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Evaluation of Contributing Factors for Pedestrian Crash by Modeling Exposure and Road Environment Variables: The Case of Burayu Town, Oromia Regional State

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ABSTRACT: *Pedestrian-vehicle crashes presents an important public health problem worldwide, above 32% of traffic fatality victims in the worlds are pedestrians die each year on the world's roads. Developing countries account for more than 40% of world's pedestrian deaths disproportionate to their vehicle population. Ethiopia is among the countries with high pedestrian crash records. Despite the worse happening of the problem, no study so far conducted with regard to pedestrian crash fatalities and injuries particularly in the selected study area. The aim of this study was to evaluate the Contributing Factors for pedestrian crash by modeling exposure and road environment variables in Burayu Town, Oromia Regional state. The method used in this research is mixed log it analysis using SPSS software. The sampling technique applied to this study is convenience sampling approach, which was chosen in order to save costs and time. The study included all pedestrian crash conducted using police record secondary data collected from police stations records in Burayu Town. Five-year pedestrian crash was also collected to conduct the analysis and modeling in SPSS software by mixed logit modeling.*

A total of 344 Pedestrian crashes were recorded from January 01, 2015 to December 31, 2019. Of these crashes, 72(21%) were fatal injury, 254(74%) severe injury and 18(5%) were slightly injury. Hence, the results of the study showed the existence of large difference in pedestrian-vehicle crash victims among drivers and pedestrian in their sex and age levels. The modeling results show that higher pedestrian crash severities were associated with increasing pedestrian age, male pedestrians, minibus, casual drivers, less educated and less experienced drivers, nighttime and weekend crashes, and residential land uses. A comprehensive evaluation was done on crashes involving pedestrians in the Burayu Town. Younger male drivers were the groups with high proportion of involvement in pedestrian crash. Pedestrians and the working age groups of the population were highly affected. Public awareness creation campaigns in line with enforcement of pedestrian safety rules were recommended.

Keywords*: Pedestrian safety, Exposure, Contributing Factor, Pedestrian Crash.*

1 INTRODUCTION

1.1 Background of the Study

As one of the most fundamental modes of transportation, walking is very important in everyday life. A small part of everyday work is accomplished by walking and sometimes used as a mode of transportation such as walking to the grocery store or work. Activities that involve leaving the house bring pedestrians into direct contact with vehicles and streets. As such, pedestrians are

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exposed to a wide range of issues when it comes to safety, mobility and accessibility. Pedestrian safety is one of the most important transportation planning issues [1]. According to world Health organization report (global status on road safety) traffic accidents in developing country accounts for the death of 37.28 persons per100,000 Populations this is 2.77% of the total death in the country placing Ethiopia 12th in the world. Almost half of all deaths on the world's roads are among those with the least protection pedestrians (32%). The African Region has the highest proportion of pedestrian deaths at 43% from all road traffic deaths. In Ethiopia, pedestrian account for 53.4% of road traffic collision deaths [2]. Road collision injuries currently ranked 9th globally among the leading causes of disease burden and by 2030 it is predicted to raise to the fifth leading cause of death doubling the current fatality to 2.4 million unless immediate action is taken [4].

The African region is known for having the highest numbers of fatalities compared to other regions around the world. Young men are overrepresented in road user crashes, as are vulnerable road users, in particular, pedestrians and drivers riding on 2 and 3-wheelers [1]. Most countries in Africa have insufficient policies and strategies to protect vulnerable road users. Furthermore, enforcement on major risk factors like speed control, alcohol impaired driving, child restraints, and seat belt and helmet use is not yet common in the majority of countries of this region. In addition to these, there is rarely traffic law enforcement traffic regulation and post-crash treatment in most counties in the region [4]. The pedestrian crash fatality rate is high in sub-Sahara Africa, especially in countries like Ethiopia disproportionate to their vehicle population. Ethiopia, together with three other African countries (Nigeria, South Africa, and Sudan) accounted for half the road traffic collision fatalities of sub-Saharan Africa [3]. According to the Ethiopian Road Authority report, nearly three-fourth of the pedestrian crash fatality occurs by poor human behaviors. Some of these identified factors associated with pedestrian crash fatality are failing to follow a speed limit, failing to give priority, following too closely, vehicular defect, using mobile phone while driving and pedestrians wrong crossing of the road [4][5]. In response to the findings, some responsible bodies for road safety have been formed within the government such as National Road Safety Council and Road Safety Committees in regional administration. Increased efforts have been made to reverse the situation of pedestrian crashes in the country; however, it is clear that road safety is at the infant stage in Burayu.

1.2 Statement of the Problem

Pedestrian safety problem is serious problem throughout the globe, particularly, in developing countries. Every year, more than 1.2 million people die in road crashes around the world and about 50 million were injured [6]. In the case of Africa, the problem of Road safety is more complicated. The African region is known for having the highest numbers of fatalities compared to other regions around the world. Young men are overrepresented in road user crashes, as are vulnerable road users, in particular, pedestrian's vehicle crash [1]. Most countries in Africa have insufficient policies and strategies to protect vulnerable road users. Furthermore, enforcement on major risk factors like speed control, alcohol impaired driving, child restraints, and seat belt and helmet use is not yet common in the majority of countries of this region. In addition to these, there is rarely traffic law enforcement traffic regulation and post-crash treatment in most countries in the region [4]. Thus, the complexity of road safety in the region requires consolidated efforts to strengthen pedestrian safety, emergency medical services, enforcement of traffic laws, and the capturing of quality crash data.

Although the mobility of people and motorization has increased in Ethiopia due to the economic advancement achieved in recent years; the adverse consequences of pedestrian crashes have become a more apparent problem. As a developing country, the problem of pedestrian crashes is severe [4]. Despite having very low road network density and vehicle ownership, Ethiopia has a relatively high accident record. The severity of pedestrian crash in Ethiopia varies from region to region, Addis Ababa and Oromia, account for 58% of all fatal collisions and two- thirds of all injuries. More than one-third of the fatal injuries (36%) occurred in Oromia regional state [8]. Oromia region has the largest number of pedestrian fatalities as vehicles from every corner of the country to the capital city (Addis Ababa) passes through the region. These increasing traffic collision injuries targeted the most economically productive age cohort; especially males in their younger age of life, doubling the hardships to the community and family members at large.

In the study area, the occurrence of pedestrian crashes has many contributing factors. From casual observation, some reasons for a high number of pedestrian fatalities, severe injuries and slightly injuries could be attributed to driver, pedestrian behavioral and road environmental factors [7]. This observation is supported by Burayu Town traffic police (2009/10-2013/14)

crash statistics which shows that 124 crashes occurred (gives an average of 24.8 Pedestrian Crash/Year). But no significance study is conducted for cause of crash and means of crash reduction in the Town. The magnitude of pedestrian crashes, fatalities, severe injuries and slightly injuries in the last five years were also evaluated.

1.3 Objectives

1.3.1 General Objectives

The main objective of this research is to evaluate the contributing factors for pedestrian crashed by modeling exposure and road environment variables to minimize the pedestrian safety problem.

1.3.2. Specific Objectives

1. To evaluate the contribution of socio-demographic characteristics of pedestrians for the occurrence of crashes.
2. To investigate the link between road environment and pedestrian crashes.
3. To evaluate the contribution of land use of the occurrence of pedestrian crashes.
4. To examine the pedestrian safety measures through identifying possible remedial measures.

1.4 Significance of the Study

Despite the worse happening of crash, there was little published research on the pedestrian crash, particularly, no such study conducted so far in the selected study area. Therefore, the current study has importance for providing more insight to road authority and traffic police officers on the extent of the problem and related factors in the study area. Recommending on possible pedestrian safety mechanisms by providing reliable information to reduce pedestrian crash in the study area and availing reliable information for researchers interested to study about pedestrian crash.

2 LITERATURE REVIEW

Pedestrian safety problem is a global concern, and a socio-economic aspect, leading to tremendous life and property loss each year around the world, that is why traffic safety system is always needed comprehensive understanding and emphasized in transportation engineering. When come to Ethiopia at least one person is killed from every five car coincidences [1]. The

theme of crash severity has been of interest to traffic safety community because of the direct impact on occupants involved. In fact, it is well-known that a traffic accident is usually caused by the failure of one or more of a multitude of factors, including the safety condition of the vehicle, the safety condition of the road and its environment and finally the safe behavior of the driver and pedestrian [18]. Reducing the number of traffic accidents therefore requires an integrated approach known as shared responsibility. The way forward would be to identify factors contributing to either a more or less severe crash in many researches and many factors are contributing to the occurrence of pedestrian crashes, so that one cannot expect that only one factor leads to traffic crash because multiple factors may be involved [9]. pedestrian vehicle collisions result from a variety of factors, including poor road design; driving above speed limit, failure to give priority to pedestrians or to other vehicle, hazardous conditions; failure to use safety devices such as helmets and seat belts; poor vehicle maintenance; unskilled or inexperienced drivers; inattention to pedestrians and cyclists; problems related to road sharing and impairment due to alcohol, drug use and fatigue among others [4][10][11]. Speed has been determined to be an important contributing factor in pedestrian crash [12]. An increase in average speed of a vehicle is directly related both to the likelihood of a collision occurring and to the severity of the consequences of the collision i.e., the higher the speed of a vehicle, the higher the probability of becoming involved in a crash and the greater the likelihood of more severe injuries occur. Vulnerable road users outside pedestrian vehicles are at especially high risk of injury from speeding motor vehicles.

Pedestrian factors include age, gender, weight, height, physical strength, health status and the direction and distribution of force, the age of pedestrians is an influential factor in severity of injury of pedestrians. Studies have identified that the risk of injury severity increases with age, and elderly pedestrians (65 years and over) are often overrepresented in injury severity statistics Pedestrians aged 25-64 appear to have the lowest injury severity [15][16][19].Younger pedestrians (aged 15-24) were susceptible to more severe injuries in some studies although these findings are inconsistent, with other studies reporting contradictory results to those discussed above [22]. Posture (standing erect, lying on the road) and weight of pedestrians is related to injury severity. The injury severity of pedestrians increases in heavier people as total energy dissipated can have two components: the impact speed of the vehicle (1/2 mv2) and the laid down energy of the pedestrian (mass of pedestrian times gravitational force times height the

pedestrian falls). It is therefore assumed that the height of a pedestrian is another factor which also intensifies the degree of severity. Physical strength and health status related to the age of pedestrians, and influences the risk of injury severity. Although previous studies on this topic are not currently available, it is generally understood by researchers [14] that better health and strength of pedestrians leads to a reduction in the severity of injury. The direction and distribution of impact force can intensify the injury to a wide variety of pedestrian body regions depending on the speed and design of the vehicle encountered.

Driver factors have been well investigated, and drivers who are intoxicated while driving are more likely to cause severe injury to pedestrians [13]. Speeding is another determinant of pedestrian injury severity, as confirmed by many researchers. Driver age, gender and education are also related to injury severity, where the older the driver, the greater the severity [20].

3 METHODOLOGY

3.1 Description of the Study Area

Burayu Town is located in Oromia National Regional State and in the western direction of capital city (Addis Ababa city) with a distance of 15 km. The Town is a high land area located at an altitude of 2580 m above sea level with an area of 66.5 km^2. Burayu Town is bounded: in the East by: Finfinne, in West by Holota Town, in North by Sululta Woreda and in South by Sebata Hawas Woreda. Burayu Town has a total population of 356,416 and the road crossing the town connects the capital city to the western parts of Ethiopia. The road is the busiest one in the country, and traffic accidents are very prevalent, the highway under consideration has very high rate of accidents.

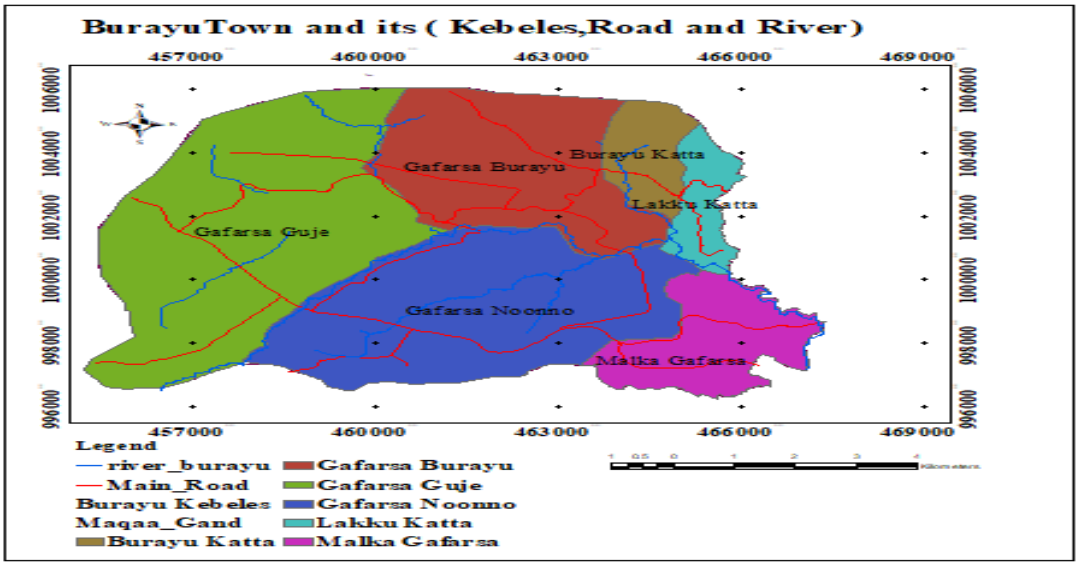


Figure 3.1: Map of Burayu Town with district (source: Burayu Town municipality, 2020)

3.2 Study Design

A retrospective cross sectional study design was used in this study. All pedestrian crash victims reported to Burayu Traffic police station and Burayu hospital between 2015 and 2019 were study population.

3.2.1 The Research Process

The methodology and procedure for data collection employed in the field was based on the qualitative and quantitative methodologies within a framework of a case study approach were done accordingly.

3.2.2 Sources of Data

This section is about how information was collected in the field, the data collected in the field were from two sources, primary and secondary data, the primary data was qualitative and the secondary data collected were mainly quantitative.

A. Primary Data

The first part of the data collection was based on a qualitative technique, the instruments used includes, interviews, direct personal observations.

B. Secondary Data

The second part of the data collection was based on quantitative method with secondary data sources, this part comprised of a retrospective review of records of pedestrian crash at Burayu Town obtained from Burayu hospital records. Data were obtained from the monthly and annual reports for a five (5**)** year period time from 2015 to 2019.

3.3 Data Collection Sources and Participants

In relation to Burayu hospital and Burayu Town Traffic police station were chosen purposively for the study. The hospital keeps all records of road accidents, type of motor involved, number of pedestrian injured, number of pedestrian fatality (killed) persons and recording where the accident took place, the hospital is also responsible for the treatment and immediate support for pedestrian crash in the area. The police station at Burayu Town is another data collection point of this study; the police in this area are the one responsible for the pedestrian and Pedestrian safety, controls, ensuring traffic rules and regulation are followed, they also record and evaluate the contributing factor of all pedestrian crash in an area, again it was relevant for the sake of this study police station to be one of the data collection sources of the study. In an interview study, sampling is connected to the decision of about which persons should be interviewed. It is also about which of the interviews should be transcribed and interpreted and which cases of text can best be used to demonstrate the findings [17].

3.4 Study Variables

I. Dependent Variables

- Pedestrian crash fatality, severe injury and slightly injury rate

II. Independent Variables

- Socio-demographic related variables
- Driver’s behavior related variables
- Vehicle factor related variables
- Road Environment factor related variables
- Pedestrian factor and behavior

3.5 Data Processing and Analysis

The data entered into and cleaned using Epi Data Version 3.02, and then transferred into and analyzed using SPSS Version 20. Descriptive statistics of percentages and frequency distribution was presented using tables and figures. Chi square for linear trend and line graphs that show the mixed log it model and Logistic regression was used to evaluate the factor between the dependent and independent variables. Multi co linearity were checked and variables with standard error (>2) were dropped from analysis. A cut off value of (P≤0.25) was used to select the variables included in the final logistic regression model. The model fitness was tested by Hosmer and Leme show goodness of fit test & fitted at p-value=0.200. Outliers deleted before analysis and no influential case (Cook's distance >1).

3.6 Descriptive Statistical Method for Contributing factor of Pedestrian Crash Modeling

A. The A Mixed Log It Model

A mixed-logit model assumes that some parameters are random across the population (and sample). Model parameters are allowed to vary across the population with a pre specified distribution for unobserved heterogeneity across observations, such that [21].

$$Yni = (\beta ni\ Xn + \varepsilon ni) \qquad (3.1)$$

βni: is a vector of alternative-specific estimable parameters, some or all of which are varied the population

Xn: are explanatory variables (pedestrian age, type of vehicle, etc.), as a vector of estimable parameters

εni: is the error term. (Using Poisson Formula of Miaou and Lum (Miaouet)

B. Goodness of Fit

I. Like Hood Ratio Test

There are number of methods to evaluate the overall fit discrete models. The likelihood ratio test is a popular method to assess computing models [21].

$$L^2 = -2[L^2(\beta_R) - L^2(\beta_u)] \quad (3.2)$$

Where, $L^2(\beta_R)$ is log-likelihood at convergence of the restricted model (sometimes considered to have all parameters in β equal to 0, or just to include the constant term, to test overall fit of the model) and $L^2(\beta_u)$ is the log-likelihood at convergence of the unrestricted model. The L^2 statistics is distributed with the degrees of freedom equal to the difference in the number of parameters in the restricted and unrestricted model (the difference in the number of parameters in the β_R and the β_u parameter vectors).

4 RESULT AND DISCUSSION

This chapter presented and describes pedestrian crash data were supplied by the Burayu Town Traffic Police Commission and Hospital for the period January 01, 2015 to December 31, 2019. (Five years), which are the latest data available at the time, a crash record at each police station and each police station reports summarized crash data to the district. The crash database variables include time of day, day of week, education, age and gender of drivers, pedestrian (age and Sex), vehicle type, road type, land use, median and lanes, terrain, pavement type, pavement conditions, weather conditions, and reason for the crash. Then, pedestrian crashes were characterized using descriptive analysis to examine the relationships among factors and to evaluate possible causes and contributing factors.

4.1 Pedestrian Crash Data in Burayu Town

Table 4.1 shows the distribution of total pedestrian crashes severity by year 2015 and 2016 had the highest number of pedestrian crashes. However, 2018, 2015 and 2017 had the highest percentages of slightly injury, severe injury and fatal injury crashes respectively. In addition, there was a very minor difference in pedestrian crashes from 2015 and 2016. Finally, severe injury crashes accounted for the majority of crashes during the five year period (2015-2019).

Table 4.1: Total Pedestrian Crash Data in Burayu Town

Year	Number	Slightly injury	Percent (%)	Severe injury crashes	Percent (%)	Fatality injury crashes	Percent (%)
2015	95	3	16.7%	82	32.3%	10	13.9%
2016	85	5	27.8%	67	26.4%	13	18%
2017	66	2	11%	43	16.9%	21	29.2%
2018	54	7	38.9%	38	14.9%	9	12.5%
2019	44	1	5.6%	24	9.5%	19	26.4%
Total	**344**	**18**	**100%**	**254**	**100%**	**72**	**100%**

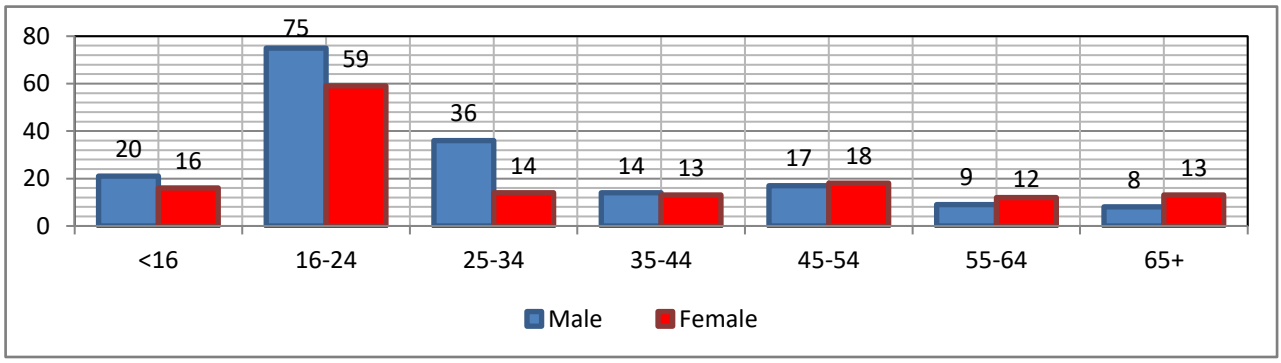
4.2 Descriptive Statistics Factors of Pedestrian Crashes in Burayu Town

The data are analyzed based on age, sex, severity of severe injury, slightly injury and fatality presence or other substance, pedestrian crash types and vehicle type, time of day, at time of night crash, and land use variables, road type local place of pedestrian crash around Burayu town. There are 344 pedestrian-vehicular crashes data in Burayu Town for a period of five (5) years analyzed in this study. Out of the 344 crashes from 2015-2019, 40% of the crashes involved female pedestrians and 60% involved male pedestrians. The distribution of the pedestrian-vehicular crash data among different age groups is 36% children, 60% adults and 4% elderly. Over 50% of these crashes resulted in injuries or fatalities. Almost 70% of all crashes occurred during dark and daylight hours. Over 10% of crash victims were found to have a substance (alcohol or drugs) present or contributing to the crash. It is interesting to note that 19% of the victims were at crosswalks and nearly 55% of these crashes occurred with pedestrians that were on the roadway but not at a crosswalk.

4.2.1 Age and Gender

Figure 4.1 shows the spatial distribution of the pedestrian-vehicle crashes differentiated by the age and Gender group of the pedestrian involved in the crash: child, adult, and elderly. The majority of crashes, nearly 60%, involved age (16-24). Less than 8% of the crashes involved the age (55+). However, over 32% of pedestrian crashes occurred with age (<16).Therefore there are disproportionably higher percentages of youngest that are involved in crashes. Although, Burayu Town has a high number of crashes involving the age (25-34). For those under the age of 45,

male pedestrians are more likely to be involved in pedestrian crashes. For those under the age of



55, females are more likely to be involved in pedestrian crashes.

Figure 4.1: Pedestrian Crashes by Age and Gender in Burayu Town

4.2.2 Pedestrian Crashes by Driver Age, Education and Sex

The age range of drivers involved the case in pedestrian crashes is shown in Figure 4.2. The highest number of pedestrian crashes (fatal, severe injury, slightly injury and percent) involved drivers in the less than 18 age group 110 (32%), 18–30 year age group 91 (26%), in the 31-54 year age group 59 (17%), more than 55 age group 50(15%) and unknown age 34(10%). Driver education levels were also recorded. However, Drivers whose education level was high school or below represented 36%, 14% and 19% of fatal, slightly injury and severe injury crashes, respectively. however it is difficult to reach conclusions about the significance of the findings without knowing the education levels of drivers in the general population. Sex also presents differentiation in crash involvement.

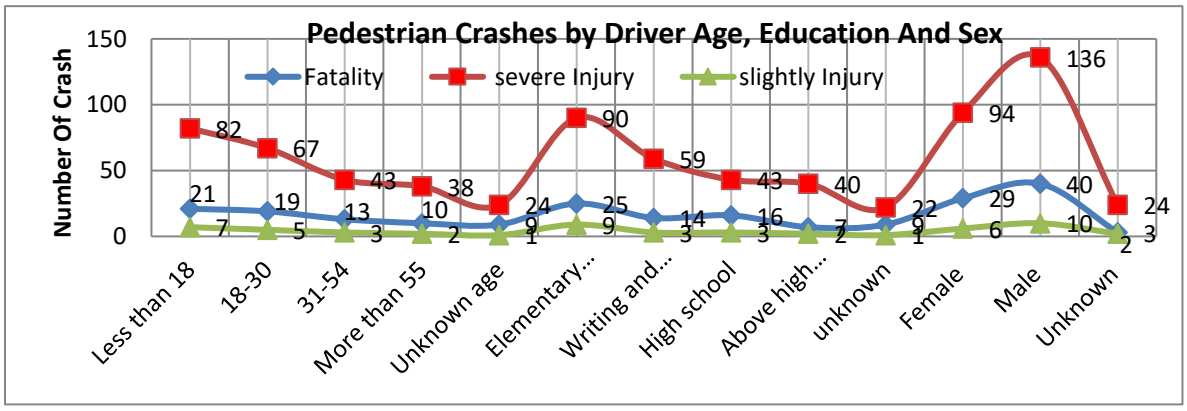


Figure 4.2: pedestrian crashes by driver factor, age, education and by sex in Burayu Town

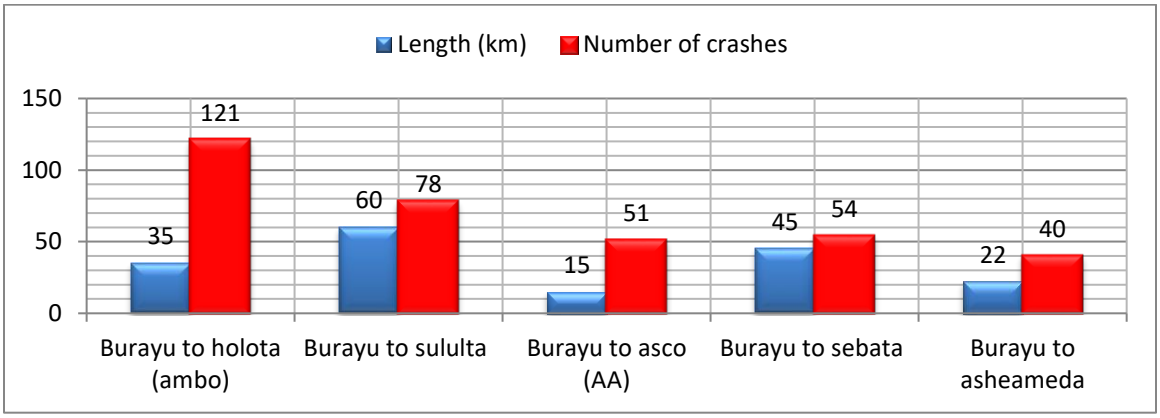


Figure 4.3: Specific road section as per their pedestrian crash resulted in Burayu Town

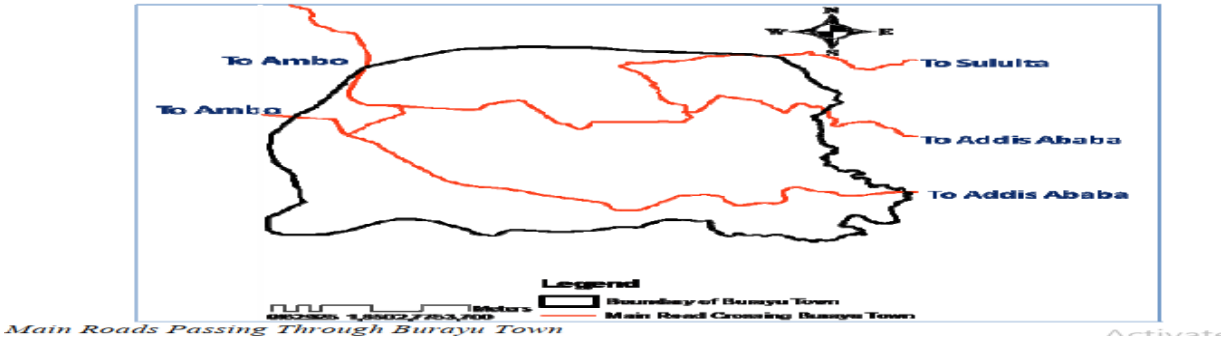


Figure 4.4: Main road passing through Burayu Town

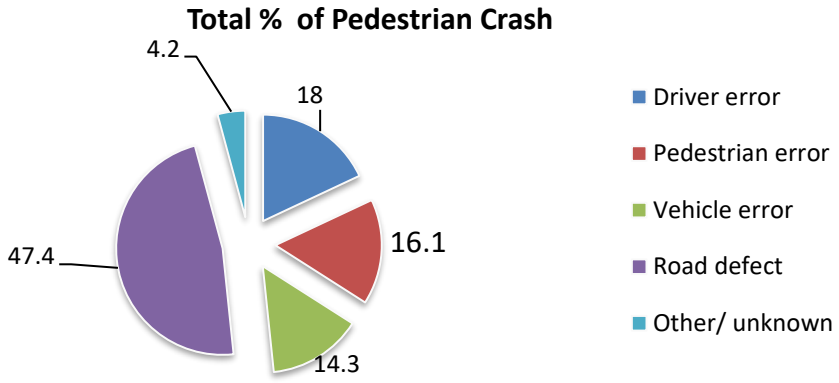


Figure 4.5: Major Causes of pedestrian crash in Burayu Town

4.2.3 Pedestrian Crashes by Location

Each pedestrian crash was assigned to one of the following three location categories depending on where the crash occurred: roadway, crosswalk, or sidewalk. It should be noted that the term crosswalk does not always refer to a painted crosswalk. In areas, officers may mark crosswalk for a crash occurring, so that convention is used in this report. The vast majority of pedestrian crashes in Burayu districts occur either on a roadway or at a crosswalk.

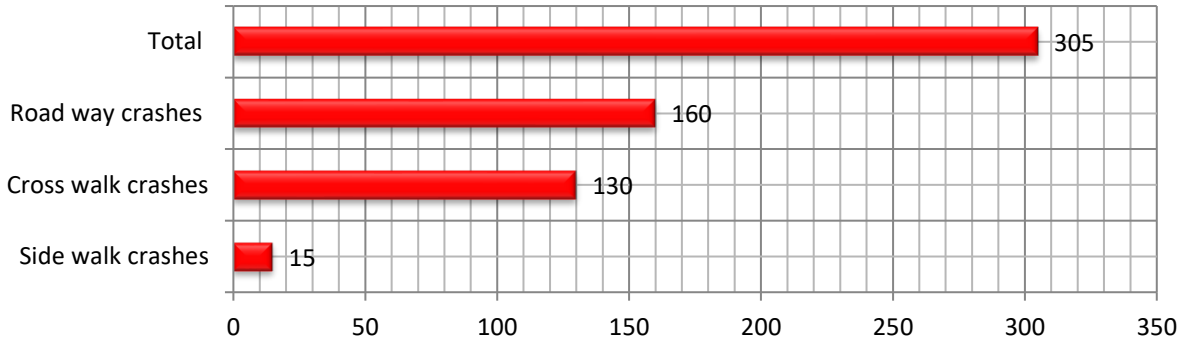


Figure 4.6: Pedestrian Crashes by Location Category in Burayu Town

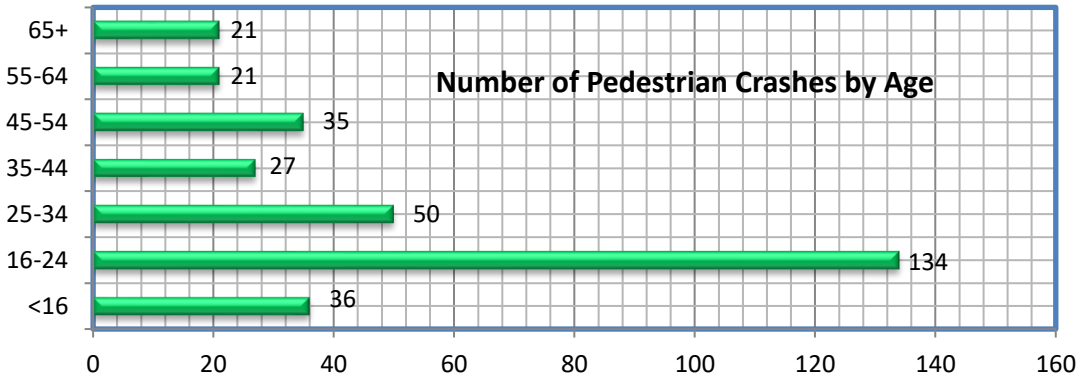


Figure 4.7: Number of pedestrian crash by age group in Burayu Town

Pedestrians are most likely to get hit in the roadway in the late afternoon and evening (3 p.m. to 11 p.m.) with the peak hour between 6 p.m. and 7 p.m. Figure 4.8. Pedestrians are most likely to get hit in a crosswalk between 4 p.m. and 7 p.m. and on a sidewalk between 7 a.m. and 9 a.m. Roadway and crosswalk crashes were not confined to just within the Town limits, but also occurred in suburban areas. Sidewalk crashes happen mostly inside the Town limits.

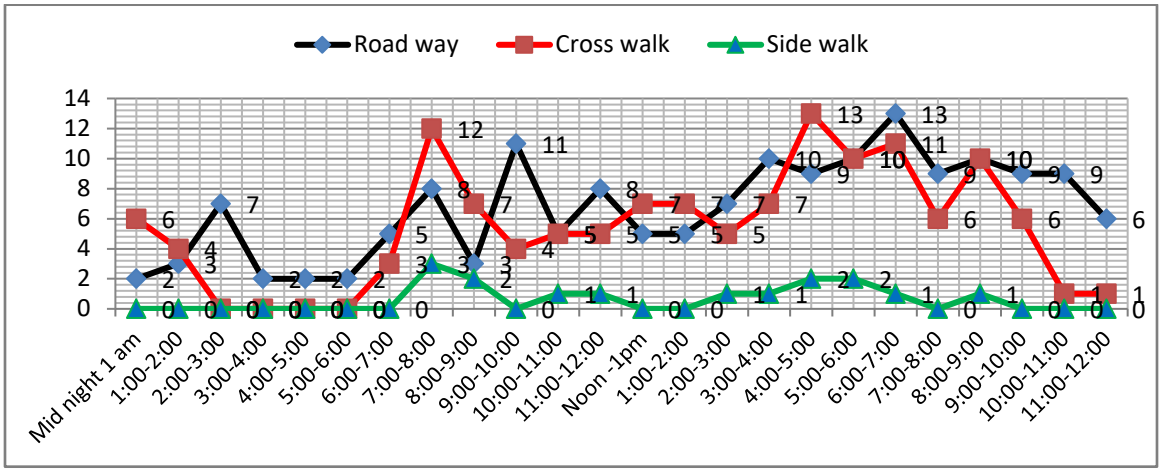


Figure 4.8: Pedestrian Crashes by Time of Day and Location Category in Burayu Town

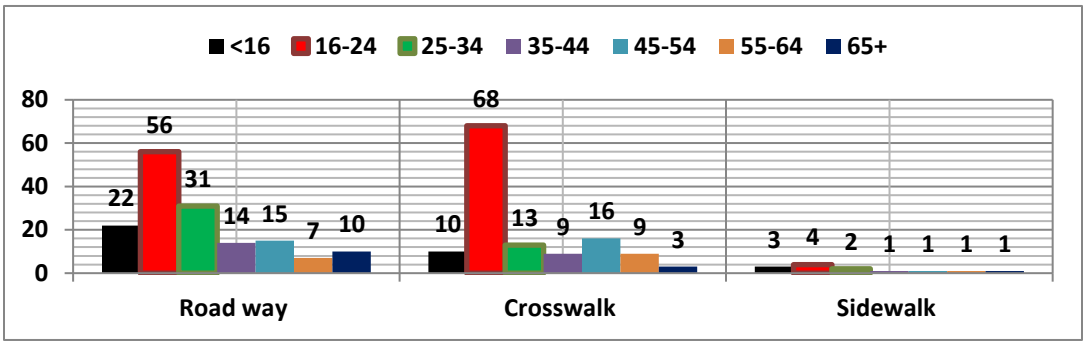


Figure 4.9: Pedestrian Crashes by Location and Age in Burayu Town

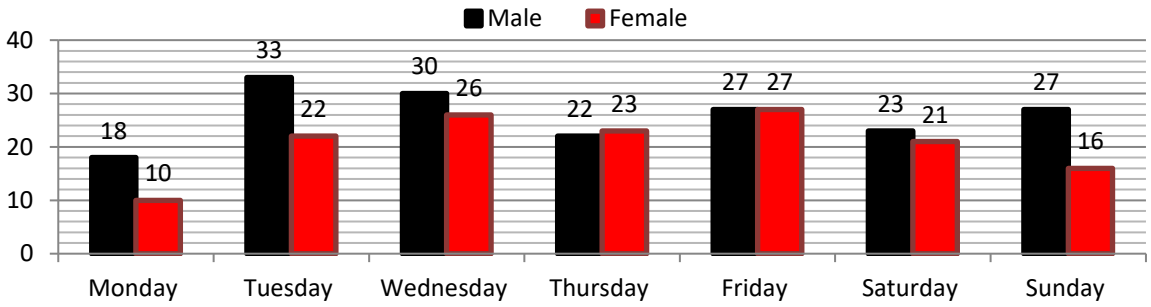


Figure 4.10: Pedestrian Crashes by Gender and Day of the Week in Burayu Town

4.2.4 Pedestrian Crashes by Land Use

There are also links between different land use types and the occurrence of crashes. The analysis indicates that most fatal injury, slightly injury and severe injury crashes occurred

in and around Towns, particularly in central business(marketing area) districts and residential areas.

4.3 Development of Pedestrian Crash Model by Mixed Log It Modeling

Table 4.2 presents the descriptive statistics of the explanatory variables (i.e., crash factors) considered in this study. All the variables are indicator variables with values (0 and 1) and the mean values represent the proportion of the variables. The mean value of the variable is meaning that the percent of (%) of the pedestrians were involved in crashes. Due to the ordered nature of the crash severity level, several researchers used the ordered log it models to examine the relationship between crash factors and severity outcomes with this in mind, this study models the pedestrian crashes as follows: 0 for Fatality, 1for severe injury, 2 for slightly injury. The dependent variable y* is specified as follows, which is a latent and continuous measure of pedestrian crashes of each observation (n).

$$y^* = \beta x + \varepsilon \qquad (3.1)$$

Where β = vector of crash parameters to be estimated, X = vector of explanatory variables (e.g., pedestrian, driver, vehicle, crash, and roadway characteristics), and ε = random error term, which is assumed to be normally distributed with a mean of (0) and a variance of (1).The observed injury severity data (y) for each observation (n) can be represented as follows under the log it modeling framework and by using Equation (3.1)

$$\begin{aligned} &y = 0 \text{ if} -\infty < y^* < \mu_0 \\ &y = 1 \text{ if } \mu_0 < y^* < \mu_1 \qquad (3.1.1) \\ &y = 2 \text{ if } \mu_1 < y^* < \infty \end{aligned}$$

Where μ = parameters to be estimated between two adjacent crash levels that define y.

Table 4.2: Descriptive statistics of the explanatory variables in Burayu Town

Explanatory Variable	Mean	SD
Driver Characteristics		
Crash by driver age		
<18 (1 if less than 18 years old; 0 otherwise)	0.367	0775
18-30 (1 if between 18 and 30 years; 0 otherwise)	0.303	0.641

31-54(1 if between 31 and 54 years; 0 otherwise)	0.197	0.415
>55 (1 if over 55 years; 0 otherwise)	0.167	0.352
Unknown age (1 if unknown age; 0 otherwise)	0.113	0.239
Crash by driver education		
Elementary school (1 if Elementary school; 0 otherwise)	0.413	0.874
Writing and reading (1 if Writing and reading; 0 otherwise)	0.253	0.536
High school (1 if High school; 0 otherwise)	0.207	0.437
Above high school (1 if Above high school; 0 otherwise)	0.163	0.345
Unknown (1 if unknown; 0 otherwise)	0.107	0.225
Crash driver gender		
Female (1 if female; 0 otherwise)	0.430	0.909
Male (1 if male; 0 otherwise)	0.620	1.311
Unknown data (1 if unknown data; 0 otherwise)	0.097	0.204
Pedestrian Characteristics		
Pedestrian crash by age		
< 16 (1 if less than 16 years old; 0 otherwise)	0.120	0.253
16-24 (1 if between 16 and 24 years; 0 otherwise)	0.447	0.944
25-34 (1 if between 25 and 34 years; 0 otherwise)	0.167	0.352
35-44 (1 if between 35 and 44 years; 0 otherwise)	0.090	0.190
45-54 (1 if between 45 and 54 years; 0 otherwise)	0.117	0.247
55-64 (1 if between 55and64 years; 0 otherwise)	0.070	0.148
>65 (1 if over 65 years; 0 otherwise)	0.070	0.148
Pedestrian crash by gender		
Female (1 if female; 0 otherwise)	0.483	1.022
Male (1 if male; 0 otherwise)	0.600	1.268
Vehicle Characteristics		
crash by vehicle type		
Motor cycle (1 if Motor cycle; 0 otherwise)	0.153	0.324
Truck (1 if Truck; 0 otherwise)	0.247	0.521
Minibus (1 if Minibus; 0 otherwise)	0.573	1.212
Others/unknown (1 if Others; 0 otherwise)	0.173	0.366
Road way characteristics		
Crash by location		
Road way (1 if Road way; 0 otherwise)	0.507	1.071
Crosswalk way (1 if Crosswalk way; 0 otherwise)	0.413	0.874
Sidewalk way (1 if Sidewalk way; 0 otherwise)	0.067	0.141
Crash by land use		
School zone/area (1 if School zone/area; 0 otherwise)	0.130	0.275
Marketing area (1 if Marketing area; 0 otherwise)	0.217	0.458

Commercial area (1 if Commercial area; 0 otherwise)	0.153	0.324
Residential area (1 if Residential area; 0 otherwise)	0.347	0.733
Church area(1 if Church area; 0 otherwise)	0.103	0.218
Hospital area (1 if Hospital area; 0 otherwise)	0.107	0.225
Recreational area (1 if Recreational area; 0 otherwise)	0.090	0.190
Lane /median		
One lane (way) (1 if One lane; 0 otherwise)	0.403	0.853
Undivided two way (1 if Undivided two way; 0 otherwise)	0.407	0.859
Two lane (way) (1 if Two lane; 0 otherwise)	0.210	0.444
Divided two way (1 if Divided two way; 0 otherwise)	0.127	0.268
Weather condition		
Fog (1 if Fog Minibus; 0 otherwise)	0.350	0.739
Cloudy (1 if Cloudy; 0 otherwise)	0.250	0.528
Rain(1 if Rain; 0 otherwise)	0.480	1.015
No data (1 if No data; 0 otherwise)	0.067	0.141

In the methodology parts of crash file were created and inserted into Spss for variable regression process. Prepared crash files were inserted to spss to get goodness of fit test and parameter estimate. Both restricted model and unrestricted model were calculated to check either the restricted model is fitted or not. Fixed-parameters ordered probit model was estimated using the maximum likelihood method and random-parameters ordered probit model was estimated using the simulated maximum likelihood method. The likelihood ratio and degree of freedom for both fixed-parameters (restricted) and random- parameters (unrestricted) model were calculated to compare the models by the following formulas.

$$L^2\text{comparison} = -2[L^2(1) - L^2(2)] \quad (3.2)$$

Where L^2 (1) and L^2 (2) are log-likelihood at the convergence of the fixed- parameters model and log-likelihood at the convergence of the random- parameters model respectively.

$$DF = df1 - df2 \quad (3.2.1)$$

Where df1 and df2 are degree of freedom of fixed-parameter model and the random- parameters model respectively.

By comparing L^2comparison and DF parameter model could be chosen or rejected. If L^2comparison statistics is not significant parameter model could be chosen. After deciding

goodness of fit test, parameter estimate would be followed. From parameter estimate significance of each parameter would be examined and if significance value of values of parameters are > 0.05 they should be out of the model.

Table 4.3: Goodness of fit test for fixed- parameter model

	Chi-Square	df	p-value(sig.)
Likelihood Ratio	1202.124	8217	0.000
Pearson	255314.383	8217	0.000

Table 4.4: Goodness of Fit Test for Random- Parameter Model

	Chi-Square	df	p-value(sig.)
Likelihood Ratio	0.000	3122	0.000
Pearson	0.000	3122	0.000

Likelihood ratio for fixed-parameter model L^2model (1) = 1202.124

Likelihood ratio for random-parameter model L^2model (2) = 0.000

Df for fixed-parameter model (1) = 8217

Df for random-parameter model (2) = 3122

L^2comparison = -2 [L^2 (1) – L^2 (2)] = -2(1202.124-0.000) = -2404.248

Df = df1 – df2 = 8217 – 3122 = 5095

So from the above result likelihood ratio is not significance compared to df. So fixed parameter model is best fitted model.

The mixed model includes 35 estimated parameters including the constant term. The model shows the log likelihood at convergence (−2404.248), which is reasonable given the amount of variance in pedestrian crashes data. The parameter for driver experience is a random variable in the best-fit statistical model. The estimated parameter is significant with a p-value of less than 0.01. As regard to the diver characteristics, only experienced was found to be statically significant. The parameter is random and is normally distributed with mean 0.03 and standard deviation of 0.01.

Table 4.5: Parameter Estimates of Pedestrian Crash in Burayu Town (2015-2019)

	Fatality Crashes		Severe Injury Crashes		Slightly injury crashes	
	estimate	**P- value**	**estimate**	**P- value**	**estimate**	**P- value**
Constant	-2.116** (0.11)+	0.00	-0.345* (0.010)+	0.047	-0.351** (0.402)+	0.01
Random Parameter						
Derivers experience	0.03*** (0.010)+	0.00				
Pedestrian age	1.10*** (0.205)+	0.00				
Mini bus			-0.024** (0.023)+	0.324		
School, hospital and recreation area	-1.93 (1.223)+				-0.23* (0.322)+	0.00
Weather cond.(cloudy)			-0.012*** (0.241)+	0.203		
Fixed Parameter						
Driver characteristics						
Crash by driver age						
<18->55	0.002***	0.004	0.170 **	0.040	0.012***	0.014
Crash by driver education						
Elementary school	0.312***	0.000	0.090 *	0.001	0.102	0.010
Writing and reading	0.090*	0.901			0.210*	0.001
High school	0.220*	0.815			0.140**	0.015
Above high school	0.231*	0.202	0.131**	0.102	0.110***	0.201
Unknown	0.302**	0.730	0.211**	0.440		
Crash driver gender						
Female	-0.136*	0.809	-1.064**	0.309	-0.055 **	0.602
Male unknown	0.533***	0.029	0.244**	0.037	0.502 **	0.120

Unknown	0.022**	0.118				
Pedestrian characteristics						
Pedestrian crash by age			0.015***	0.118	0.002***	0.000
Pedestrian crash by gender						
Female	0.001***	0.105	0.203 **	0.015	0.101*	0.005
Male	0.003*	0.005	0.041***	0.054	0.033***	0.000
Vehicle characteristics						
crash by vehicle type						
Motor cycle	0.631***	0.010	0.501***	0.011		
Truck	-0.936***	0.017	-0.126**	0.006	-0.244**	0.011
Minibus					0.431**	0.010
Others/unknown	0.226**	0.004	0.236**	0.015	0.131**	0.000
Road way characteristics						
Crash by location						
Road way	-1.614***	0.388	-0.731***	0.303	-1.415***	0.245
Crosswalk way	0.160***	0.001	0.152***	0.000	0.155***	0.021
Sidewalk way	0.201**	0.001	0.231**	0.003	0.231**	0.000
Crash by land use						
School zone/area	0.004***	0.000	0.224***	0.010		
Marketing area	0.312**	0.011	0.343*	0.001		
Commercial area	0.063**	0.001			-0.163**	0.101
Residential area	-1.212***	0.583	-1.203***	0.347	-0.312***	0.288
Church area	0.470*	0.001				
Hospital area	0.283***	0.015				
Recreational area	0.152*	0.087				
Lane /median						

One lane (way)	0.102***	0.311				
Undivided two way	1.312**	0.001	0.314**	0.021	1.334**	0.301
Two lane (way)	0.002*	0.000	0.117*	0.103	0.102*	0.000
Divided two way	0.101***	0.001	0.024 ***	0.000	0.311***	0.011
Weather condition						
Fog	0.103***	0.106	1.231**	0.411		
Cloudy	1.221*	0.405				
Rain	-1.201***	0.435	-1.102***	0.135	-0.221*	0.005
No data	0.402**	0.169	0.141**	0.104		
Log-likelihood value at convergence $\mathbf{L^2(\beta)}$	-2404.248		-2404.248		-2404.248	
Number of observations	344		344		344	

Note: *** Statistically significant at 0.01;
** Statistically significant at 0.05;
* Statistically significant at 0.1 and
+ The value in parenthesis represents the standard deviation of the random parameter

Table 4.6: Parameter Elasticity of the Variables Affecting pedestrian injury Severity

Variable	Fatality Injury Crashes	Severe Injury Crashes	Slightly Injury Crashes
Driver characteristics			
Crash by driver age			
<18->55	6.13%	17.1%	3.2%
Crash by driver education			
Elementary school	3.03%	1.9%	2.3%
Writing and reading	8.4%		1.5%
High school	5.3%		3.1%
Above high school	1.6%	2.7%	0.3%
Crash driver gender			
Female	-7.2%	-10.7%	-3.3%
Male unknown	11.9%	6.6%	0.9%
Pedestrian characteristics			
Pedestrian crash by age		3.8%	1.2%
Pedestrian crash by gender			
Female	8.1%	9.4%	1.7%
Male	5.65%	3.24%	1.08%
Vehicle characteristics			
crash by vehicle type			
Motor cycle	8.32%	11.1%	0.4%
Truck	-9.5%	-12.3%	-3.8%
Minibus			4.1%
Others/unknown	2.6%	7.3%	0.6%
Road way characteristics			
Crash by location			
Road way	-10.0%	-7.7%	-3.2%

Crosswalk way	4.065	6.2%	1.1%
Sidewalk way	5.85	9.1%	2.3%
Crash by land use			
School zone/area	2.9%	3.08%	0.22%
Marketing area	7.0%	8.34%	3.0%
Commercial area	6.21%		0.88%
Residential area	-9.03%	-11.25%	4.4%
Church area	4.17%		
Hospital area	3.44%		
Recreational area	3.04%		
Lane /median			
One lane (way)	7.01%		
Undivided two way	5.3%	9.1%	0.77%
Two lane (way)	3.55%	4.04%	0.895
Divided two way	1.9%	2.3%	0.8%
Weather condition			
Fog	5.08%	7.3%	4.9%
Cloudy	6.8%	5.7%	3.15
Rain	-12.1%	-14.4%	-6.9%

The parameter for minibus was found to be random and associated with crash injuries with p-values of less than 0.05. Thus, if the vehicle involved in the crash was a mini bus. Fatal injury is more likely to occur to pedestrians when the vehicle is driven by people other than the owner or the primary driver of the vehicle. However, female drivers were also statistically significant with an estimated parameter -0.136, -1.064 and -0.055 with a p-value below 0.1 for fatal, severe and slightly injury respectively. The estimated parameter for owner drivers is negative, which shows that owner drivers are less likely to be involved in severe (fatal) injury and slightly. According to the model, road way characteristics rain is negatively associated with the risk of slightly and fatal injury with an estimated and p-values less than 0.01. In terms of the vehicle type, the analysis results showed that mini bus were statistically significant factors. The variable "mini bus" was found to be random and normally distributed with mean -0.024 and standard deviation of 0.023. Furthermore, being by a mini bus was found to decrease the likelihood of fatality by 9.5 percent and decrease the likelihood of severity injuries by 12.3 percent and also decrease likelihood of slightly injuries by 3.8 percent. The difference in activities of each district manifests the variation in magnitude of pedestrian safety in Burayu.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

A comprehensive evaluation was done on crashes involving pedestrians in the Burayu Town, and the factor and risk behaviors for pedestrian crashes had been evaluated. Pedestrian crashes were recorded from 2015 to 2019. Of these crashes, (21%) were fatal injury, (74%) severe injury and (5%) were slightly injury. When considering demographic characteristics, the majority of pedestrian crashes involved males, and crashes involving males tended to be more severe than crashes involving females. Pedestrian crashes that involved alcohol tended to be more severe. Additionally, pedestrian age group from 16 to 24 years old accounted for the majority of pedestrian crashes. Younger male drivers were the groups with high proportion of involvement in pedestrian crash. Pedestrians and the working age groups of the population are the highly affected groups. In regards to environmental conditions, the majority of pedestrian crashes occurred during the daylight and dark-lighted lighting conditions and during fog and cloudy weather conditions. Based on crash data for five years (2015-2019), in terms of roadway characteristics, the majority of pedestrian crashes occurred at road way or roads with one lane

and residential land use development. In this study, risk factors contributing to the cause of pedestrian crash have been identified into the following categories:

- Human Behavior Elements
- Road Environmental Risk Factor
- Types of Vehicle Factor Elements
- The Traffic Regulations Enforcement

5.2 Recommendations

In order to reduce pedestrian crash in Burayu Town and district, I would recommended based on my studies the following measures to rectify the problem:

A. About Human Behavior

- There is a need of government to improve the pedestrian safety.
- High living standards would affect the public and government view on risk and safety culture and also reduce bribery and corruption.
- All drivers of heavy goods vehicles and pedestrian should participate that the inevitable bad habits acquired can be reduced at a relatively early state.

B. About Environment and Road Network

- The Government under responsible ministries should make sure road signs are repaired and more land use area in Burayu.
- Traffic rights and roundabout are important features to be considered in improving highways.
- The construction of new roads especially highways must consider traffic separation to harmonize all road users and facilitate pedestrian safety.

C. About Vehicles

- There is a need of establishing a permanent control unit (Vehicle examination unit) for regular vehicle inspection of all vehicles at least once a year and certificate of approval should be provided to the qualified vehicles.
- All types of vehicles to be used in the country, should meet safety standards such as proper brakes, lights, seat belts, indicators and good tires.

D. About Traffic Control, Regulation and Legislation

- The government should improve the conditions of police force, instituting better working conditions and pay them.
- A new driving license system should be implemented, and priority should be given to international harmonization.
- A driving license database should be developed and implemented. It should be noted that properly educated drivers would be a positive impact on pedestrian safety.
- The traffic police should strengthen surveillance and enforcement to net drivers who drink alcohol beverages and then drive their vehicles to reduce those accidents which occur during of crash time

E. About the Hospital After Accident

- The hospital staff should be considered for intensive training on emergency, preparedness.
- They should be also motivated to care for the accident victims.
- The hospital should establish a full equipped and staffed orthopedic section.
- The ambulance personnel and hospital staff especially those in casualty section should be trained on how to give first aid to injured pedestrian and how to handle different types of injuries while transporting them to hospital.
- The hospital and police data collection and record keeping should be strengthened.

F. Engineering

- There are clearly many inadequacies in the provision of road infrastructure for pedestrians.
- This can be seen in the high exposure of pedestrians walking along roads where there are no footpaths, having to cross where there are no facilities, and being at risk at night due to a lack of adequate lighting.
- While full provision of pedestrian infrastructure is prohibitively expensive for existing roads, it is possible to incorporate footpaths and crossing points into new roads without a large additional cost.

G. Education

- Road safety education for pedestrians would involve alerting them to road traffic rules, and there is a similar need for drivers to understand their legal requirements, such as when pedestrians have right of way.
- Providing education at school about safe crossing should assist in reducing their risk.

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