12.473	1	.000
No. of lane of major road	.476	1	.490
No. of lane of minor road	.002	1	.964
Width of major road	.293	1	.588
Width of minor road	5.047	1	.025

Parameter Estimates

			95% Wald Confidence Interval		Hypothesis Test				95% Wald Confidence Interval for Exp(B)	
Parameter	***B***	*Std. Error*	*Lower*	*Upper*	*Wald Chi-Square*	df	***Sig.***	***Exp(B)***	Lower	Upper
(Intercept)	-.832	.2953	-1.411	-.253	7.941	1	.005	.435	.244	.776
[4-leg Intersection Configuration=1.00]	-.527	.0552	-.635	-.419	91.046	1	.000	.591	.530	.658
[4-leg Intersection Configuration=.00]	0[a]	.	.	.	.	.	.	1	.	.
[Presence of Crosswalk on major road=1.00]	-.185	.0674	-.318	-.053	7.560	1	.006	.831	.728	.948
[Presence of Crosswalk on major road=.00]	0[a]	.	.	.	.	.	.	1	.	.
[Presence of Crosswalk on minor road=1.00]	-.225	.1016	-.424	-.026	4.898	1	.027	.799	.654	.975
[Presence of Crosswalk on minor road=.00]	0[a]	.	.	.	.	.	.	1	.	.
[Presence of Sidewalk along major road=1.00]	-.278	.0586	-.392	-.163	22.461	1	.000	.758	.675	.850
[Presence of Sidewalk along major road=.00]	0[a]	.	.	.	.	.	.	1	.	.
[Presence of Sidewalk along minor road=1.00]	-.202	.0744	-.348	-.056	7.371	1	.007	.817	.706	.945
[Presence of Sidewalk along minor road=.00]	0[a]	.	.	.	.	.	.	1	.	.
[Presence of Raised Median along Major road=1.00]	-.313	.0658	-.442	-.184	22.535	1	.000	.732	.643	.832
[Presence of Raised Median along Major road=.00]	0[a]	.	.	.	.	.	.	1	.	.
[Presence of Alcohol Bar within 300m Radius=1.00]	.100	.0421	.018	.183	5.666	1	.017	1.105	1.018	1.201
[Presence of Alcohol Bar within 300m Radius=.00]	0[a]	.	.	.	.	.	.	1	.	.
[Presence of Stop or Yield Control =1.00]	.276	.0583	.161	.390	22.300	1	.000	1.317	1.175	1.477

[Presence of Stop or Yield Control =.00]	0[a]	.	.	.	.	.	.	1	.	.
[Intersection is at office and commercial areas=1.00]	.474	.0891	.299	.648	28.310	1	.000	1.606	1.349	1.913
[Intersection is at office and commercial areas=.00]	0[a]	.	.	.	.	.	.	1	.	.
[Presence of School within 300m Radius=1.00]	.352	.1016	.152	.551	11.965	1	.001	1.421	1.165	1.735
[Presence of School within 300m Radius=.00]	0[a]	.	.	.	.	.	.	1	.	.
Pedestrian Crossing Volume	.001	.0002	.001	.001	23.856	1	.000	1.001	1.001	1.001
Motorized Traffic Volume	.001	.0004	.001	.002	12.473	1	.000	1.001	1.001	1.002
No. of lane of major road	-.019	.0271	-.072	.034	.476	1	.490	.981	.931	1.035
No. of lane of minor road	-.002	.0375	-.075	.072	.002	1	.964	.998	.928	1.074
Width of major road	.003	.0057	-.008	.014	.293	1	.588	1.003	.992	1.014
Width of minor road	.043	.0193	.006	.081	5.047	1	.025	1.044	1.006	1.085
(Scale)	1[b]									
(Negative binomial)	3.453E-8	2.1964E-5	.000	.						