



INVESTIGATION OF PEDESTRIAN SAFETY PROBLEMS AND THEIR  
REMEDIAL SOLUTIONS IN ADDIS ABABA: THE CASE OF KIRKOS SUB CITY

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By

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**SCHOOL OF GRADUATE STUDIES**

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## DECLARATION

I, the undersigned, declare that this thesis is my original work performed under the supervision of my research advisor Dr. Bikila Teklu and has not been presented as a thesis for a degree in any other university. All sources of materials used for this thesis have also been duly acknowledged.

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**Dedicated**

**To**

**The Bright Stars in My Sky**

**My**

**Grandmothers**

**Beyenech Abbay**

**&**

**Sahlemaryam Berhé**

## ABSTRACT

The road traffic crash statistics of Addis Ababa shows pedestrian injuries have the highest share among all road users. This research aims to investigate current pedestrian safety problems in Addis Ababa and tries to identify factors influencing it. The study area, Addis Ababa has ten sub cities where Kirkos sub city ranks first with the highest total road traffic crashes. This sub city is selected as a study site and pedestrian-vehicle crash data for three consecutive years were collected. These data were analyzed using odd ratio analysis and logistic regression analysis. Moreover, sample pedestrians and drivers were selected randomly and filled out questionnaire with list of hundred factors related to pedestrian safety in four categories: pedestrian related, driver related, vehicle related and road and environment related; which was analyzed by Likert scale rating and reduced it to top twenty ranked factors. Then these twenty factors; five from each categories were taken and pair wise comparison by senior experts was employed by Analytical Hierarchical Process (AHP) technique. Analyzing these resulted in a rank for each factor with their global weight. The top three are related to driver behavior: alcohol use by drivers (11.55%), driver rush and negligence (6.084%) and improper or erratic lane changing (6.048%). The twenty factors were then grouped to the four categories with their local ranking. In the odd ratio analysis, four hypothesis were tested and only one hypothesis is accepted indicating drivers with experiences of more than 10 years are most responsible to pedestrian serious injury. From the logit model driver-vehicle relationship, junction type, pedestrian age and pedestrian sex are positively associated with pedestrian injuries. Thus in order to take appropriate measures towards pedestrian safety: pedestrian related factors, driver related factors, vehicle related factors and road and environment related factors need to be considered and appropriate measure has to be considered in a systematic way. Rather than a scattered spots approach by a piecemeal basis; a perspective towards looking the urban network of road infrastructure, pedestrian facilities and the urban land use is considered in this research. This research concludes a strategic way has to be followed towards promoting road safety and pedestrian safety in Addis Ababa that would be an area-wide and multi-disciplinary approach, that is, urban safety management.

**KEY WORDS:** Road Traffic Crash, Pedestrian Injuries, Addis Ababa, Kirkos Sub City, Pedestrian Safety, Urban Safety Management.

## ACKNOWLEDGMENT

As to the thesis specific area, I decided this title after looking different options and submitted the proposal. But later on after a couple of months I have doubted whether my past has some contribution. I as an elementary school student and pedestrian was a victim of pedestrian-vehicle crash in Addis Ababa. And later on after many years, my dorm mate and friend had a fatal crash while he was driving in Addis Ababa. Probably these may have piqued my interest from my yore.

The successful completion of this thesis was the result of the assistance of many individuals and organizations. First I sincerely acknowledge the full sponsorship of this study by the Ethiopian Roads Authority and Bekele Negussie, Deputy Director General: Planning and ICT, for his kind understanding and help throughout the program of study.

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## Acronyms/Abbreviations

AACRA	Addis Ababa City Roads Authority
AADT	Average Annual Daily Traffic
AHP	Analytic Hierarchy Process
CI	Consistency Index
CR	Consistency Ratio
MAUT	Multi-Attribute Utility Theory
MCA	Multi-Criteria Analysis
MCDM	Multi-Criteria Decision Making
MIR	Mean Importance Rating
MLE	Maximum Likelihood Estimate
MS	Microsoft
RI	Random Index
SPSS	Software Package for Statistical Analysis
UK	United Kingdom
UN	United Nations
UNECE	United Nations Economic Commission for Europe
US	United States
WHO	World Health Organization

# 1. INTRODUCTION

Road transportation in Ethiopia is focused on increasing the network coverage with much less attention given to pedestrians and their safety. The road traffic crash statistics of Ethiopia shows pedestrians have the highest injury percentage out of all road users.

Under this chapter background of the study, definition of the problem, objective of the study, scope of the study, organization of the study and significance of the study are included.

## 1.1. Background of the Study

Road traffic may be considered as a system in which the human, the vehicle and the road interact with each other. The efficiency and safety of road traffic depends on the performances and interactions of these components. Therefore, road traffic crash may be regarded as an event caused by a failure in one of the components or in the system interactions between these components (1).

Currently road traffic injuries are estimated to be the eighth leading cause of death globally. There were 1.25 million road traffic deaths on the world's roads in the year 2013, and another 20 to 50 million sustain non-fatal injuries as a result of road traffic crashes (2).

The majority or 90% of road traffic deaths occur in the low and middle income countries that have 82% of the world's population and 54% of all registered vehicles. It has been estimated that, unless immediate action is taken, road deaths will rise to become the fifth leading cause of death by 2030, resulting in an estimated 2.4 million fatalities per year (2).

More than 20% of the people killed on the world's roads each year are pedestrians (3). When we look our continent, 39% of all African road traffic deaths occur among pedestrians (2).

According to a report by Ethiopian federal police in the year 2011/12, for instance, there were 2521 traffic crash fatalities, 2981 serious injuries and 2987 slight injuries. In this year the percentage of pedestrian fatalities was 51.6 and pedestrian non-fatal injuries were 45.3 per cent.

With the increasing exposure which can be measured indirectly by the increase in population, motorization, and road network expansion in Ethiopia, and low-level of safety awareness and road safety work, road crash is a serious issue to handle well. Ethiopia is one of the seven African countries that account for 64 % of road deaths in the continent (4).

The issue of road safety has already become multidimensional; that is, it has become an economic, social and health issue. The increase in number of motorized vehicles is making roads more dangerous for those road users who use alternative modes of transport – notably those who walk, cycle and use motorcycles (2).

Urban transport generates major social and economic problems through traffic crash. Traffic crash is one of the most critical problems of road transport in Ethiopia. Despite having very low

road network density and vehicle ownership, the country has a relatively high crash record and is losing unbearable human and economic resources.

In the city of Addis Ababa, pedestrian fatalities are about 88 per cent of the total road crash fatalities. For instance in 2012/13, the Addis Ababa Police Commission reported 329 pedestrian fatalities out of total 374 fatalities. As a society we are still too tolerant and accepting fatalities and injuries as a phenomenon that cannot be prevented.

When we look road safety in Ethiopia, pedestrian safety problems have not yet been a focus area. In this respect this study investigates pedestrian safety problems in Addis Ababa and proposes measures that will contribute to a culture of safety, make walking safe and ultimately: save pedestrian lives.

## **1.2. Definition of the Problem**

Road traffic crashes are a huge public health and development problems in Ethiopia. In 2011/12, the Federal Police Commission data shows that 51 percent of the reported roadside fatalities in Ethiopia were pedestrians. In Addis Ababa, pedestrian fatalities were about 90 percent of the total road crash fatalities.

Unlike many modern cities, Addis Ababa has road network which is not adequately planned to meet the current traffic demand. In addition road network hierarchies are not well established. The rapidly increasing traffic on the undeveloped road infrastructure adds up to unsafe behavior of road users result in a highly conflicting traffic which results many road crashes (1).

It is known that walking is one mode of travel and is a fundamental part of the transportation system. However, a pedestrian is not taken into account in the planning and design of traffic and transportation systems, with the same importance that is given to vehicular modes of travel.

People who walk from place to place must travel along the roads. Pedestrians must share those roads with every type of vehicle—buses, trucks, cars, motorcycles, bicycles. Pedestrians and other vulnerable road users who are tending to their daily activities are often caught off guard, struck, and instantly killed (5).

The data from Addis Ababa Police Commission for consecutive years show the most vulnerable road user in Addis Ababa is the pedestrian. These are indicators of the poor safety awareness of road users and lack of pedestrian facilities. Unless the current trend is changed, the social and economic problem continues.

Therefore, it is important to investigate the problems behind pedestrian safety issues in Addis Ababa, so that remedial solutions that can enhance safety be promoted.

## **1.3. Objective of the Study**

The general objective of the study is to investigate pedestrian safety problems in Addis Ababa. Accordingly, remedial measures will be suggested to promote pedestrian safety.

The specific objectives of the study are:

- To investigate current pedestrian safety problems in Addis Ababa including trends of pedestrian vehicle crashes particularly in Kirkos sub city.
- To identify the factors influencing pedestrian safety in Addis Ababa particularly in Kirkos sub city.
- To recommend solutions for identified pedestrian safety problems.

#### **1.4. Scope of the Study**

The scope of the study is limited to selected sites in Addis Ababa. The study focuses on investigation of pedestrian problems in Addis Ababa in general and on the sites specifically in Kirkos sub city on pedestrian-vehicle crash trends and characteristics. Pedestrian safety promotion measures were proposed finally based on the findings.

#### **1.5. Description of the Study Area**

Addis Ababa, the capital city of Ethiopia, is the study area. A population projection value of 2014 for Addis Ababa is 3,195,000 (6). The selected study site is Kirkos sub city where the highest total road traffic crashes occur among the ten sub cities of Addis Ababa. For the same projection year Kirkos sub city has 258,035 total populations.

#### **1.6. Organization of the Study**

This research consists of five main chapters as followings:

- **Chapter One: Introduction:** this chapter shows definition of the problem, objective of the study, scope of the study and organization of the study.
- **Chapter Two: Literature Review:** this chapter shows reviews of studies related to identifying factors influencing pedestrian safety.
- **Chapter Three: Methodology and Data Collection:** this chapter describes the main methodologies used in previous studies and the methodology and methods used in this research in order to achieve the required objectives. It shows trend and situation of road traffic crashes in Addis Ababa.
- **Chapter Four: Result and Discussion:** this chapter shows trend of pedestrian-vehicle crashes in Kirkos sub city for three years; presentation and analysis of the findings, description and discussion of research results.
- **Chapter Five: Conclusion and Recommendation.**
- **References**
- **Appendix**

## **1.7. Significance of the Study**

This research has the following major significance:-

- Helps to understand the pedestrian safety problems and possible remedial solutions in Addis Ababa, Ethiopia particularly in Kirkos sub city.

## 2. LITERATURE REVIEW

### 2.1. Definition of Terms

#### 2.1.1. Road Traffic

Road traffic is the interaction between humans (pedestrians and drivers), vehicles and road infrastructure. The following figure shows the interaction of factors on crash involving pedestrians.

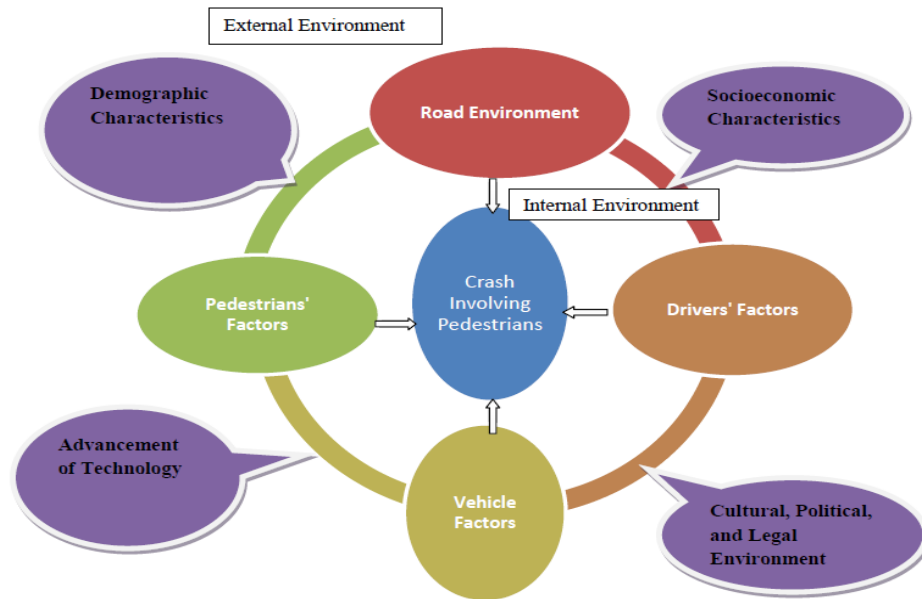


Figure 2.1.1. Interaction of Internal and External Factors on Crash involving Pedestrians as a System

Source: (7)

The road transport traffic control regulation of Ethiopia (8) defines traffic as follows:

*“Traffic means pedestrians, animals, whether ridden, driven, herded or led, vehicles and other conveyances, either singly or together, while using any road for purposes of travel or locomotion.”*

The increased vulnerability of pedestrians may be attributed on the one hand on the lack of speed, mass and protection, compared to other road users and on the other hand on their particular characteristics (e.g. flexibility, ample space requirements, diversity of attention etc.) and behavior affecting the nature of their interaction with motorized traffic. Moreover, pedestrian safety needs are not always adequately considered in road infrastructure design and traffic management (9).

Despite heavy pedestrian traffic in urban areas in Ethiopia, there are not sufficient pedestrian facilities on the road network. Sidewalks, if available, are in most cases not in proper condition. This brings the heavy traffic of pedestrians and pack animals on the smooth road surface and thus mixes with motor traffic which adds a dangerous condition for the occurrence of traffic crash (1).

Engineering measures to segregate vehicles and pedestrians or to facilitate safety on shared surfaces such as fences, guard rails, crossings, under or overpass, and speed calming facilities are inadequate or totally absent in urban areas of Ethiopia (1).

Mixed traffic presents hazards in urban areas and affects the capacity of the streets adversely. Any city will have to, therefore, develop a system of rules to regulate such traffic and enforce them strictly (10).

### **2.1.2. Road Traffic Crash**

The commonly accepted definition of **road accident** is by UK Department of Transport accident investigation manual, that road crash is “A rare, random, multiple factor event, always preceded by a situation in which one or more road users have failed to cope with the road and its environment. It is a random event from time and location (space) aspects (11).

However, World report on road traffic injury prevention (12) quests the definition as follows: “One reason for the historical neglect of “injury” in public health is the traditional view of accidents and injuries as random events that happen to others. Such events are looked upon as an inevitable outcome of road transport.”

The report further goes on and says the term “accident”, which is widely used, can give the impression, probably unintended, of inevitability and unpredictability – an event that cannot be managed. And yet it prefers to use the term “crash” instead, to denote something that is an event, or series of events, amenable to rational analysis and remedial action.

Although crashes are the result of human choices and behavior, they are not chosen (except for suicidal ones). On the contrary, when a crash happens, it is because certain road users (the crash victims) did not succeed in avoiding it, although they certainly did want to. Crashes are the unintentional side effects of certain actions taken for other reasons than that of causing injury or damage.

They are random and unpredictable in the striking sense that had they been anticipated, they would most probably not have happened. Each single crash is, in a sense, unpredictable by definition (13).

No matter how much we learn about crash generating mechanisms or countermeasures, we would never be able to predict exactly where, when, and by whom the single crash is going to occur. Crashes are random in a much more fundamental sense than almost any other event occurring in society. Although the single event is impossible to predict, the accumulation of such events may very well behave in a perfectly predictable way (13).

Research has shown that crashes tend to cluster at particular points of the network or among particular groups of road users, implying that there is often likely to be a non-random component in the occurrence of an crash. Indeed otherwise, if crashes are completely random then it is unlikely that anything could be done to prevent them save for banning all traffic (11).

The US Department of Transportation states continuous use of the word "accident" promotes the concept that events that produce injury and/or damage are outside of human influence or control. And yet "Crash", "collision", "incident"... are more appropriate terms and should be encouraged as substitute for the word "accident".

In one study (14) Oppe stresses because crashes are rare, unexpected and unpredictable events, and because crash conditions are rather complicated, it is, in general, difficult to give an unambiguous explanation for their cause or to give a reliable estimate based on historical data of the probability of a particular type of crash in the future.

A recent definition by UNECE states:-

A road traffic crash is a collision or incident involving at least one road vehicle in motion, on a public road or private road to which the public has right of access, resulting in at least one injured or killed person. Included are: collisions between road vehicles; between road vehicles and pedestrians; between road vehicles and animals or fixed obstacles or with one road vehicle alone. Included are collisions between road and rail vehicles (3).

### **2.1.3. Road Traffic Crash Severity Types**

In Ethiopia, road traffic crashes are classified into three severity categories: fatal, injury and property damage. A study in Ethiopia (15) after interviews with police officers developed appropriate definition for each crash type as follows:

A **fatal crash** is the one in which one or more individuals die as a result of traffic crash within the same reporting year of the occurrence of the crash. This definition is somehow different from the standard definition of UN which limits within 30 days.

A **serious injury** is one in which a victim sustains severe cuts, bleeding, breaks, and other damages which requires him a medical treatment as "in-patient" in hospital.

A **slight injury** is the one as a result of which the victim sustains only small cuts, scratches, and other small damages which may be treated as an out-patient without requiring admission to a hospital.

**Damage only** crash is the one as a result of which no person is injured only one or more vehicles involved in the crash are damaged.

Generally, traffic crash statistics are taken as assessment indicators of traffic safety. Traffic safety in terms of historical statistics is the resultant of two components, crash frequency (e.g.

total crashes per million vehicle kilometers per year) and crash severity (e.g. proportion of crashes with fatalities, hospitalizations, slight injuries and property damage-only (10).

#### **2.1.4. Pedestrian**

The English “**pedestrian**” stems from the Latin *pedester* which again is related to the Latin *pedes* “one who goes on foot” being derived from *pes* “foot”. There are different definitions for a pedestrian.

A recent definition by WHO states **pedestrian** is any person who is travelling by walking for at least part of his or her journey. In addition to the ordinary form of walking, a pedestrian may be using various modifications and aids to walking such as wheelchairs, motorized scooters, walkers, canes, skateboards, and roller blades. The person may carry items of varying quantities, held in hands, strapped on the back, placed on the head, balanced on shoulders, or pushed/pulled along. A person is also considered a pedestrian when running, jogging, hiking, or when sitting or lying down in the roadway (3).

Pedestrian population consists of a category of users, which can be classified as “vulnerable”. Children, the elderly, the physically challenged and those with sensory and cognitive limitations who constitute this category, deserve equal access to pedestrian facilities and protection from vehicular traffic.

Children are impulsive and have difficulty judging speed, spatial relations, distance and velocity. Auditory and visual acuity, depth perception and proper scanning ability develop gradually and do not fully mature until at least age 10.

The elderly will have physiological changes like sight and hearing impairments, and reduced walking speeds, put the elderly at a considerable disadvantage when confronting vehicular traffic on the roads.

The disabled pedestrians – visually impaired, wheelchair users and pedestrians who use special aids to walk – experience significantly higher crash risks. The accessibility of the pedestrian environment to all categories of users is a prime concern.

Pedestrian collisions, like other road traffic crashes, should not be accepted as inevitable because they are, in fact, both predictable and preventable. Walking in an environment that lacks pedestrian infrastructure and that permits use of high-speed vehicles increases the risk of pedestrian injury. The risk of a motor vehicles colliding with pedestrian increases in proportion to the number of motor vehicles interacting with pedestrians (3).

## **2.2. Pedestrians and Modes of Transport in Addis Ababa**

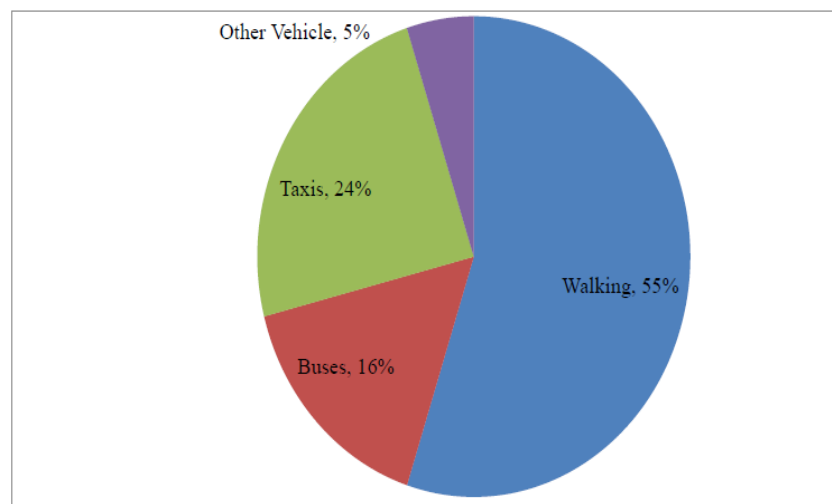
Addis Ababa is a walking city, with walking accounting for 50 to 60% of the urban trips. Though this is the case, the road network has not sufficient pedestrian walkways indicating that there is a clear policy neglect of non- motorized modes in the design of road infrastructure (16).The following table shows the coverage of roads and walkways in Addis Ababa.

**Table 2.2.1. Addis Ababa Road Network and Pedestrian Walkway Coverage as of 2010**

Road Hierarchy	Length of Varying width (Km)	Length of 7meter width (Km)	Total (Km)	Pedestrian Walkway		
				Left Side (Km)	Right Side (Km)	Total (Km)
A) Asphalt Roads						
Arterial	73	58	131	73	58	131
Sub Arterial	63	57	120	63	57	120
Collector	55	55	110	55	55	110
Local	13	13	26	13	13	26
<b>Total</b>	<b>204</b>	<b>183</b>	<b>387</b>	<b>204</b>	<b>183</b>	<b>387</b>
B) Gravel Roads		1521				
Total Network		2657				

Source: (16)

Public transport network of the city is at its lowest level with the city bus taking the lowest market share 16% in the provisions of the urban transport service. According to a transport study, walking takes a modal share of 55% and is followed by taxis 24%.



**Figure 2.2.1. Transport modes and modal share in Addis Ababa**

Source: (7)

The percentage of pedestrianized roads in Addis Ababa shows the primary focus of road design is moving cars from A to B. This means automobile-oriented environments are neither safe nor convenient for the non-motorized modes of transport. And yet pedestrians will be more vulnerable to crashes in such typical environments

The following figure shows pedestrian facilities classification given in the Addis Ababa City Roads Authority (AACRA) manual (17):

**Table 2.2.2. Classifications of Pedestrian Facilities**

<b>Classification</b>	<b>Objective</b>	<b>Treatment</b>
Time separated Facilities	To minimize conflict between pedestrians and vehicles by allotting short time periods for use of a section of road by pedestrians alternating with periods of use by vehicles	Pedestrian crossings (Zebra) School crossings Pedestrian actuated traffic signals (mid-block) Pedestrian crosswalks at signalized intersections Pedestrian refuges
Physical Pedestrian Aids	To increase the safety of pedestrians by use of physical aids within the roadway so as to reduce conflict between pedestrians and vehicles and simplify the decisions which both pedestrians and drivers have to make	Traffic islands Medians Footpath (Kerb) extensions Pedestrian fencing
Physically Separated Facilities	To increase the safety of pedestrians by eliminating conflict between pedestrians and vehicles	Subways and bridges Pedestrian malls
Integrated Facilities	To provide an environment in which pedestrians and vehicles may share existing road space in a largely unsupervised manner	Pedestrian warning signs Shared zones School zones Local area traffic management schemes Lighting

Source: (17)

### **2.3. Pedestrian Crashes Magnitude in the World**

Each year more than 270 thousand pedestrians die on the world's roads as a result of traffic crashes. In the western world, typically 10 to 30% of all road crash fatalities are pedestrians

(18). In 2010, over 70,000 pedestrians were injured and 4,200 pedestrians were killed in traffic crashes in the U.S.; nearly 75% of these pedestrian fatalities occurred in urban environments (19).

## 2.4. Road Traffic Safety, Crash Contributing Factors and Reduction Measures

### 2.4.1. Road Traffic Safety: An Overview

Traffic safety is a term that is related to the negative performance of the traffic system to generate traffic crashes that involve injury or fatality. At the individual level, traffic safety is related to the absence of danger and experience of security (20).

In the 1950s and 1960s, road safety policies in developed world emphasized the role of individual responsibility and used legislation, traffic management, drivers' licensing and vehicle inspections, and information and communication to change road users' behaviors (12). World report on road traffic injury prevention) During this time, person behind the wheel was considered as the prime reason for the crash and **focus was on driver's behavior** (21). In this course, little progress was made in reducing road injuries.

However, in 1968, Dr. William Haddon Jr., the first head of the US Highway Traffic Safety Administration, developed the Haddon Matrix in order to assist researchers to systematically address injury prevention (5). He developed **system intervention approach**.

Haddon inspired safety professionals when he talked about road transport as an ill-designed, "man-machine" system needing comprehensive systemic treatment. He defined three phases of the time sequence of a crash event that are pre-crash, crash and post-crash – as well as the epidemiological triad of human, machine and environment that can interact during each phase of a crash (12).

The Haddon Matrix shown below is a model that applies basic principles of public health to the problem of pedestrian safety.

**Table 2.4.1. The Haddon Matrix to Pedestrian Injuries from a Developing Country Context**

PHASE	FACTORS				
	Driver	Pedestrian	Vehicles	Environment	
				Road Environment	Operating Environment
Pre-crash	-Alcohol and drug impaired driving -Driver Vision problems	-Alcohol and drug impaired walking Pedestrian behavior -Pedestrian volume and mix	-Vehicle design standards -Vehicle types -Vehicle height, volume and speed	-Midblock pedestrian crossing - Standard of roads and design -Intersection	- Demographic (age, sex, education background, and ethnicity)

	<ul style="list-style-type: none"> <li>-Licensing</li> <li>-Capacity/experience of driver</li> <li>-Distance travelled (fatigue)</li> <li>-Unsafe driving behaviour</li> </ul>	<ul style="list-style-type: none"> <li>-Mobility issues for, or awareness of road safety by child pedestrians</li> <li>-Mobility, Sight or Hearing issues for Older pedestrians</li> <li>-Pedestrian distraction</li> <li>-Pedestrian disability</li> <li>-Visibility or conspicuousness of pedestrians (ease with which they can be seen)</li> </ul>	<ul style="list-style-type: none"> <li>-Large truck factor (mass)</li> <li>-Vehicle noise</li> <li>-Proportion of heavy vehicles</li> <li>-Maintenance of brakes/tires</li> <li>-Vehicle weight/power ratio</li> <li>-Vehicle movement</li> </ul>	<ul style="list-style-type: none"> <li>types and geometry</li> <li>-Urban planning (mixed use urban planning and design)</li> <li>-Traffic control devices</li> <li>- Illumination</li> <li>-Vehicle volume and speed</li> <li>-Bus stop design</li> <li>- Weather</li> <li>- Road width, median, shoulder, fence</li> <li>-Maintenance</li> <li>-Friction of road pavement</li> <li>- Sight distance (visibility)</li> </ul>	<ul style="list-style-type: none"> <li>-Land use and zoning (built up or non- built up, commercial or residential, alcohol bars' density)</li> <li>-Population density and housing development practices</li> <li>- On-road and off-road parking design and operational practice</li> <li>-Financing schemes</li> <li>-Climate change</li> <li>-Cultural safety practices for proper use of road facilities</li> </ul>
Crash	<ul style="list-style-type: none"> <li>-Knowledge</li> <li>-Use of restraints fitted and worn</li> </ul>	<ul style="list-style-type: none"> <li>-Pedestrian knowledge of self-protection strategies (has been taught methods to reduce the severity of injuries)</li> </ul>	<ul style="list-style-type: none"> <li>-Vehicle size</li> <li>-Vehicle Crashworthiness</li> <li>- Protection kits</li> </ul>	<ul style="list-style-type: none"> <li>-Highway design (footpath, shoulder, road width, etc.)</li> <li>- Placement of road furniture</li> <li>- Street lighting</li> </ul>	<ul style="list-style-type: none"> <li>-Enforcement of traffic regulation for pedestrians</li> <li>-Duties and tax incentive for imported crash worthiness cars</li> </ul>
Post-crash	<ul style="list-style-type: none"> <li>-Driver knowledge of first aid (has been taught emergency response procedures)</li> <li>- Driver knowledge of emergency drills (has been taught)</li> </ul>	<ul style="list-style-type: none"> <li>-Pedestrian crash victims' health status</li> <li>-Age and sex of victims</li> </ul>	<ul style="list-style-type: none"> <li>-Prevention of fire risk</li> <li>- Avoid leakage of hazardous materials</li> </ul>	<ul style="list-style-type: none"> <li>-Rehabilitation of the road</li> <li>-Furnish traffic control device</li> <li>-Traffic congestion priority</li> </ul>	<ul style="list-style-type: none"> <li>-Public participation in injury rehabilitation</li> <li>-Laws and regulation of transportation system regarding the injury</li> <li>-Technology (medical, road construction)</li> </ul>

	how to respond when incidents occur (phone emergency) - Prevention of delay in detecting crash				
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Source: (7)

The importance of Haddon’s matrix is that it implies the significance of working with both loss reduction and crash prevention and the significance of working with all elements of the system, not only the road-user, in order to identify causes and countermeasures (22). This work led to substantial advances in the understanding of the behavioral, road-related and vehicle-related factors that affect the number and severity of casualties in road traffic.

In the early 1990s **total harm concept** was developed by Thulin and Nilsson. According to this approach, total harm is conceptualized as a product of exposure, risk and consequences (21).

Total Harm= exposure x risk x consequences

Exposure can be defined as a measure for the amount of involvement in an activity to which a probability of certain types of harm is associated. For road traffic exposure different units of measure may be used, in relation to a certain period and a certain geographic area: (number of inhabitants, registered vehicles, vehicle kilometers, road user kilometers, vehicle hours, road user hours, trips or traffic situations (14).

Crash risk can be defined as a ratio expressing a number of crashes (all, or of a certain type) per unit of (a certain type of) exposure, for a certain period and a certain geographic area. Relevant types of crashes are distinguished based on the type (or severity) of harm, e.g. fatal crash, injury crash, and property damage-only crash.

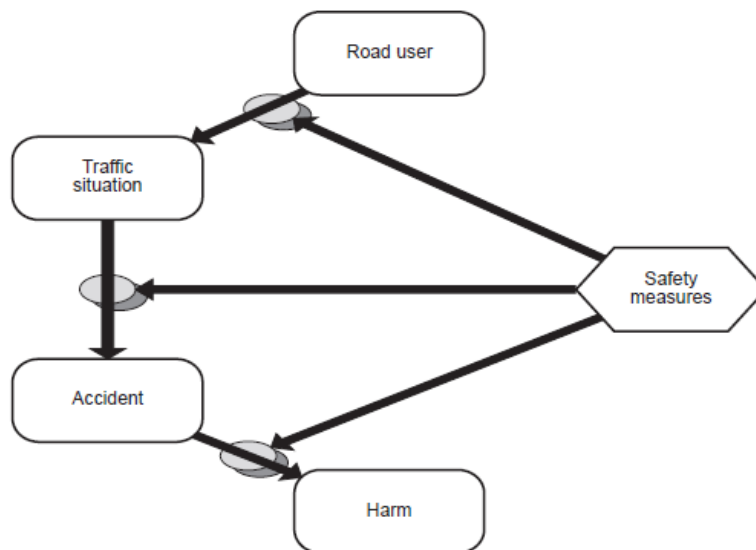
The various types of risk related to road traffic injury, and the factors influencing these risks, are (12):

- **For exposure to risk**, the determinants include economic and demographic factors, level of motorization, modes of travel, the volume of unnecessary trips and land-use planning practices.
- **For crash occurrence**, the risk factors include excessive speed, drinking and driving, unsafe vehicles, unsafe road design, and the related lack of effective law enforcement and safety regulations.

- **For injury severity**, the risk factors include the non-use of seat-belts, child restraints and crash helmets; lack of “forgiving” vehicle fronts to protect pedestrians in a collision; roadside infrastructure that is unprotective in a crash; and human tolerance factors.
- **For post-crash injury outcomes**, the risk factors include delays in detecting a crash and providing life-saving measures and psychological assistance; lack of or delayed emergency care on the spot and transport to a health facility; and the availability and quality of trauma care and rehabilitation.

Crash consequence can be defined as the number of cases of a certain type of harm per crash, or a number of crashes, of a certain type, for a certain period and a certain geographic area. Multiplication of the three dimensions provides an absolute measure for the level of traffic safety, while multiplication of only crash risk and crash consequence provides a relative measure of traffic safety, per unit of exposure.

Intervention at any level i.e. to reduce exposure or risk or the consequences of the crashes will determine the volume of the ‘total harm’ in a given environment. Intervention should be based on the ability to bring about change in any of these elements to improve road safety.



**Figure 2.4.1. Points at which road safety measures may be introduced**

Source: (23)

By the late 1990s, most comprehensive approach was developed in the field of road safety. It is the ‘**Safe System**’ approach that highlights the shared responsibility and accountability by all parties to the road transport system for improved road safety performance.

The safe system approach has four pillars (4S): safe roads and roadsides, safe speeds, safe people and safe vehicles (24). A safe system approach to road safety has as its goal the elimination of fatal crashes and reduction of serious injuries through provision of a safe transport

system that is forgiving of human error and takes into account people's vulnerability to serious injury (3). The guiding principles of the safe system approach are:

- Not all road crashes can be prevented, but traffic injuries can be reduced.
- Road traffic systems should be designed and operated to cope with human error and take better account of the vulnerability of the human body.
- Responsibility and accountability for road safety is shared by road and car designers and road users.

#### **2.4.2. Road Traffic Crash Contributing Factors in Ethiopia**

A study on road safety in Ethiopia (1) stresses the traffic safety situation can primarily be determined by conditions of the following four elements:

- The general level of traffic safety awareness and behavior of road users;
- The safety standard of road and its environment;
- The quality of the vehicle fleet; and
- The availability of comprehensive and adequate legislation and enforcement

A recent study (25) examined some of the main structural and operational problems of the road sub sector in Ethiopia and the main findings include the following constraints:

- absence of sectoral and or sub sectoral policy and comprehensive strategy,
- shortage of transport management and planning professionals in the sector,
- poor quality of human factor development, mainly training and provision of driving skill remains a significant hindrance to road safety policies,
- poor attention to the environmental protection from operators and government institutions sides, and
- there is still no integrated transport system, management and communication among the federal and regional transport offices with poor attention given to the development of non motorized transport modes and their facilities.

#### **2.4.3. Pedestrian Vehicle Crash Contributing Factors and Crash Reduction Measures: A Review**

Investigating causes of traffic crashes is complicated by the fact that a given crash seldom has a single cause. The causes of crashes and fatalities are usually complex and involve many factors. Generally, crashes occur due to factors related to the vehicle, the roadway environment and the human. The last one causing, either by itself or associated with other factors, more than 90% of vehicle crashes.

Human factors involve the actions taken by or the condition of the driver of the vehicle, including speeding, being affected by alcohol or drugs, violating traffic laws, inattention, decision errors, and age. Roadway environment factors include the design of the roadway, roadside hazards,

and roadway conditions. Vehicle factors include any failures that may exist in the automobile or design of the vehicle. Human factors are generally seen as the most prevalent contributing factor of crashes, followed by roadway environment and vehicle factors.

### **a) Human Factors**

Human factors involve the driver's actions (speeding and violating traffic laws) or other condition (effects of alcohol or drugs, inattention, decision errors, and age). Two examples of human factors that have a significant impact on traffic crashes are speeding and alcohol. The first one speeding is driving either faster than the posted speed limit or faster than conditions would safely dictate contributes to traffic crashes. Speeding reduces a driver's ability to steer safely around curves or objects in the roadway, extends the distance necessary to stop a vehicle, and increases the distance a vehicle travels when a driver reacts to a dangerous situation. The second one alcohol consumption is a significant human factor that contributes to many motor vehicle crashes. There is also a strong relationship between a driver's age and the likelihood of being involved in a crash. Some of the characteristics displayed at various ages can lead to a higher probability of being involved in traffic crashes (26).

#### **➤ Alcohol**

Drinking alcohol is determined by the driver's blood alcohol level called the 'blood alcohol concentration' (BAC), which indicates the degree of intoxication. Breathalyzer is the most common non-invasive test where a person blows air into the breath alcohol content (BrAC) is measured and converted into the corresponding BAC. Legal limits for alcohol levels in blood have been set globally, especially in Europe and the USA. The limits vary from one country to another, from as low as 0.02g/dl in Sweden reaching as high as 0.1g/dl in the United States (27& 28).

The risk of involvement in a crash increases significantly at BAC above 0.04 g/dl. The crash risk increases by at least 9 times at 0.05-0.09 BAC and at very high BAC ( $\geq 0.15$ ) the crash risk increases 3-600 fold compared to zero BAC. (35) BAC limit in Ethiopia is less or equal to 0.08g/dl both for the general population and for young or novice drivers (2).

One study (29) reviewed that alcohol intoxicated pedestrians are exposed to high fatality and injury risks in some developing countries. But as to the laws either pedestrians' alcohol levels or pedestrians' drug use are not restricted either developed nations or developing countries.

In many countries drink driving have been reduced substantially by applying the following (30):-

- Political commitment and legislation on levels of illegal BAC ;
- Well-publicized enforcement campaigns and public education to change attitudes to drinking and driving;
- Implementing good practice;
- Strict and swiftly enforced penalties for those caught breaking the law.

### ➤ **Khat**

Khat chewing is common in the countries of the horn of Africa (Ethiopia, Somalia, Somaliland, Kenya, Eritrea, Djibouti and Uganda), and across the Arabian Sea into Yemen and Saudi Arabia (31). The leaf is commonly chewed by drivers in Ethiopia and other countries in the horn and the Arabian Peninsula.

Khat is implicitly outlawed in Ethiopia under a federal law banning “driving under the influence of mind-affecting drugs”. But when it comes to enforcement, there are no readily available tests for khat consumption (32). The effect of khat on driver performance has only been studied minimally. More research is needed to explore the contribution of khat-chewing to driving impairment and to determine whether a safe level of khat consumption exists in relation to driving (33).

### ➤ **Fatigue**

There is no universally accepted definition of fatigue. The European Transport Safety Council has defined it as: “tiredness concerning the inability or disinclination to continue an activity, generally because the activity has been going on for too long” (34). The most general factors that cause fatigue are lack of sleep, bad quality sleep and sleep demands induced by the internal body clock. Besides these general factors, prolonged driving (time-on-task) can increase driver fatigue, especially when drivers do not take sufficient breaks (35). It has been estimated that driving after being awake for 17 hours leads to impaired driving skills similar to those observed for a driver with a blood alcohol concentration of 0.05 BAC (36). Moderate sleep deprivation produces impairments in cognitive and motor performance equivalent to legally prescribed levels of alcohol intoxication.

Driver fatigue is a contributing factor to reduced cognitive capacity (lower threshold of perception, poorer memory, poorer motor capacity) causing the driver to make unintentional mistakes (e.g., running a red light, failing to yield). These mistakes can cause crashes (37). Fatigue also leads to a deterioration of driving performance, manifesting itself in slower reaction time, diminished steering performance, lesser ability to keep distance to the car in front, and increased tendency to mentally withdraw from the driving task (35).

In developing countries there appear to be few studies addressing pedestrian fatigue in pedestrian crashes. In Ethiopia, police records of crashes do not provide details about the causes of pedestrian crashes, such as fatigue. One study review (29) has shown that pedestrian fatigue may result when pedestrians are walking when exhausted for example after extended physical work or walking after taking heavy medication, fasting or under the influence of alcohol or other drugs.

### ➤ **Distracted Driving**

Driving is a complex task, requiring the concurrent execution of various cognitive, physical, sensory and psychomotor skills. Driving does not always take place in ideal conditions, in which

a well-rested, well-trained and well behaving individual interacts with a simple, undemanding road environment (38).

Inattention occurring when drivers focus on an activity other than driving is known as distracted driving. Driver distraction has been found to be a contributing factor in 8 to 25 percent of road crashes (39). There are distractions internal to the vehicle such as using a mobile phone and external to the vehicle such as looking at billboards. These distractions can be visual (e.g. taking your eyes off the road), manual (e.g. taking your hands off the wheel), or cognitive (e.g. taking your mind off driving). Impairments due to distracted driving become dangerous when something unexpected happens and a distracted driver is slower to react, or may not notice the event at all (40).

There are many potential in-vehicle sources of distraction. One of the most frequently reported is the use of mobile phones (38). Many studies have shown that the use of cell phones has adverse consequences on a driver's probability of being involved in a crash. One of the most consistent findings is that drivers' use of cell phones increases their reaction times to vehicles braking ahead and responding to stop signs and stop lights (41). Some studies have shown that the reaction time of drivers increases by 0.5 to 1.5 seconds when they are talking on handheld phones. In addition, the drivers have difficulty maintaining the correct positions in their lanes, maintaining appropriate speeds and judging and accepting safe gaps in traffic (42).

### ➤ **Speeding**

Speed has been regarded as one of the major factors in the traffic safety issue. Most drivers select speed at a tradeoff between travel time and safety, at which they can both govern and feel comfortable (43). Excessive speed (driving faster than the posted limit or too fast for the prevailing conditions) has been found to contribute to a substantial number of crashes (44).

Vehicle speed could be related to traffic safety in two ways: the first one is the greater a vehicle's velocity the less time available for the operator to react to a hazard; and the second one the physical relationship of mass and speed to energy. If the first relationship exists, it would be expressed in the relative incidence of crashes at different speeds. If the second relationship exists, it would be expressed in the relative severity of crashes at different speeds. Crash rates were lowest for travel speeds near the mean speed of traffic, and increased with greater deviations above and below the mean (45).

The pedestrian fatality risk at 50 km/h is more than twice as high as the risk at 40 km/h and more than five times higher than the risk at 30 km/h (46). It can be estimated that increased driving speed increases the risk of a pedestrian injury as follows (47):

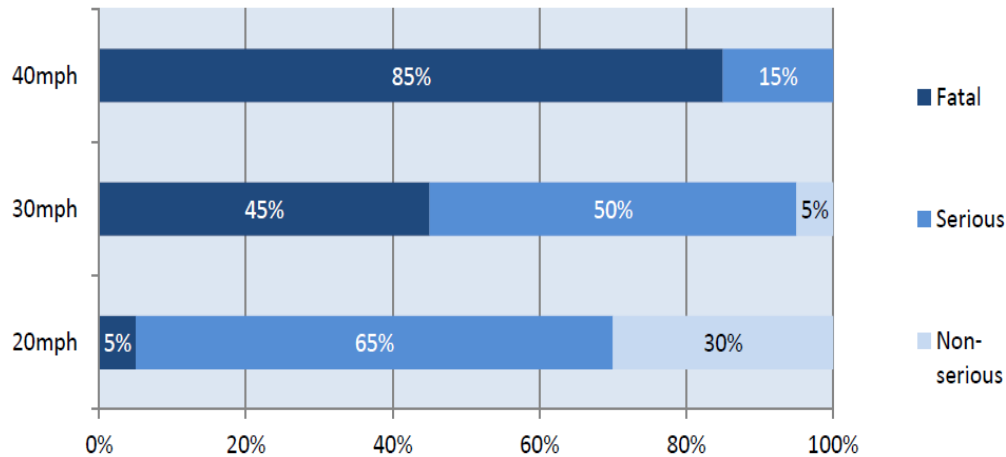


Figure 2.4.2. Effect of impact speed on pedestrian injury type

Source: (47)

An adult pedestrian has less than a 20% chance of dying if struck by a car at less than 50 km/h but almost a 60% risk of dying if hit at 80 km/h (2). The relationship between speeding and the likelihood of crashing should also be seen in a way increasing speed increases the reaction distance (the distance travelled while the driver is reacting to a situation) and the braking distance (44).

It is predicted that, if the number of speeding drivers is reduced, both the likelihood and severity of a crash will be lowered. Therefore, interventions aimed at reducing traffic speed are considered essential to preventing road injuries (44). Reductions in traffic speed were the most effective means for reducing road crash fatalities more effective than other safety interventions like reducing the amount of drunk driving (48).

Typical speed reduction measures besides posted speed limit reductions include the following (49):-

- Traffic calming (roadway design measures that force drivers to reduce speed e.g. chicanes and speed humps, and which separate different types of road-users).
- Speed enforcement using new and more sophisticated techniques including speed camera.
- Driver education and public service announcements.
- Signs that provide speed feedback to drivers to increase their awareness of speeding.

➤ **Flow**

In a seminal work by Belmont and Forbes in the mid 1950's a theory whose aim was to relate the volume of traffic and the occurrence of accidents was modeled. And it was revealed that the rate of crashes tends to increase in a linear manner with the traffic flow per hour especially on

two-lane road sections during the day. With respect to the rate of crashes, there is seemingly a U-shaped relationship with the rate of traffic flow per hour (50).

➤ **Pedestrian Exposure**

Pedestrian exposure may be defined as “the exposure risk of pedestrians to collision with motor vehicles”. Some of the common measurements of exposure in practice nowadays are based on the following: population, pedestrian volume, the travel distance approach, exposure based on time and number of trips. The greater the pedestrian volume, the higher the number of pedestrian crashes in nominal terms as compared to smaller volumes of pedestrians. That is pedestrian volume has a positive correlation with pedestrian crashes (7).

**b) Road and Environment Factor**

Roadway environment factors that contribute to, or are associated with, crashes include the design of the roadway, including features such as medians, narrow lanes, a lack of shoulders, curves, access points, or intersections; roadside hazards or features adjacent to the road that vehicles can crash into such as poles or trees; and roadway conditions (for example, rain, ice, snow, or fog).

In developing countries there is a total lack of adequate pedestrian infrastructure and a total absence of foot friendly facilities, and yet pedestrians are forced to use the roadway for walking, so their journeys often force them to cross busy roads with high volume motorized traffic, placing them in conflict at high risk of death or severe injury (7).

Pedestrian risk is increased when roadway design and land-use planning fail to plan for and provide facilities such as sidewalks, or adequate consideration of pedestrian access at intersections (3).

**c) Vehicle Factors**

Vehicle factors can also contribute to crashes through vehicle-related failures and vehicle design characteristics (attributes that may increase the likelihood of being involved in certain types of crashes).

➤ **Vehicular exposure**

Vehicular exposure can be quantified in a number of approaches, such as by distance travelled; time spent in travelling, or number of vehicles passing a point. Vehicle Kilometers are widely used in practice to measure vehicle exposure. However, vehicular exposure is not measured to quantify the risk of crashes in Ethiopia (7).

The following traffic engineering measures to reduce pedestrian-vehicle crashes include speed control, separation of pedestrians from vehicles (in time and space), and increased visibility of pedestrians (51).

### **a) Managing Vehicle Speeds or Speed Control**

Principal measures to manage vehicle speeds include modern roundabouts, traffic calming and multiway stop-sign control (51).

Roundabouts are circular intersections defined by 2 operational and design principles: yield at entry and deflection of entering traffic, which causes vehicles to enter at low speed.

European studies indicate that, on average, converting conventional intersections to roundabouts can reduce the rate of pedestrian crashes by about 75%. Moreover, single-lane roundabouts have been reported to involve substantially lower pedestrian crash rates than comparable intersections with traffic signals.

Traffic calming techniques include lane narrowing, adjustments in roadway curvature, pedestrian refuge islands, and speed humps. Although traffic calming measures clearly are effective in reducing traffic speeds effects on pedestrian–vehicle crashes are less certain.

Multiway stop sign control produces low vehicle speeds near intersections relative to traffic signal control or conventional two-way stop signs. Pedestrian collisions decreased by 25%, when multiway stop signs were installed in place of traffic signals at low-traffic volume urban intersections.

### **b) Separation of Pedestrians from Vehicles in Time and Space**

One of the measures is to separate pedestrians and vehicles by time and the second measure is to separate pedestrians and vehicles by space (51). The first one includes installation of traffic signal, traffic signal change interval timing and exclusive pedestrian signal phase. Measures under this category have generally been evaluated in terms of their effects on road user behavior and pedestrian–vehicle conflicts rather than crashes.

Installation of traffic signals reduces conflicts occurring at high speed intersections where previously no signals were present and pedestrians had difficulty in crossing.

Adequately timed yellow and all-red clearance signals ensure drivers sufficient time to clear the intersection before the display of pedestrian walk signals. In one study combined changes in the duration of yellow and all-red signal timing reduced the risk of pedestrian and bicycle crashes at intersections by 37% relative to control sites.

Exclusive traffic signal phasings—which stop all vehicle traffic for part or all of the pedestrian crossing signal— have shown to significantly reduce conflicts. A comparative analysis showed that the risk of pedestrian–vehicle crashes at intersections with exclusive timing was approximately half that at intersections with standard pedestrian signals.

The second measure that is to separate pedestrians and vehicles by space that includes pedestrian overpasses/underpasses, pedestrian barriers and fences, sidewalks and refuge islands.

Overpasses and underpasses can substantially reduce conflicts and associated pedestrian crashes. Safety effects may be limited in cases pedestrians are reluctant to use these because of security concerns or inconvenient access points.

Barriers and fences channel pedestrians to safe crossing areas and prevent them from running into traffic. These have been found to reduce midblock crossings and substantially decrease crash rates.

Sidewalks can reduce the risk of pedestrian crashes in residential areas. A study of 495 locations in urban streets with and without sidewalks was done in US. And in residential and mixed residential areas, pedestrian crashes were more than 2 times as likely to occur at locations without sidewalks than would be expected on the basis of exposure.

Residential areas with no sidewalks had 23% of all pedestrian–vehicle crashes and only 3% of exposures; commercial areas with no sidewalks were only slightly more hazardous than commercial areas with sidewalks.

Refuge islands located in the medians of two-way streets allow pedestrians to cross in two stages, simplifying the crossing task. This facility is especially helpful for pedestrians who walk at slower speeds. Refuge islands decrease conflicts, and there are significantly lower pedestrian crash rates on multilane roads with raised medians than on those without such medians.

### c) Increase Visibility and Conspicuity of Pedestrians

Table 2.4.2. Pedestrian Safety Interventions towards Visibility and Conspicuity

Intervention	Study	Results
<b>Increased intensity of roadway lighting</b>	Before-and-after at 57 urban crosswalks in Australia	Number of nighttime pedestrian crashes <b>decreased 59%</b>
<b>Crosswalk markings</b>	Crash data at 1000 marked crosswalk sites and 1000 matched unmarked comparison sites in US	On 2-lane roads, marked crosswalk was associated with no difference in pedestrian crash rate  On wider roads with traffic volumes > 12 000 vehicles per day, marked crosswalks were associated with <b>higher</b> pedestrian crash rates

<b>Bus stop relocation</b>	1 bus stop was relocated from the near side to the far side of a traffic-signal-controlled intersection on a 2-way 5-lane urban arterial	<b>Significant</b> decrease was observed in percentage of pedestrians entering roadway in front of a stopped bus
<b>Diagonal parking</b>	Diagonal parking replaced parallel parking on a 34-ft-wide 1-way, 2-lane urban street	Number of pedestrians entering roadway in front of a parked vehicle <b>significantly decreased</b>  Percentage of pedestrians who scanned for traffic before entering the roadway <b>significantly increased</b>  Vehicle speeds significantly <b>decreased by 5 mph</b>

Source: (51)

## 2.5. Methodologies and Methods of the Road Crash Investigation

Many mathematical models were developed to investigate causes of road traffic crashes. Various factors contribute towards the occurrence of crashes. The most significant are human behavior factors.

Crash modeling is based on elaboration of data relating to: exposure (e.g. distance travelled), risk (the probability of crash occurring), and loss (the value of the damage or the human injury).

The term methodology refers to the general approach taken to the research process. And the term methods refer more specifically to the various ways in which data is collected and analyzed. In this research different modeling methods were described. The methods can be applied for evaluation of significance of various factors (explanatory variables).

### 2.5.1. Crash Investigation Models

Crash investigations attempted to examine the relationship between the level of severity (dependent variable) and a set of explanatory variables, which usually include: driver attributes (e.g., age and gender), vehicle features (e.g., body type, vehicle age and number of vehicles involved in the crash), road characteristics (e.g., number of lanes, road surface conditions, intersection control and types of road), and crash characteristics (e.g., crash’s main cause) (52).

Also the influence of other variables on crash severity like speed limit, day of the week, time of the day, average traffic characteristics (AADT), weather and traffic conditions have also been investigated.

Among the wide variety of approaches, the majority of the modeling approaches were framed in the discrete response models. Statistical regression models such as the logistic regression model are broadly employed in the identification of contributing factors to crash severity. Also

ordered probit models are used to identify specific crash characteristics that increase the likelihood of crash severity. The following table shows different methodological approaches (53):

**Table 2.5.1. Methodological Approaches for Crash Research**

Dependent Variable	Method
Binary (Dichotomous)	Logistic Regression, Probit and Related Models
Count Data	Poisson Regression, Negative Binomial Regression and Related Models
Nominal (Polytomous)	Multinomial Logit, Conditional Logit
Ordered Outcomes	Ordered Logit/Probit, and Related Models
Limited/Bounded	Censored Regression (e.g. Tobit)
(Censored) Duration Data	Survival Models, Event History Analysis (e.g. Cox Regression)

Source: (53)

### **A. The Logistic Regression Model**

In assessing different risk factors, logistic regression models are appropriate if a simple random sample from the population at risk has been drawn. Logistic regression model represents the dependence of crash involvement risk (as a probability) on risk factor status variables like age of trip-maker and annual sum of hours spent travelling or annual Kilometer of vehicle (54).

Whenever units with different crash involvement status can be found in the sample and when risk factor status varies over the units, one can answer the question whether or not a certain risk factor (e.g. being a male trip-maker) significantly affects the chance of being involved in an crash.

In the classical regression, the interest is in modeling a continuous response variable  $y$  as a function of one or more predictor variables. Most regression problems are of this type.

However, there are numerous cases where the response of interest is not continuous, but binary. Logistic regression is a statistical method used to model dichotomous or binary outcomes using predictor variables.

It is used when the research method is focused on whether or not an event occurred, rather than when it occurred. Simple logistic regression is logistic regression with single predictor variable whereas multiple logistic regression is logistic regression with multiple predictor

variables. Researchers often use logistic regression to isolate the effect of specific factors on a dichotomous outcome (54).

Multinomial Logistic regression is the extension for the logistic regression when the categorical dependent outcome has more than two levels. For example: fatal, serious and slight injury types.

### **Logistic function**

$$f(z) = \frac{1}{1 + e^{-z}}$$

This function is well suited for modeling a probability because the values of  $f(z)$  range from 0 to 1 as  $z$  varies on either infinities.

### **Maximum Likelihood Estimates (MLE)**

Logistic Regression Models are estimated by Maximum Likelihood. The method of maximum likelihood estimation chooses values for parameter estimates (regression coefficients) which make the observed data “maximally likely.”

Results from logistic regression models can be presented in a variety of ways, such as an odds ratio, a risk ratio, or a risk difference. Odds ratios are easily calculated from the logit model and thus are commonly reported.

### **B. The Poisson Regression Model**

In a Poisson regression model (55), the probability of roadway entity (segment, intersection, etc.)  $i$  having  $y_i$  crashes per some time period (where  $y_i$  is a non-negative integer) is given by:

$$P(y_i) = \frac{\lambda_i^{y_i} e^{-\lambda_i}}{y_i!}$$

where  $P(y_i)$  is the probability of roadway entity  $i$  having  $y_i$  crashes per time period and  $\lambda_i$  is the Poisson parameter for roadway entity  $i$ , which is equal to roadway entity  $i$ 's expected number of crashes per year,  $E[y_i]$ .

Poisson regression models are estimated by specifying the Poisson parameter  $\lambda_i$  (the expected number of crashes per period) as a function of explanatory variables, the most common functional form being  $\lambda_i = \text{EXP}(\beta X_i)$ , where  $X_i$  is a vector of explanatory variables and  $\beta$  is a vector of estimable parameters.

Poisson models cannot handle over- and under-dispersion and they can be adversely affected by low sample means and can produce biased results in small samples.

Estimation of regression coefficients in Poisson regression model is not obtained of a direct equation, but the Newton-Raphson iteration procedure is used for estimating unknown parameters of the model.

### C. Ordered Probit Model

There is a need to understand the factors which affect the crash rate and cause higher injury severity. Ordered probit models are applied in relation to injury severity types. It identifies statistically significant relationships between explanatory variables and a dependent variable (output i.e. injury severity).

Where a unit change in explanatory variable happens, it does not assume that a minor injury and no injury is the same. Hence, ordered probit model captures qualitative differences between different injury severity types (56).

The ordered probit model uses the following form:

$$y^*_i = \beta X_i + \varepsilon_i$$

where  $y^*_i$  is a latent variable measuring the injury severity of  $i$ th crash or damage severity of  $i$ th vehicle;  $X_i$  is a  $(1 \times k)$  vector of observed non-random explanatory variables;  $\beta$  is a  $(k \times 1)$  vector of unknown parameters;  $\varepsilon_i$  is the random error term, which is assumed to be normally distributed with zero mean and unit variance.

### D. Odd Ratio

#### Basic Terms

**Odds** :Odds are simply a different expression of the probability: the probability of an event divided by the probability of the event not happening. Thus, the odds of an event would be probability/ (1– probability). Because this is a ratio, its values range from zero to infinity.

**Probability**: Probability is the proportion of times an event would occur if an observation were repeated many times. Probabilities range from 0.0 to 1.0.

**Hypothesis Testing** :The chi-squared test is a particular useful technique for testing whether observed data are representative of a particular distribution.

**Chi-Square Test** :The chi-square test is used to determine whether there is a significant difference between the expected frequencies and the observed frequencies in one or more categories. Do the numbers of individuals or objects that fall in each category differ significantly from the numbers you would expect?

The test statistic can be computed in several ways:

**Pearson chi-square** is a comparison of the observed and expected counts when the null hypothesis is true.

**Likelihood ratio chi-square** is a weighted average of the ratio of the observed and expected counts.

The two test statistics often are very similar and there is no objective way to choose between them.

## **2.5.2. Multi-Criteria Decision Making (MCDM) Methods**

This topic assesses common multi-criteria decision making (MCDM) methods. Multi-Criteria Decision Analysis has seen an incredible amount of use over the last several decades. Its role in different application areas has increased significantly including transportation problems. The following four methods were reviewed in this research: Multi-Attribute Utility Theory, Analytic Hierarchy Process, Fuzzy Theory and Data Envelopment Analysis (57).

### **A. Multi-Attribute Utility Theory (MAUT)**

MAUT is an expected utility theory that can decide the best course of action in a given problem by assigning a utility to every possible consequence and calculating the best possible utility. This method is extremely data intensive. It is most applied in economic, water management and energy management problems. MAUT needs a lot of input and preferences need to be precise.

### **B. Analytic Hierarchy Process (AHP)**

AHP is one of the more popular methods of MCDM and has many advantages, as well as disadvantages. Ease of use is one of its advantages. It uses pair wise comparisons that allow decision makers to weigh coefficients and compare alternatives with relative ease.

AHP is scalable, and can easily adjust in size to accommodate decision making problems due to its hierarchical structure. And although it requires enough data to properly perform pair wise comparisons, it is not nearly as data intensive as MAUT.

The method has experienced problems of interdependence between criteria and alternatives. The approach of pair wise comparisons can be subject to inconsistencies in judgment and ranking criteria and it does not allow individuals to grade one instrument in isolation, but in comparison with the rest, without identifying weaknesses and strengths.

### **C. Fuzzy Theory**

Fuzzy theory allows a few rules to encompass problems with great complexity. Fuzzy set theory is an extension of classical set theory that “allows solving a lot of problems related to dealing the imprecise and uncertain data”. The disadvantages include difficulties to develop it and also it can require numerous simulations before use.

#### **D. Data Envelopment Analysis (DEA)**

Data Envelopment Analysis (DEA) is used to provide policy makers with a model to aid in prioritizing actions to improve the safety of their respective roadways in the most efficient ways possible. DEA uses a linear programming technique to measure the relative efficiencies of alternatives. It rates the efficiencies of alternatives against each other. The most efficient alternative will have a rating of 1.0 and all other alternatives a fraction of 1.0.

**Analytic Hierarchy Process (AHP)** uses pair wise comparisons that allow all road users to weigh numerous factors related to pedestrian safety and these can be compared with relative ease. In this research, AHP was applied for the analysis of questionnaires designed for pedestrians, drivers and experts. Finally, factors responsible were ranked with relative ease.

### **3. METHODOLOGY AND DATA COLLECTION**

#### **3.1. Introduction**

The research was carried out in the following six phases:

1. Road traffic crash six years data were collected from Addis Ababa police Commission that includes the years 2000 up to 2005 in Ethiopian calendar (or 2007/08 up to 2012/13 G.C.)
2. To the Addis Ababa road traffic crash 6 years data; the historical pedestrians and other road users crash data were organized by severity types, motor vehicle crash involvement, reported causes of crashes, percentage of crashes, daily and hourly variation of crashes, pedestrian crash type by age group and sex and reported pedestrian activities considered as causes of crashes.
3. Pedestrian-vehicle crash three years data that includes the years 2004, 2005 and 2006 in Ethiopian calendar (or 2011/12, 2012/13 and 2013/14 G.C.) were collected from Kirkos sub city Police Main department daily crash record book.
4. To the Kirkos sub city pedestrian-vehicle crash 3 years data; pedestrian, driver, vehicle and road & environment related characteristics charts were generated for each year and different modeling methods (odd ratio and logistic regression) were applied to analyze the 3 years data in identifying the responsible factors.
5. Two types of questionnaires were designed to investigate pedestrian safety problems. These were circulated to pedestrians and drivers in Addis Ababa. Both were collected with the importance Likert scale ranking of different factors that are responsible for pedestrian safety by pedestrians and drivers of Addis Ababa. Then classifications of variables were made according to their mean importance rating, where the unimportant variables were removed from the lists.
6. After the results of the importance rating, AHP Questionnaire was designed and circulated to senior experts of highway and transportation engineering in Addis Ababa. This was to seek their opinion on pair wise comparison between Alternatives. It was analyzed using AHP calculations to determine the weight for ranking of factors (criteria and sub criteria) according to their weight influencing pedestrian safety in Addis Ababa. Finally, for the identified pedestrian safety problems possible solutions were proposed.

### 3.2. Methodological Framework

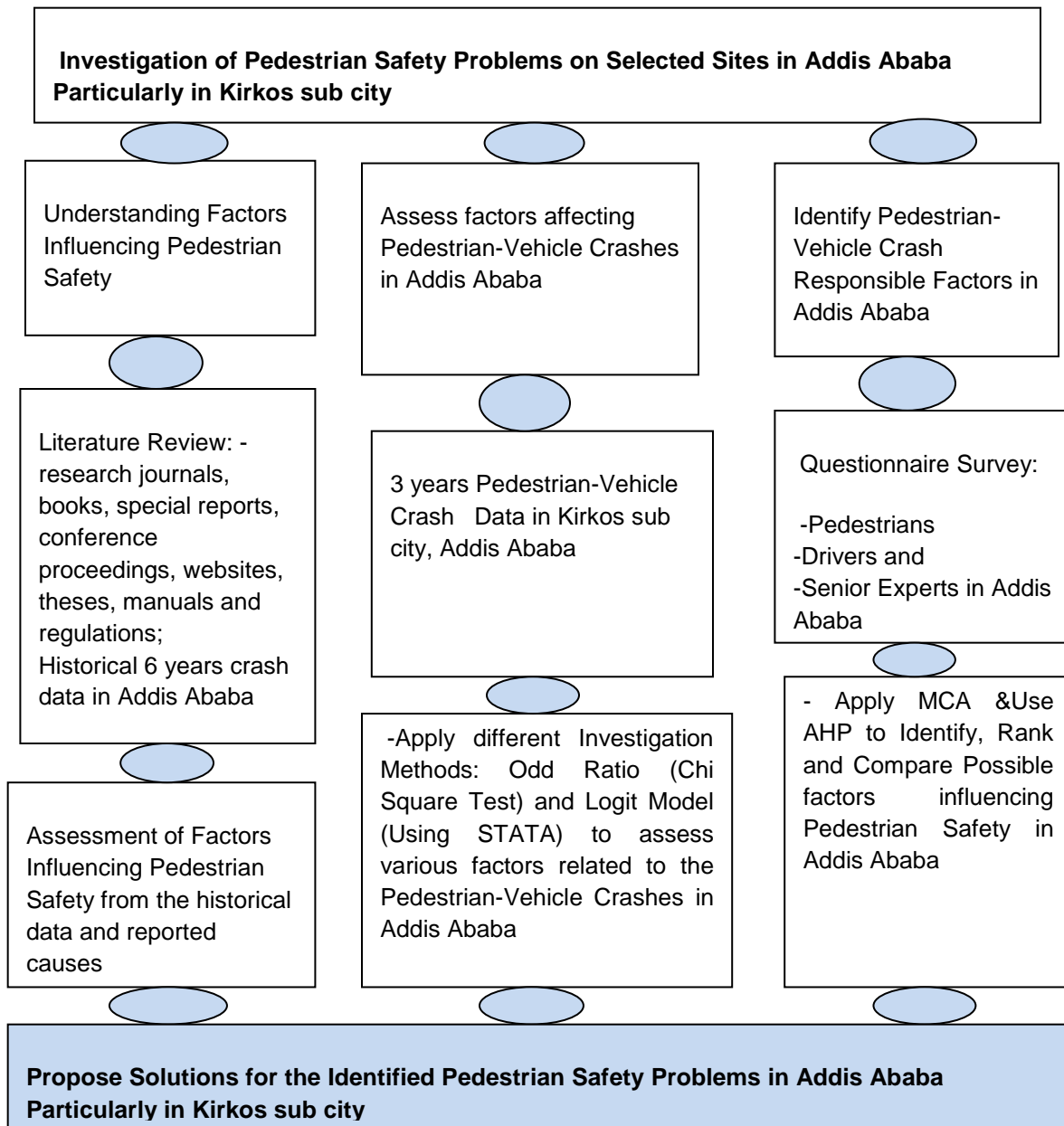


Figure 3.2.1. Methodological Framework of the Research

### 3.3. Historical Crash Data in Addis Ababa

Below is shown the road crash trend in the capital city, Addis Ababa. Secondary data were collected from Addis Ababa Police Commission.

### a) Road Traffic Crash Severity Types of Pedestrians and Other Road Users

As shown in the figure below the highest decrease during the period shown in fatal crashes is seen between 2008/09 and 2009/10.

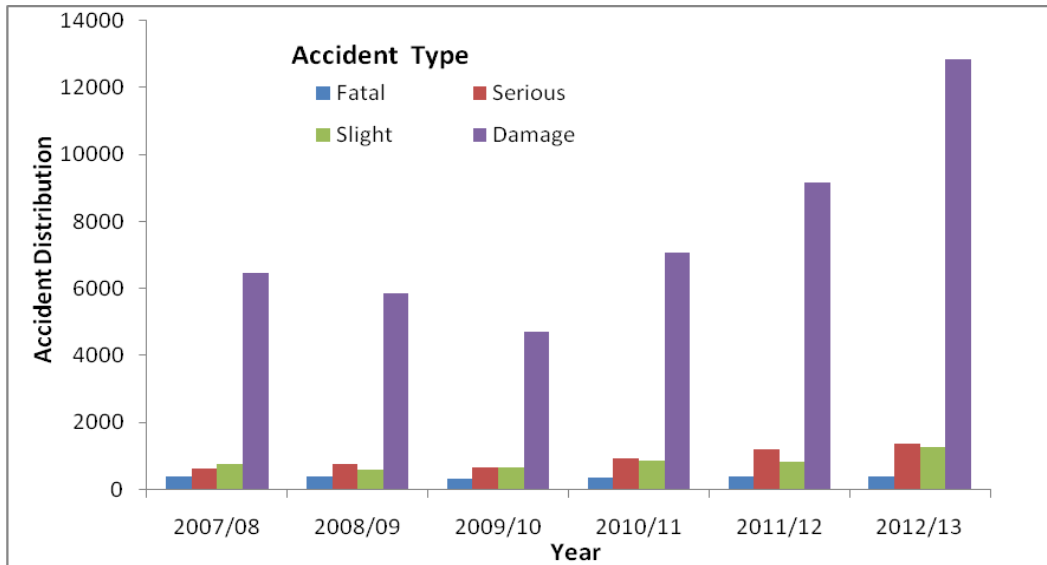


Figure 3.3.1. Road Traffic crash trend in Addis Ababa from 2007/08-2012/13

Source: Addis Ababa Police Commission

The following table shows the severity of traffic crashes over the period 2007/08-2012/13. Of the total traffic crash occurring yearly; between 2.3 to 5.6 % are fatal crashes. And over 12 to 23.1% of total traffic crash injuries are fatalities.

Table 3.3.1. Severity of Road Traffic Crashes in Addis Ababa from 2007/08-2012/13

Ethiopian Fiscal Year	Severity of crashes			Severity of injuries		
	Fatal crashes	Total crashes	% Fatal crashes	Total fatalities	Total Injuries	Fatalities as % of Injuries
2007/09	381	8169	4.7	395	1710	23.1
2008/09	371	7523	4.9	379	1678	22.6
2009/10	318	6285	5.6	340	1596	21.3
2010/11	332	9134	3.6	368	2067	17.8

2011/12	369	11529	3.2	411	2379	17.3
2012/13	367	15815	2.3	382	2966	12.9

Source: Addis Ababa Police Commission

### a) Motor Vehicle Crash Involvement on Pedestrians and other Road Users

The following table shows types of vehicles responsible for the crash types over the period 2007/08-2012/13. Fifty five percent of fatal crashes are shared by taxi (18.9%), automobile (15.1%) buses (12.6%) and Pick up (9.1%) . However, in the overall traffic crashes sixty four percent are shared by automobile (29.2%), taxi (13.1%), station wagon (12%) and pick up (10.1%).

**Table 3.3.2. Vehicle involvement in Traffic Crashes in Ethiopia between 2007/08-2012/13**

Crash Type	Automobile	Station wagon	Pick up 10qt	Truck 11-40qt	Truck 41-100qt	Truck with trailer	Taxi	Mini bus	Bus 13-45seat & >46seat	Others
Fatal	323	126	195	181	175	69	404	124	270	271
Serious	1364	603	516	362	243	67	810	399	351	666
Slight	1420	525	445	248	209	33	950	382	246	419
Damage	13979	5753	4769	2806	3184	892	5486	3249	3974	1967
Total	17086	7007	5925	3597	3811	1061	7650	4154	4841	3323

Source: Addis Ababa Police Commission

### b) Reported Causes of Road Traffic Crashes on Pedestrians and other Road Users

Major causes of road traffic crashes are shown below in figure below. Failure to give pedestrian accounted for 69% of all fatal crashes. On the other hand, the rest five causes mentioned account for 5% of all fatal crashes.

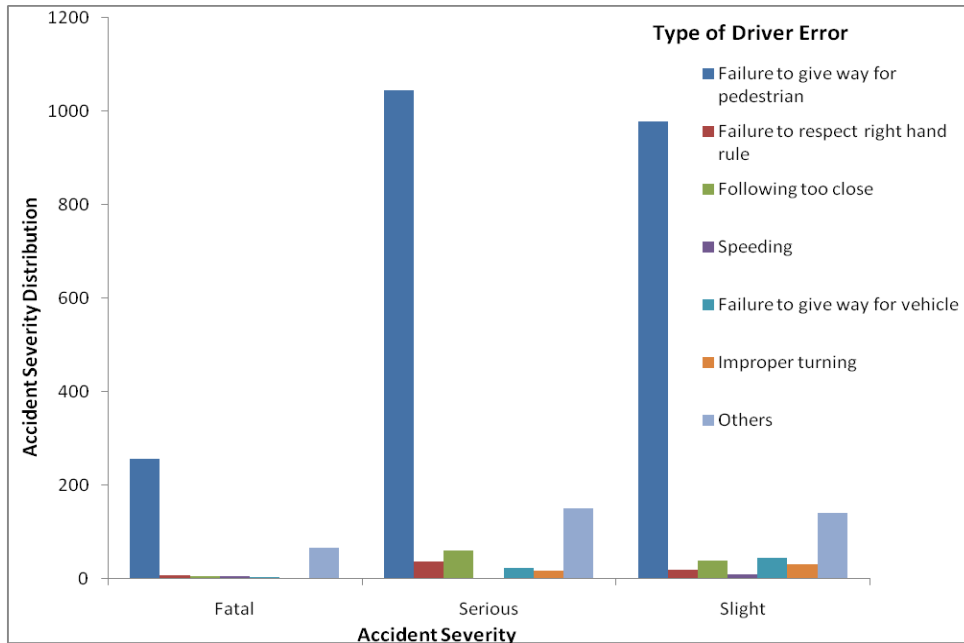


Figure 3.3.2. Major Causes of Road Traffic Crashes in Addis Ababa in 2012/13

Source: Addis Ababa Police Commission

### c) Road Crash Deaths of Pedestrians and other Road Users

The following figure shows traffic crash deaths by road user types. On average, about 88.6 percent of the road traffic crash fatalities are pedestrians, 7.7 percent are passengers and only 3.7 percent are drivers.

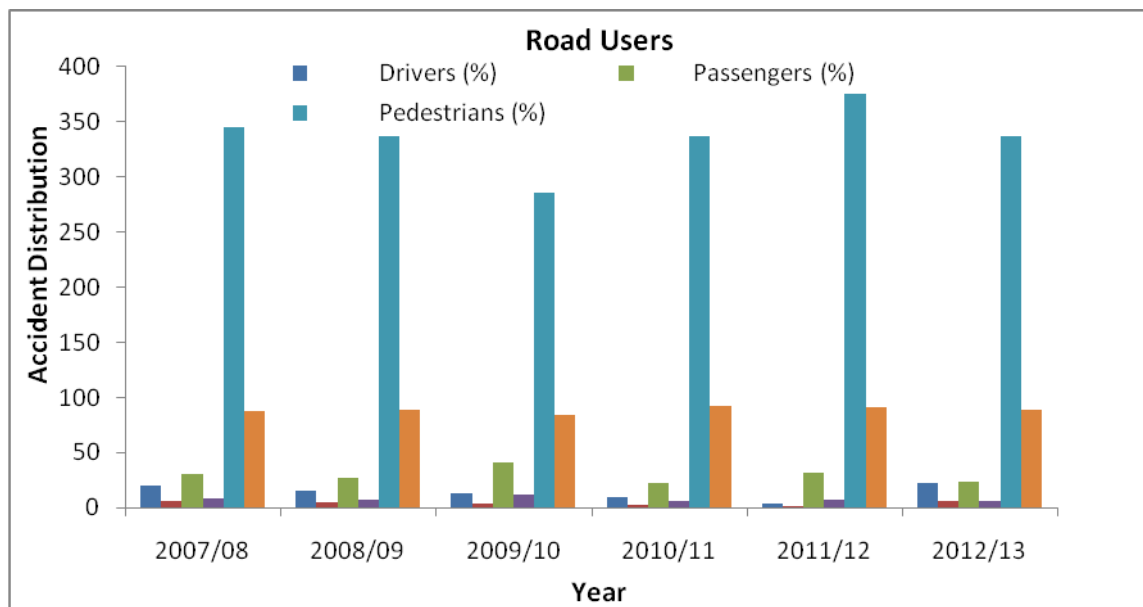


Figure 3.3.3. Traffic Fatalities in Addis Ababa by Road user type from 2007/08-2012/13

Source: Addis Ababa Police Commission

#### d) Daily and Hourly Variations of Crashes on Pedestrians and other Road Users

As shown in figure below the road crashes in Addis Ababa are fairly uniformly distributed between Tuesday and Saturday; while Monday is the peak and Sunday the lowest as shown in the figure below.

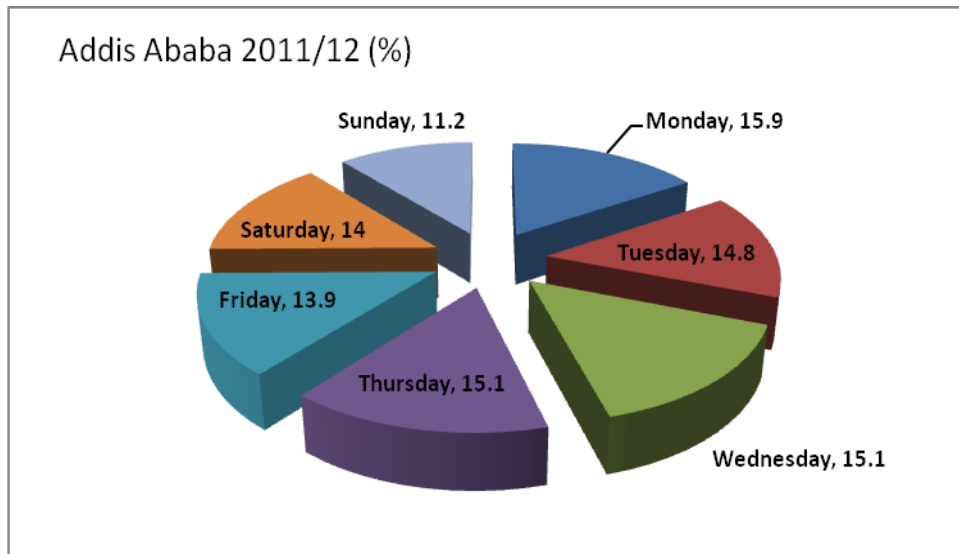


Figure 3.3.4. Road crash distribution by days of week in Addis Ababa

Source: Addis Ababa Police Commission

In figure shown below the variation of crash occurrences in hours of a day are shown for Addis Ababa for the year 2011/12. The peak occurrences in Addis Ababa were during the time where many vehicles and residents are on the road to and from work, school, etc. It coincides with peak traffic hours in the morning and afternoon.

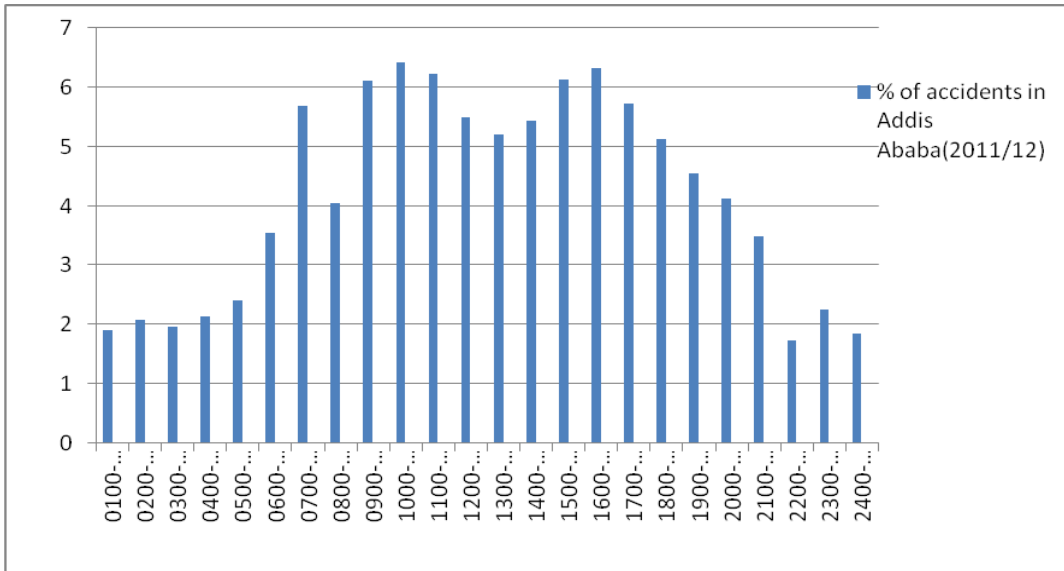


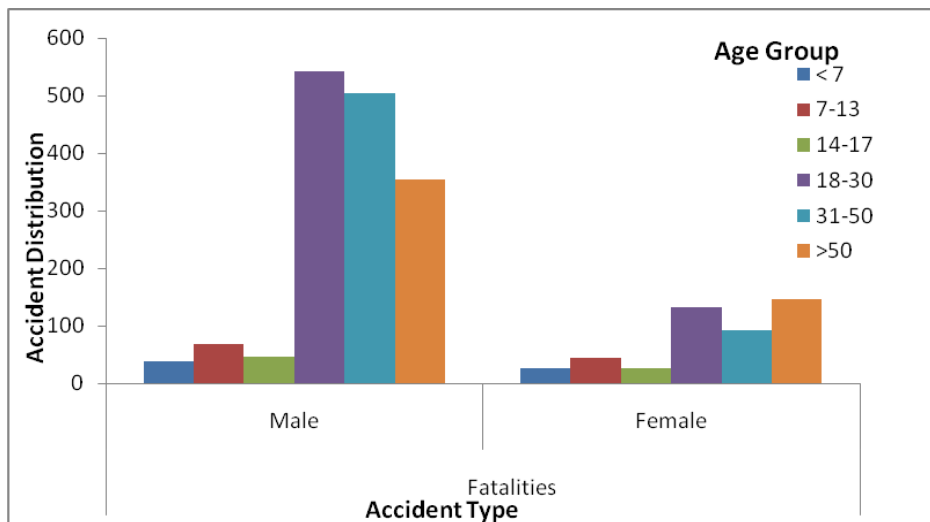
Figure 3.3.5. Hourly distributions of crashes in Addis Ababa

Source: Addis Ababa Police Commission

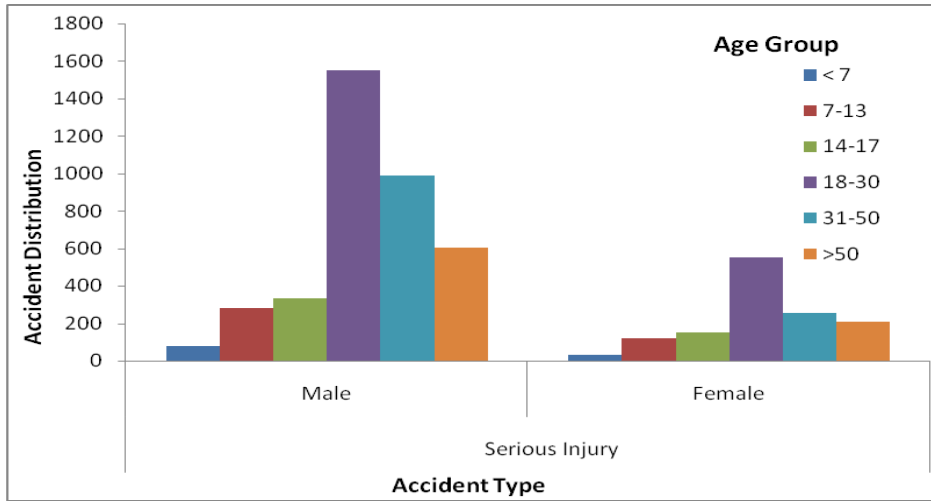
### e) Pedestrian Crash Types by Age Group and Gender

Out of total pedestrian fatalities male are 77% and female 23%. Ninety percent of male pedestrian fatalities are shared by three age groups: 18-30(34.95%), 31-50(32.5%) and >50(22.8%). And seventy nine percent of female pedestrian fatalities are shared by same age groups like males and with shares: 18-30(28.1%), 31-50(19.8%) and >50(31.3%). As to serious and slight injuries about ¾ are male and ¼ are female pedestrians.

#### a) Fatalities



b) Serious Injuries



c) Slight injuries

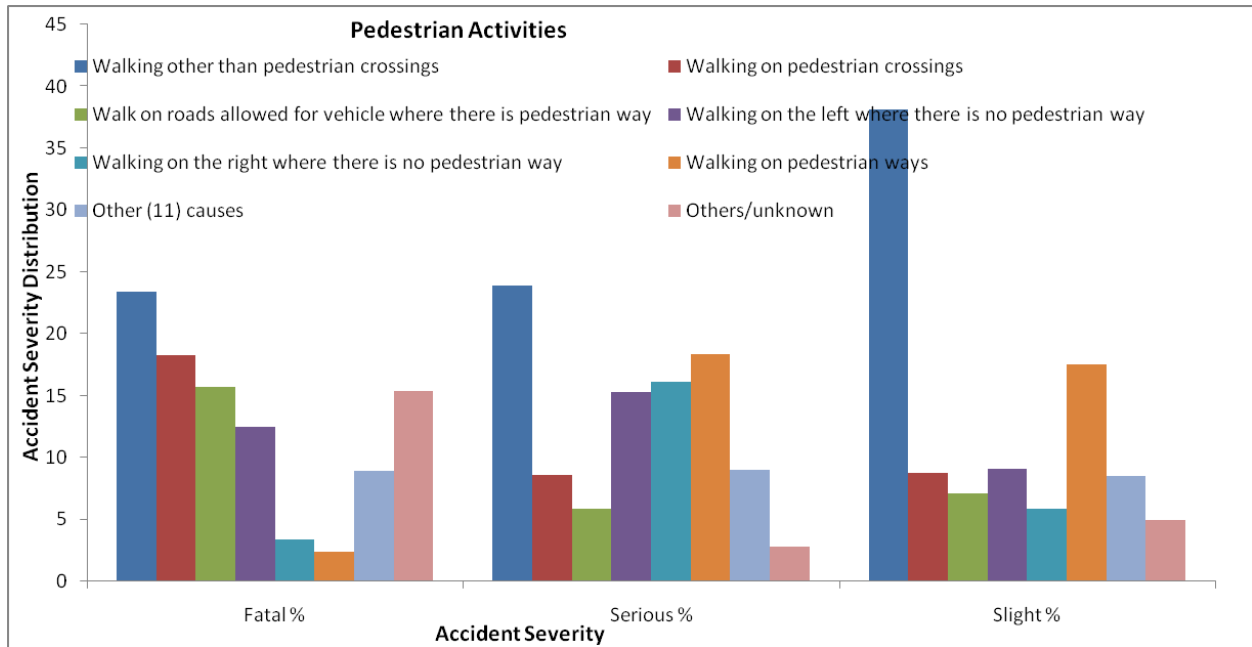


Figure 3.3.6. Pedestrian crashes in Addis Ababa between 2007/08-2012/13 by age group and sex

Source: Addis Ababa Police commission

f) Pedestrian Activities Reported to be Causes of Crashes

As shown in figure below, the six causes mentioned below contributed to 75.7, 88.2 and 86.5 per cent to fatal, serious and slight crashes respectively.



**Figure 3.3.7. Pedestrian activities reported as causes of crashes in Addis Ababa in 2011/12**

Source: Addis Ababa Police Commission

### 3.4. Survey Data Collection

Data were gathered from primary and secondary sources. Primary data were collected using questionnaire prepared for drivers and pedestrians in Addis Ababa. The questionnaire was developed in accordance with the objectives of the research which was to identify the factors that affect pedestrian safety in Addis Ababa.

The questionnaire surveys helped to get the information on rate list of pedestrian related factors affecting pedestrian safety. Similarly, drivers' information on rating of pedestrian, driver, vehicle, road and environment factors affecting pedestrian safety were collected.

Secondary data were collected from Federal Police Commission, Addis Ababa Police Commission and Kirkos sub city Police Main department. Most data attributes in the daily crash record at the Kirkos department were filled well and pedestrian-vehicle crash records for the years 2011/12, 2012/13 and 2013/14 were collected.

#### ➤ First Round of Survey

For this round of survey, the questionnaire was organized in two types.

Type I.....Rating of List of Factors affecting Pedestrian Safety by Pedestrians (Appendix B-1)

Type II..... Rating of List of Factors affecting Pedestrian Safety by Drivers (Appendix B-2)

The list of factors in the questionnaire for this study is grouped into the following categories: Pedestrian-related factors, Driver-related factors, Vehicle-related factors and Road and environment related factors.

The first one contained questions that seek to identify the rating of the respondents on the list of possible factors affecting pedestrian safety. It was filled by pedestrians and drivers. The option of evaluation was based upon Likert scale ranging from extremely important (1st level) to unimportant (5th level).

Likert Scale is named after Dr. Rensis Likert, a sociologist who developed the technique. The scale primarily is used in questionnaires to obtain participant's preferences or degree of agreement with a statement or set of statements. Respondents are asked to indicate their level of agreement with a given statement by way of an ordinal scale. Most commonly on a 5 point scale ranging from "Extremely Important" at 1st level to "Unimportant" on 5th level with "Neither" in the middle.

### ➤ **Second Round of Survey**

For this round of survey, the questionnaire was one type.

Type III.....Comparison Rating of List of Factors affecting Pedestrian Safety by Senior Experts (Appendix B-3).

In this survey questionnaire was filled by ten senior experts of highway and transportation engineering in Addis Ababa. It includes practitioners and/or educators.

#### **3.4.1. Definition**

Sampling is the selection of a subset of individuals from within a population to estimate the characteristics of whole population. The two major advantages of sampling are the faster data collection and lower cost. The following are definition of key terms:

**Population:** A population can be defined as including all people or items with the characteristic one wish to understand. That means the population should be defined in connection with the objectives of the study.

**Sample:** A sample is "a smaller collection of units from a population used to determine truths about that population".

Why sample? The population of interest is usually too large to attempt to survey all of its members.

**Probability Samples:** each member of the population has a known non-zero probability of being selected. Methods include random sampling, systematic sampling, and stratified sampling.

**Non probability Samples:** members are selected from the population in some nonrandom manner. Methods include convenience sampling, judgment sampling, quota sampling, and snowball sampling.

### 3.4.2. Sampling Technique

Sample size was determined for the survey taking the population size of the sub city and using the following formulas; and three hundred eighty four drivers and three hundred eighty four pedestrians were considered as sample population size.

Sample size Formula (SS)= $Z^2 * (p) * (1-p)$  divided in to  $c^2$

Where Z = Z value (1.96 for 95% confidence level)

p = percentage picking a choice, expressed as decimal (0.5 used for sample size needed)

c = confidence interval, expressed as decimal (0 .05 =  $\pm 5$ )

Therefore sample size=  $(1.96)^2 * (0.5) * (1-0.5)$  divided in to  $(0.05)^2 = 384.16$

Correction for finite population is necessary and the following formula was used:

New SS=SS divided in to  $(1+ (SS-1)/Population) = 384.16 / (1+ (384.16-1)/258,035) = 383.59$ ;

Population in Kirkos sub city=258,035

Therefore, the sample necessary for the survey will be three hundred eighty four.

### 3.4.3. Methods of Data Processing and Analysis

To the secondary data (pedestrian crash data) collected from Kirkos sub city, descriptive statistics was employed to analyze it. For hypothesis testing based on the pedestrian crash data, odd ratio analysis was employed using MS Excel. The relationship between dependent variable (Pedestrian crash by severity types) and independent variables, Logistic regression using STATA program was applied. For the primary data from questionnaire survey, primarily Likert scale was used to the first round survey which was analyzed using MS Excel and to the second survey Saaty scale was used where Analytic Hierarchical Process (AHP) technique was applied using MS Excel.

## 3.5. Study Area

The study was conducted in Addis Ababa, which is the capital city of Ethiopia. Addis Ababa is located in the heartland of the country with an area of 540 sq km. A population projection value of 2014 for Addis Ababa is 3,195,000 (6).

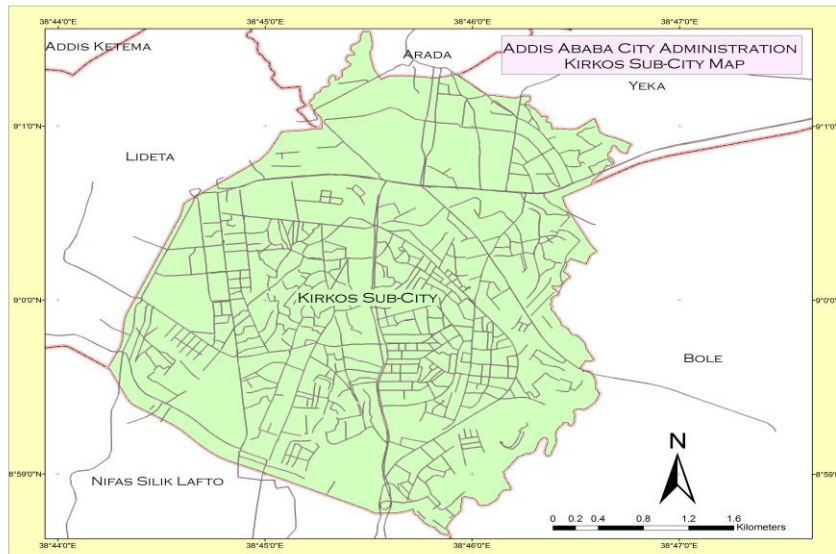
Administratively, the city is a chartered city having three layers of government: city government, sub-city administrations, and district (Wereda) administrations. There are totally 10 sub cities and the selected study site is Kirkos sub city with an area of 14.62 sq km where frequent crashes occur among the 10 sub cities of Addis Ababa. For the same projection year Kirkos-Sub City has 258,035 total populations (6).

A recent study in Addis Ababa (58) has shown there were 125 major crash black-spots in Addis Ababa as a whole. The distribution by sub city shows 10, 11, 24, 10, 21, 10, 20, 6, 4 and 9 black spots in Kirkos, Bole, Arada, Yeka, Lideta, Nifas Silk-Lafto, Addis-Ketema, Akaki, Kolfe and Gullele sub cities respectively. When the sub cities were ranked according to total road traffic crashes Kirkos ranked first followed by Bole and Arada as second and third. Based on this study and interviews with Addis Ababa Traffic Police officers; Kirkos sub city was selected for this research because of the highest total road traffic crashes.

The city has a total built up area of 169.02 sq Km and road coverage of 17.5 percent. The pedestrian walkways length in total reached 1731 Km and the total length of roads with 7 meters width reached 4671 Km (59). In Addis Ababa the public transportation is served mainly by mini bus taxis, midi buses and public buses.

### 3.5.1. Study Area Map

The following is a map showing Kirkos sub city which is located at central Addis Ababa and shares boundaries with five sub cities: Arada, Yeka, Bole, Nifas Silk-Lafto and Lideta.



**Figure 3.4.1.Kirkos Sub city Map**

Source: Ethiopian Roads Authority (2015)

### 3.6. Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (AHP) is a multi-criteria decision making (MCDM) method. It was originally developed by Prof. Thomas L. Saaty.

Basically the AHP is a method of:-

- breaking down a complex, unstructured situation into its component parts;

- arranging these parts, or variables into a hierarchic order;
- assigning numerical values to subjective judgments on the relative importance of each variable;
- synthesizing the judgments to determine which variables have the highest priority and should be acted upon **to influence the outcome of the situation.**

### **The Analytic Hierarchical Process:**

To make a decision we need to know the problem, the need and purpose of the decision, the criteria of the decision, their sub criteria, stakeholders and groups affected and the alternative actions to take. In order to make a decision and to generate priorities using AHP, we need to decompose the decision into the following **four** major steps (60):

#### **Major Steps of AHP:**

**Step 1:** Define the problem and determine the kind of knowledge sought.

**Step 2:** Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).

**Step 3:** Construct a set of pair wise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.

**Step 4:** Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom most level are obtained.

#### **Mean Importance Rating of Factors:**

The level of importance in the questionnaire for pedestrians and drivers was given five Likert-scale from 1 to 5 (where 1 is **Extremely Important (1st level)** and **Unimportant (5th level)**). Lower mean scores reflect responses that indicate lower importance of the respective factors.

The mean scores ratings were calculated using:-

$$a = \frac{1(n1) + 2(n2) + 3(n3) + 4(n4) + 5(n5)}{(n1 + n2 + n3 + n4 + n5)}$$

Where “a” is the mean importance rating of an attribute and n1, n2, n3, n4, and n5, represent the number who rated the factors as 1, 2, 3, 4 and 5, respectively. The data from the survey was analyzed using mean and standard deviation to rate the factors.

### The Saaty Rating Scale:

The Saaty rating scale is shown below including the definition and explanation for each intensity of importance. A basic, but very reasonable, assumption is that if attribute A is absolutely more important than attribute B and is rated at 9, then B must be absolutely less important than A and is valued at 1/9. These pair wise comparisons are carried out for all factors considered in the questionnaire for senior experts.

Table 3.4.1. The Saaty Rating Scale

Intensity of Importance	Definition	Explanation
1	Equal importance	Two factors contribute <b>equally</b> to the objective
3	Somewhat more important	Experience and judgment <b>slightly</b> favor one over the other
5	Much more important	Experience and judgment <b>strongly</b> favor one over the other
7	Very much more important	Experience and judgment <b>very strongly</b> favor one over the other. Its importance is demonstrated in practice.
9	Absolutely more important.	The evidence favoring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed

The basic procedure is as follows:

#### 1. Develop the ratings for each decision alternative for each criterion by

- developing a pair wise comparison matrix for each criterion
- normalizing the resulting matrix
- averaging the values in each row to get the corresponding rating
- calculating and checking the consistency ratio

#### 2. Develop the weights for the criteria by

- developing a pair wise comparison matrix for each criterion
- normalizing the resulting matrix
- averaging the values in each row to get the corresponding rating
- calculating and checking the consistency ratio

3. Calculate the weighted average rating for each decision alternative. Choose the one with the highest score.

### The Consistency Index:

Step 1. Multiply each column of the pair wise comparison matrix by the corresponding weight.

Step 2. Divide of sum of the row entries by the corresponding weight.

Step 3. Compute the average of the values from step 2, denote it by  $\lambda_{max}$

Step 4. The approximate Consistency index  $CI = \lambda_{max} - n / n - 1$  where  $n$  = order of the matrix

Consistency Ratio  $CR=CI/RI$ , where  $RI$  is a random index.

**Table 3.4.2. Random Index Values for n=1-10**

<b>n</b>	1	2	3	4	5	6	7	8	9	10
<b>RI</b>	0.00	0.00	0.58	0.9	1.12	1.24	1.32	1.41	1.46	1.49

## 4. RESULT AND DISCUSSION

In this process first the primary and secondary data were organized to MS excel sheet and prepared for different analysis methods which are shown below. The basic aim of these data analysis is to investigate the main problems and identify contributing factors for pedestrian safety in Addis Ababa.

In this research odd ratio analysis and logistic regression analysis were applied to the pedestrian-vehicle crash secondary data collected from Kirkos sub city. In addition to these, the primary data collected through questionnaires which were filled by drivers, pedestrians and senior experts in Addis Ababa that were analyzed using analytic hierarchical process.

### 4.1. Pedestrian Crashes in Kirkos sub city

The following picture is the daily crash data report format used in all Addis Ababa sub cities police main departments.

Figure 4.1.1. Crash Daily Report Format Used in Addis Ababa

The following were major data items that existed in the daily crash data report format of the sub city main police department shown in nine cells of Haddon’s Matrix:

Table 4.1.1. Major Data Collected in Daily Crash Report Format shown in Haddon’s Matrix

PHASE	FACTORS		
	Pedestrian	Vehicles & Driver	Environment
Pre-event	-Age -Gender -Health Condition -Impairment	Vehicle - Vehicle code - Vehicle year of service Driver	-Road Junction, Pavement Type, Alignment, Median or not, Surface Condition -Date, Time

		-Age, Gender, Experience, Education -Driver-Vehicle relation	-Illumination condition -Weather condition -Location
Event	-Maneuver/action	--Maneuver/action	Pedestrian Crossing Facilities
Post-event	-Severity of Injury	-Convictions following collision	

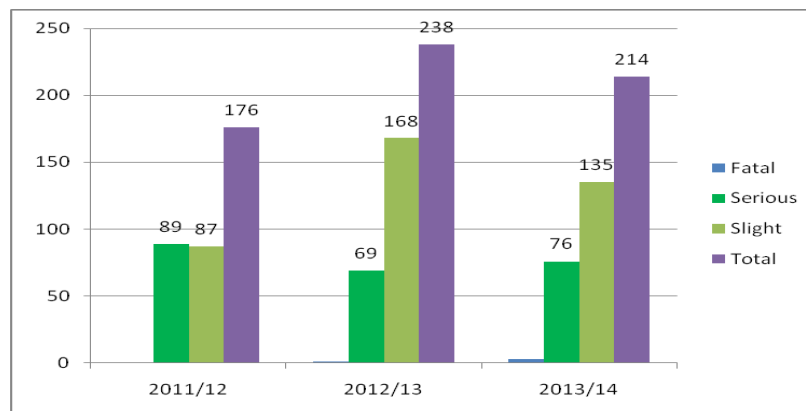
To the Kirkos pedestrian-vehicle crash 3 years' data; pedestrian, driver, vehicle and road & environment related characteristics were categorized and summarized below; the charts for each year can be referred on Appendix A. The data is summarized from the charts according to different attributes:

**Table 4.1.2 Summarized Daily Crash Data Items in Four Categories**

Pedestrian Related	Driver Related	Vehicle Related	Road & Environment Related
<b>According to</b> - Severity Types - Age Groups - Gender - Action	<b>-According to</b> -Age, -Gender -Experience -Education -Driver-Vehicle relation	<b>According to</b> - Code - Year of service	<b>According to</b> Road Junction, Pavement Type, Alignment, Median or not, Surface Condition <b>According to</b> -Date, Time -Illumination condition -Weather condition -Location

### Pedestrian Crash Severity Types

The following chart shows percentages for each year in the severity types. Pedestrian-vehicle crashes in the three years have resulted into the highest percentage of slight injuries followed by significant percentage of serious injuries and the lowest percentage of fatal injury.



**Figure 4.1.2. Pedestrian Crash Severity Types in Kirkos Sub city**

## A. Pedestrian Related Data

Table 4.1.3 Summarized Pedestrian Related Crash Data (From Pedestrian-Vehicle Crash 3 Years Data)

According to Pedestrian Crash Severity Types				
Year		%(2011/12)	%(2012/13)	%(2013/14)
Severity Types	Slight	49.4	70.6	63.1
	Serious	50.6	29.0	35.5
	Sub Total	100	99.6	98.6
	Fatal	0	0.4	1.4
According to Pedestrian Age Groups				
Age Group	18-30	47.7	45.4	43.9
	31-50	25.6	27.3	23.4
	Sub Total	73.3	72.7	67.3
	>50	17.0	15.5	22.0
	Total	90.3	88.2	89.3
According to Pedestrian Gender				
Gender	Female	24.4	24.4	27.1
	Male	75.6	75.6	72.9
According to Pedestrian Action During the Crash				
Pedestrian Action	Crossing from left to right	11.9	16.0	13.1
	Crossing the road	17.6	24.4	20.6
	Walking/standing along the roadway	25.6	22.3	25.7
	Crossing from right to left	31.3	23.5	32.7
	Total	86.4	86.2	92.1

## B. Driver Related Data

Table 4.1.4 Summarized Driver Related Crash Data (From Pedestrian-Vehicle Crash 3 Years Data)

According to Driver Age Groups				
Year		2011/12 %	2012/13 %	2013/14 %
Age Group	18-30	32.4	32.4	35.0

	31-50	58.0	54.6	53.3
	Sub Total	90.4	87.0	88.3
	>50	8.0	13.0	11.7
<b>According to Driver Gender</b>				
<b>Gender</b>	Female	5.1	2.9	5.1
	Male	94.9	97.1	94.9
<b>According to Driver Experience</b>				
<b>Experience</b>	>10 Years	54.0	51.7	54.2
	5-10 Years	22.7	20.2	19.6
	Sub Total	76.7	71.9	73.8
	2-5 Years	15.9	14.7	12.6
	Total	92.6	86.6	86.4
<b>According to Driver Education</b>				
<b>Education</b>	>Secondary	22.2	20.2	14.5
	Secondary	61.9	61.3	60.7
	Sub Total	84.1	81.5	75.2
	Primary	14.8	18.5	24.3
	Total	98.9	100.0	99.5
<b>According to Driver-Vehicle Relation</b>				
<b>Relation</b>	Employed	69.3	71.4	74.3
	Owner	11.9	18.5	13.1
	Sub Total	81.2	89.9	87.4
	Others	18.8	10.1	12.6
	Total	100.0	100.0	100.0
<b>According to Driver Action during the Crash</b>				
<b>Action</b>	Failure to give way to pedestrian	63.3	63.2	61.2
	Improper use of steering wheel	7.2	16.4	16.4
	Improper driving	27.7	18.4	21.4
	Total	98.2	98.0	99.0

### C. Vehicle Related Data

Table 4.1.5. Summarized Vehicle Related Crash Data (From Pedestrian-Vehicle Crash 3 Years Data)

<b>According to Vehicle Code</b>				
<b>Year</b>		<b>2011/12 %</b>	<b>2012/13 %</b>	<b>2013/14 %</b>
<b>Vehicle Code</b>	3	36.9	45.0	37.9
	2	34.1	28.2	34.1
	Sub Total	71.0	73.2	72.0
	1	16.5	16.8	13.1
	Total	87.5	90.0	85.1
<b>According to Vehicle Year of Service</b>				
<b>Year of Service</b>	2-5 Years	5.1	2.9	5.1
	5-10 Years	94.9	97.1	94.9
	Sub Total			
	>10 Years			
	Total			
<b>According to Driver Experience</b>				
<b>Experience</b>	>10 Years	54.0	51.7	54.2
	5-10 Years	22.7	20.2	19.6
	Sub Total	76.7	71.9	73.8
	2-5 Years	15.9	14.7	12.6
	Total	92.6	86.6	86.4
<b>According to Driver Education</b>				
<b>Education</b>	>Secondary	22.2	20.2	14.5
	Secondary	61.9	61.3	60.7
	Sub Total	84.1	81.5	75.2
	Primary	14.8	18.5	24.3
	Total	98.9	100.0	99.5
<b>According to Driver-Vehicle Relation</b>				
<b>Relation</b>	Employed	69.3	71.4	74.3
	Owner	11.9	18.5	13.1
	Sub Total	81.2	89.9	87.4
	Others	18.8	10.1	12.6
	Total	100.0	100.0	100.0

## D. Road and Environment Related Data

Table 4.1.6. Summarized Road and Environment Related Crash Data (From Pedestrian-Vehicle Crash 3 Years Data)

<b>According to Road Junction</b>				
<b>Year</b>		<b>%(2011/12)</b>	<b>%(2012/13)</b>	<b>%(2013/14)</b>
<b>Type Of Junction</b>	Intersection	9.7	17.6	20.6
	No Intersection	90.3	82.4	79.4
	Total	100.0	100.0	100.0
<b>According to Road Alignment</b>				
<b>Type of Alignment</b>	Curve	1.1	2.5	1.4
	Straight	98.9	97.5	98.6
	Total	100.0	100.0	100.0
<b>According to Road Median</b>				
<b>Road Median or not</b>	Median	87.5	80.7	88.8
	No Median	12.5	19.3	11.2
	Total	100.0	100.0	100.0
<b>According to illumination Condition</b>				
<b>illumination</b>	Night with Street Light	15.3	9.2	6.1
	Night with no Street Light	13.1	20.6	18.7
	Day light	71.6	70.2	75.2
	Total	100.0	100.0	100.0
<b>According to Weather Condition</b>				
<b>Weather Condition</b>	Raining	1.1	2.9	3.7
	Cold	4.0	1.7	6.5
	Good	94.9	95.4	89.7

	Total	100.0	100.0	100.0
<b>According to Time of the Day</b>				
<b>Time of the Day</b>	0600-1200	32.4	28.2	37.4
	1200-1800	26.7	36.1	33.2
	1800-2200	24.4	20.6	20.1
	Total	83.5	84.9	90.7
<b>According to Day of the Week</b>				
<b>Day of the Week</b>	Week Days	66.5	71.5	74.3
	Weekend	33.5	28.6	25.7
	Total	100.0	100.0	100.0
<b>According to Month of the Year</b>				
<b>Month of the Year</b>	Sep. to Nov.	21.6	23.9	25.2
	Dec. to Feb.	28.4	24.8	23.3
	Mar. to May	27.9	28.1	25.6
	Jun. to Aug.	22.1	23.0	25.7
	Total	100.0	100.0	100.0

## Summary

Based on the above data according to different attributes for pedestrian crashes in Kirkos sub city, the following is a summary of the main points:

- Most of pedestrian crashes have resulted into slight and serious injuries.
- Males accounted for higher number of pedestrian crashes as compared to females.
- The pedestrian age group 18-30 accounted for the highest pedestrian crash rate as compared to other age groups.
- The majority of pedestrian crashes occurred at locations with straight alignment, no intersection having road median during daylight hours and good weather condition.
- The majority of involved drivers in pedestrian crashes were in the age group 31-50 years and with driving experience more than ten years.
- Male drivers accounted for higher number of pedestrian crashes as compared to female drivers.
- Private and commercial vehicles with codes 2 and 3 respectively accounted for higher number of pedestrian crashes as compared to others.
- The majority of pedestrians were hit by vehicles while crossing the road from right to left and the driver reported action during the crash failure to give way to pedestrians.

## 4.2. Analysis: Hypothesis Testing and Odd Ratio

The following are a list of hypotheses to be tested using odd ratio analysis and chi square test.

### Research Hypotheses:

- **Hypothesis 1:** Drivers with Age Group 18-30 are the most responsible to pedestrian serious injuries,
- **Hypothesis 2:** Private (Code-2) vehicles are the most responsible for the occurrence of serious pedestrian injuries,
- **Hypothesis 3:** Pedestrians with Age Group 18-30 are the most vulnerable to pedestrian serious and fatal injuries and
- **Hypothesis 4:** Drivers with experiences of more than 10 years are the more responsible to pedestrian serious and slight injuries.

### Chi Square Values:

Table 4.2.1. Probability, degrees of freedom and Chi Square Values

Degrees of Freedom	Probability				
	0.99	0.95	0.05	0.01	0.001
1	0	0.004	<b>3.84</b>	6.64	10.83

### Objectives:

- To determine whether some age group of pedestrians is the most vulnerable, drivers of some age group is the most responsible and drivers of more experience are the more responsible for pedestrian crashes.
- To determine whether private vehicles are the most responsible for pedestrian crashes.

**Hypothesis 1 Testing:** Drivers with **Age Group 18-30** are the most responsible to pedestrian serious injuries.

Table 4.2.2. Parameters of Test and Age Group (18-30) of Drivers

Parameters	Drivers (18 -30)	Others	Total
Observed numbers (O)	82	152	234
Expected numbers (E)	78	156	234
O - E	4	-4	0
(O-E) <sup>2</sup>	16	16	0
(O-E) <sup>2</sup> / E	0.205	0.103	0.308

**Results:** Since the value is less than chi square value 3.84, the hypothesis has been rejected indicating that drivers in 18-30 years age group are not the most responsible to cause serious injury crashes.

**Hypothesis 2 Testing:** Private (code-2) vehicles are the most responsible for the occurrence of serious pedestrian Injuries.

**Table 4.2.3. Parameters of Test And Private Vehicles**

Parameters	Private Vehicles	Others	Total
Observed numbers (O)	75	159	234
Expected numbers (E)	75	159	234
O - E	0	-0.4777	0
(O-E) <sup>2</sup>	0.2282	0.2282	0
(O-E) <sup>2</sup> / E	0.003	0.001	0.004

**Results:** Since the value is less than chi square value 3.84, the hypothesis has been rejected indicating that code 2 vehicles are not the most responsible to cause serious injury crashes.

**Hypothesis 3 Testing:** Pedestrians with Age Group 18-30 are the most vulnerable to pedestrian serious and fatal injuries.

**Table 4.2.4. Parameters of Test and Age Group(18-30) Pedestrians**

Parameters	Pedestrians(18-30)	Others	Total
Observed numbers (O)	102	136	238
Expected numbers (E)	108	130	238
O - E	-6.39	6.39	0.00
(O-E) <sup>2</sup>	40.81	40.81	0.00
(O-E) <sup>2</sup> / E	0.377	0.315	0.691

**Results:** Since the value is less than chi square value 3.84, the hypothesis has been rejected indicating that pedestrians of age group 18-30 are not the most vulnerable to serious and fatal injuries.

**Hypothesis 4:** Drivers with experiences of more than 10 years are most responsible to pedestrian serious and slight injuries.

**Table 4.2.5. Parameters of Test and Drivers with Experience >10 years**

Parameters	Drivers with Experience >10 years	Others	Total
Observed numbers (O)	124	114	238

Expected numbers (E)	108	130	238
O - E	15.61	-15.61	0.00
(O-E) <sup>2</sup>	243.72	243.72	0.00
(O-E) <sup>2</sup> / E	2.249	1.880	4.129

**Results:** Since the value is greater than chi square value 3.84, the hypothesis has been accepted indicating drivers with experiences of more than 10 years are most responsible to pedestrian serious and slight injuries.

**Conclusion:** The last hypothesis is accepted and it implies educational measures have to target drivers with experiences more than 10 years.

### 4.3. Analysis: Multinomial Logistic Regression

There were 628 pedestrian crashes in the three years data which are rows in the MS Excel sheet and different parameters related to pedestrian, driver, vehicle and road & environment which are 23 columns in total 14,444 cells of data sets in MS Excel sheet. This data set is analyzed using STATA and the results are shown on appendix C-1. It uses maximum likelihood estimation that is iterative.

The first iteration is the log likelihood of the null or empty model; that is, a model with no predictors. At the next iteration, the predictors are included in the model. At each iteration, the log likelihood decreases because the goal is to minimize the log likelihood. When the difference between successive iterations is very small, the model is said to be converged, the iterating stops, and the results are displayed. The results are shown on appendix C-1.

#### Dependent Variable

Crash severity type is the dependent variable. Crash severity in the crash dataset was divided into three ordered categories: fatal, severe injury and slight injury.

#### Independent Variable

Pedestrian related variables, Driver related variables, Vehicle related variables, Road and Environment related variables and Time related variables.

**Objective:** To identify and describe the contributing factors to crash severity.

#### Chi-Square Test

Testing the significance of association of each explanatory variable could have with the dependent variable is done using SPSS. The chi square test results are shown in the table below. The test indicates that the variables: pedestrian sex, driver sex, driver-vehicle relation and junction type are significantly associated with the dependent variable severity type. The cross tabulation of each contributing attribute verses fatal, serious and slight injury is shown on Appendix C-2.

The chi-square test of association assumes that for variables having p-value less than the  $\alpha$ -value (0.05), the null hypothesis can be rejected at that specified level of significance and there will be sufficient evidence to conclude that there were significant relationship between those explanatory variables and the dependent variable, otherwise not.

**Hypothesis:** (**H0:** There is no association between the occurrence of accident and the different independent variable categories; **H1:** There is association).

**Table 4.3.1. Statistical Inference: Association of Crash Severity Types with different Independent Variables**

<b>Variables</b>	<b>Chi-Square</b>	<b>Df</b>	<b>P-value</b>
Pedestrian Age	8.555	12	0.740
<b>Pedestrian Sex</b>	10.193	2	<b>0.006*</b>
Pedestrian Condition	1.387	8	0.994
Pedestrian Activity	14.028	14	0.448
Driver Age	3.212	8	0.920
<b>Driver Sex</b>	6.530	2	<b>0.038*</b>
Driver Education	3.018	6	0.807
<b>Driver-Vehicle relation</b>	9.547	4	<b>0.049*</b>
Driver Experience	7.197	8	0.516
Vehicle Code	9.432	10	0.492
Vehicle Year of Service	11.623	8	0.169
Median	0.705	2	0.703
Alignment	0.078	2	0.962
<b>Junction</b>	8.738	2	<b>0.013*</b>
Pavement Type	4.160	4	0.385
Road Condition	1.036	2	0.596
Light Condition	2.995	4	0.559
Weather Condition	5.521	4	0.238
Crash Time	34.790	46	0.887
Crash Day	11.970	12	0.448
Crash Month	23.858	22	0.355

### **Multinomial Logit Model Goodness of Fit Test**

The dependent variable, severity type, was described as fatal, serious and slight injuries respectively. In the process of model estimation in the STATA software, crash severity was described in terms of alternatives 1, 2 and 3 representing crash injury severity ranging from fatal to slight severity types respectively.

The response variable, severity type is going to be treated as categorical under the assumption that the levels of injury status have no natural ordering and are going to allow STATA to choose the reference group, as default.

### Overall Test of Model Adequacy

**LR chi2(42)** is the Likelihood Ratio (LR) Chi-Square test that at least one of the predictors' regression coefficient is not equal to zero in the model. The number in the parenthesis indicates the degrees of freedom of the Chi-Square distribution used to test the LR Chi-Square statistic and is defined by the number of predictors in the model.

For the analysis taking slight injury as a base outcome, the LR Chi-Square statistic can be calculated by  $-2*(L(\text{null model})-L(\text{fitted model})) = -2*((-437.02768)-(-402.11906)) = 69.81724$ , where  $L(\text{null model})$  is from the log likelihood with just the response variable in the model (Iteration 0) and  $L(\text{fitted model})$  is the log likelihood from the final iteration (assuming the model converged) with all the parameters. The null hypothesis is that all regression coefficients across models are simultaneously zero. The small p-value from the LR test  $<0.01$  shows at least one of the regression coefficients is not equal to zero. And Likelihood Ratio Index is calculated by  $1-(L(\text{fitted model})/L(\text{null model}))=1-(-402.11906/-437.02768)=0.08$  or 8%; which is greater than zero. This means the estimated parameters do better in terms of likelihood function than zero parameters or null model.

**Conclusion:** Factors contributing to crash injury severity from the analysis output are identified. The results show driver vehicle relationship, junction type, pedestrian age and pedestrian sex are the main contributing factors associated with pedestrian crash serious injury severity type.

### 4.4. Analysis: Analytic Hierarchical Process (AHP)

Pedestrians and drivers questionnaire includes in total hundred lists of responsible factors for pedestrian safety. The filled out questionnaire by pedestrians and drivers gives the importance rating by each individual. Then five top factors were selected from the four categories related to: Pedestrian, Driver, Vehicle and Road and Environment which reduced the list to a total of twenty.

#### 4.4.1. Pedestrian Safety Problems Identified from Crash Data Analysis

The last hypothesis in the **odd ratio analysis** is accepted and it implies educational measures have to target drivers with experiences more than 10 years. Since the values shown are less than chi square value 3.84, the other three hypothesis have been rejected indicating that: drivers in 18-30 years age group are not the most responsible and pedestrians of age group 18-30 are not the most vulnerable to serious and fatal injuries; and that code 2 vehicles are not the most responsible to cause serious injury crashes.

#### 4.4.2. Pedestrian Safety Problems Identified from Questionnaire Survey

The following table shows the factors with their rating and rank.

**Table 4.4.1. Mean Importance Ranking of Selected Twenty Pedestrian Safety Problems Based on Pedestrians and Drivers Rating of Hundred List of Responsible Factors**

<b>1. Human Factors: Pedestrian Related</b>	<b>MIR</b>	<b>Rank</b>	<b>Average of MIR</b>
Pedestrian Not Using Crossings	2.28	1	<b>2.71</b>
Distracted Pedestrian (e.g. Using Mobile Phone)	2.53	2	
Pedestrian of the Opinion that they are Seen by the Driver	2.57	3	
Pedestrian Disability or illness, Mental or Physical	2.62	4	
Alcohol/Drug Impaired Walking	2.64	5	
<b>1. Human Factors: Driver Related</b>	<b>MIR</b>	<b>Rank</b>	<b>Average of MIR</b>
Safety Awareness of Drivers	2.08	1	<b>2.91</b>
Driver Rush and Negligence	2.42	2	
Alcohol Use by Drivers	2.51	3	
Improper or Erratic Lane Changing	2.53	4	
Drivers Fatigue	2.55	5	
<b>2. Vehicle Related Factors</b>	<b>MIR</b>	<b>Rank</b>	<b>Average of MIR</b>
Speed Management	2.64	1	<b>3.08</b>
Dazzling headlights	2.88	2	
Manufacturing Defects (Related to Quality Control)	2.93	3	
Visor or windscreen dirty or scratched	2.95	4	
Vehicle Brake System Bad Condition	2.97	5	
<b>3. Road and Environment Related Factors</b>	<b>MIR</b>	<b>Rank</b>	<b>Average of MIR</b>
Road Design and Layout (e.g. Bend, Hill, narrow Carriageway)	2.13	1	<b>2.79</b>
Insufficient Pedestrian Facilities	2.2	2	
Insufficient Traffic Signs/Signals/Markings	2.28	3	
Land Use Pattern and Composition (School/Market Area etc)	2.33	4	
Lack of Integration of Needs of Pedestrians in the Planning	2.37	5	

Then these twenty factors; five from each categories were taken and pair wise comparison by senior experts was employed by Analytical Hierarchial Process (AHP) technique. Analyzing these resulted in a rank for each factor with their global weight.

Three experts failed consistency check in relation to pedestrian related (Absolute value of  $0.15 > 0.1$ ), driver related (Absolute value of  $0.18 > 0.1$  and  $0.12 > 0.1$ ) and vehicle related ( $0.13 > 0.1$ ) and yet rejected from being considered for average weighting.

The first rank shows the most responsible factor and the last with the lowest. The following table shows the list of twenty factors with their rank and respective global weight.

**Table 4.4.2. Top Twenty Pedestrian Safety Problems Identified with their Global Weight**

Parameter	Rank	Global Weight%
Alcohol Use by Drivers	1	11.55
Driver Rush and Negligence	2	6.804
Improper or Erratic lane Changing	3	6.048
Distracted Pedestrian (e.g. Using Mobile Phone)	4	5.424
Insufficient Pedestrian Facilities	5	5.3148
Lack of Integration of Needs of Pedestrians in the Planning	6	5.0882
Drivers Fatigue	7	4.704
Alcohol or Drug Impaired Walking	8	4.6556
Pedestrians Not Using Crossings	9	4.633
Safety Awareness of Drivers	10	4.494
Vehicle Brake System Bad Condition	11	4.08
Land Use Pattern and Composition (School, Market Area, etc)	12	4.0376
Speed Management	13	4.035
Pedestrian Disability or illness, Mental or Physical	14	3.7742
Road Design and Layout (e.g. Bend, Hill, Narrow Carriageway)	15	3.399
Insufficient Traffic Signs/ Signals/Markings	16	2.7398
Manufacturing Defects (Related to Quality Control)	17	2.04
Pedestrians of the Opinion that they are seen by the Driver	18	1.8532
Dazzling Headlights	19	1.71
Visor or Wind Screen- Dirty or Scratched	20	1.65

The twenty factors can be grouped to the four categories related to: Pedestrian, Driver, Vehicle and Road and Environment. The following table shows five factors in each category with their local and global ranking.

**Table 4.4.3. Pedestrian Safety Problems Identified in Four Categories with their Rank and Global Weight Based on Senior Experts Rating**

<b>1. Human Factors: Pedestrian Related</b>	<b>Local Rank</b>	<b>Global Rank</b>	<b>Global Weight%</b>
Distracted Pedestrian (e.g. Using Mobile Phone)	1	4	5.424
Alcohol or Drug Impaired Walking	2	8	4.6556
Pedestrians Not Using Crossings	3	9	4.633
Pedestrian Disability or illness, Mental or Physical	4	14	3.7742
Pedestrians of the Opinion that they are seen by the Driver	5	18	1.8532
<b>2. Human Factors: Driver Related</b>	<b>Local Rank</b>	<b>Global Rank</b>	<b>Global Weight%</b>
Alcohol Use by Drivers	1	1	11.55
Driver Rush and Negligence	2	2	6.804
Improper or Erratic lane Changing	3	3	6.048
Drivers Fatigue	4	7	4.704

Safety Awareness of Drivers	5	10	4.494
<b>3. Vehicle Related Factors</b>	<b>Local Rank</b>	<b>Global Rank</b>	<b>Global Weight%</b>
Vehicle Brake System Bad Condition	1	11	4.08
Speed Management	2	13	4.035
Manufacturing Defects (Related to Quality Control)	3	17	2.04
Dazzling Headlights	4	19	1.71
Visor or Wind Screen- Dirty or Scratched	5	20	1.65
<b>4. Road and Environment Related Factors</b>	<b>Local Rank</b>	<b>Global Rank</b>	<b>Global Weight%</b>
Insufficient Pedestrian Facilities	1	5	5.3148
Lack of Integration of Needs of Pedestrians in the Planning	2	6	5.0882
Land Use Pattern and Composition (School, Market Area, etc)	3	12	4.0376
Road Design and Layout (e.g. Bend, Hill, Narrow Carriageway)	4	15	3.399
Insufficient Traffic Signs/ Signals/Markings	5	16	2.7398

#### 4.5. Discussion on Solutions to Improve the Identified Problems

This approach attempts to give solutions to the problems by bringing active institutions, a road safety policy and an urban safety strategy so that the current conditions will be changed towards better road safety situations to pedestrians in Addis Ababa.

##### 4.5.1. Institutions and Road Safety: Existing Condition and Proposed Approach

###### ✓ Road Safety Policy: An Umbrella

The National Road Traffic safety Council of Ethiopia was established in 2011 and the objective of the council is to devise road traffic safety strategy and coordinate the concerned organs for its implementation where the Council is accountable to the Ministry of Transport. There is not yet a road safety policy and an active institution responsible for road safety in Ethiopia (61).

Road Safety Policy needs to be formulated and implementing it is necessary. The policy will set institutional responsibilities with a framework for action which is very useful towards improving road safety existing condition in Ethiopia.

###### ✓ National Road Traffic Crash Data: A Responsible Institution

Currently crash data is being collected in Addis Ababa by sub cities police main departments and summarized at city level finally by Addis Ababa Police Commission. The data are being recorded manually in the sub cities and the daily crash data record books are kept in the archives.

These demand to formulate new and standard formats that are acceptable internationally and establish an institution responsible for the crash data management. This would help a lot in understanding the problems and it will become reliable input to researches related to road safety.

#### ✓ **Research on Road Safety: Road Safety Research Centre**

Road safety research demands quality and detailed crash data. Based on these researches can be made that can mainly help understand the underlying problems. Road safety related decisions need the input of scientific research and information. Without the help of focused research on the current problems of road safety in Ethiopia, it would be difficult to alleviate the problems towards the safety of all road users including pedestrians.

Establishing Road Safety Research Centre of Ethiopia is necessary in order to address the current safety problems in a modern and scientific way in the capital Addis Ababa and at national level. As pedestrians are the majority in injuries and the most vulnerable in Addis Ababa, the priority research area will logically be on identifying the problems and possible solutions for them.

There are **International Experiences of Research** efforts that played a significant role in reducing road crashes and helped in developing policies related to road safety. The Transportation Research and Injury Prevention Program in New Delhi, India, made a contribution towards a better understanding of the problems of vulnerable road users and possible interventions for low and middle income countries (12).

#### **4.5.2. Basic Concept to Acculturate**

Crash statistics shows numbers and different crash data attributes. But the human life is far beyond numbers and losing one person by crash is losing a unique one; that means it will never be replaced by another one. This concept is what we learn from the Vision Zero: **Every Human being is Unique and Irreplaceable**". The meaning of losing would be better if it is looked and understood from this perspective by all road users. This concept has to be one of the issues to educate to pedestrians and other road users in Addis Ababa and Ethiopia.

#### **4.5.3. Urban Safety Management: An Area-wide and Multi-disciplinary Approach**

Pedestrian safety is an issue in Addis Ababa which demands an approach to improve the current problems and make the walking safe for pedestrians. The top twenty factors responsible for pedestrian safety in Addis Ababa shows the responsible bodies to handle the issues are many. For example, alcohol use by drivers' needs involvement of traffic police, provision of sufficient pedestrian facilities lie under city roads authority and land use pattern lie under the responsibility of the city municipality office. These show the problems have to be addressed in an integrated and holistic manner involving all responsible.

**Urban Safety Management** involves all aspects of urban management: safety, enforcement, engineering, traffic, land use, planning, public transport, education, environment, etc. The Urban Safety Management is appreciable as it is based on the expertise, knowledge and opinions of everyone concerned or affected: The Public, The Politicians and The Practitioners (62).

The overall road hierarchy is considered according to the road function with the aim of getting traffic onto appropriate routes. And the approach has shown significant benefits in casualty reduction as it looks the traffic and the pedestrian movement as a whole and sets a vision and strategy for road safety management.

**Urban Safety Management** defines the principles of a good safety management strategy as one which (62):

- ✓ formulates a safety strategy for the urban area as a whole;
- ✓ integrates safety with other urban strategies (e.g. transportation, land use planning, safer routes to schools);
- ✓ considers all kinds of road users, especially vulnerable road users;
- ✓ considers the functions of different kinds of road;
- ✓ integrates existing casualty reduction efforts into the strategy;
- ✓ uses opportunities where other policies and strategies may help to enhance safety (e.g. improving safety within an urban regeneration ongoing projects in Addis Ababa city centers);
- ✓ encourages all professional groups to help to achieve safety objectives;
- ✓ guards against possible adverse safety affects of other policies; encourage residents and all road users to become actively involved in the process and thereby take ownership of it;
- ✓ translates the strategy and objectives into local area safety schemes;

The **Urban Safety Management** approach has the following main features where it stresses problems are not approached at piecemeal basis (62):

- ✓ In urban areas, multiple objectives are set concerning the promotion of local activities and the movement of traffic, often under competing interests. In this context, road safety problems cannot be treated separately.
- ✓ Crashes are usually dispersed across an urban area. However this distribution is subject to fluctuation. Therefore, it would be inappropriate to design countermeasures for individual crash sites only.
- ✓ Safety measures are more effective if they form part of a comprehensive safety policy. To ensure maximum impact complementary measures of a policy should be identified and coordinated.
- ✓ Traffic safety may not be a leading priority issue for local policy makers or citizens. Therefore, as well as direct safety initiatives, there is a need for embedding safety measures in other policies.

- ✓ Integrated safety programmes help local authorities compile a complete picture of existing problems before defining priorities for action.

In general, the approach we employ has to consider the whole situation and it has not to treat problems at individual level. For pedestrian safety, creating safer and connected pedestrian routes would help enable the pedestrians' safe walking culture. This has to start from the planning stage which needs consultation of stakeholders and basically the vulnerable majority who are pedestrians of the city.

In land use planning and in urban road network planning, consideration has to be given to pedestrians needs. The network has to be safety conscious giving priority to the pedestrian safety.

It is possible to modify and moderate the attitudes and behavior of drivers and pedestrians through training, information and enforcement of traffic regulations and laws. This will enhance the awareness level of drivers and pedestrians whereby drivers will be able to respect road rules like improper or erratic lane changing and rushing and negligence, etc. and also by introducing legislation for the improved enforcement of pedestrian behaviour; pedestrians will be able to respect road rules like using mobiles while crossing, not using pedestrian crossings, etc.

Drivers' alcohol use ranked first in the survey made in Addis Ababa. It needs serious attention and appropriate measure towards safe driving habits. Drink driving could be reduced substantially by formulating legislation on levels of illegal 'blood alcohol concentration' (BAC) and enforcement of it and public education to change attitudes to drinking and driving. Drivers fatigue could be moderated by having flexible working hours or education would contribute in understanding or grasping taking rest is basic for attentive driving and is necessary towards safe driving habits. In such a way it is possible to moderate attitude of drivers.

## **5. CONCLUSION AND RECOMMENDATION**

### **5.1. Conclusion**

In this research, driver behavior factors ranked the top three responsible for pedestrian crashes in Addis Ababa. It shows the need to moderate the behavior and attitude of drivers that is necessary to reduce the current pedestrian crash in Addis Ababa. The logistic regression results show driver vehicle relationship, junction type, pedestrian age and pedestrian sex are the main contributing factors associated with pedestrian crash serious and slight injury severity types.

Road safety problems and pedestrian safety problems in Addis Ababa has to be approached not at a piecemeal way; rather in a holistic way. In this regard, road safety policy needs to be formulated and implementing it will follow where an area-wide and multi-disciplinary approach: urban safety management, that considers safety in the whole urban area could be adapted in a strategic way towards promoting road safety and pedestrian safety in Addis Ababa.

### **5.2. Recommendation**

This research shows the level of pedestrian crashes in recent years. The policy makers have to take the lead in bringing an organized system at the city level so that every stakeholder has to take their share of objectives in order to achieve a common goal towards pedestrian safe city, Addis Ababa.

There is very limited research activity related to pedestrian safety in Addis Ababa. One of the factors that can favor pedestrian safety being priority issue by decision making professionals and officials could be research output on this issue. But research needs reliable and quality data. Currently the data we have from police is not sufficient and with low quality and formulating a new and standard crash data format and how to collect, store and analyze has to be given attention.

Therefore, further detailed study on pedestrian safety factors on pedestrian crashes, driver factors on pedestrian crashes, vehicle factors on pedestrian crashes and road and environment factors on pedestrian crashes would help more in understanding the current problems on pedestrians in Addis Ababa; so that in a holistic way the city could become safer.

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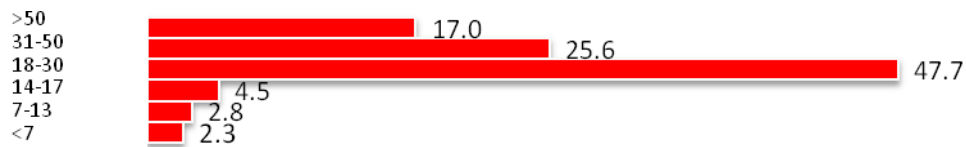
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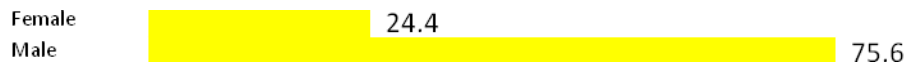
## APPENDICES

Appendix – A  
Pedestrian-Vehicle Crash Characteristics in Kirkos Sub city

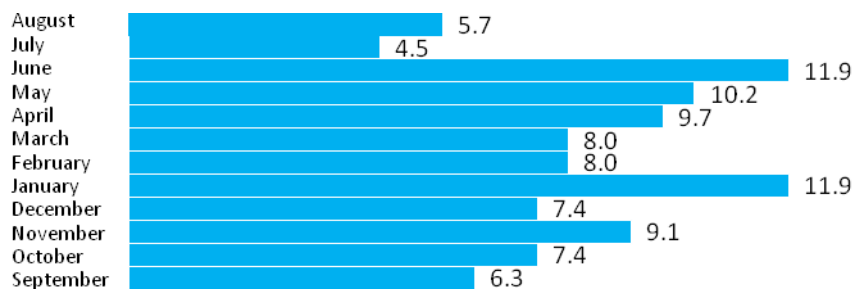
Appendix A-1  
For the Year 2011/12



Pedestrian Age



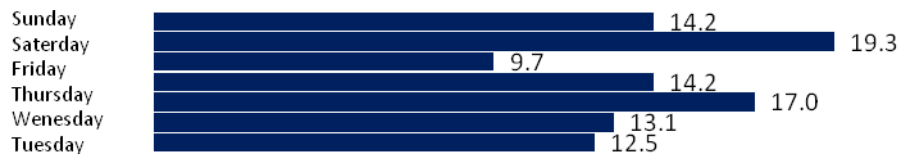
Pedestrian Sex



Crash Month



Pedestrian Condition



Crash Day



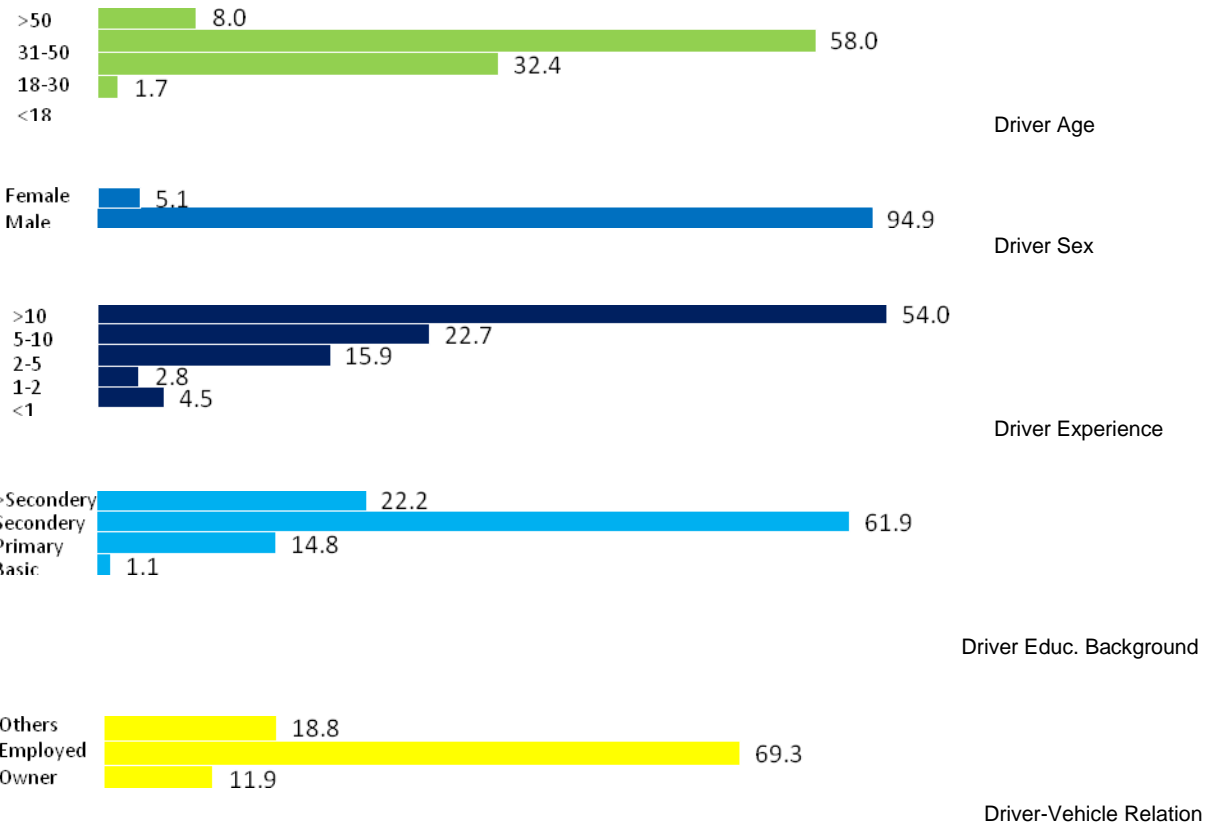
Crash Time



Severity Type

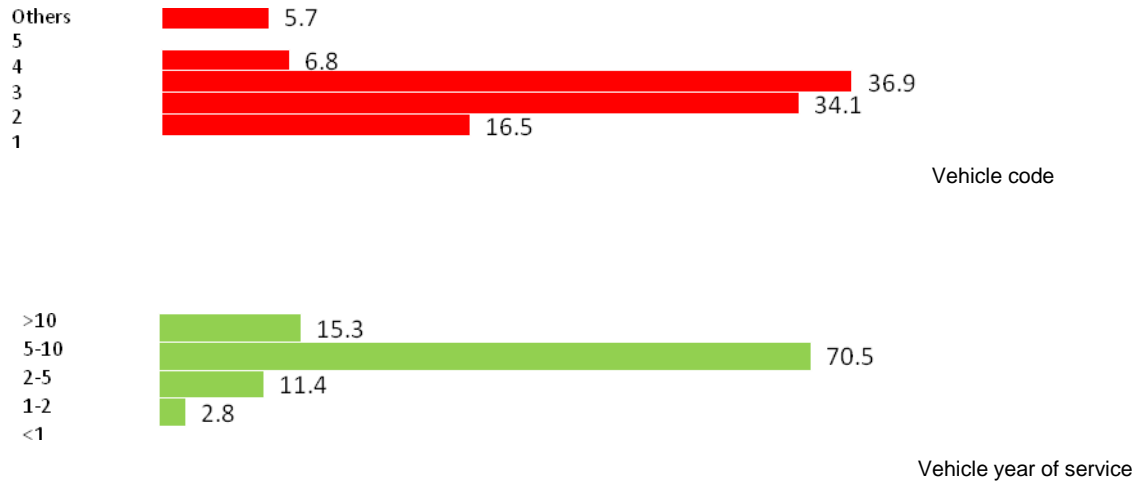
Year 2011/12 G.C. Or Year 2004 E.C.

**Pedestrian – Vehicles Crash ( Driver Related Characteristics) ( %)**



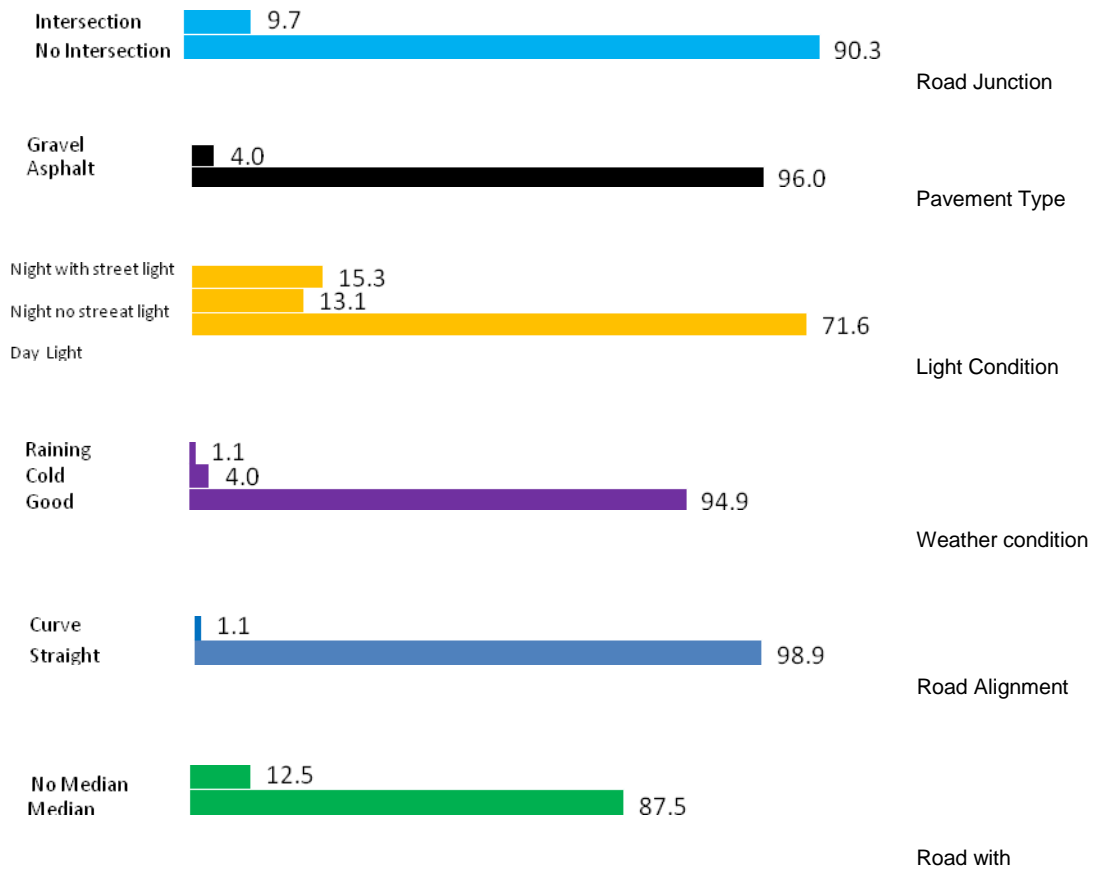
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**Pedestrian – Vehicle Crash (Vehicle Related Characteristics)(%)**



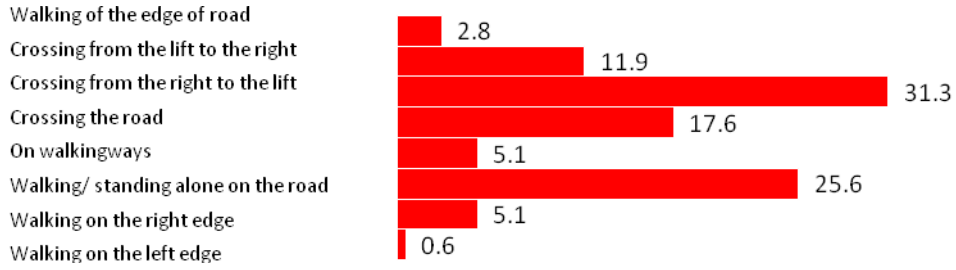
Year 2011/12 G.C. or Year 2004 E.C.

**Pedestrian – Vehicle Crash ( Road and Environment Related Characteristics ) (%)**

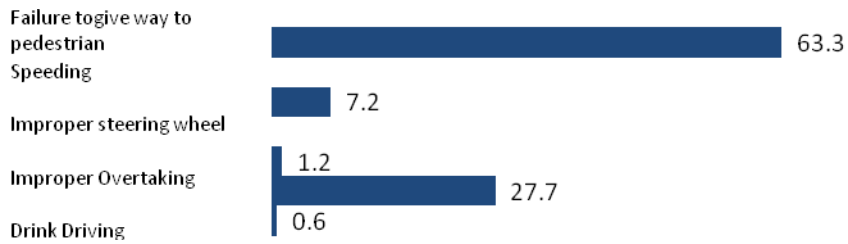


Year 2011/12 G.C. or Year 2004 E.C.

**Pedestrian Vehicle Crash ( Pedestrian Activity During the crash) (%)**



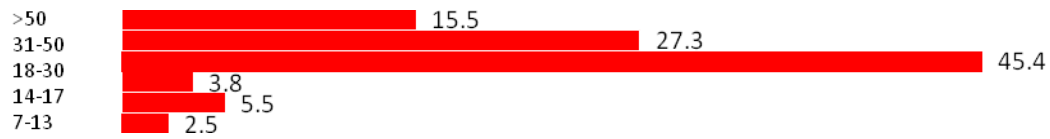
**Pedestrian Vehicle Crash (Driver Activity During the Crash) (%)**



Year 2011/2012 G.C. or Year 2004 E.C.

Appendix A-2  
For the Year 2012/13

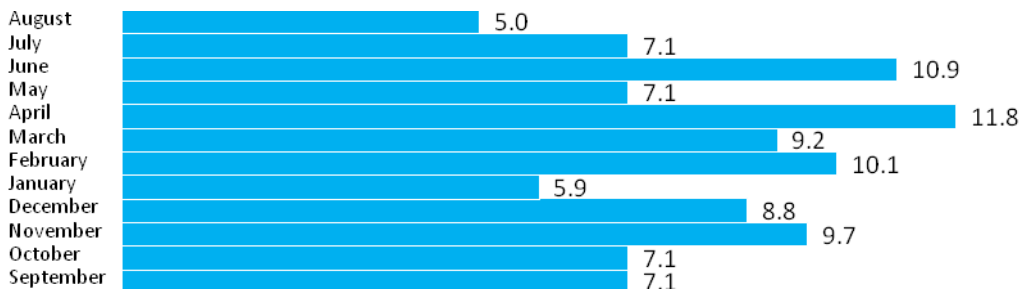
**Pedestrian – Vehicle Crash (Pedestrian Related Characteristics)(%)**



Pedestrian Age



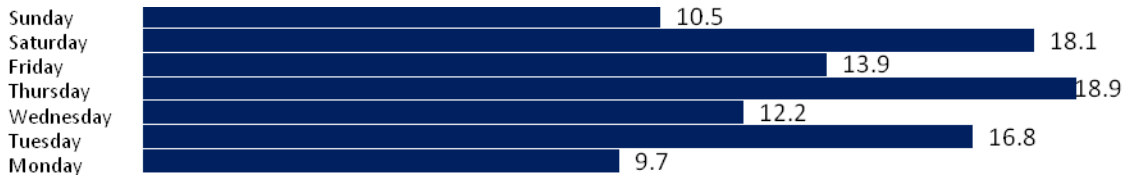
Pedestrian Sex



Crash Month



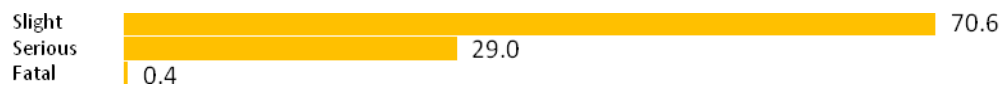
Pedestrian condition



Crash Day



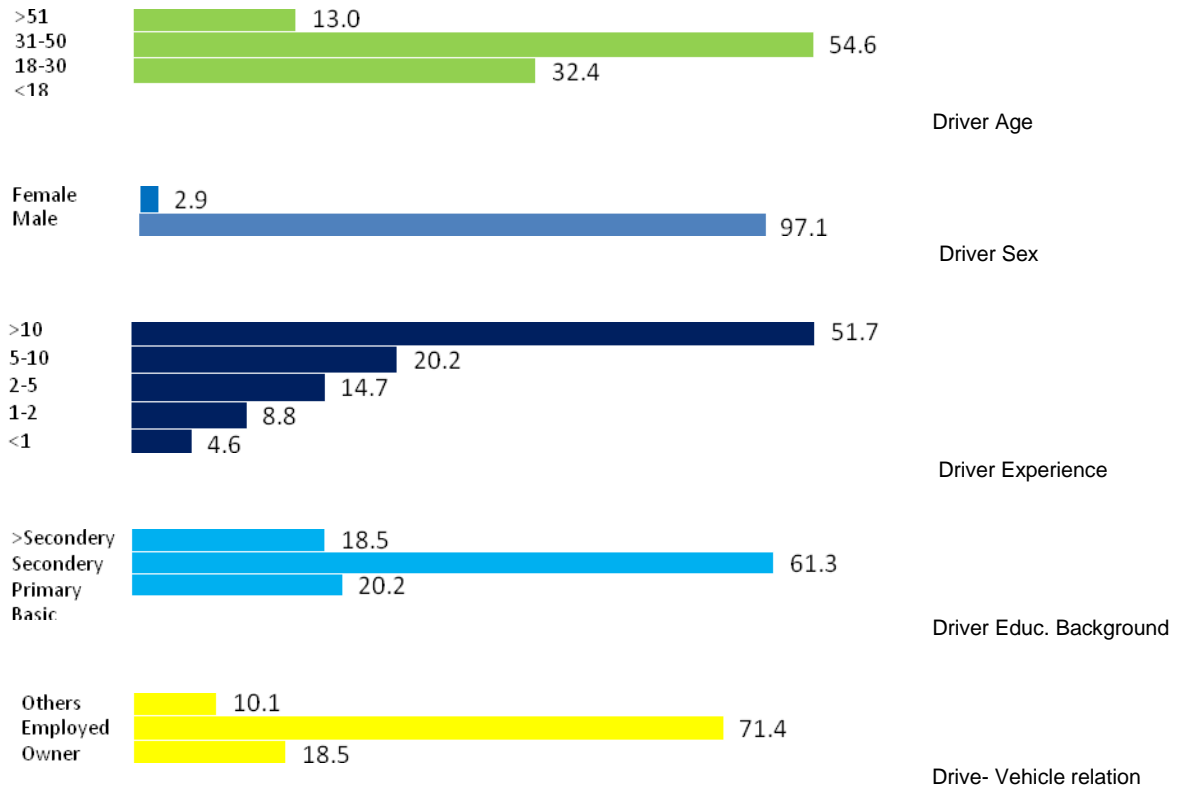
Crash Time



Severity Type

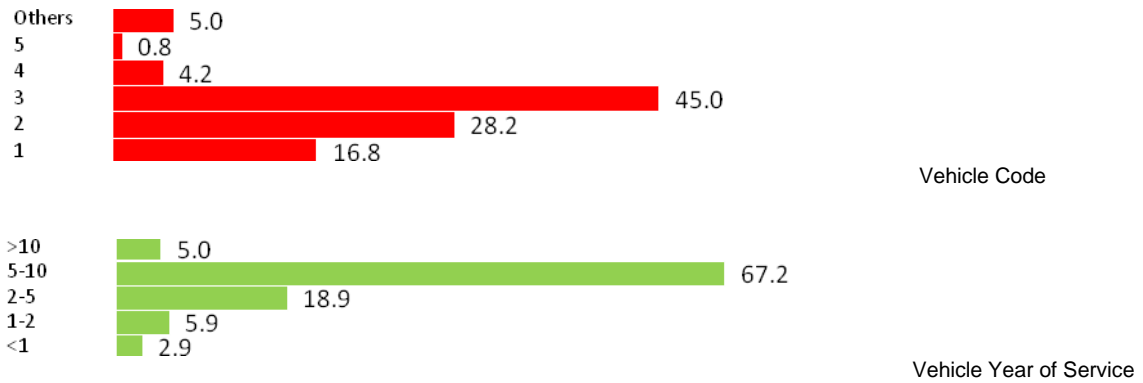
Year 2012/13 G.C. or Year 2005 E.C.

**Pedestrian – Vehicles Crash ( Driver Related Characteristics) ( %)**



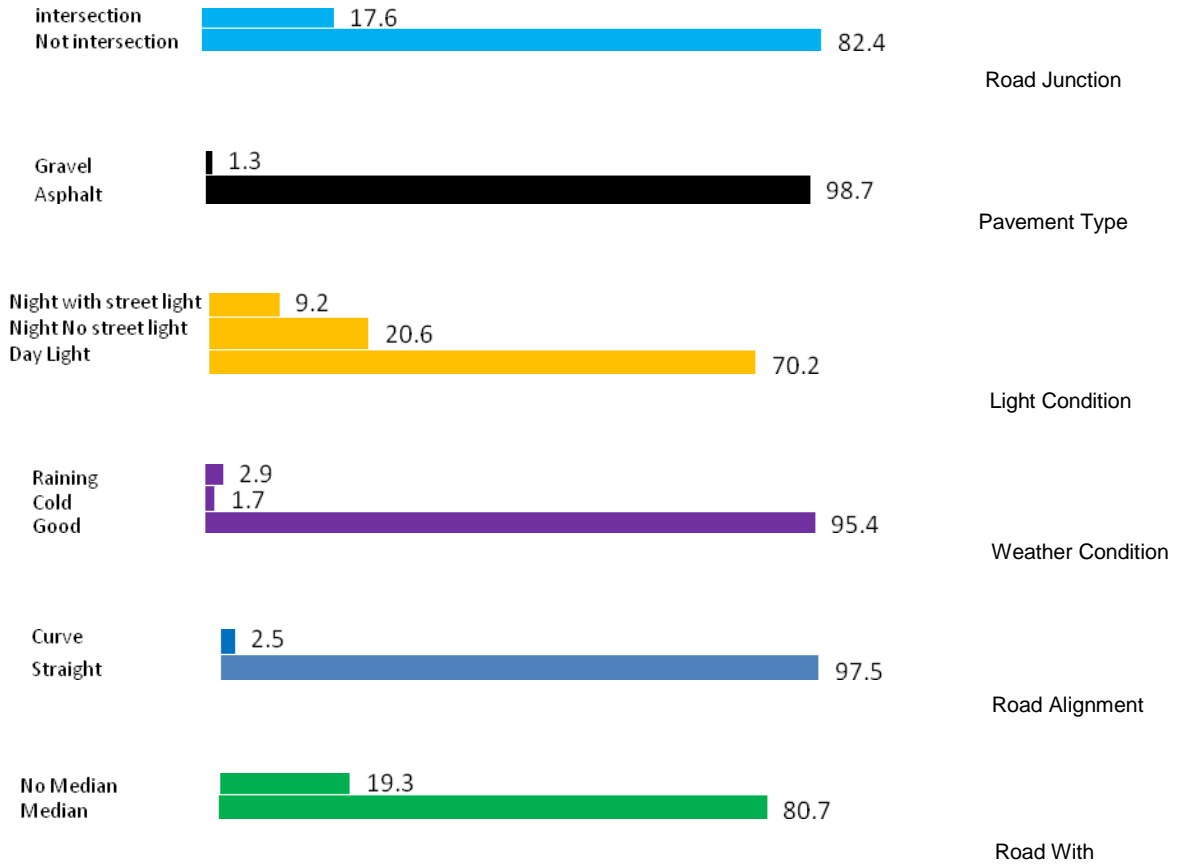
Year 2012/13 G.C. or Year 2005 E.C.

**Pedestrian Vehicles Crash (Vehicle Related characteristics) (%)**



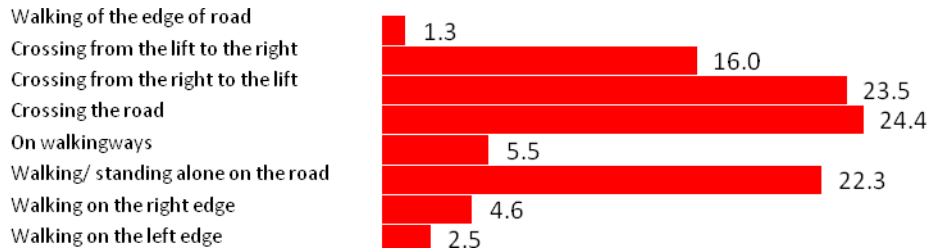
Year 2012/13 G.C. or Year 2005 E.C.

**Pedestrian – Vehicle Crash ( Road and Environment Related Characteristics ) (%)**

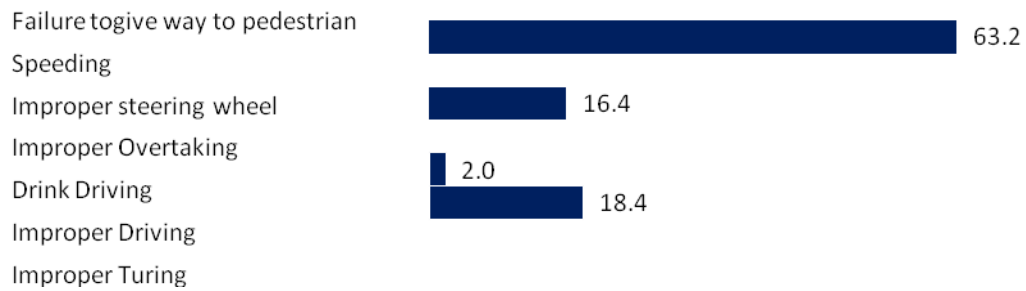


Year 2012/13 G.C. or Year 2005 E.C.

**Pedestrian Vehicle Crash ( Pedestrian Activity During the Crash) (%)**



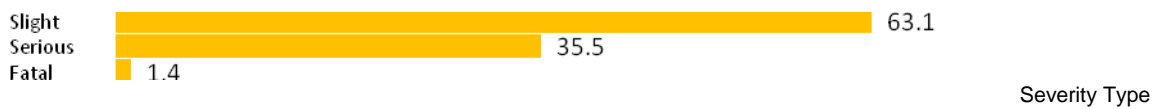
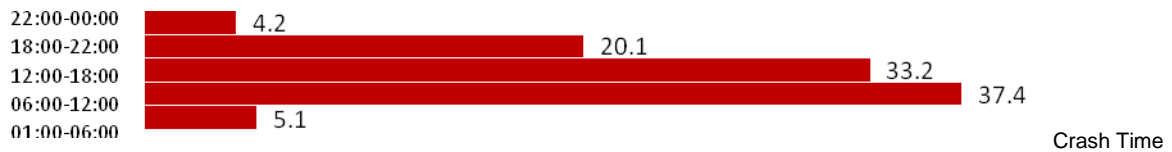
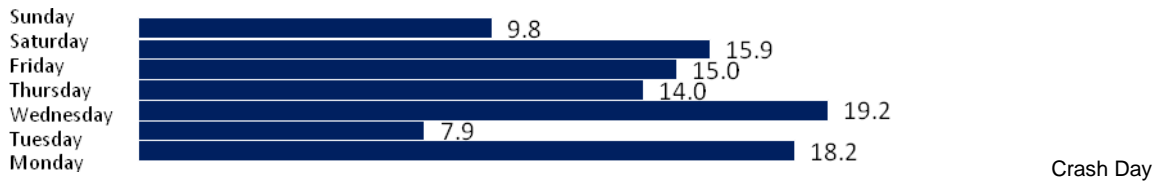
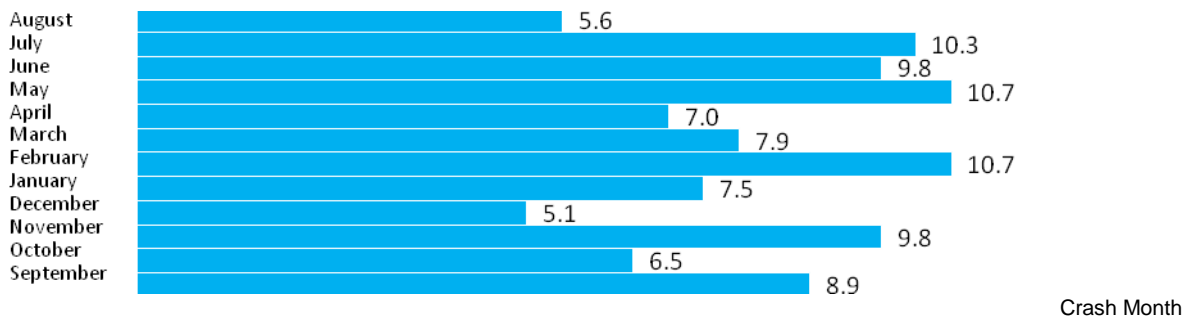
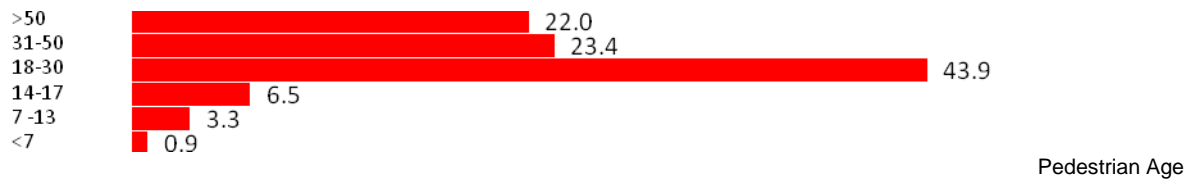
**Pedestrian Vehicle Crash (Driver Activity During the Crash) (%)**



Year 2012/13 G.C. or Year 2005 E.C.

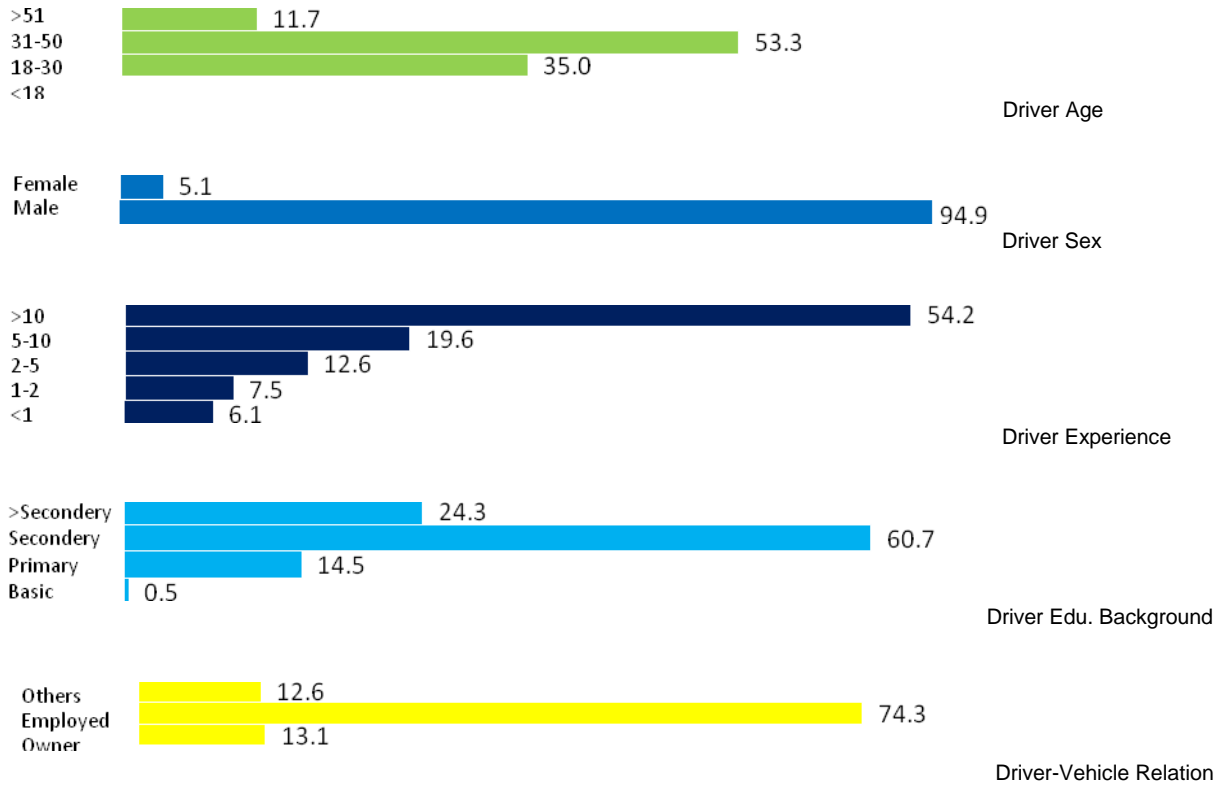
Appendix A-3  
For the Year 2013/14

**Pedestrian – Vehicle Crash (Pedestrian Related Characteristics)(%)**



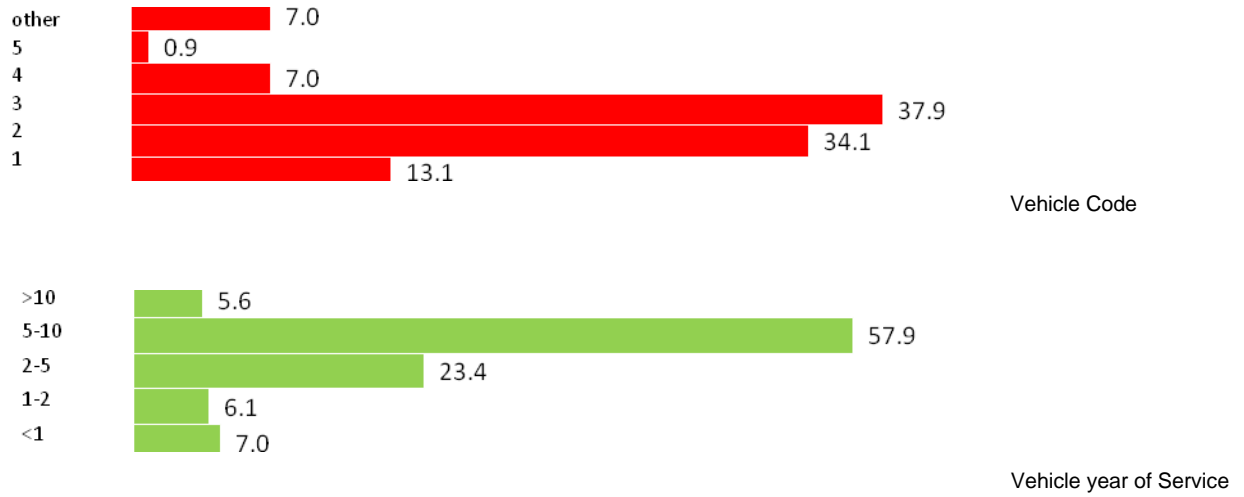
Year 2013/14 G.C. or Year 2006 E.C.

**Pedestrian – Vehicle Crash ( Driver Related Characteristics) ( %)**



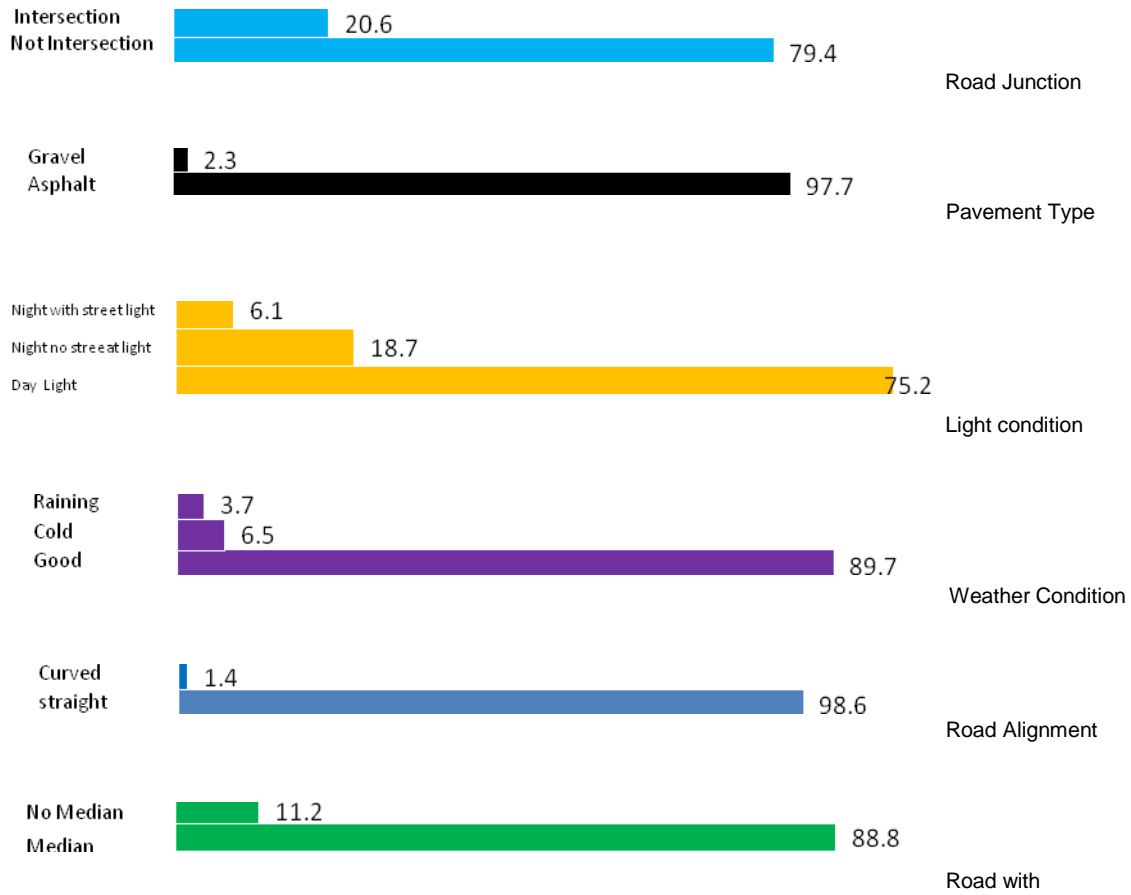
Year 2013/14 G.C. or Year 2006 E.C.

**Pedestrian Vehicles Crash (Vehicle Related Characteristics) (%)**



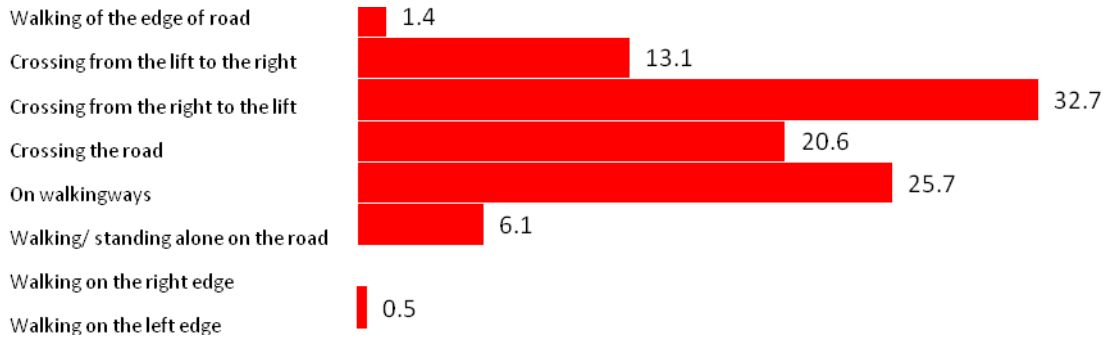
Year 2013/14 G.C. or Year 2006 E.C.

**Pedestrian – Vehicle Crash ( Road and Environment Related Characteristics ) (%)**

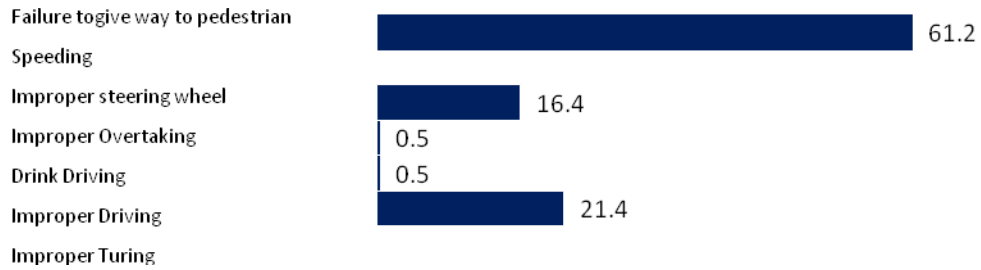


Year 2013/14 G.C. or Year 2006 E.C.

**Pedestrian Vehicle Crash ( Pedestrian Activity During the Crash) (%)**



**Pedestrian Vehicle Crash (Driver Activity During the Crash) (%)**



Year 2013/14 G.C. or Year 2006 E.C.

Appendix B  
Questionnaire for Pedestrians and Drivers

## Appendix B-1

Type I Questionnaire:

Rating of List of Factors affecting Pedestrian Safety by Pedestrians

## Rating of List of Factors affecting Pedestrian Safety by Pedestrians

The general objective of the questionnaire is to investigate pedestrian safety problems in Addis Ababa. Factors influencing pedestrian safety are listed and you are expected to rate the importance from your experience as a pedestrian in Addis Abeba (No 1-14).

The option of evaluation is based upon Likert scale ranging from **Extremely Important (1st level)** to **Unimportant (5th level)**.

### **INSTRUCTIONS**

- The variables were rated on the Five Point Likert Scales which have importance rating values from 1 to 5. Please, give your details by ticking one of the boxes provided.
- Ticking in more than one box on the same row of variable is not allowed.
- You can use any symbol you want for ticking (X,.....).

FACTORS INFLUENCING PEDESTRIAN SAFETY						
	Human Factors (Pedestrian Related)	Importance rating				
		1	2	3	4	5
1	Distracted Pedestrian (e.g. Using Mobile Phone)					
2	Pedestrian Not Using Crossings					
3	Pedestrian of the Opinion that they are Seen by the Driver					
4	Pedestrian Dangerous action in Carriageway e.g. Playing on the Road					
5	Pedestrian Wrong use of Pedestrian Crossings					
6	Alcohol/Drug Impaired Walking					
7	Pedestrian Crossing Road Masked by Stationary or Parked Vehicle					
8	Pedestrian Violation of Traffic Rules					
9	Pedestrian entered Carriageway without due care (Driver not to blame)					
10	Pedestrian failed to judge Vehicle's Path or Speed					
11	Pedestrian Careless, Reckless or in a Hurry					
12	Pedestrian Disability or illness, Mental or Physical					
13	Pedestrian failed to look Properly					
14	Safety Awareness of Pedestrians					

## Appendix B-2

Type II Questionnaire:

Rating of List of Factors affecting Pedestrian Safety by Drivers

## Rating of List of Factors affecting Pedestrian Safety by Drivers

The general objective of the questionnaire is to investigate pedestrian safety problems in Addis Ababa. Factors influencing pedestrian safety are listed and you are expected to rate the importance from your experience as a Driver in Addis Abeba (No 15-100).

The option of evaluation is based upon Likert scale ranging from **Extremely Important (1st level)** to **Unimportant (5th level)**.

### INSTRUCTIONS

- The variables were rated on the Five Point Likert Scales which have importance rating values from 1 to 5. Please, give your details by ticking one of the boxes provided.
- Ticking in more than one box on the same row of variable is not allowed.
- You can use any symbol you want for ticking (X,.....).

<b>FACTORS INFLUENCING PEDESTRIAN SAFETY</b>						
	<b>Human Factors (Driver Related)</b>	<b>Importance rating</b>				
		<b>1</b>	<b>2</b>	<b>3</b>	<b>4</b>	<b>5</b>
15	Reaction time of Drivers (In Relation to Fitness, Age effect and Sensory Defect)					
16	Excessive Drivers Speed					
17	Distracted Driving(e.g. Using Mobile Phone)					
18	Distraction (Conversation with Passenger, Looking Roadside Billboard, Operating the Radio)					
19	Misprioritised Attention (Checking the Rear-View Mirror -When Turning an Intersection)					
20	Driver Rush and Negligence					
21	Drivers Fatigue					
22	Drivers Ignored Lights at Crossing					
23	Drivers Emotional Condition (Upset, Angry, Anxious, Happy)					
24	Inattention of Driver (Bored/Unmotivated)					
25	Interaction/competition with Other Road Users					
26	Low Driving Experience (Learner or inexperienced driver)					
27	Inexperience and Youthfulness Together					
28	Aggressive Driving					
29	Driver Failed to Judge Road User's Path or Speed					

30	Prior Experience of the Driving Environment					
31	Poor turn or Maneuver					
32	Starting or Backing Improperly					
33	Poor Overtaking					
34	Failure to Yield Right of Way					
35	Following Improperly					
36	Improper or Erratic Lane Changing					
37	Driver Unfamiliar with Model of the Vehicle					
38	Leaving Vehicle Unattended					
39	Drivers Disobeying Signs/Signals/Markings					
40	Illegal Driving in Road Shoulder, Ditch and sidewalk or median					
41	Drivers failed to Stop (at Mandatory Signs)					
42	Drivers failed to see Pedestrian in blind spot					
43	Alcohol Use by Drivers					
44	Chat (Khat) Use by Drivers					
45	Confusion/Lack of Information from Other Road Users					
46	Lack of Lane Disciplines, Carelessness of Road Users					
47	Cat and Mouse Game between Drivers and Police					
48	Safety Awareness of Drivers					
49	Distractions from outside the vehicle					

50	Vision Affected by Stationary or Parked vehicle(s)					
51	Drivers -Uncorrected, defective eyesight					
52	Driver Not displaying lights at Night or in Poor Visibility					

	Vehicle-Related Factors	Importance rating				
		1	2	3	4	5
53	Defected Vehicle Driving					
54	Defective Steering or Suspension					
55	Vehicle Brake System Bad Condition					
56	Accelerator Defect					
57	Manufacturing Defects (Related to Quality Control)					
58	Speed Management					
59	Overloaded Vehicles					
60	Vehicle Year Of Service (Older ones)					
61	Incomplete or defective Vehicle Lighting					
62	Missing or Defective Mirrors					
63	Tire Problem					
64	Electrical Defects or Failure					
65	Engine Defects					
66	Visor or windscreen dirty or scratched					
67	Dazzling headlights					
	<b>Road and Environment-Related Factors</b>					
68	Road Design and Layout (e.g. Bend, Hill, narrow Carriageway)					

69	Lack of Safety-Awareness in the Planning					
70	Lack of Integration of Needs of Pedestrians in the Planning					
71	Bend/winding of the Road					
72	Insufficient Pedestrian Facilities					
73	Insufficient Traffic Signs/Signals/Markings					
74	Inappropriate or Unexpected Traffic Signs/Signals/Markings					
75	Inadequacy of Traffic Segregation					
76	Legally or Illegally Parked Vehicles Blocking Visibility					
77	Road Signs Poor Positioning					
78	Poor or Defective Road Surface (Ruts, Holes, Bumps)					
79	Signal Timing for Pedestrians					
80	Low Coordination of Crosswalk with Desired Pedestrian Routes					
81	Lack of Rumble Devices for Blind Pedestrians					
82	Obscured Line of Sight					
83	Traffic Density and Composition					
84	Land Use Pattern and Composition (School/Market Area etc)					
85	Inadequate or Masked Signs or Road Markings					
86	Excess Conflicts					
87	Prevailing Speed					
88	Insufficient Traffic Policing and Legislation					
89	Insufficient or No Road Side/Street Lighting					
90	Wet or Slippery Road Surface					

91	Raining Weather Condition					
92	Obstacles to Pedestrians on Walkways					
93	Parking on Sidewalks					
94	Animal or Object on Carriageway					
95	Road Side Shopping or on the Sidewalks					
96	Road Side Advertisement					
97	Vision Affected by Vegetation					
98	Vision affected by Buildings/Street Furniture					
99	Defective Traffic Signals					
100	Sun Glare					

## Appendix B-3

Type III Questionnaire:

Pair wise Comparison Rating of List of Selected Factors affecting  
Pedestrian Safety in Addis Ababa by Senior Experts

**Factors Influencing Pedestrian Safety**

**Pedestrian  
Related**

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Pedestrian Not Using Crossings																		Distracted Pedestrian (e.g. Using Mobile Phone)
Pedestrian Not Using Crossings																		Pedestrian of the Opinion that they are Seen by the Driver
Pedestrian Not Using Crossings																		Pedestrian Disability or illness, Mental or Physical
Pedestrian Not Using Crossings																		Alcohol/Drug Impaired Walking
Distracted Pedestrian (e.g. Using Mobile Phone)																		Pedestrian of the Opinion that they are Seen by the Driver

**Factors Influencing Pedestrian Safety**

**Pedestrian  
Related**

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Distracted Pedestrian (e.g. Using Mobile Phone)																		Pedestrian Disability or illness, Mental or Physical
Distracted Pedestrian (e.g. Using Mobile Phone)																		Alcohol/Drug Impaired Walking
Pedestrian of the Opinion that they are Seen by the Driver																		Pedestrian Disability or illness, Mental or Physical
Pedestrian of the Opinion that they are Seen by the Driver																		Alcohol/Drug Impaired Walking

**Factors Influencing Pedestrian Safety**

Vehicle  
Related

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Speed Management																		Dazzling headlights
Speed Management																		Manufacturing Defects (Related to Quality Control)
Speed Management																		Visor or windscreen dirty or scratched
Speed Management																		Vehicle Brake System Bad Condition
Dazzling headlights																		Manufacturing Defects (Related to Quality Control)

**Factors Influencing Pedestrian Safety**

**Vehicle Related**

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Dazzling headlights									1									Visor or windscreen dirty or scratched
Dazzling headlights									1									Vehicle Brake System Bad Condition
Manufacturing Defects (Related to Quality Control)									1									Visor or windscreen dirty or scratched
Manufacturing Defects (Related to Quality Control)									1									Vehicle Brake System Bad Condition
Visor or windscreen dirty or scratched									1									Vehicle Brake System Bad Condition



**Factors Influencing Pedestrian Safety**

**Driver  
Related**

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Driver Rush and Negligence																		Drivers Fatigue
Driver Rush and Negligence																		Improper or Erratic Lane Changing
Alcohol Use by Drivers																		Drivers Fatigue
Improper or Erratic Lane Changing																		Drivers Fatigue

**Road and Environment Related**

Factor 1	Factor weighting score																		Factor 2	
	More importance than									Equal	Less importance than									
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9			
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI			
Road Design and Layout (e.g. Bend, Hill, narrow Carriageway)																			Insufficient Pedestrian Facilities	
Road Design and Layout (e.g. Bend, Hill, narrow Carriageway)																			Insufficient Traffic Signs/Signals/ Markings	
Road Design and Layout (e.g. Bend, Hill, narrow Carriageway)																			Land Use Pattern and Composition (School/Market Area etc)	
Road Design and Layout (e.g. Bend, Hill, narrow Carriageway)																			Lack of Integration of Needs of Pedestrians in the Planning	
Insufficient Pedestrian Facilities																			Insufficient Traffic Signs/Signals/	



**Road and Environment Related**

Factor 1	Factor weighting score																Factor 2	
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8		9
	A	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Insufficient Pedestrian Facilities																		Land Use Pattern and Composition (School/Market Area etc)
Insufficient Pedestrian Facilities																		Lack of Integration of Needs of Pedestrians in the Planning
Insufficient Traffic Signs/Signals/Markings																		Lack of Integration of Needs of Pedestrians in the Planning
Land Use Pattern and Composition (School/Market Area etc)																		Lack of Integration of Needs of Pedestrians in the Planning

Four Categories Related

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
<b>Pedestrian Related</b>	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Pedestrian Related Factors																		Driver Related Factors
Pedestrian Related Factors																		Vehicle Related Factors
Pedestrian Related Factors																		Road and Environment Related Factors
Driver Related Factors																		Vehicle Related Factors
Driver Related Factors																		Road and Environment Related Factors

Factor 1	Factor weighting score																	Factor 2
	More importance than								Equal	Less importance than								
	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
	AI	VVSI	VSI	SPI	SI	MPI	MI	WI	EI	WLI	MLI	MPLI	SLI	SPLI	VSLI	VVLSI	ALI	
Vehicle Related Factors																		Road and Environment Related Factors

## Appendix C

### Kirkos Sub city Pedestrian-Vehicle Crash Data Analysis

## Appendix C-I

### Multinomial Logit Model Analysis STATA Output

#### Slight Injury as a Reference

```
. mlogit Sev_Type Crsh_Time Crsh_Day Crsh_Mnth Driv_Age Driv_Sex Dri_Educ Driv_Veh Driv_exper Driv_Veh Driv_exper Veh_Code Veh_Y_S Median Ali
> gnmnt Junction Pavt_Typ R_Condtn L_Condtn W_Condtn Ped_Age Ped_Sex Ped_Cond Ped_Activ
```

```
note: Driv_Veh omitted because of collinearity
note: Driv_exper omitted because of collinearity
Iteration 0: log likelihood = -437.02768
Iteration 1: log likelihood = -432.59738
Iteration 2: log likelihood = -408.24945
Iteration 3: log likelihood = -403.17941
Iteration 4: log likelihood = -402.34671
Iteration 5: log likelihood = -402.16154
Iteration 6: log likelihood = -402.12752
Iteration 7: log likelihood = -402.12099
Iteration 8: log likelihood = -402.11952
Iteration 9: log likelihood = -402.11916
Iteration 10: log likelihood = -402.11908
Iteration 11: log likelihood = -402.11906
```

```
Multinomial logistic regression          Number of obs =      628
                                         LR chi2(42)      =      69.82
                                         Prob > chi2     =      0.0045
Log likelihood = -402.11906             Pseudo R2       =      0.0799
```

Sev_Type	Coef.	Std. Err.	z	P> z	[95% Conf. Interval]
1					
Crsh_Time	.2198711	.2035026	1.08	0.280	-.1789867 .6187289
Crsh_Day	.4345223	.4147567	1.05	0.295	-.3783858 1.24743
Crsh_Mnth	-.3316036	.2123502	-1.56	0.118	-.7478023 .0845951
Driv_Age	.1002592	.0919375	1.09	0.275	-.079935 2.804534
Driv_Sex	-3.733637	2.31327	-1.61	0.107	-8.267563 .8002902
Dri_Educ	.0216864	1.101646	0.02	0.984	-2.137501 2.180873
Driv_Veh	.9178617	1.325293	0.69	0.489	-1.679666 3.515389
Driv_exper	-.1647985	.1521437	-1.08	0.279	-.4629947 .1333977
Driv_Veh	0	(omitted)			
Driv_exper	0	(omitted)			
Veh_Code	.063665	.9510193	0.07	0.947	-1.800299 1.927629
Veh_Y_S	.2101808	.1992061	1.06	0.291	-.1802559 .6006174
Median	-12.57874	1098.538	-0.01	0.991	-2165.675 2140.517
Alignment	-9.821721	7158.236	-0.00	0.999	-14039.71 14020.06
Junction	-14.14893	1460.872	-0.01	0.992	-2877.406 2849.108
Pavt_Typ	-12.01164	3192.233	-0.00	0.997	-6268.674 6244.65
R_Condtn	-17.53228	2312.274	-0.01	0.994	-4549.506 4514.441
L_Condtn	-1.139905	1.269171	-0.90	0.369	-3.627436 1.347625
W_Condtn	3.777436	2.194609	1.72	0.085	-.5239181 8.078791
Ped_Age	.1026201	.0561229	1.83	0.067	-.0073787 .2126189
Ped_Sex	19.95421	673.6851	0.03	0.976	-1300.444 1340.353
Ped_Cond	-6.195561	1007.749	-0.01	0.995	-1981.347 1968.956
Ped_Activ	.8759803	.6231689	1.41	0.160	-.3454084 2.097369
_cons	31.07447	8460.9	0.00	0.997	-16551.98 16614.13
2					
Crsh_Time	-.0150049	.0176817	-0.85	0.396	-.0496605 .0196506
Crsh_Day	-.050084	.044986	-1.11	0.266	-.138255 .038087
Crsh_Mnth	-.0216901	.0259596	-0.84	0.403	-.0725701 .0291898
Driv_Age	-.0090236	.0098896	-0.91	0.362	-.0284067 .0103596
Driv_Sex	.735265	.4942648	1.49	0.137	-.2334761 1.704006
Dri_Educ	.0740705	.1396882	0.53	0.596	-.1997134 .3478543
Driv_Veh	.440322	.1705467	2.58	0.010	.1060567 .7745873
Driv_exper	.001125	.018267	0.06	0.951	-.0346778 .0369277
Driv_Veh	0	(omitted)			
Driv_exper	0	(omitted)			
Veh_Code	.1229711	.0735989	1.67	0.095	-.02128 .2672222
Veh_Y_S	.0462181	.0272811	1.69	0.090	-.0072519 .099688
Median	.1959413	.257339	0.76	0.446	-.3084338 .7003165
Alignment	-.1811954	.6569812	-0.28	0.783	-1.468855 1.106464
Junction	-.6775388	.2555854	-2.65	0.008	-1.178477 -1.1766005
Pavt_Typ	-.250293	.4616689	-0.54	0.588	-1.155147 .6545614
R_Condtn	-.6135919	.4606014	-1.33	0.183	-1.516354 .2891704
L_Condtn	.1074297	.1501912	0.72	0.474	-.1869396 .401799
W_Condtn	.2188833	.2799156	0.78	0.434	-.3297411 .7675077
Ped_Age	.0130767	.006357	2.06	0.040	.0006173 .0255361
Ped_Sex	.6437243	.2127607	3.03	0.002	.226721 1.060728
Ped_Cond	-.1310375	.1383855	-0.95	0.344	-.402268 .140193
Ped_Activ	.1064631	.0591177	1.80	0.072	-.0094054 .2223316
_cons	-2.154917	1.311511	-1.64	0.100	-4.725432 .4155986
3					
(base outcome)					

## Appendix C-2

Cross tabulation of Associated Factors verses  
Injury Severity Type

SPSS Output

**Crosstab**

		Ped_Age					Total	
		(<7)	(7-13)	(14-17)	(18-30)	(31-50)		(>50)
Sev_Type	1	0	0	0	1	2	1	4
	2	5	6	11	101 (16%)	59 (9.3%)	52 (8.2%)	234
	3	7	19	20	184 (29.3%)	99 (15.7%)	61 (9.7%)	390
Total		12	25	31	286	154	114	628

**Crosstab**

		Ped_Sex		Total
		0(Female)	1(Male)	
Sev_Type	1	0	4	4
	2	44	190 (30.2%)	234
	3	115	275 (43.8%)	390
Total		159	469	628

**Crosstab**

		Driv_Veh			Total
		1 (owner)	2 (employee)	3 (others)	
Sev_Type	1	0	3	1	4
	2	25	169 (26.9%)	40	234
	3	68	279 (44.4%)	43	390
Total		93	451	84	628

**Sev\_Type \* Driv\_Sex Crosstabulation**

Count

		Driv_Sex		Total
		0(female)	1(male)	
	1	1	3	4
Sev_Type	2	6	228 (36.3%)	234
	3	20	370 (58.9%)	390
Total		27	601	628

**Sev\_Type \* Junction Crosstabulation**

		Junction		Total
		1 (no intersection)	2 (intersection)	
	1	4	0	4
Sev_Type	2	208 (33.1%)	26	234
	3	313 (49.8%)	77	390
Total		525	103	628

**Note:**

Sev\_Types: 1 (Fatal), 2 (Serious) and 3 (Slight).