ISLAMIC UNIVERSITY OF TECHNOLOGY

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THESIS TITLE

DEVELOPMENT AND APPLICATION OF ACCIDENT PREDICTION MODEL FOR INTERSECTIONS AT DHAKA CITY

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AN UNDERGRADUATE THESIS
SUBMITTED TO THE
DEPARTMENT OF CIVIL AND ENVIRONMENTAL ENGINEERING
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE
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November 2016

DECLARATION

DECLARATION OF ORIGINAL WORK

This declaration is made on the 4th November, 2016.

Student's Declaration:

We, Shahriar Mohammad Raihan, Abrar Fahim and Shah Mostofa Touhiduzzaman declare that the work entitled "**Development and Application of Accident Prediction Model for Intersections at Dhaka City**" is our original work. We have not copied from any other students' work or from any other sources except where due reference or acknowledgement is made explicitly in the text, nor has any part been written for us by another person.

Student's name: ____________________

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Date submitted

Supervisor's Declaration:

I, Dr. Shakil Mohammad Rifaat, Associate Professor, Department of CEE, IUT, hereby certify that the work entitled "**Development and Application of Accident Prediction Model for Intersections at Dhaka City**" was prepared by the above named students and was submitted to the "FACULTY" as a fulfillment for the conferment of BACHELOR OF SCIENCE in CIVIL AND ENVIRONMENTAL ENGINEERING, and the aforementioned work, to the best of my knowledge, is the said student's work.

Signature: ____________________

Date: ____________________

ACKNOWLEDGEMENTS

"***In the name of Allah, Most Gracious, Most Merciful***"

"Dedicated to our beloved parents"

Without their patronage and guidance nothing was possible. So, No matter how far we come, our parents are always in us.

This achievement would never be possible without the help, support, and love of many wonderful people to whom we are always indebted.

First and foremost, we would like to express our sincere gratitude to our supervisor Associate Professor Dr. Shakil Mohammad Rifaat. We are extremely thankful to his patient guidance, valuable advice, and constant support. Without his help, diligence, insights, and enthusiasm this work would never be possible. His availability during this course and encouragement increases our workability and is greatly appreciated.

We also would like to acknowledge the Accident Research Institute (ARI), BUET for their great support in providing the most important crash data for initializing our work about the pedestrian vehicle crashes in Dhaka City.

The resources and references of different research papers from Bangladesh and around the world which are followed throughout the thesis are listed at the last in 'Reference' section.

ABSTRACT

Pedestrians are some of the most vulnerable road users, especially in large congested cities in developing countries. Commencing with the data that every year more than 1.3 million people die in road accidents around the world (Building Leaders in Urban Transport Planning, LUTP, 2012). So, this indicates that the major mortality rate is procured by the road accidents no question asked. Not only in USA or any other developed countries of the world, but also in developing country like Bangladesh, with regard to safety, the pedestrians are of major concern as they represent up to 72 percent of road traffic fatalities in Dhaka Metropolitan City (Rahman et al., 2006). So, it can be stated that pedestrian safety is not only a problem in global range, but also acute in developing country like Bangladesh. In order to develop appropriate countermeasures to improve safety, research has to be conducted to understand the factors contributing to vehicle-pedestrian collisions. This study is especially designed to predict accident probability only for pedestrian-vehicle crashes at intersections as accurate as possible. The statistical model developed in this study are focused in predicting traffic accidents at four-legged signalized and tee or three legged intersections. For data analyzing and modeling of the pedestrian-vehicle crashes at intersection, at first annual crash data were collected from 1998-2009 from ARI (Accident Research Institute), BUET. There is a total of 54 intersection's data were available and we worked on 45 selected intersections. After getting all the data analyzed by the statistical software, a projected equation is possible to make with the help of the critical and significant factors to get accident prediction for accident forecasting at any particular intersection. Using data from the capital of Bangladesh, Dhaka, this study finds that waste deposit facilities, overhead bridges and underpasses, solar panel system, law enforcement authority and vehicle volume are associated with an increase in the number of vehicle-pedestrian crashes, whereas roads with the rail crossings, similar approach road, commercial land uses, maximum number of inbound and outbound lanes, roads with greater number of lanes, absence of bus stop, speed breakers and pedestrian volume are associated with a reduction in the number of vehicle-pedestrian crashes.

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SYMBOL	DEFINITION
AIC	Akaike Information Criterion
AADT	Average Annual Daily Traffic
ADT	Average Daily Traffic
LL	Log Likelihood
ML	Maximum Likelihood
MLR	Multiple Linear Regression
PRM / PR	Poisson Regression Model
NBM / NB	Negative Binomial Model
OPER ALC	Driver Alcohol Use
PED ALC	Pedestrian Alcohol Use
3L / 4L	3 Lanes Or 4 Lanes
M / B	Motorized Vehicles or Motorized and Non-Motorized Both

CHAPTER 1 INTRODUCTION

1.1 Background of the Study

In recent times, the most number of people died in Bangladesh is because of the road accidents all over the country. Statistics shows that at least 48631 fatalities and 25437 injuries in 29319 reported traffic collisions occurred in eight year's study period (1998-2005) (Anjuman et al., 2007). Statistics even suggest that the number is even more than the death from different vital and viral diseases. Problems related to road safety are now the most important task for the policy makers to solve with. It is perhaps understandable that road safety cannot be ensured overnight. For this reason, planned proposals of long term basis are mostly needed to be implemented in national policy for ensuring road safety for all the road users- pedestrians, drivers, vehicle users, inhabitants just outside the road.

Previously very few research has been done in the context of pedestrian safety, let alone in the intersection pedestrian-vehicle crashes in Dhaka City. But the pedestrians are the most vulnerable part suffered from a road accident, "Pedestrians are of major concern as they represent up to 72 percent of road traffic fatalities in Dhaka Metropolitan City (Rahman et al., 2006). So, with that in mind our study focuses on making a safety prediction model and to compare the results with developed country's perspective to get the evaluative scenario.

1.2 Statement of the Problem

The main problem was to collect the previous year's data regarding pedestrian-vehicle crashes as in Bangladesh very few researches or data collection is done for the road accidents and we needed the huge amount of data. It is essential to have an accurate data system to develop a good representative model, finally we collected 12 years data. With that data we used the Negative binomial model to analyze and get the prediction model, but our final result showed the model should be Poisson regression model. However one particular problem often encountered in accident studies is that of underreporting, which hides true information about accidents causing only a fraction of accidents to be reported.

The important thing is that even if the injury accidents are to be reported according to the law, there may be many injury accidents that are not reported especially slight injuries. So the number of accidents remain unknown and some accidents are never documented.

The presence of excess zeroes is another problem in any statistical model. Excess zero means no accidents, so the intersection may be safe or it may indicate that there is chance of occurring accidents, so it may not be safe totally. It may also indicate the presence of over-dispersion in the data set.

1.3 Objective of the Study

The prime objective of the study is to develop suitable statistical models to represent pedestrian-vehicle crashes at selected intersections of Dhaka city mainly three-legged or four-legged intersection approaches correlating the geometric characteristics, regulatory control characteristics and exposure variables. Attention is given to the possible problems such as underreporting and excess zeroes for searching over dispersion and inadequacy in model. The study also suggests possible causes for the identified significant factors based on the engineering judgment. In addition to that, the identification of hazardous intersection approaches and a slight comparison of factors affecting intersection approaches of developed and developing countries is also done.

Previously due to time limitation, exposure variables like vehicle volume and pedestrian volume of the intersections were not introduced in this study. We have collected pedestrian and vehicle data by conducting survey at pre-selected 45 intersections. Therefore we can now redevelop the previous model and check the effect of exposure variables on reducing or increasing pedestrian crashes at the intersection along with the other variables.

1.4 Outline of the Thesis

The first part of the thesis is the ‘‘INTRODUCTION’’ introducing the background of the study, objective of the study, problem statement.

The second part is the ‘‘LITERATURE REVIEW’’ including the previous study on pedestrian-vehicle crashes on developed and developing nation’s scenario, crash contributing factors, general divergence factors of Dhaka city and cities of developed countries, like Singapore.

The next chapter is the ‘‘METHODOLOGY’’ which contains different statistical model description for crash frequency analysis, model evaluation, as a whole the data collection process and analysis by software procedure.

Chapter four is named as ‘‘DESCRIPTION OF CRASH FACTORS’’. In this chapter all the factors both the insignificant and critical ones are described in short with pictures. Factors are described in three major parts- first one is the geometric characteristics, second one is the regulatory characteristics and the last one is exposure variables.

After that, the chapter five ‘‘RESULTS AND DISCUSSION’’ introduces the significant factors from our study along with the engineering evaluation of the causes of these crash factors.

The last chapter is the ‘‘CONCLUSION’’ and it includes the summary of research, main results, recommendations and the possibility of future research.

At the end the references are provided in alphabetic order for further information.

CHAPTER 2   LITERATURE REVIEW

2.1   Pedestrian-Vehicle Crashes on Developed Nations

Commencing with the data that every year more than 1.3 million people die in road accidents around the world (Building Leaders in Urban Transport Planning, LUTP, 2012),so its indicates that the major mortality rate is procured by the road accidents. Nowadays with the increase in population along with other socio-economic-demographic characteristics (like – versatile use of land pattern, increase in vehicle ownership, increase in household income), the increase in road traffic accident is growing simultaneously at an alarming rate. The literature review will be separated into three major categories. First, the history, data, present condition of the road traffic accidents will be discussed in terms of international perspective of intersection crashes. Then the same situation will be discussed in terms of developing countries and Bangladesh perspective giving emphasize on vehicle-pedestrian crashes. Next, the crash contributing factors from previous published papers will be analyzed. At last, the divergence factors between Dhaka city and cities of other developed nations will be discussed and developed nations perspective will be compared with the pros and cons of pedestrian-vehicle crashes in Bangladesh at recent times.

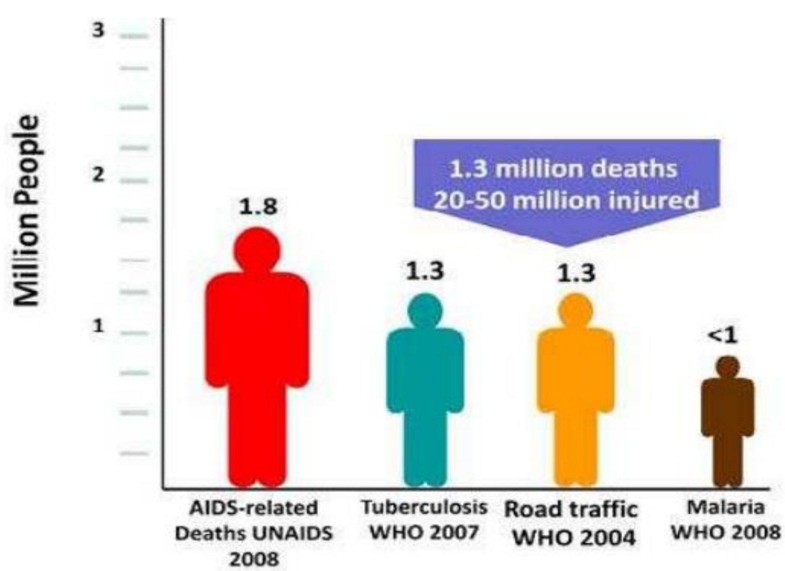


Figure 2-1: Road Safety is a Growing Health and Development Issue

2.1.1 Pedestrian-Vehicle Crashes

In spite of the declining rate of pedestrian fatalities (most notably declines among children and older adults), pedestrian crash injuries remain a serious public health problem. It is estimated that, each year, 80 000 to 120 000 pedestrians are injured and 4600 to 4900 die in motor vehicle crashes in the United States. Pedestrians account for 11% of all motor vehicle deaths, and in cities with populations exceeding 1 million, they account for about 35% (Retting et al., 2003). Children aged 5 to 9 years have the highest population-based injury rate and people older than 80 years have the highest population-based fatality rate. Pedestrians older than 65 years are more likely than younger pedestrians to be struck at intersections. The prevalence of alcohol use among injured pedestrians is well documented.

With a view to constructing a framework for prevention of pedestrian injuries, primary approaches include modification of the built environment, enforcement of traffic safety laws, motor vehicle design changes and pedestrian education. Modification of car fronts and other vehicle features to reduce the severity of injuries to pedestrians is a focus in Europe, where approximately 20% of all fatalities among road users involve pedestrians and cyclists; however, this approach has not been a priority in the United States despite research showing potential benefits (Retting et al., 2003).

Pedestrian education is a popular approach, but with the exception of children, there is a lack of evidence regarding the effectiveness of safety education. Modification of the built environment is a widely used approach that can be highly effective. But it is only possible for the developed countries to make any kind of highly equipped or state of the art technical modification to provide safety on the roadway or on the highway. For developing countries it’s impossible for the cost-benefit perspective.

2.1.2 Pedestrian-Vehicle Crashes at Intersection

The global economic losses due to road traffic crashes exceed US$ 500 billion. Over 1.2 million people are killed and over 20 million injured globally in crashes every year (WHO Report, 2009).

Research on different feasibility of modeling crash counts at intersections as a function of traffic volume and other variables has been ongoing for over a decade. Such efforts are made by taking different types of evaluating criteria to give emphasize on roadway safety. Each researcher takes unique factors to study the crash characteristics, for modeling and forecasting crashes between pedestrian and vehicles. Some examples of recent efforts include forecasting crashes at the planning level (Ladron de Guevara et al., 2004) and crash prediction modeling in New Zealand and Australia (Turner and Wood, 2009).

Brude and Larsson (1993) studied the effect of pedestrian and traffic volumes on pedestrian crashes at intersections (121 signalized, 155 non-signalized, and 9 roundabouts) in Sweden. They found that pedestrian volume has a significant and positive relationship to pedestrian crashes in a single predictive model that covered all intersection types.

Shankar et al. (2003) found that predictor variables such as average daily traffic, traffic signal spacing, illumination, network design variables, social policy variables, and presence of center-turn lanes have a statistically significant effect on pedestrian crash probabilities.

Lyon and Persaud (2002) used data from Toronto, Canada in the development of pedestrian crash prediction models using pedestrian and vehicular volumes only for three and four-legged urban intersections, with and without signal control.

Kennedy (2008), based on models developed using data for two hundred signalized intersections in Washington DC, reported that pedestrian volume and vehicular volume are two strong predictor variables that can be used to estimate pedestrian crashes.

Hess et al. (2004), examined the relationship between pedestrian crash locations on state-owned facilities (highways and urban arterials) and transit riders at transit (bus) stops in Washington State. Based on a sampling approach and logistic regression models, the study showed that transit stop usage, retail location size, traffic volume, and the number of traffic lanes affect the number of pedestrian crashes.

Lee and Abdel-Aty (2005) used log-linear models and found that demographic factors, road geometry, traffic and environment conditions are closely correlated to the frequency of occurrence and the severity of pedestrian crashes at intersections in Florida.

Elvik (2009) found that the total number of pedestrian crashes could go down if a substantial share of trips by motorized travel were transferred to walking or cycling. The effect depends strongly on the degree of non-linearity of risk.

After reviewing the previous research information from all around the world, it can be said that most important factors are pedestrian and traffic volume and both of these factors are high in the developing countries like Bangladesh. Crashes can be dramatically decreased if trips are transferred to walking or cycling as speed which is the detrimental factor to injury will be decreased in non-motorized vehicle. In another opinion Harwood et al. (2008) suggested that the relationship between the number of pedestrian crashes and the vehicular volume and pedestrian traffic are not altered when other variables such as the proximity to a school, the presence of a bus stop or the presence of an alcohol sales establishment are included in a model. It was observed that the use of pedestrian volume information results in a much richer model, emphasizing the importance of collecting this information in routine traffic counting programs. Research has also been undertaken to understand pedestrian safety problems and estimate risk to pedestrians which is needed for both developed and developing countries.

2.1.3 Vulnerability of Pedestrians

Pedestrians have been largely ignored or given minimal consideration in the design of much of the nation’s roadway system. When the built environment assigns low priority to pedestrians, it can be difficult for vehicles and pedestrians to share the road safely. Modifications to the built environment can reduce the risk and severity of vehicle–pedestrian crashes. Engineering modifications generally can be classified into 3 broad categories: separation of pedestrians from vehicles by time or space, measures that increase the visibility and conspicuity of pedestrians, and reductions in vehicle speeds (Retting et al., 2003)

Altering or Separating of countermeasures like change in at-grade, grade separation reduce the probability of pedestrians to potential harm both on the roadside and when they are crossing streets. Because in many pedestrian crashes the driver reportedly does not see the pedestrian before the accident, measures are needed to increase the visibility of pedestrians. Higher vehicle speeds are strongly associated with a greater possibility of crashes involving in-vehicle passenger crashes as well as more serious pedestrian injuries. Conflicts generally are defined as "near-miss" situations in which a vehicle need to suddenly brake to avoid striking a pedestrian or a pedestrian had to take sudden evasive action to avoid being struck. So in any condition or any environment pedestrians are the most of vulnerable parts among the road users.

2.2 Pedestrian-Vehicle Crashes on Developing Nations

In regard to safety, the pedestrians are of considerable or major concern as they represent up to 72 percent of road traffic fatalities in Dhaka Metropolitan City (Rahman et al., 2006). So the Dhaka city is not as safe as it needed to be for the sound and secure movement of the pedestrians. Now, data showed that the intersection accidents represent around 40 percent of total accidents occurring in Metropolitan City of Dhaka (Rahman, 2012).

2.2.1 Study on Developing Countries

By just a decade since 1990, WHO estimates suggest that road traffic death rates per head of population between 1975 and 1998 increased by 44% in Malaysia , by 79% in India .Rahman et al., (2006) showed the causes causing fatalities were identified as Human factors accounted for 79.7%, condition of vehicle for 10.7% and traffic conditions 9.6% .A study was conducted by Aggrawals (2006), at JFMT with the objective of studying various aspects of cranio-intracranial injuries in roadside vehicular accidents cases in India .

The analyzed 1132 vehicular accidents, pedestrians (50.7%) and motorcyclists (18.28%) comprised most common victims.

The common age group involved was 21-40 years (46.01%). Head injury was responsible for causing death in 71.99% of the cases.

Most of the victims died on the spot (36.30%), incidences of crashes were highest among cyclists (78.9%) and motor cyclists (72.46%), pedestrians (6.02%). A retrospective study analysis for a 10-year period (1976-1985) of road traffic accidents (RTA) fatalities was in Port Moresby, the capital of Papua New Guinea.

Highest fatality rates are in the age group 15-44 years, followed by children below 14 and then adults above 45 years of age. Males were far more prone to be involved in RTA fatalities than females.

In 40.2% of all the fatalities the accidents occurred between 6 PM to 6 AM, in 35.3% between 6 AM to 6 PM.

Most fatal accidents occurred during the weekend. Head injury was the dominant and possible cause of death in all these categories of victims.

So, it’s obvious that road accident has become very threatening in developing nations in recent years as with the economic development motorized vehicles are increasing quickly.

2.2.2 Study on Bangladesh Perspective

2.2.2.1 Major Findings of Pedestrian Accident Analysis Characteristics

Research on pedestrian accident characteristics and safety is concerned with accident statistics because they provided basic information on the relative importance of the many and various factors which contribute to accidents. The following are the major findings of pedestrian accidents in metropolitan Dhaka city. From MAAP5 data base (1998-2004):

- Pedestrians accounted for 72% for all reported fatalities in the accident data base.

- While during night time and with light and dusk /dawn conditions the proportions are 26.3% and 12.67%. City road pedestrian accident is higher than other road classes. The amount of city road accident is 98.85%

- About 81% fatal accident in Dhaka metropolitan involved male and 19% pedestrian accident involved female pedestrians.

- The high rate of pedestrian causalities crash occur between the age 26 and 30 and the rate is 15% low rate of pedestrian causalities involve persons over 75 years age and the rate is 1%.

- About 47% pedestrian fatalities in Dhaka metropolitan occurred at center of road and about 47.65% pedestrian fatalities occur on road side.

- Nearly 11% pedestrian casualties occur on January and July individually.

- Most pedestrian causality related accidents occur on link sections of roads and the amount of accident is 67% and about 99% pedestrian accident occurred on straight and flat road.

- Nearly 74% of pedestrian causalities occurred in daytime, 68% pedestrian accident causalities occurring between 8 A.M. and 5 P.M.

- Roads with no traffic controls constitute the most dangerous roads for pedestrians. About 85% of pedestrian causalities occurs on this type of roads. Nearly 96% pedestrian causalities occurs on two lane two-way roads.

Indeed jaywalking appears to be a major contributor to sustainable transport strategy. Pedestrian can still claim to be most forgotten and neglected part of road user group. Many developed countries even have different lanes for only cycling. In Bangladesh different lane is impossible as roads are already narrow in width. But secure and clean sidewalk is still very much possible.

2.2.2.2 Accident Majority of Hit-Pedestrian

It becomes common in Bangladesh if any vehicle hit a pedestrian the driver of the vehicle tries to move far away from the accident spot as soon as possible creating more damage to people and property. From National Road Safety Council Annual Report (2001), accident type analysis showed ‘hit pedestrian’ as the dominant accident type both in urban and rural areas, 45 percent involvement in fatal accidents. Accident types which are highly overrepresented in fatalities and injuries are ‘hit pedestrian’, ‘head-on’, ‘running-off-the-road’ and ‘out-of-control’ vehicles. The accident analysis of 2001 presented by the National Road Safety Council in their Annual Report shows that hit pedestrian is the dominant accident type (51.4%). Even in the intersection ‘hit-and-run’ is often occurred at any time in a day in Bangladesh.

From overall observation it can be told that major characteristics of pedestrians in Dhaka City are, Pedestrian do not need a license to use the roads, they are a mobile group and are generally able to go almost anywhere. Pedestrians are dispersed across the road network and can be seen all time, day and night, in all weathers, and on all types of roads. They constitute the most vulnerable group of road users and, in the event of an accident with a motor vehicle, the pedestrian is the most likely to be injured - more frequently and quite seriously. Pedestrians need protection in the form of facilities by ensuring their legitimacy is safety and convenience. It will take years of coordinated and concerted effort in the developed countries to address pedestrian education completely and effectively. And for the developing countries with the less literacy rate pedestrian education is much more difficult. A complex and long term effort from both government and public is much needed.

2.3 Crash Contributing Factors

2.3.1 General Crash Contributing Factors for Dhaka City

2.3.1.1 In-Situ Factors Causing Accidents at Intersections

Rahman, (2012) stated that,

- ✓ Most of the intersection's light doesn't work and they are operated by traffic police.
- ✓ Road marking are insufficient or not clearly visible.
- ✓ Road signs are incorrect or blocked with poster.
- ✓ In many intersection , the rule angle between the approaches should be 75 degree aren't maintained and so taking turn is difficult and conflict in movement occurs
- ✓ Drainage system is inadequate. As a result in rainy season roads are flooded with water even in little rainfall and which causes skidding for vehicle and ultimately accidents occur
- ✓ Footpaths are reserved by flying homeless people. This is mainly a problem for pedestrians. As a result pedestrians move to road and cause hazard for vehicle movement
- ✓ Traffic jam is one of the most important factors of accident. As driver wants to pass the intersection with one signal they drive fast and accident can easily occur with straight going and right turning or with crossing vehicle
- ✓ Rickshaw is a very severe problem in Dhaka city. The combination of this non-motorized transport and motorized vehicle make the traffic jam more terrible. As because the speed difference between these vehicle reduce overall speed.

- ✓ Drivers are not eager to follow any rule of driving. They recklessly overtake another vehicle, change lane without following rule and drive with over speed.

2.3.1.2 Risk Factors for Pedestrian Accidents

Rahman, et al., (2006) stated that Pedestrian fatality risk as a function of the impact speed of a car - The principal risk factor for unprotected road users in the mixing of unprotected people with motor vehicles capable of high speeds, other risk factors for pedestrian and cyclists include:

- Poor roadway facilities
- Poor street visibility
- Poor understanding on the part of pedestrians of road safety
- Poor design of the fronts of cars
- Poor detailed design of junctions and road sections (Binnie, 1994)

Rahman (2012) stated that Accidents increase in good weather, it may be because in good weather drivers may be more relax and less conscious as they think that everything is seen clearly. Again number of accidents increase with increase in number of approaches in an intersection and decrease with increase in road width.

From this prediction it can be approximately told that proper steps and precautions such as speed breakers, road dividers, proper signs, marking, speed limit and proper signal are needed to design to avoid pedestrian-vehicle crashes.

Haworth (1995), identified that a range of road user behavior problems that contributed to vehicle-pedestrian crashes at intersection that accident risk and poor traffic flow in Dhaka, the prevalent behavior problems include-

- Failure to give away
- Lack of lane discipline

- Counter-clockwise travel at roundabouts
- Failure to slow down when approaching an intersection

2.3.2 General Crash Contributing Factors of Developed Countries

2.3.2.1 Environmental and Behavioral Factors

The Chicago area Spatial Decision Support System (SDSS) integrates a multi-criteria decision making with housing, community development, economic development and physical planning. Using a variety of data sources and transportation modeling outputs, it consists of a number of indicators on traffic and transportation, accessibility measures, regional employment opportunities, small –area employment estimates based on forecasted job openings and actual jobs, affordable housing, school quality, crime, health, land use and the built environment . Factors can be divided into two groups: one relate to the physical environment of the area including the level of vehicular traffic flow, quality and complexity of the walking environment, pedestrian crowding possibilities, road crossing opportunities which present possibilities of conflict with vehicular traffic, population density and the extent of crime. The other group relates to social behavior, demographics, percent of carless households and percent of school going children (Caitlin and Piyushimita, 2010).

2.3.2.2 Illegal Pedestrian Crossing

Several studies conducted between 1940 and 1982 found that about 25% of pedestrian crossed illegally at intersections (Mullen et al, 1990). More recently Keegan and O'Mahony (2003) reported that 35% of pedestrians entered illegally at a signalized crossing. Pedestrian crashes account for around 15% of fatalities each year in Queensland (Australia) and about 8% of hospitalized causalities and illegal pedestrian movements are a factor in these crashes.

Pedestrians want to cross where it is convenient for them, and with as little delay as possible.

Engineering measures also tend to be resisted, with measures such as overpasses and underpasses (Hollo et al., 1995) having little effect on illegal crossing behavior.

2.3.2.3 Factors Contributing to Injury Severity of Pedestrians

Many human factors and factors describing driving conditions have been previously considered in studying pedestrian injury severity. Following is a list of control variables and the effects of them to have on pedestrian injury severity, this research was done in the rural area of Connecticut-

- Pedestrian age 65 years or older (PED 65): increases severity (Jensen, 1999).
- Pedestrian alcohol use (PED ALC): increases severity (Jensen, 1999).
- Driver alcohol use (OPER ALC): increases severity.
- Speed limit (SPEED): increases in speed limit increase severity (Jensen, 1999).
- Vehicle type (VEHTYPE): larger vehicles increase severity.
- Annual average daily traffic (AADT): increases in AADT decrease severity (Klop and Khattak, 1999).
- Darkness (DARK): increases severity (Jensen, 1999; Klop and Khattak, 1999).
- Illumination (ILLUM): decreases injury severity (Klop and Khattak, 1999).
- Weather (WEATHER): rain, fog, or snow increase severity (Klop and Khattak, 1999).
- Road surface condition (SURFACE): wet, snowy, or icy conditions increase severity (Klop and Khattak, 1999).

Factors contributing to crashes also depends on gender in some of the findings. From Bedard et al. (2002) male drivers are more likely than female drivers to be involved in fatal crashes. Ulfarsson and Mannering (2004) estimated gender-specific models for passenger-car accidents and found significant differences among females and males with respect to injury severity. In Bedard et al. (2002) and Hutchings et al. (2003), age was found to be positively related to fatalities. They found that drivers between ages of 40-49 had a lower probability of suffering fatalities compared to older drivers and that the probability of fatal injury among young drivers involved in a crash was less than that of drivers aged 40 to 49.

(Obeng at el., 2007). An overall gesture can be got from Luis et al. (2011), about the pedestrian safety at intersection. It is explained in the diagram below.

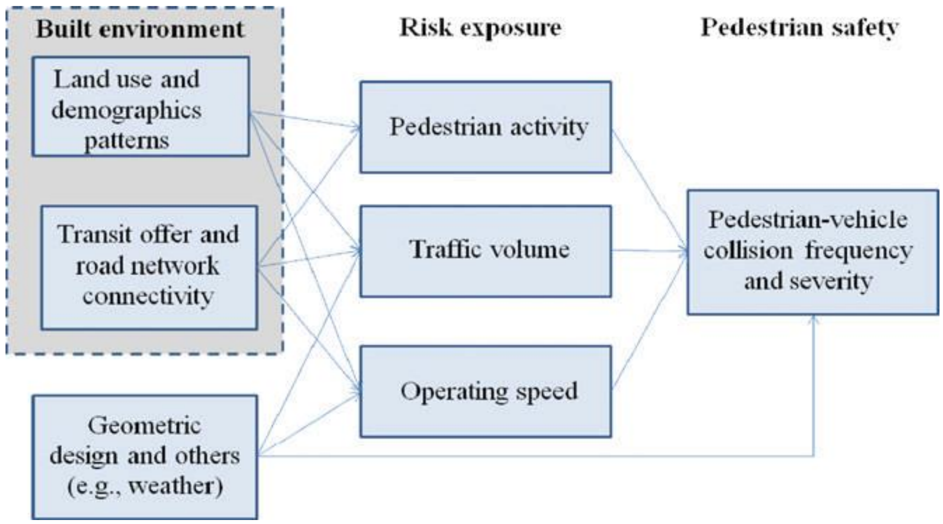


Figure 2-2: Pedestrian Safety at Intersection

After all, it's obvious that different macro or general factors like the age, gender, driver alcohol use, weather, illumination, darkness, road surface condition and pedestrian alcohol use play vital role in occurring the accidents at intersection and at any position of the total length of the roadway. The implication of laws at road is not so sincerely monitored mainly in developing countries. The condition is even worse when the heavy land use and demographic activities are continuously happening in overpopulated countries like Bangladesh.

2.3.3 Divergence Factors between Dhaka City and Cities of Developed Countries

2.3.3.1 Knowledge Level of Road Users

In Bangladesh there is a major gap in research on user knowledge level, despite the fact that in most of the studies regarding assessment of causes behind road accidents, lack of understanding of traffic signal signs comes up as a vital point. One study in 2010 by Razzak and Hasan, found assessment of driver understanding of some selected regulatory, warning and informatory signs through a survey. The survey was conducted among 202 Dhaka city drivers and 42 traffic signs were evaluated. of these, 20 were regulatory, 17 were warning signs and 5 were informatory signs. Multiple choices were used for the study, with answer options for each of the traffic signs (Razzak and Hasan, 2010).

The result indicated that the overall understanding level, measured in terms of percentage of correct responses was only about 50%. The percentage of drivers who correctly identified all the regulatory signs, warning signs, informatory signs were 49%, 52%, 55% respectively, indicating a major gap between existing and desired level of understanding. Considering educational qualification, respondents with Bachelor degree scored higher compared to those of lower qualification (Rubayat and Sultana, 2013).

Whereas in most of the developed nations the intersection traffic signal is completely obeyed by every type of drivers. But this is quite impossible for the road users of developing countries as they not only disobey traffic rules but also make their own rules to make their journey as short as possible even taking life risk more often.

2.4 Studies of Engineering Measures: Grade Separation

The first preference is the overpass. As the overpass has been stood in first preference level, it has some positive characteristics. Here safety 41%, security 23% , comfort 21%, less time consuming 7% have been identified as the major positive characteristics of overpass which have made it in number one priority (Ahmed, 2007). But wrong design or bad construction monitoring in making overpass can be lethal, as it happened at the overpass of Science Laboratory Intersection, Dhanmondi, Dhaka where two car passengers were died few years back.

The second preference is the at grade system. A study in Bangladesh showed that, the reason behind the preference are illustrated as comfort 28%, security 12%, less time consuming 8%, safety 5% are the most prominent features among the positive reasons.

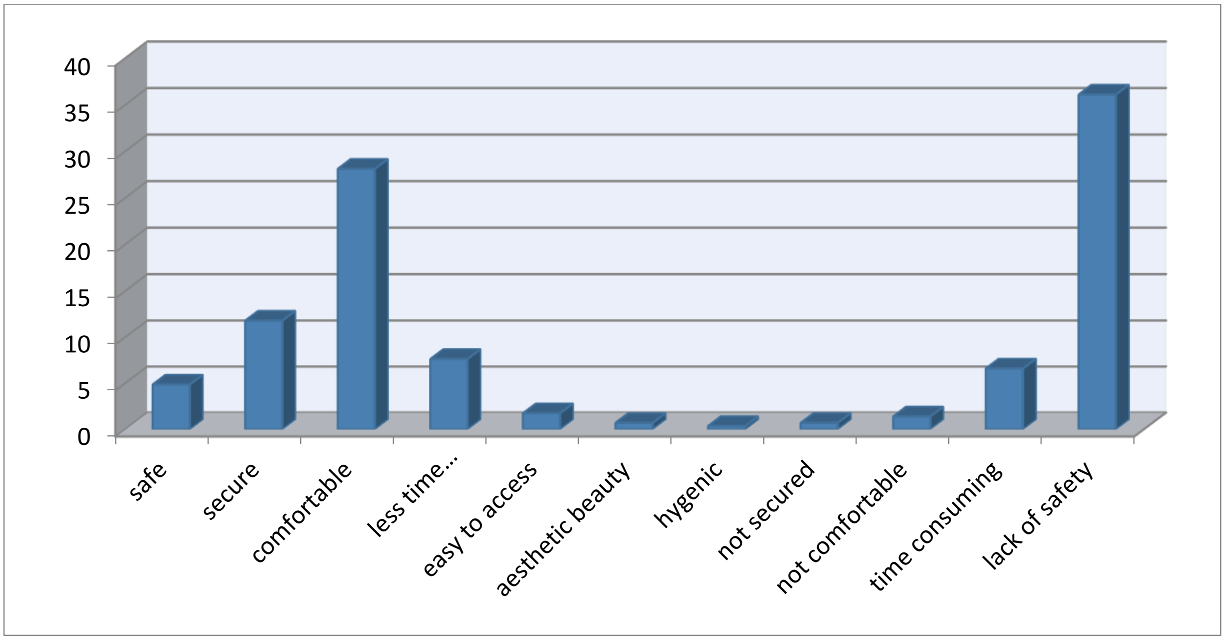


Figure 2-3: Percentage of Cause for Choosing Zebra or Grade Crossing

The third preference is the underpass crossing system and it's the worst among the various types of road crossing system at Dhaka city. The most influencing factor is the lack of security 20%, which compel pedestrian for not choosing underpass. Lack of comfort and time consuming are another two strong reasons here to make the underpass as third preference.

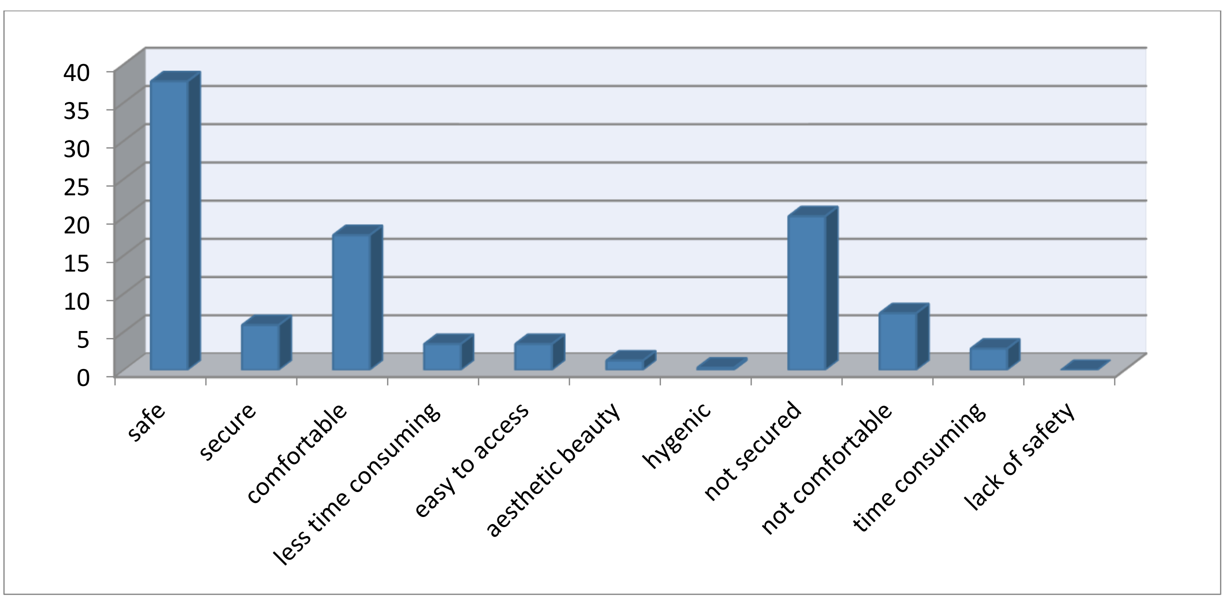


Figure 2-4: Percentage of Cause for Choosing Underpass

Now in the developed nations the use of grade separation is mainly done by underpass in the urban and rural highways and in the cities by at grade systematic way provided in accordance with the traffic signal system which is strictly maintained by every road users. Even the use of metro rail, underground rail, sky train, hill tunnel, tram car makes life easier with efficient decrease in the personal driven motor vehicles. On the opposite side in developing countries, the overpass and underpass is sometimes usable as all the time it is insecure and unhygienic to use.

However, by reviewing previous workings it can be told that the factors including day-night, clear weather–cloudy weather, age-gender of pedestrians and drivers, places of interest, knowledge of pedestrian-driver, visibility of pedestrian, vehicle–lighting system, clear or jammed road and most importantly systematic at-grade, underpass, overpass will be the key criteria for pedestrian-vehicle crash at the accident prone intersections of Dhaka City. On the other hand, some factors like pedestrian and traffic volume always a key factor in both developed and developing nations.

CHAPTER 3 METHODOLOGY

3.1 Introduction

In our study, we only assess crash frequency of intersections of Dhaka city, crash severity analysis is not done as it needs more time with complex human behavior factor to work with the help of logit model. For the study of pedestrian-vehicle intersection crashes in Dhaka City three recognized models are selected as those are used for a long time with efficiency in many traffic accidents studies worldwide. Statistical models selected for the study are:

1. Multiple Linear Regression model (MLR)
2. Negative Binomial model (NB)
3. Poison's Regression model (PR)

However there are several statistical properties that are stated as discrete, random and sporadic. It is because the accidents occurring in the road network are sporadic in nature and thus many researchers face difficulties while analyzing the accident data as lack of evidence or accident records in a certain accident prone site is usual. Same situation happened while collecting the previous year's accidents records of Dhaka City's intersections. At first statistical models are elaborately described and then the working systems are in scripted, first previously collected data are presented in chart as dependent factors. Then different experimental factors are taken for the model prediction and analysis. The methodology can be divided into three main steps:

a) Selection of statistical models to express annual accident frequency as a function of various geometric and traffic characteristics and exposure variables of the corresponding intersections.

b) Collection and processing of previous intersection accident data, traffic control, regulatory data and vehicular-pedestrian volume data to develop the selected statistical models.

Analysis and interpretation of model findings i.e. engineering judgment of factors affecting pedestrian-vehicle crashes. A detailed description of the above-mentioned steps is presented in the following sections.

3.2 Selection of Statistical Models

The process of selection of a statistical model can be divided into two steps. In the first step an investigation of the available set of models is done. Then the best model is chosen among the competitive models. The steps are elaborately described below.

3.2.1 Available Statistical Models

Researchers have been using various statistical techniques to model accident frequencies, ranging from the use of Multiple Linear regression to methods involving exponential distribution families such as Poisson and Negative Binomial regression models. However, it has been observed that for random, discrete, nonnegative and sporadic accident data, multiple regression models have several undesirable statistical limitations such as the assumption of normality (Jovanis and Chang, 1986; Joshua and Garber, 1990; Miaou and Lum, 1993). To overcome the problems associated with multiple linear regression models, Jovanis and Chang proposed the Poisson regression model. In their studies, Joshua and Garber (1990), as well as Miaou and Lum (1993) showed the appropriateness of Poisson model over linear regression technique to model accident frequencies.

Poisson distribution however suffers from an important limitation. It assumes that the mean and variance of the accident frequency is same, which is often violated in traffic accident studies. Accident data is generally over dispersed with variance much greater than mean. In such cases the use of Poisson model may lead to biased coefficient estimates. To deal with this problem a more general distribution namely negative binomial distribution (NB) has been employed by researchers .The appropriateness of NB model when over dispersion is now proved to be right.

3.2.2 Choice of Appropriate Models

The choice of an appropriate model from the available set of count models is one of the important steps in the methodology as wrong model selection can lead to incorrect as well as biased coefficient estimates. To do so the accident data set should be checked for over dispersion, excess zeros as well as serial correlation. For example, if the data suffers from over dispersion, NB model will be the best model to use.

3.3 Statistical Models for Crash Frequency Analysis

The principal objective of a statistical model is to identify a probabilistic system of the form,

$$Y = f(X) \qquad \ldots \ldots \ldots \ldots \ldots \ldots (3.1)$$

where the dependent variable Y is a function of a set of independent variables X. The regrression analysis of the above mentioned form examines:

a) wheather the observed patterns in the data are consistent with theoretical prediction and

b) relationship between a quantitative dependent variable and one or more quantitative or qualitative independent variables.

In many accident frequency studies, the dependent variable Y usually represents the total number of annual traffic accidents as a count outcome and the independent variables X represent the associated roadway geometrics, traffic and regulatory controls, and other relevant characteristics. The theoretical effect of X on Y is called systematic effect (Winkelmann, 1997). Traffic planners and researchers are mainly interested with the systematic variations as it can be affected by changes in geometry and other road features. The other component, called the random variation, disturbs the identification of the systematic variation. It is the coexistence of the systematic and random effects that is addressed by statistical regression models.

3.3.1 Multiple Linear Regression Model

The most widely used regression model to analyze collision frequency data is the multiple linear regression model (Hakkim, 1984) which is given by:

$$y = X\beta + \varepsilon \qquad \ldots\ldots\ldots\ldots\ldots\ldots (3.2)$$

where y is the number of collisions

X is a vector of explanatory variables

β is a vector of parameters to be estimated

ε is the error term

The assumptions of the OLS model are:

a) Expectation of the error term is zero

b) Homoskedasticity: variance of the errors is the same regardless of the value of ***X***

c) Normality: the error is normally distributed

d) Independence: the observations are free from autocorrelation.

The above model is usually estimated using the ordinary least square method (OLS). If the assumptions are valid, then the OLS estimator is the best linear unbiased estimator.

However, since accident data are usually random, discrete, nonnegative, sporadic and count data, there are a lot of undesirable properties in MLR such as assumption of normality and common variance as well as the possibility of negative outcomes that results in misinterpretation of count data (Jovanis and Chang, 1986).

3.3.2 Poisson Regression Model

Joshua and Garber (1990), Miaou (1994) and Miaou and Lum (1993) studied the relationship between highway geometric factors and accidents and all of them came to the conclusion that Poisson regression model is superior to MLR to describe discrete, random, non-negative, sporadic accident data. The basic assumptions of Poisson distribution are:

a) Probability of more than one event occurring in a short period of time is zero;

b) Probability of one count in a subinterval is the same for all subintervals and proportional to the length of the subinterval and

c) Count in each subinterval is independent of other subintervals.

If event n occurs according to a Poisson process with parameter μ , then the Poisson distribution can be written as:

$$\mathbf{Pr}(\boldsymbol{n_{it}}|\boldsymbol{\mu_{it}}) = \frac{\mathbf{exp}(-\boldsymbol{\mu_{it}})\boldsymbol{\mu_{it}}^{\boldsymbol{n_{it}}}}{\boldsymbol{n_{it}}!} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(3.3)}$$

Where $P(n_{it})$ is the probability of n accidents occurring on roadway section ì in time t is the expected number of accidents on roadway section ì in time t.

Now if X_{it} is a vector of covariates which describes the geometric, traffic control and regulatory characteristics of a roadway section i in a given time period t and β is a vector of estimable coefficients, then μ_{it} can be estimated by the equation

$$\mathbf{ln}\, \boldsymbol{\mu_{it}} = \boldsymbol{\beta}\, \mathbf{X}_{\boldsymbol{it}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \text{(3.4)}$$

The coefficient β , which is the effect of the explanatory variables on the dependent variable, can be estimated by the method of Maximum Likelihood (Greene, 1997).

In case of Poisson distribution, the likelihood of the expected number of event, when the observed number of event (n_{it}) is known and can be expressed as:

$$L(\mu_{it} \mid n_{it}) = \prod_{i=1}^{N} \prod_{t=1}^{T} \frac{\exp(-\mu_{it})\mu_{it}^{n_{it}}}{n_{it}!} \qquad (3.5)$$

Correspondingly, the log-likelihood function is then given by:

$$\begin{aligned} L(\boldsymbol{\beta}) &= \ln(L(\mu_{it} \mid n_{it})) \\ &= \sum_{i=1}^{N} \sum_{t=1}^{T} [n_{it} \ln(\mu_{it}) - \mu_{it} - \ln(n_{it}!)] \end{aligned} \qquad (3.6)$$

The main limitation of using Poisson regression model for accident analysis, as described in a considerable number of studies (Cox, 1983; Dean and Lawless, 1989), is that the variance of the data is restrained to be equal to the mean i.e.

$$Var(n_{it}) = E(n_{it}) = \mu_{it} \tag{3.7}$$

3.3.3 Negative Binomial Model

In many previous studies, it has been observed that accident frequency data tend to be over-dispersed; that is, the variance is significantly greater than the mean (Shankar et al., 1995; Poch and Mannering, 1996). Consequently, the choice of Poisson distribution model can lead to erroneous coefficient estimate and wrong inference. To overcome this problem, the negative binomial distribution, which includes a gamma-distributed error term in the parent Poisson model, was developed. This relaxes the Poisson's mean- variance equality constraint and takes the unobserved heterogeneity into account.

The negative binomial model is derived by rewriting equation (3.4) as:

$$\ln \mu_{it} = \boldsymbol{\beta} \ \boldsymbol{X}_{it} + \varepsilon_{it} \tag{3.8}$$

Where exp (ε_{it}) is a gamma-distributed error term with a mean one and variance k.

The resulting probability distribution under the negative binomial assumption is:

$$\Pr(n_{it} \mid \mu_{it}, k) = \frac{\Gamma(n_{it} + 1/k)}{\Gamma(1/k) n_{it}!} \left(\frac{k\mu_{it}}{1 + k\mu_{it}} \right)^{n} \left(\frac{1}{1 + k\mu_{it}} \right)^{1/k} \tag{3.9}$$

In which k > 0 is often referred to as over-dispersion parameter. If k reduces to zero, then the NB model reduces to the Poisson regression model. In this way, the Poisson regression model is nested within the NB and a t-test for k = 0 can be used to evaluate the significant presence of over-dispersion in the data. In negative binomial model, it is assumed that unconditional mean μit is independently distributed over time. For this specification, the mean and variance will respectively be:

$$E(n_{it} \mid \mu_{it}, k) = \mu_{it} \tag{3.10}$$

$$Var(n_{it} \mid \mu_{it}, k) = \mu_{it}(1 + k\mu_{it}) \tag{3.11}$$

The mean variance relationship of the distribution is given by:

$$Var(n_{it} \mid \mu_{it}, k) = E(n_{it})[1 + kE(n_{it})] \tag{3.12}$$

Estimation of μit can be obtained through standard maximum likelihood as mentioned in the previous section and is given by:

$$L(\mu_{it}) = \prod_{i=1}^{N}\prod_{i=1}^{N} \frac{\Gamma(n_{it} + 1/k)}{\Gamma(1/k)n_{it}!}\left(\frac{k\mu_{it}}{1 + k\mu_{it}}\right)^{n}\left(\frac{1}{1 + k\mu_{it}}\right)^{1/k} \tag{3.13}$$

This function is maximized to obtain coefficient estimates for β and k. Several researchers have employed this negative binomial (NB) distribution and they have proved that NB model is better than Poisson model to analyze accident data (Miaou, 1994; Kulmala, 1995; Shankar et al., 1995; Poch and Mannering, 1996; Abdel-Aty and Radwan, 2000).

3.3.4 Model Evaluation

The statistical models will be evaluated to select the best model from the competitive set of models. The evaluation will be done with the help of three statistics:

1) Likelihood Ratio Test

2) Akaike Information Criterion (AIC)

3) Log-likelihood Ratio Index (ρ2)

Likelihood ratio test is a common test used to assess two competing models. It provides evidence in support of one model, usually a full or complete model, over another competing model that is restricted by having a reduced number of model parameters. AIC is used to identify the best subset of independent variables and the model with minimum AIC value is selected as the best model (Akaike, 1973). The models are also tested for an overall goodness-of-fit with the help of log-likelihood ratio index. Finally, the elasticity values are calculated for the final model to find the relative effects of different independent variables. These are described in detail in the following.

3.3.4.1 Likelihood Ratio Test

The likelihood ratio test statistic is:

$$X^2 = -2[LL(\boldsymbol{\beta_R}) - LL(\boldsymbol{\beta_U})] \qquad (3.14)$$

Where LL(β_R) is the log likelihood at convergence of the 'restricted' model
LL(β_U) is the log likelihood at convergence of the 'unrestricted' model.

The test statistic is X^2 distributed with the degrees of freedom equal to the difference in the numbers of parameters in the restricted and unrestricted model.

3.3.4.2 Akaike Information Criteria

Akaike Information Criteria provides an important tool for evaluating models estimated by maximum likelihood. This procedure identifies significant independent variables and determines the best model without the necessity to stipulate a level of significance.
The AIC criterion is given by:

$$AIC = -2\ln L + 2k \qquad \ldots \ldots \ldots \ldots \ldots \ldots (3.15)$$

Where, ln L is the maximized log-likelihood of the model
k is the number of parameter estimated in the model.

Using this criterion, the model yielding the minimum AIC is to be selected as the best model. Therefore, starting with a full set of independent variables and their interactions, a systematic procedure has been used to eliminate the insignificant variables one at a time by comparing the different AIC values. The resulting model with minimum AIC value may be considered the best-fitted and parsimonious model.

3.3.4.3 Log-Likelihood Ratio Index

To measure the overall goodness of the models, the log-likelihood ratio index will be calculated. The R2 as a goodness-of-fit measure for OLS estimator has been used by traffic safety engineers and researchers for many years. However, since count data models are non linear, there is no R2. Instead, the common practice is to use a pseudo R2 statistic, which is often known as log-likelihood ratio index (Ben-Akiva and Lerman,1985) which is given by:

$$\rho^2 = 1 - \frac{L(\boldsymbol{\beta})}{L(0)} \tag{3.16}$$

where L(β) is the log-likelihood value of the fitted model

L(0) is log-likelihood value of the model only with constant term .

Everything else being equal, a specification with a higher maximum value of log-likelihood function is considered to be better. The lowest value of log-likelihood function corresponds to the model with constant term only and is considered the worse case. The value of ρ^2 is between 0 and 1, the better models approaching the latter. Like the R2 statistic, it has the undesirable characteristic that for same data set, it will increase whenever new variables are added to the model. To overcome this disadvantage Ben-Akiva and Lerman (1985) incorporated a correction for the number of covariates, p, to give the adjusted log-likelihood ratio index as

$$\bar{\rho}^2 = 1 - \frac{L(\boldsymbol{\beta}) - p}{L(0)} \tag{3.17}$$

3.3.5 Elasticity of Variables

In order to check the relative significance of independent variables from the final model, the elasticity of the variables was calculated. Elasticity is defined as the percent change in dependent variable due to one percent change in the independent variable. It is:

$$E_{x_{itk}}^{\mu_t} = \frac{\partial \mu_{it}}{\mu_{it}} \times \frac{x_{itk}}{\partial x_{itk}} \quad (3.18)$$

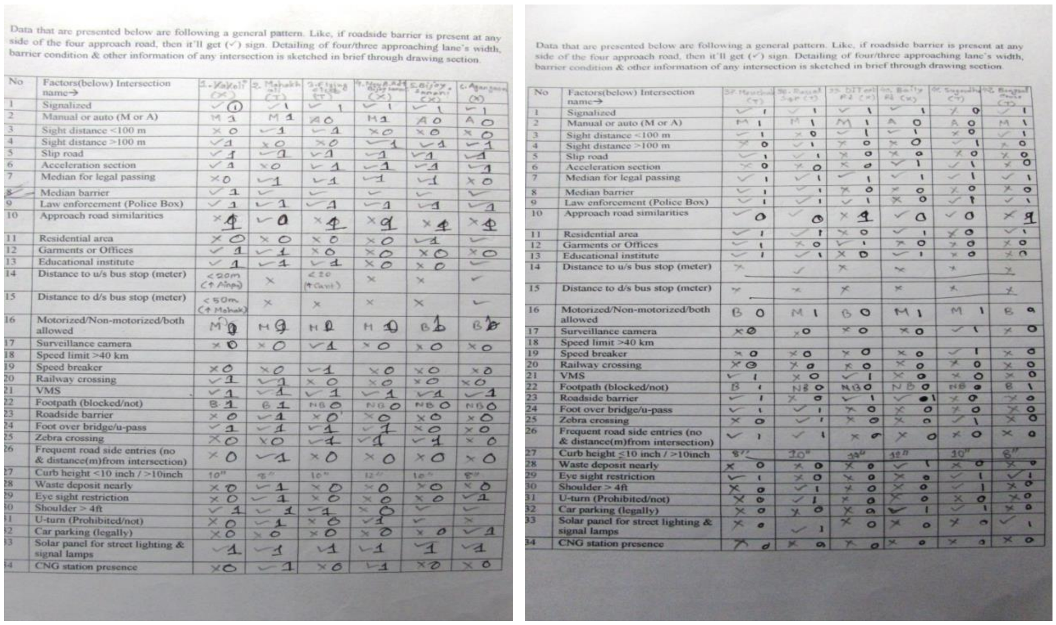
Where 'x_{itk}' is the kth independent variable for section i in year t.

With the increase in elasticity value the sensitivity of accident occurrence to a change in the specific variable also increases. The elasticity in Equation 3.18 is only appropriate for continuous variables. It is not valid for non continuous variables such as indicator variables that take on values of 0 or 1. For an indicator variable, a pseudo-elasticity is computed to estimate an approximate elasticity of the variables. The pseudo-elasticity gives the incremental change in frequency caused by a discrete (0-1) change in the indicator variables. The pseudo-elasticity for indicator variable is computed as:

$$E_{x_{itk}}^{\mu_{it}} = \frac{exp\,(\beta) - 1}{exp\,(\beta)} \quad (3.19)$$

3.4 Methodology for Data Collection and Analysis

The data collection process was totally laborious and full of hardship because there is no such fixed place or institute in Bangladesh to collect the crash data of pedestrian-vehicle intersection crashes for the primary use of our study. Thanks to ARI, BUET that their recent study about Dhaka city accident prone intersections helped us to get annual crash data collected from 1998-2009, exact 12 year's information that was very much needed for the starting of our work. We even visited LGED head office at Agargaon, Dhaka and some other road related government agencies at Tejgaon, Dhaka. But ARI research data was most helpful. After this, by thorough reviewing of the literature review of the crash contributing factors, a total of 46 factors were selected for further study purpose. There was a total of 54 intersections' data were obtained initially. We visited 45 intersections and collected all the necessary information regarding geometric-regulatory characteristics and pedestrian and vehicular volume of every single one of them. Hand drawn pictures were prepared on spot of the intersections to collect the geometric factors accurately. Some of the collected data was like below:



Data that are presented below are following a general pattern. Like, if roadside barrier is present at any side of the four approach road, then it'll get (✓) sign. Detailing of four/three approaching lane's width, barrier condition & other information of any intersection is sketched in brief through drawing section.

No	Factors(below) Intersection name→	1. Kakoli (X)	2. Mohakhali (T)	3. [illegible] (T)	4. [illegible] (X)	5. Bijoy Sarani (X)	6. Agargaon (X)
1	Signalized	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1
2	Manual or auto (M or A)	M 1	M 1	A 0	M 1	A 0	A 0
3	Sight distance <100 m	× 0	✓ 1	✓ 1	× 0	× 0	× 0
4	Sight distance >100 m	✓ 1	× 0	× 0	✓ 1	✓ 1	✓ 1
5	Slip road	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1
6	Acceleration section	✓ 1	× 0	✓ 1	✓ 1	✓ 1	✓ 1
7	Median for legal passing	× 0	✓ 1	✓ 1	✓ 1	✓ 1	× 0
8	Median barrier	✓ 1	✓	✓	✓	✓	✓
9	Law enforcement (Police Box)	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1
10	Approach road similarities	× 4	✓ 0	× 4	× 9	× 4	× 4
11	Residential area	× 0	× 0	× 0	× 0	✓ 1	✓
12	Garments or Offices	✓ 1	✓ 1	× 0	× 0	× 0	× 0
13	Educational institute	✓ 1	✓ 1	✓ 1	× 0	× 0	✓
14	Distance to u/s bus stop (meter)	<20m (↑ Airpt)	×	<20 (↑ Cant)	×	×	✓
15	Distance to d/s bus stop (meter)	<50m (↑ Mohak)	×	×	×	×	✓
16	Motorized/Non-motorized/both allowed	M 0	M 9	M 2	M 0	B 1	B 1
17	Surveillance camera	× 0	× 0	✓ 1	× 0	× 0	× 0
18	Speed limit >40 km						
19	Speed breaker	× 0	× 0	✓ 1	× 0	× 0	× 0
20	Railway crossing	✓ 1	✓ 1	× 0	× 0	× 0	× 0
21	VMS	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1
22	Footpath (blocked/not)	B 1	B 1	NB 0	NB 0	NB 0	NB 0
23	Roadside barrier	× 0	✓ 1	× 0	× 0	× 0	× 0
24	Foot over bridge/u-pass	✓ 1	✓ 1	✓ 1	✓ 1	× 0	× 0
25	Zebra crossing	× 0	× 0	✓ 1	✓ 1	✓ 1	× 0
26	Frequent road side entries (no & distance(m)from intersection)	× 0	✓ 1	× 0	× 0	× 0	× 0
27	Curb height <10 inch / >10inch	10"	8"	10"	12"	10"	8"
28	Waste deposit nearly	× 0	✓ 1	× 0	× 0	× 0	× 0
29	Eye sight restriction	× 0	✓ 1	× 0	× 0	× 0	✓ 1
30	Shoulder > 4ft	✓ 1	✓ 1	✓ 1	× 0	✓	✓
31	U-turn (Prohibited/not)	× 0	✓ 1	× 0	✓ 1	✓	×
32	Car parking (legally)	× 0	× 0	× 0	× 0	× 0	✓ 1
33	Solar panel for street lighting & signal lamps	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1
34	CNG station presence	× 0	✓ 1	× 0	✓ 1	× 0	× 0

Data that are presented below are following a general pattern. Like, if roadside barrier is present at any side of the four approach road, then it'll get (✓) sign. Detailing of four/three approaching lane's width, barrier condition & other information of any intersection is sketched in brief through drawing section.

No	Factors(below) Intersection name→	37. [illegible] (T)	38. [illegible] (T)	39. [illegible] Rd (X)	40. Baily Rd (X)	41. [illegible] (T)	42. [illegible] (T)
1	Signalized	✓ 1	✓ 1	✓ 1	✓ 1	× 0	✓ 1
2	Manual or auto (M or A)	M 1	M 1	M 1	A 0	A 0	M 1
3	Sight distance <100 m	✓ 1	× 0	✓ 1	✓ 1	× 0	✓ 1
4	Sight distance >100 m	× 0	✓ 1	× 0	× 0	✓ 1	× 0
5	Slip road	✓ 1	✓ 1	× 0	× 0	× 0	× 0
6	Acceleration section	× 0	× 0	× 0	✓ 1	✓ 1	× 0
7	Median for legal passing	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1	✓ 1
8	Median barrier	✓ 1	✓ 1	× 0	× 0	× 0	× 0
9	Law enforcement (Police Box)	✓ 1	✓ 1	✓ 1	× 0	✓ 1	✓ 1
10	Approach road similarities	✓ 0	✓ 0	× 9	✓ 0	✓ 0	× 9
11	Residential area	✓ 1	✓ 1	× 0	✓ 1	× 0	✓ 1
12	Garments or Offices	✓ 1	× 0	✓ 1	× 0	× 0	× 0
13	Educational institute	✓ 1	✓ 1	× 0	✓ 1	× 0	× 0
14	Distance to u/s bus stop (meter)	×	✓	×	×	×	×
15	Distance to d/s bus stop (meter)	×	×	×	×	×	×
16	Motorized/Non-motorized/both allowed	B 0	M 1	B 0	M 1	M 1	B 0
17	Surveillance camera	× 0	× 0	× 0	× 0	✓ 1	× 0
18	Speed limit >40 km						
19	Speed breaker	× 0	× 0	× 0	× 0	✓ 1	× 0
20	Railway crossing	× 0	× 0	× 0	× 0	× 0	× 0
21	VMS	✓ 1	× 0	✓ 1	× 0	× 0	× 0
22	Footpath (blocked/not)	B 1	NB 0	NB 0	NB 0	NB 0	B 1
23	Roadside barrier	✓ 1	× 0	✓ 1	✓ 1	× 0	× 0
24	Foot over bridge/u-pass	✓ 1	✓ 1	× 0	× 0	× 0	× 0
25	Zebra crossing	× 0	✓ 1	× 0	× 0	✓ 1	× 0
26	Frequent road side entries (no & distance(m)from intersection)	✓ 1	✓ 1	× 0	× 0	× 0	× 0
27	Curb height ≤10 inch / >10inch	8"	10"	14"	12"	10"	8"
28	Waste deposit nearly	× 0	× 0	× 0	✓ 1	× 0	× 0
29	Eye sight restriction	✓ 1	× 0	× 0	× 0	✓ 1	✓ 1
30	Shoulder > 4ft	× 0	✓ 1	× 0	× 0	✓ 1	× 0
31	U-turn (Prohibited/not)	× 0	✓ 1	× 0	× 0	× 0	× 0
32	Car parking (legally)	× 0	× 0	× 0	✓ 1	✓ 1	× 0
33	Solar panel for street lighting & signal lamps	× 0	✓ 1	× 0	× 0	× 0	✓ 1
34	CNG station presence	× 0	× 0	× 0	× 0	× 0	× 0

Figure 3-1: Data Collection Chart (Filled On Spot)

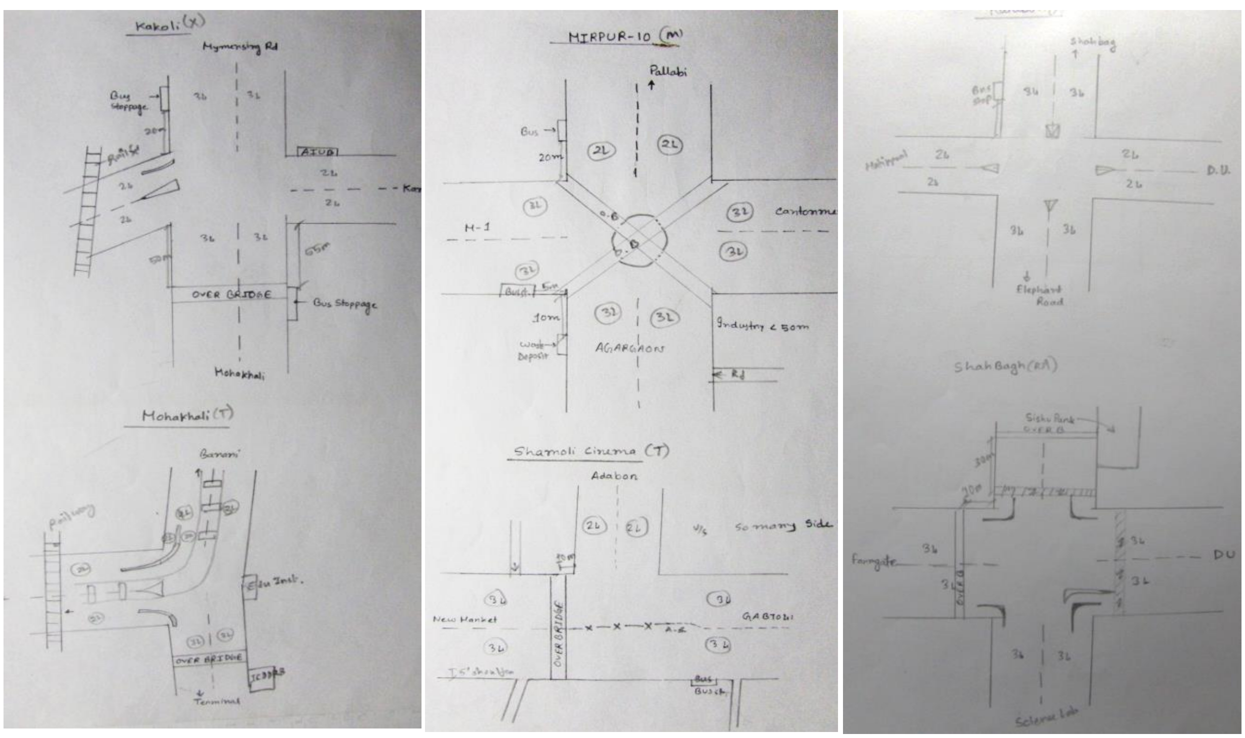


Figure 3-2: In-Situ Hand Drawn Data Collection

Table 3-1: Field Survey-2004, Nobuaki et al., (2004)

Crash Type	Name of Blocks				
	Farmgate	New Market	CBD area	Malibag	Mohakhali
Dart-out	40%	30%	18%	15%	12%
Walking Along roadway	12%	10%	14%	10%	10%
Multiple Threat	12%	18%	20%	19%	11%
Vehicle Turn	6%	7%	10%	6%	6%
Vendor Truck	1%	5%	1%	1%	1%
Backing up	5%	8%	11%	10%	9%
Intersection Dash	4%	3%	5%	6%	5%
Crossing in front of Bus	2%	3%	6%	7%	10%
Waiting for a bus	15%	14%	14%	23%	35%
Others	1%	2%	1%	1%	1%
Total	100	100	100	100	100

3.4.1 Vehicle and Pedestrian Data Collection and Conversion Method

Among 54 major accident prone intersections, we have considered 45 intersections for our study. For initiating our data collection procedure, we have planned our collection procedure, which includes time length of data collection, collection station and lane selection.

Time period for data collection at tee-sections have slight difference than that of four legged intersection. As for data collection time period, we have considered 20 minutes for every four legged intersection providing 5 minute for four alternate lanes and 15 minutes for tee-section providing 5 minutes in three alternate lanes.

We have collected our data during peak periods of the day and week days only. Our peak period was divided into two category: 1) Morning peak and 2) Evening peak. For morning peak, we have collected our data from 8 a.m. to 12 p.m. and as for evening peak we have collected data from 3 p.m. to 6 p.m. We have conducted our data collection from Sunday to Thursday as the data for week days.

For pedestrian data collection, we have considered 20 minutes providing 5 minutes per lane for data collection regardless of tee-section or four legged intersection. Reason behind taking same procedure for pedestrian count in these two types of intersections will be discussed in the further section.

3.4.1.1 Vehicle Data Collection and Conversion

For a typical four legged intersection like Bijoy sarani intersection, we have recorded data for road no. 1, road no. 2, road no. 3 and road no. 4. We have divided the vehicle flow into three category:

1) vehicles taking left turn,
2) vehicles moving straight and
3) vehicles taking right turn.

We didn't recorded the flow for road no. 5, road no. 6, road no. 7 and road no. 8 as the vehicle flow from other roads contribute to the total flow of these roads. Suppose, if we are to take vehicle flow for road no. 7, the total major flow for this road is constructed using the flow from road no. 1, road no. 4 and road no. 2. Vehicle taking left turn from road 1, vehicle moving straight from road no. 4 and vehicle taking right turn from road no. 2 enter road no. 7 and thus make the total flow for road no. 7. Similar explanation goes for road no. 5, road no. 6 and road no. 8.

We have selected suitable data collection location so that we can cover as much vehicle as possible before they take any turn. As for data collection, we have recorded data for those vehicles that have crossed our predetermined line. We have indicated this predetermined line by the dotted lines in figure 3-4 and figure 3-5.

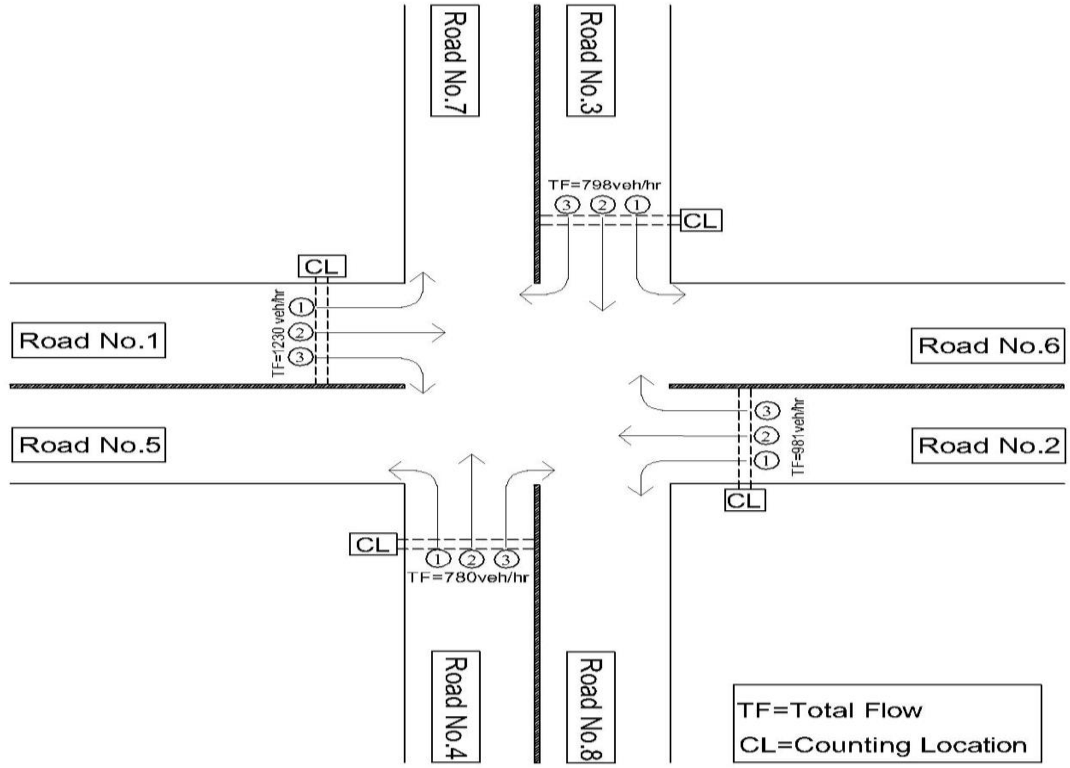


Figure 3-3: Vehicle Volume per Hour at Bijoy Sarani Intersection (A Typical Four Legged Intersection).

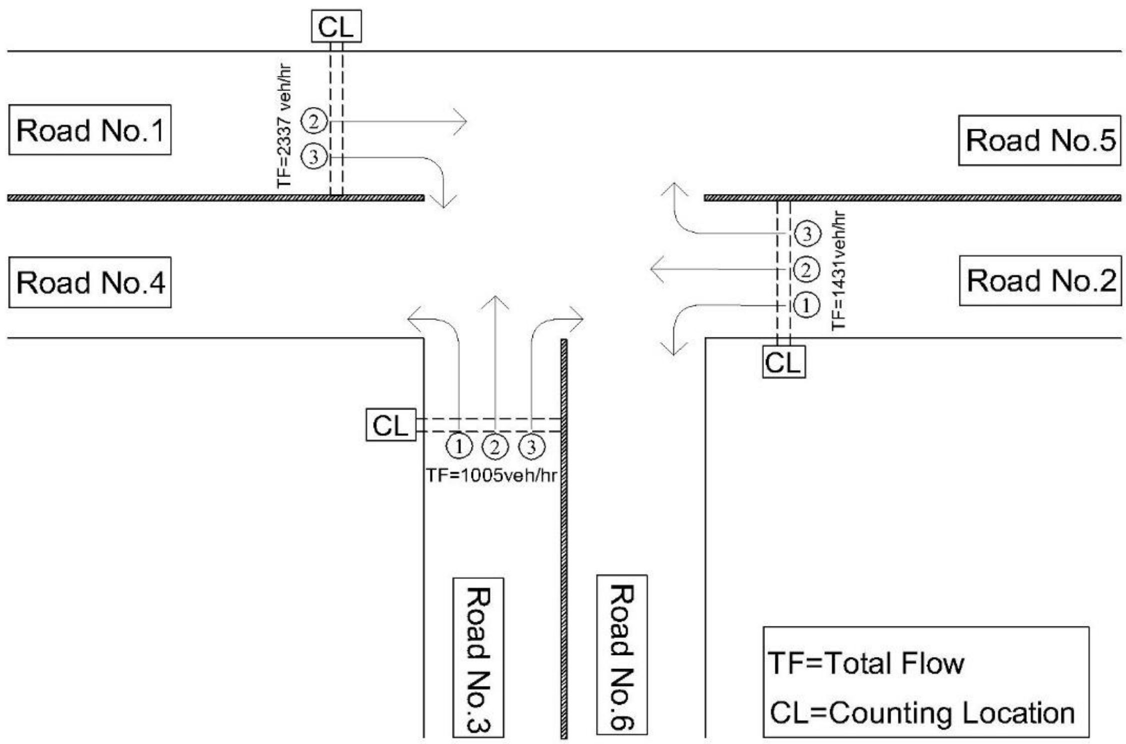


Figure 3-4: Vehicle Volume per Hour at Jasim Uddin Intersection (A Typical Three Legged Intersection).

We have recorded vehicle movement for 5-minutes. During our recording time, when traffic sergent stopped the vehicle movement, we paused collecting our data. When traffic sergent allowed the vehicles to move on, we resumed our data collection procedure. In this way, we have collected data for road no. 1, road no. 2, road no. 3 and road no. 4 in every four legged intersections. We have recorded data total 20-minutes in each four legged intersections, providing each leg 5-minutes. As for bijoy sarani our data was like below:

Table 3-2: Vehicle Data of Bijoy Sarani Intersection (A Typical Four Legged Intersection)

Vehicle type	**First leg (veh/5-min)**	**Second leg (veh/5-min)**	**Third leg (veh/5-min)**	**Fourth leg (veh/5-min)**	**Total (veh/ 20-min)**
Passenger car/ Pickups	19	23	18	16	76
Bus	13	7	10	4	34
Mini bus	9	3	7	8	27
Micro bus	2	0	3	1	6
Truck	0	0	0	0	0
Tempo/ CNG	12	4	10	7	33
Motorcycle	8	12	3	5	28
Machine Rickshaw/ Easy Bike	0	0	0	0	0
Rickshaw/ Pedal van	0	0	0	0	0
Pedal cycle	1	3	0	6	10
Total converted value (veh/5-min)	103	67	82	65	
Total converted value (veh/hr)	1230	798	981	780	

After collecting the data, we have converted all the data into a single passenger car equivalent (pce) value so that we can convert it into a vehicle per hour value and thus we can maintain uniformity in our data convertion. For our convertion purpose we have used under mentioned pce value:

Table 3-3: Passenger Car Equivalent (PCE) Value (MoC, 2000)

Vehicle Catagories	PCE
Passenger car/ Pickup	1.0
Bus	3.0
Minibus	3.0
Microbus	1.0
Truck	3.0
Tempo/ CNG	0.75
Motorcycle	0.75
Machine Rickshaw/ Easy Bike	0.75
Rickshaw/ Pedal van	0.75
Pedal cycle	0.50

We have multiplied each vehicle with their corresponding pce value according to their type. Then we summed all the converted data into single vehicle data value. For Bijoy sarani, our total converted value was 315.75. Since we needed vehicle flow data for each hour we converted our PCE value, that was recorded for total 20-minutes, into hourly value by multipling it with factor of 3. Thus we obtained our desired vehicle per hour flow which is one of the major exposure variables in our accident prediction model.

As for three legged intersection, we have collected data for road no. 1, road no. 2 and road no.3. We can consider Jasim Uddin road crossing as three legged intersection. In here we have collected vehicle movement data for in total 15-minutes, providing each leg 5-minutes. All the procedures were similar as four legged intersection except for vehicle flow pattern in road no. 1. In this particular type of road in all three legged intersection we have consider two types of flow. Type 2 flow, vehicle moving straight; and type 3 flow, vechiles taking right turn.

Converting collected data into a single PCE value is same as four legged intersection. However, there is small change in converting this PCE value into vehicle per hour value. As it is a three legged intersection, we have data for total 15-minutes providing 5-minutes in each leg. Therefore, we multilpied the total PCE value with factor of 4. Thus we obtained our desired value of vehicle per hour value for three legged intersections.

Table 3-4: Vehicle Data of Bijoy Sarani Intersection (A Typical Four Legged Intersection)

Vehicle type	**First leg (veh/5-min)**	**Second leg (veh/5-min)**	**Third leg (veh/5-min)**	**Total (veh/15-min)**
Passenger car/ Pickups	60	50	23	133
Bus	19	17	0	36
Mini bus	18	0	14	32
Micro bus	6	0	0	6
Truck	0	0	0	0
Tempo/ CNG	17	14	11	42
Motorcycle	6	9	14	29
Machine Rickshaw/ Easy Bike	0	0	0	0
Rickshaw/ Pedal van	0	0	0	0
Pedal cycle	1	2	0	3
Total converted value (veh/5-min)	194.75	119.25	83.75	
Total converted value (veh/hr)	2337	1431	1005	

3.4.1.2 Pedestrian Data Collection and Conversion

For collecting pedestrian volume data of four legged and three legged intersections we followed a simple procedure. We have counted every pedestrian who are crossing the intersection regardless of their crossing direction. We have selected four different suitable counting location for both three legged and four legged intersention. We started our counting when pedestrians were allowed to cross the intersection. We didn't consider those pedestrian who were crossing the intersection when they were not supposed to cross. In this way we have continued our collection process for 5-minutes in each leg.

Though three legged intersection lack similarity with four legged intersection, we considered fourth movement using which we removed the dissimilarity caused due to lacking of fourth leg. Schneider et al. (2009) has mentioned this method in his study.

After collecting all the pedestrian volume, we summed all the value for a intersection which gives us pedestrian volume for total 20-minutes. We converted this volume data into hourly volume data by multipling it with factor of 3. Thus we get our other exposure variable value for our accident prediction model.

Table 3-5: Pedestrian Volume per Hour for A Typical Four Legged and Three Legged Intersection.

Pedestrian Count	**Bijoy Sarani (Four legged intersection)**	**Jasim Uddin (Three legged intersection)**
First leg (ped/hr)	324	492
Second leg (ped/hr)	228	276
Third leg (ped/hr)	300	204
Fourth leg (ped/hr)	276	396

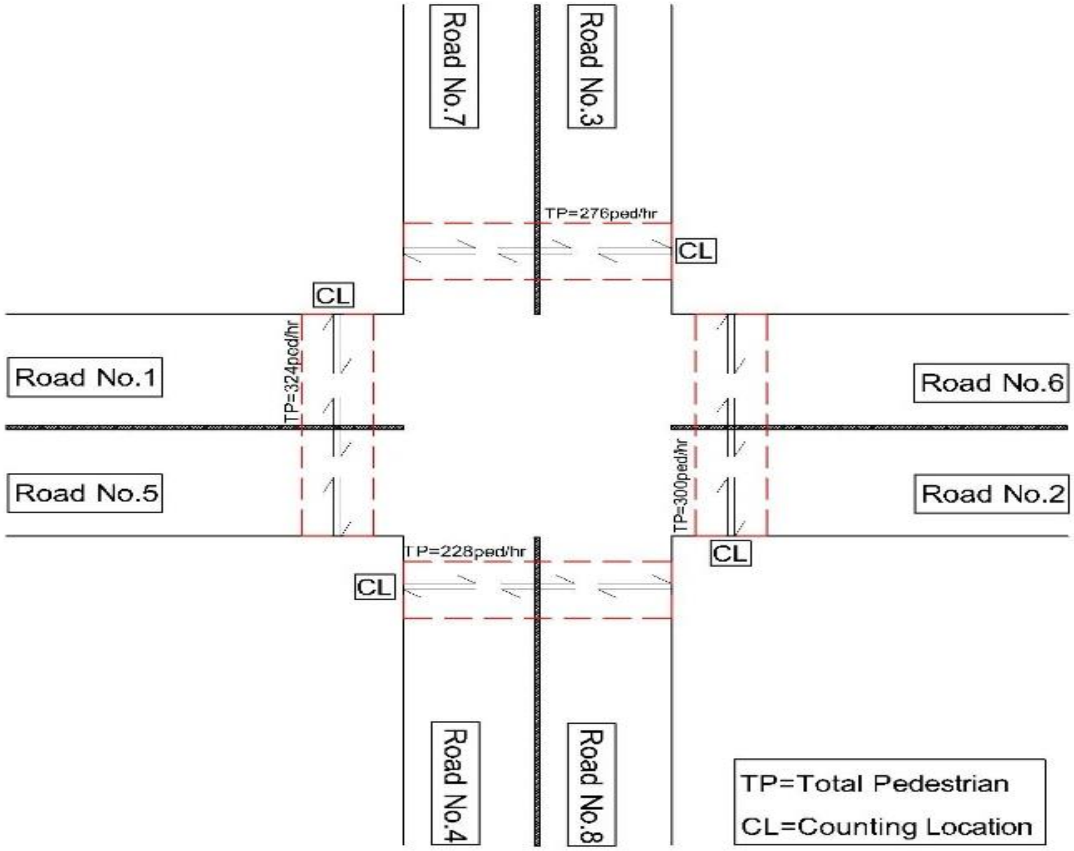


Figure 3-5: Pedestrian Volume per Hour at Bijoy Sarani Intersection (A Typical Four Legged Intersection).

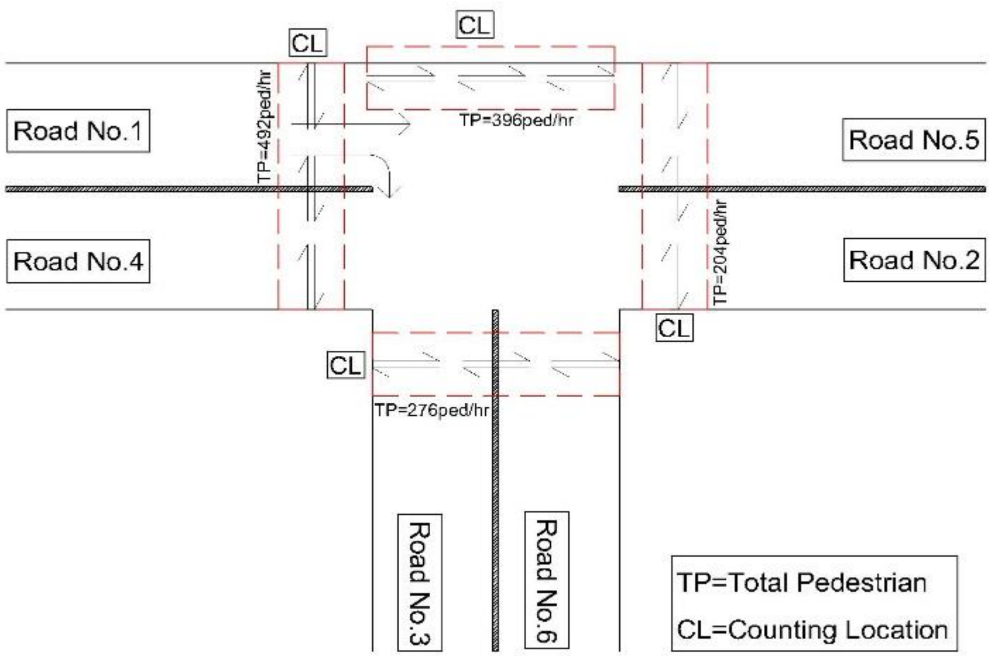


Figure 3-6: Pedestrian Volume per Hour at Jasim Uddin Intersection (A Typical Three Legged Intersection).

3.4.2 Dependent Variables

It's the recorded pedestrian accident data of Dhaka City's 54 intersection from 1998-2009. (Source: ARI, BUET).

Table 3-6: Recorded Pedestrian Accident Data of Dhaka City

Serial No	Name of the intersection	Type	Total Accident	Pedestrian Accident	Percentage
1	Jatrabari	Roundabout	158	83	52.5
2	Farmgate	Multiple	111	57	51.4
3	Sonargaon-Panthapth ETV	Roundabout	98	39	39.8
4	Bijoy Sarani	Cross	87	21	24.1
5	Topkhana-Purano Paltan	Cross	79	27	34.2
6	Saidabad	Tee	77	56	72.7
7	Sonir Akhra Crossing	Cross	76	50	65.8
8	Jasim Uddin Road Crossing	Tee	70	22	31.4
9	Kakoli (Mymen. Rd+Kamal At Av)	Cross	67	25	37.3
10	Shahbag	Roundabout	66	22	33.3
11	Staff Rd. Crossing (Dhk-Mymen. Road)	Tee	58	29	50
12	GPO(Abdul Gani Road)	Multiple	57	19	33.3
13	Hotel Sheraton(Kazi Naz+Minto Road)	Multiple	57	16	28.1
14	Shapla Chattar	Roundabout	55	29	52.7
15	New Eskaton (NE rd. +Kazi Naz. Rd)	Tee	51	23	45.1

16	Kakrail,Bhasani R. 10m N Star Gate	2 Tee	51	21	41.2
17	New Airport Road+Bijoy Sarani	Tee	50	12	24
18	Tongi Diversion Road	1Cross+1Tee	49	29	59.2
19	Moghbazar	Cross	49	14	28.6
20	Mirpur Rd + Cresent Lake	Multiple	45	9	20
21	Sangsad,Manikmia Avenue	Tee	44	13	29.5
22	Progoti Sarani (Badda)	Tee	43	22	51.2
23	Manik Mia Av-Indira Rd(Rajabazar)	Multiple	41	3	7.3
24	Malibag Crossing	Tee	41	23	56.1
25	Joar Shahara	Tee	40	17	42.5
26	Kakrail Traffic Signal	Stag X	38	13	34.2
27	Hatkhola Crossing	Tee	37	20	54.1
28	Mahakhali Crossing	Tee	36	16	44.4
29	Asad Gate	Stag X	35	8	22.9
30	New Market, Mirpur Road	Stag X	34	14	41.2
31	Kuril Bishwa Rd. at level crossing	Railway	33	21	63.6
32	Mohakhali	Tee	33	18	54.5
33	Rokeya Shoroni(Mirpur 10)	Multiple	33	18	54.5
34	Green rd Junction (Science Lab)	Tee	33	12	36.4
35	Gulistan	Multiple	32	18	56.3
36	Shyamoli, Mirpur Road(At Shyamoli Cinema Hall)	Multiple	32	15	46.9
37	Mowchak	Tee	31	10	32.3
38	Ramna, Bhasani Gate	Roundabout	31	10	32.3

39	Rokeya Shoroni(At Agargaon)	Tee	30	18	60
40	Motijheel	Cross	28	17	60.7
41	Shatrasta Round Circle	Roundabout	27	13	48.1
42	Osmani Uddyan	Tee	26	18	69.2
43	Flying Club Crossing	Tee	26	6	23.1
44	Cantt Zia Colony Gate,Mym Rd	Tee	25	17	68
45	Tikatuli, Toyenbee Cir. Rd At Noor Community Center	Cross	24	9	37.5
46	Russel Square	Tee	23	5	21.7
47	DIT Extension Rd. Police Hospital(Near Motijheel Thana)	Cross	22	11	50
48	Mirpur 10 Round Circle	Multiple	22	15	68.2
49	Katabon Crossing (Elephant Rd)	Cross	21	6	28.6
50	Rainbow Crossing (Tongi Div rd)	Tee	21	3	14.3
51	Postagola (Railway+Madrasa Rd)	Cross	18	14	77.8
52	Baily Rd. Crossing	Cross	18	5	27.8
53	Sugandha Crossing (Hare Rd)	Tee	18	5	27.8
54	Bongshal Crossing (N-S Rd)	Railway+Tee	16	6	37.5

3.4.3 Independent Variables

It is the factors taken as the main criteria to the possibility of the intersection pedestrian vehicle crashes in Dhaka City. The main reason may be the indiscriminate road intersections, railway crossing presence, narrow road, inconsistent roadway width, poor turning radius, side frictions, scattered parking, non-motor activities along the road, frequent side road entries, bus stop at the upstream and downstream side of the roadway but not given proper placement to load and unload people and goods, unfinished repair of road side pavement, displacement of the roadside barriers or median barriers, poor road discipline, uncontrolled pedestrian crossing, poor road surface crossing, speed breaker, presence of law enforcement officers, vehicular and pedestrian volume and so on. Now to get the proper less crash, more effective, safe roadway movement the Negative Binomial Method will be used as the statistical model along with the multiple linear regression model. Then these data will be compiled in the software to determine the safety model and to apply engineering judgment for safety provision of Dhaka City.

Table 3-7: Independent Factors Comparison of Developing and Developed Nations

Serial no	**Factors to study in contributing to intersection crashes in developing countries (Dhaka City)**	**Comparisons of factors contributing to intersection crashes in developing countries with developed countries**
1	Presence of workable signalized traffic intersection, sometimes it is present, but most of the time it is absent	All intersections are mostly signalized and work efficiently
2	Traffic signal at intersection whether by manual or totally automatic in day and night	Most of the time the signals are automatic
3	Sight distance 1(1 if <100 m)	In these countries , if <100 m then there is less accident occurrence
4	Sight distance 2 (1 if >300 m)	Astonishingly , if >300 m , then there is high possibility of accident occurrence
5	Presence of slip road or not. If present then if it is controlled or not	Most of the time slip roads are uncontrolled

6	Acceleration section present or not mainly to slow down to give the right-of-way of the oncoming vehicle or to slow down	It is present near most of the cross sections
7	Presence of median for legal passing of the pedestrians, width <2 m	It is mainly prohibited and some other facilities are present
8	Presence of median barrier to control pedestrian movement	Presence of it's a must in developed countries
9	Law enforcement presence(like police box) for immediate action	Mainly road traffic police present all the time alert
10	Residential intersection with industry presence	Mainly industrial areas are separated on the outskirt of the city
11	Number of approach roads and opposing roads; Similar or inconsistent	It's similar all the time
12	Nearby garments or offices presence and provision for public transport at intersection	Garments and offices are far away from the residential area
13	Educational institutes within 100 m of the intersection	It is strictly maintained that no educational institute will be present near 100 m of the intersection
14	Distance to upstream bus stop < 100 m within intersection	Distance to bus stop >100 m maintained at upstream
15	Distance to downstream bus stop < 100 m within intersection	Distance to bus stop >100 m maintained at downstream

16	Motorized and non-motorized both allowed at night. But at day only motorized allowed	Both motorized and non-motorized have Different lanes (like cycling road)
17	Right turn channelization or not	Both right and left turn are channelized according to the need
18	Presence of surveillance camera or any other manual facilities to monitor vehicle maneuver	Surveillance camera is a must in all intersections
19	Speed limit >40 km allowed	Normally different speed limit for different zone
20	Presence of speed breaker or other facilities	Speed breaker present in needed situation
21	Presence of railway crossing at level	Railway crossing mainly at grade facilitate or metro, underpass is present
22	VMS presence at intersection	VMS is always present at intersection. It may be electrical or fixed written informatory
23	Proper orientation of footpath, in width, placement, unblocked condition to use freely	Pavement management is the mostly studied nowadays in developed nations
24	Presence of roadside barrier to control pedestrian movement within 20 m of intersection	Roadside barrier near the intersection is present where needed
25	Presence of foot over bridge or underpass near 10 m near the intersection's any approach road	Sometimes foot over bridge or sometimes underpass is present for pedestrian movement

26	Zebra crossing facilities at the entry or 10 m within the intersection approach road entries, exit	In many cities zebra crossing facilities are present with controlled even signalized way
27	Frequent side road entries near the 10 m of any approach road of intersection	It's very rare in developed countries because their right of way is large
28	Presence of curb <= 2 ft. (easy for pedestrian movement)	Curb height is well maintained
29	Presence of waste deposit facilities within 10 m near the intersection in any approach road	No waste deposit facility present adjusted to the road
30	Eye sight restriction due to the random billboard, island trees, police box, sculptures	Eye sight restriction is within control and checked regularly
31	Shoulder presence >4 ft. at any approach road	General requirement is maintained
32	U-turn prohibited or not	General requirement is maintained with situation occurred
33	Car parking facilities near the 10 m of the any approach road of the intersection	Differs from place to place. But no such blockage will happen by it
34	Pedestrian volume data of the intersection	They have adequate facility to collect pedestrian volume data for each intersection
35	Vehicular volume data of the intersection	adequate facility to record traffic flow data for every intersection

The map below is collected from the website of the Accident Research Institute, BUET. Among the accident prone intersections, we worked on 45 intersections to collect data.

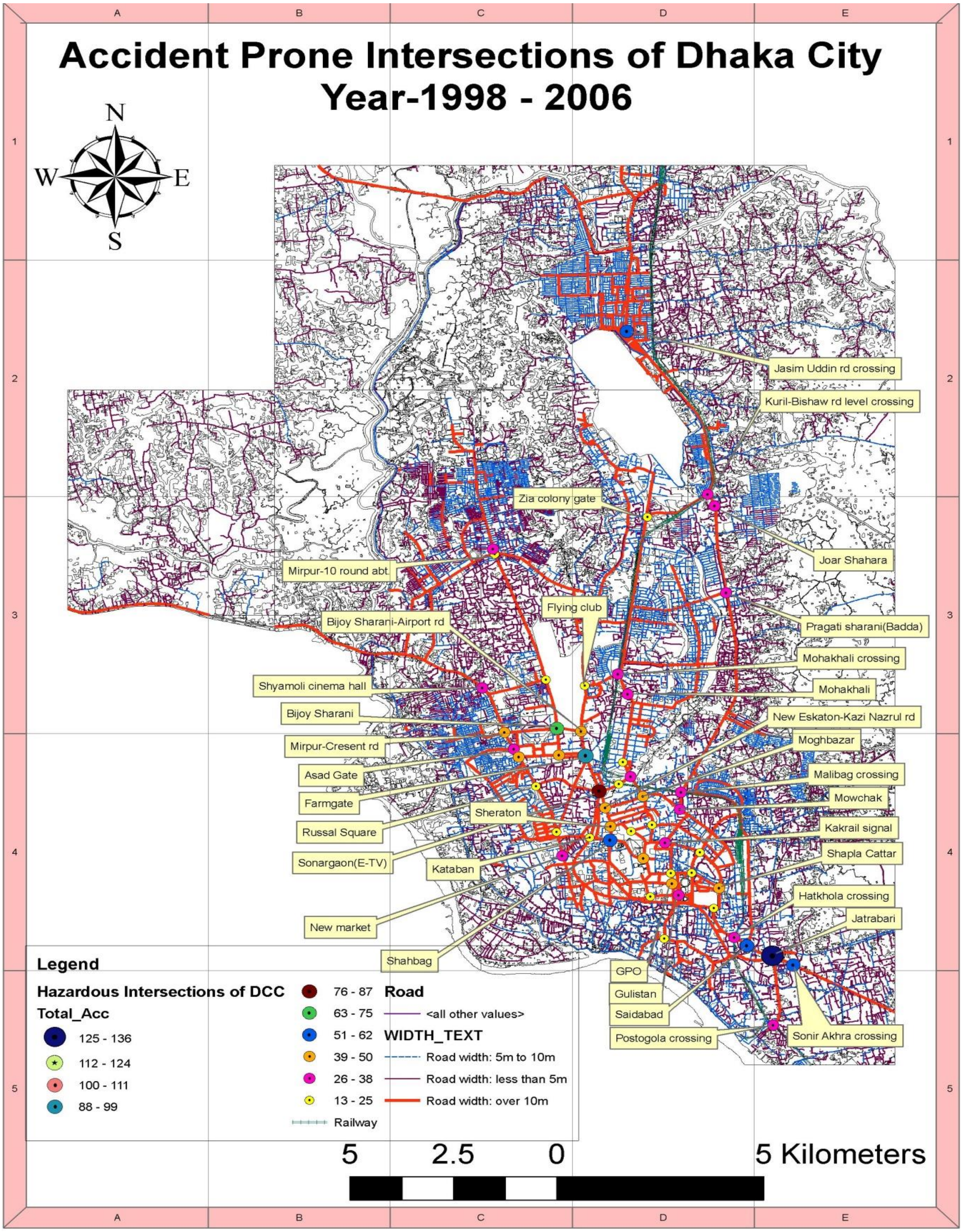


Figure 3-7: Map of Accident Prone Intersections of Dhaka City

CHAPTER 4 DESCRIPTION OF CRASH FACTORS

4.1 Geometric Characteristics

4.1.1 Sight Distance > 200 Ft.

Sight distance is a length of road surface which a particular driver can see with an acceptable level of clarity. Sight distance plays an important role in geometric highway design because it establishes an acceptable design speed, based on a driver's ability to visually identify and stop for a particular, unforeseen roadway hazard or passes a slower vehicle without being in conflict with opposing traffic. We took it by conjecture with only our judgment and made sure that if it is over 200 ft. or not.

Figure 4-1: Sight Distance > 200 Ft.

4.1.2 Presence of Slip Road

A road entering or leaving a motorway or dual carriageway. So, it is taken by the on sight observation that whether there is slip road present or not. And if present then it is on one direction or in both directions too.

Figure 4-2: Presence of Slip Road

4.1.3 Presence of Acceleration Section

This is the part of any roadway mainly near the intersection where merging traffic gets an acceleration zone as its local speed at that time is not up to the level to cope up with the straight going roadway traffics. Even the vehicle operators get some time to think whether he or she will accelerate or decelerate. Sometimes it is present just at the end of slip road.

Figure 4-3: Presence of Acceleration Section

4.1.4 Approach Road Similarities

It is checked that whether the approaches in the roadway intersection are same in number or different. Because it has severe possibility to create traffic jam if any opposite direction road width is narrow or the lane number is greater or lesser. Both side there are three lanes.

Figure 4-4: Approach Road Similarities

4.1.5 Nearby Residential Area

The presence of residential area is also important. If there is a residential area present, then the chance of accidents occurring is also greater. A chance is that victim will be the children mainly under these circumstances. Here in the picture, a mosque is indicated as the starting of residential area within 20 ft. from a vital intersection.

Figure 4-5: Nearby Residential Area

4.1.6 Nearby Official Area

The presence of official area near the intersection is another important factor. If there is an official area present, then the chance of accidents occurring is also greater than the regular.

Figure 4-6: Nearby Official Area

4.1.7 Nearby Educational Institute

The presence of educational institute near the intersection is also important. If there is educational institute present, then the chance of accidents occurring is also greater. Small school going children are in great risk at this situation.

Figure 4-7: Nearby Educational Institute

4.1.8 Presence of Speed Breaker

Speed breaker is provided to reduce the excessive speed of any vehicle in any important places like- school, office, market etc. Speed breakers nearby the intersections are also rare in Dhaka city. Sometimes it’s better to have one, in other time it is not.

Figure 4-8: Presence of Speed Breaker

4.1.9 Presence of Railway Crossing

Presence of railway crossing is regular in Dhaka city intersections. But the popular practice is to make grade separation for the vehicle maneuver in rail crossing. It's not possible for the government here in Bangladesh to afford such structures.

Figure 4-9: Presence of Railway Crossing

4.1.10 Footpath Occupied

Footpath is made for the easy movement of the pedestrians. The condition of the footpath near every intersection is also observed. Sometimes it is blocked by different hawkers, sometimes by temporary food sellers. So, these create jamming in the roadway especially near intersection.

Figure 4-10: Footpath Occupied

4.1.11 Presence of Foot Over Bridge and Underpass

Foot over bridge is provided in about every important intersection to give pedestrian comfortable and safe movement. The same purposes can also be fulfilled by the underpass, though this is very low in number. People are not interested to use over bridge and therefore they fall a victim to a massive number of accidents.

Figure 4-11: Presence of Foot Over Bridge

4.1.12 Presence of Zebra Crossing

The zebra crossing is provided for the pedestrian to walk across the street in the direction straight and opposite wherever over bridge and underpass is not available.

Figure 4-12: Presence of Zebra Crossing

4.1.13 Frequent Roadside Entries

Smaller, arterial roads are sometimes frequently entering into a small distance within the intersection. Therefore, the total speed of the traffic becomes lesser, these creating great crash probabilities. It's actually within 50 ft. from a three legged intersection.

Figure 4-13: Frequent Roadside Entries

4.1.14 Curb Height

Curb height is counted nearby the intersection. It actually gives comfort to pedestrian movement. If the curb height is low, it causes pedestrian conscience increasing positively about using curbs in the footpath.

Figure 4-14: Curb Height (Indicated Portion)

4.1.15 Waste Deposit Facility

In developing country like Bangladesh it is a common scene that waste like solid waste, building rubbles are haphazardly dispersed over the roadway and even nearby the intersections of the major arterial in the city like Dhaka. These rubbish presence blockage of road increasing injury severity possibility. This waste bin is within 50 ft. from the intersection.

Figure 4-15: Waste Deposit Facility (Indicated to Intersection)

4.1.16 Eye Sight Restriction

Visual perception is the ability to interpret the surrounding environment by processing information that is contained in visible light. The resulting perception is also known as eyesight, sight, or vision. Here in Dhaka city different blocking objects like trees, billboards, police box on the island causing major eye sight restriction.

Figure 4-16: Eye Sight Restriction

4.1.17 Presence of Shoulder

A shoulder, often serving as an emergency stopping lane, is a reserved lane by the verge of a road or motorway, on the right in countries which drive on the right or on the left side which drive on the left. Its presence is must in any major lanes. So, it is also carefully observed.

Figure 4-17: Presence of Shoulder

4.1.18 Car Parking Facility

A car lot or parking facility is a cleared area that is intended for parking vehicles. Usually, the term refers to a dedicated area that has been provided with a durable or semi-durable surface. But if this type of facility is nearby the intersections then it creates jamming, crashing possibilities. So, this facility should be made at some distance away. In our study, we take the presence of car lot if it is within 50 ft. from the main intersection.

Figure 4-18: Car Parking Facility

4.1.19 Presence of Solar Panel System

Nowadays solar panel system is used in about every intersection in Dhaka city with a view to getting uninterrupted supply of electricity for traffic signals and street lighting. It is useful as because power shortage is a common scenario in Dhaka city. Even at night it can for some time by accumulating the day's sunrays.

Figure 4-19: Presence of Solar Panel System

4.1.20 Presence of CNG Station

Most of the time the CNG stations near an intersection is a reason for very long queue of cars and other vehicles which can be taken into consideration for pedestrian accident at intersection. This CNG station is within 50 ft. from the busy intersection.

Figure 4-20: Presence of CNG Station

4.1.21 3 Lanes or 4 Lanes

It means whether the intersections are three/tee legged or four legged. It gives about the geometric condition of any particular intersection.

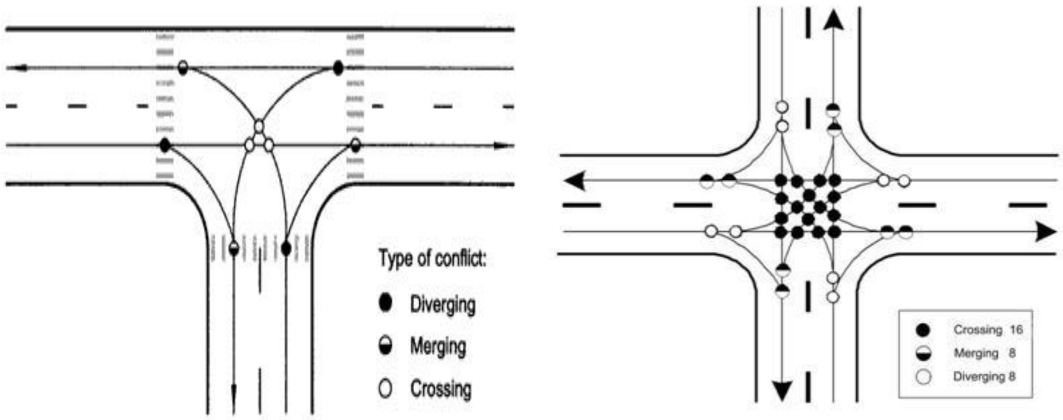


Figure 4-21: Tee Legged and Four-Legged Intersection

4.1.22 Median Barrier

Median barrier present in all approach roads of an intersection (yes or no).

Median barrier not present in all approach roads of an intersection (yes or no).

Figure 4-22: Median Barrier

4.1.23 Roadside Barrier

Roadside barrier present in all approach roads of an intersection (yes or no).

Roadside barrier not present in all approach roads of an intersection (yes or no).

Figure 4-23: Roadside Barrier

4.1.24 Lane Number

Maximum number of lanes in any individual approach road.

Minimum number of lanes in any individual approach road.

Figure 4-24: Lane Number

4.1.25 Bus Stop

Presence of bus stop

Bus stop distance from intersection within 0-40 ft.

Bus stop distance from intersection within 40-80 ft.

Bus stop distance from intersection greater than 80 ft.

Figure 4-25: Bus Stop

4.1.26 Foot Over Bridge Distance from Intersection

Foot over bridge distance from intersection within 0-30 ft.

Foot over bridge distance from intersection within 30-60 ft.

Foot over bridge distance from intersection within 60-100 ft.

Foot over bridge distance from intersection greater than 100 ft.

Figure 4-26: Foot Over Bridge Distance from Intersection

4.2 Regulatory Characteristics

4.2.1 Signalized Intersection

Most of the intersections of Dhaka city are signalized with electric automatic lights with Green-Go, Red-Stop and Yellow-Take Caution signs. But they are rarely followed by both the driver and even the traffic police. But it is strictly maintained over the world for safety purpose. Even some signals are modified with a timer to show the cycle time.

Figure 4-27: Signalized Intersection

4.2.2 Manually or Automatic Controlled Traffic

It means manual or automatic traffic signals system. If there is signalized intersection and it is followed properly by drivers, then that signal is named ‘A’. But if there is signal system, but it is not maintained or if there is no signal system and traffic polices are controlling them manually by maintaining a certain period then it is named ‘M’.

Figure 4-28: Manually and Automatically Controlled Traffic

4.2.3 Median for Legal Passing

The median strip is the reserved area that separates opposing lanes of traffic on divided roadways, such as divided highways, dual carriageways, freeways, or motorways. The term also applies to divided roadways other than highways, such as some major streets in urban or suburban areas. The term legal passing is used to introduce the gap in the continuous section of the median to permit legal passing of pedestrian. In addition to it, a zebra crossing may also be present.

Figure 4-29: Median for Legal Passing

4.2.4 Presence of Law Enforcement

Law enforcement authorities, mainly traffic police are always on duty in the selected sites to ensure roadway safety, fitness checking of the vehicles, stop reckless driving and impose traffic rules. Even a temporary police box is also made to make contact with headquarter, file case against the law breakers. Normally these police patrol is available in all the important intersections in Dhaka city.

Figure 4-30: Presence of Law Enforcement

4.2.5 Motorized or Both (Motorized and Non-Motorized)

It means whether the motorized vehicles are only allowed in the roadway and marked as ‘M’. On the other hand, if both motor and non-motorized vehicles are authorized to maneuver, then it is marked as ‘B’.

Figure 4-31: Both Motorized and Non-Motorized (Red Marked Vehicles are Non-motorized)

4.2.6 Surveillance Camera Presence

Presence of CC camera or any other such facility is very much popular all over the world, mainly in developed countries, but in our country it is installed in only few places hand-picked all through Dhaka city.

Figure 4-32: Surveillance Camera Presence

4.2.7 Variable Message Sign

Variable Message sign's presence near any intersection is also observed and recorded. However it must be mentioned that these signs can be informatory, regulatory even mandatory by law application.

Figure 4-33: Variable Message Sign

4.2.8 U-Turn Prohibition

The turning of a vehicle in a U-shaped course so as to face in the opposite direction. It is vital as because it often creates crash situation with the vehicles from the opposite side. In some road the U-turn is completely prohibited.

Figure 4-34: U-Turn Prohibition

4.3 Exposure Variables

4.3.1 Pedestrian Volume

Regardless of four legged or three legged intersection, for pedestrian volume, number of pedestrians crossing the roads in any direction has been collected. For counting pedestrian number, suitable location was picked and then from there the counting was done.

Figure 4-35: Pedestrian Movement

4.3.2 Vehicular Volume

When collecting vehicular number, collection point was selected in this way that vehicle number was collected before any vehicle took left turn via any by pass road before reaching the intersection.

Figure 4-36: Vehicle Movement

CHAPTER 5 RESULTS AND DISCUSSION

Although quite a good number of studies related to crashes occurred at the intersection have been done in context of developed countries but in regarding developing and third world countries very few researches have been done, let alone about the significant crash factors related to pedestrian crashes. Besides the capability to predict future accident occurrence at a given site, prediction model can also identify which variables are relatively more critical to the safety performance of the site and what percentage of reduction in accidents can be expected from various improvements in site geometric and traffic elements. But most of the prediction models have generally been unable to explain the variability in observed accident rates adequately and have not proven to be good predictors of accident occurrences at intersections due to proper interpretation of these models. A good prediction model with better interpretation is therefore very much needed.

5.1 Negative Binomial Regression and Poisson Regression

Number of observation = 45

LR chi2 (13) = 35.46

Dispersion = mean

Prob > chi2 = 0.0007

Log likelihood = -60.166011

Pseudo R2 = 0.2276

Table 5-1: Result of Significant Crash Factors from Negative Bi-Nominal Regression

Variables	Co-efficient	Std. Err.	z	P > |z|
Geometric Characteristics				
Approach road similarities	-1.108	0.436	-2.54	0.011

Nearby office area	-0.613	0.449	-1.36	0.173
Presence of speed breaker	-0.608	.439	-1.38	0.167
Presence of rail-crossing	-1.071	0.513	-2.09	0.037
Presence of over bridge or underpass	1.206	0.448	2.69	0.007
Nearby waste deposit facility	0.895	0.325	2.75	0.006
Presence of solar panel system	1.055	0.385	2.74	0.006
Maximum number of lanes in any individual approach road	-0.423	0.271	-1.56	0.119
Absence of bus stop	-0.574	0.323	-1.77	0.076
Regulatory Characteristics				
Signalized intersection	-2.029	0.666	-3.04	0.002
Presence of law enforcement	2.012	0.806	2.50	0.013
Exposure Variables				
Vehicle volume	0.000757	0.0003	2.49	0.013
Pedestrian volume	-0.001528	0.0009	-1.66	0.097

Likelihood-ratio test of alpha=0, chibar2(01) = 0.23, Prob>=chibar2 = 0.317

Now the result getting process is described in short in the following:

1) The ‘nbreg’ command is used in STATA for getting the model result in Negative Binominal model.
2) After getting the evaluation result: Likelihood-ratio test of alpha=0; chibar2(01) = 0.23 Prob>=chibar2 = 0.317
3) As the over dispersion parameter alpha=0, so the result is published in Poisson regression.
4) Result by PR model can be got using ‘poisson’ command in STATA.

Number of observation = 45

LR chi2 (13) = 63.66

Prob > chi2 = 0.0000

Log likelihood = -60.278907

Pseudo R2 = 0.3456

Table 5-2: Result of Significant Crash Factors from Poisson Regression

Variables	Co-efficient	Std. Err.	z	P > |z|
Geometric Characteristics				
Approach road similarities	-1.053	0.386	-2.73	0.006
Nearby office area	-0.684	0.393	-1.74	0.082
Presence of speed breaker	-0.655	0.408	-1.60	0.109
Presence of rail-crossing	-1.087	0.484	-2.25	0.025
Presence of over bridge or underpass	1.227	0.432	2.84	0.004

Nearby waste deposit facility	0.887	0.289	3.07	0.002
Presence of solar panel system	1.125	0.343	3.28	0.001
Maximum number of lanes in any individual approach road	-0.451	0.254	-1.78	0.075
Absence of bus stop	-0.609	0.296	-2.06	0.039
Regulatory Characteristics				
Signalized intersection	-2.180	0.579	-3.77	0.000
Presence of law enforcement	2.038	0.777	2.62	0.009
Exposure Variables				
Vehicle volume	0.000786	0.0002812	2.79	0.005
Pedestrian volume	-0.001537	0.0008445	-1.82	0.069

5.2 Significant Variables in the Model

For the Poisson model, which is apposite to describe the total vehicle accidents at intersection approaches, several parameters are found to be highly significant.

5.2.1 Signalized Intersection

Among the significant variables we got from the study, signalized intersection is one of the important one ($t = -3.77$, $p = 0.000$). From this result as p value is equal to zero this variable may have severe impact on intersection crash possibilities. As t is negative so if the intersection is signalized then the probability of crashes at intersection may decrease in terms of pedestrian-vehicle crashes. It is obvious that if an intersection is signalized then there is less possibility of pedestrian-vehicle conflicting, as there is separate right of way. For this reason, no interaction between pedestrian and vehicle will be occurred and no chances of crashes. In developed countries all the intersections may be signalized but the scenario is not the same at developing countries. So it may be a severe cause of crash at the intersections in developing country like Bangladesh.

5.2.2 Approach Road Similarities

Among the significant variables we got from the study signalized intersection has important impact on intersection crashes ($t = -2.73$, $p = 0.006$). Here p value is close to zero which indicates this factor may have a severe effect on probability of crashes. However, negative t value indicates if the approach roads are similar then probability of crashes at intersections may decrease.

5.2.3 Nearby Office Area

Presence of office area is another significant variable that we got from this study which may have important impact on intersection crashes ($t= -1.74$, $p = 0.082$). As t value is negative and p is greater than zero so the possibility of intersection crashes decrease with the presence of nearby office area at the intersections.

5.2.4 Presence of Rail Crossing

Presence of rail crossing may be a fundamental factor for crashes occurred at the intersections ($t= -2.25$, $t = 0.025$). As t value is negative and p value is closer to zero so the possibility of crashes will decreases with the presence of rail crossing. From the study of Read et al. (2015) and Australian Transport Council (2010) it was found that pedestrians are more vulnerable at rail crossing than road. Providing proper and safe rail crossing can ensure less pedestrian-vehicle conflicts. There is no doubt that railroad-highway crossing accidents are common in developing countries like ours. Accidents may occur either because of the driver tend to cross the rail track ignoring the signal or because the driver simply fails to see the train coming. Proper rail crossings can eradicate this type of misfortunate events.

5.2.5 Presence of Over Bridge or Underpass

Presence of over bridge or underpass is one of the fundamental factors for controlling the frequency of crashes occurring at the intersections (t= 2.84, p= 0.004). Here t value is positive and p value is very closer to zero indicate that it may have a severe effect on increasing vehicle pedestrian crashes. Our study shows that presence of over bridges or underpasses are not reducing crashes as those are not properly useful to pedestrians. Moreover insufficient security, time factor, poor entrance of the over bridges and under passes are discouraging people to use them. So increasing the number of over bridges is not a solution to tackle vehicle pedestrian crashes rather it has become a contributory factor increasing the severity of pedestrian-vehicle crashes.

5.2.6 Presence of Speed Breaker

In developed countries speed breaker is seemed to be a curse in roadway system. However in our study we found out this to be a significant variable in reducing the frequency of pedestrian-vehicle crashes (t= -1.60, p = 0.109). Value of z is negative and p value is equal to 0.1. It means the presence of speed breakers on roads decreases pedestrian-vehicle crashes in context of Dhaka city. However, a previous study on 540 intersections in the Netherlands found that road humps were associated with an increase in the number of vehicle-bicycle crashes (Schepers et al., 2011). From our perspective, having manual traffic system and low capability of law enforcements gets help from speed breakers to control and reduce vehicular speed at many points of intersections which also reduces the probability of crashes.

5.2.7 Waste Deposit Facility

Waste deposit facility’s presence has become another significant variable from the study of signalized intersection with result (t = 3.07, p = 0.002). Here as the t value is positive and p value is close to zero, so it is obvious that with the increase of waste deposit facility within 50 ft. from the intersection, the number of pedestrian vehicle crashes may also increase. This situation may happen as because when there is the waste deposit facility in a country like developing country, there is always a chance that it may not be well maintained. So, waste, rubbishes will be scattered all over the road. This may create a blockage or narrowing of the main road. Pedestrians try to pass the blocked space using main road with running vehicles. Vehicles will then try to move across the blocked place, the pedestrian and the possibility of crashes may increase with the shortage of maneuvering zone comfortably. Even when the dump truck will come, it need more place to move and work along the road creating more shortage of roadway for road users. Therefore, leaving less place for the vehicles and pedestrian to move safely.

5.2.8 Presence of Law Enforcement

Presence of law enforcement is another significant variable that we got from the study which may have important impact on intersection crashes ($t = 2.62$, $p = 0.009$). As t value is positive and p value is closer to zero so the possibility of intersection crashes increases with the increase of law enforcement. Manual traffic controlling rather than automatic controlling often leads to pedestrian-vehicle crash. Law enforcement officers not only control movement of pedestrian and vehicles, they also bear the responsibility of increasing the conflicts between vehicle and pedestrian. Law enforcement can have a significant effect on the compliance of traffic rules and regulations. The extent to which road users are influenced by traffic law enforcement depends on the strategies used in police surveillance and on the efficiency of the punitive system. Although these law can have limited and transient effects, the punitive system does not seem able to cope with the demands of the traffic system. Alternative approaches to traffic behavior control are suggested that could have far greater impact on the behavior of road users.

5.2.9 Maximum No. of Lane in Any Approach Road

Among the significant variables from the study maximum lane is one of the important one resulting ($t= -1.78$, $p= 0.075$). As the t value is negative, maximum number of lanes reduces the possibility of pedestrian-vehicle crashes because if the lane number is less people will try to cross the road more often whereas if there are more lane pedestrians will wait for the signal. Therefore maximum number of lane will certainly reduce the number of accidents. Although Femandes et al. (2012) have found that an increase in the total number of lanes was associated with an increase in the frequency of vehicle-pedestrian crashes. However, from our study we found this is not applicable for our country.

5.2.10 Presence of Solar Panel System

Presence of solar panel system may be a fundamental factor for crashes occurring at the intersections (t= 3.28, p = 0.001). As t value is positive and p value is nearly to zero the possibility of crashes will increases with the presence of solar panel system. Pole carrying solar board can be a cause for sight restriction for the driver driving at high speed. With increasing speed, driver's sight limitation get shorten. Therefore they may not notice any pedestrian who is crossing the road suddenly. This will result in causing pedestrian-vehicle crashes.

5.2.11 Absence of Bus Stop

Absence of bus stop is another important factor in our pedestrian-vehicle crash study (t = -2.06, p = 0.039). As the t value is negative, the probability of accident occurring at the intersection may decrease with the absence of bus stop. Quddus et al. (2001) in their study mentioned that, the presence of bus stops, which may be considered as an obstacle for through traffic near the intersection, effectively decreases the width of the approach road that may cause higher conflicts but when there is no bus stop the sight distance is not restricted for both the drivers and the pedestrians. Diogenes and Lindau (2010) also found that presence of crossings located close to bus stops experience higher pedestrian crash rates. Therefore absence of bus stop can be associated with the reduction of pedestrian-vehicle crashes.

5.2.12 Vehicle Volume

Exposure variable like vehicle volume is another important significant variable (t= 2.79, p= 0.005). Here t value is positive and p value is close to zero which means vehicle volume has a severe impact on increasing the possibility of crashes at intersections. From the study of Wong et al. (2007) it was found that traffic volume and pedestrian-vehicle crash risk at the intersection share an inverse relationship. Miaou (1994) in his study suggested that traffic volume can be considered as a proxy for influencing traffic intensity or exposure on safety criteria rather than considering it as a direct predictor variable of crash. Increased traffic amount can increase crash severity and therefore total casualties. Besides, increased amount of vehicle volume motivates many drivers to be competitive with each other. Due to the high vehicle speed on the road, if one car develops a problem and suddenly halts, those behind it cannot stop in time and may hit it. Considering that these roads often have high vehicle volumes, more cars are forced into braking and skidding, darting into other lanes and in front of oncoming traffic and so more vehicles become involved, creating a chain reaction effect.

5.2.13 Pedestrian Volume

Pedestrian volume is another exposure variable controlling the pedestrian-vehicle crash severity at the intersections (t= -1.82, t = 0.069). Negative t value and p value greater than zero indicates that it may decrease probability of crashes. This may happen due to the higher pedestrian volume influenced them to use the foot over bridge and zebra crossing. However, Lyon and Persaud (2002) found out in there study that pedestrian and vehicle crashes occurs highly at the area that has higher pedestrian volume and higher vehicle volume. It is often seen that area in higher pedestrian volume Government provide more overpasses, underpasses, zebra-crossing, speed breakers. With the presence of law enforcement and other available beneficial traffic measures may be taken into account seriously thinking of the pedestrians who will use the intersection.

CHAPTER 6 CONCLUSION

6.1 Summary of Research

6.1.1 Background and Rationale

However, the current condition of pedestrian movement in Dhaka Metropolitan City is a total jeopardy .Though the government in Bangladesh are trying their best , but it is not possible for the govt. alone to increase the mass education in terms of the road using. People from all walks of life who are the pedestrians need extra care about crossing the road and obviously need to obey related traffic rules. No one is interested to maintain or obey any single law or regulation during the time of their journey and so accident occurs on a regular basis. Moreover, a great number of pedestrians and drivers of different vehicles actually don't know about the signal system properly or don't even care about the system as the total system of safety is full of faulty variables. Like if there is a signal light is present at an intersection, the electricity to light the light is not present at that place, so manual handling is needed every time. This scenario can't be greatly changed overnight. Illegal crossing is increased more than the developed countries, in Dhaka City because - for floating low income people walking is a must; lack of female friendly transport system forcing women to become pedestrian; inadequate mass transport at pick hour; unplanned city development; over population causing too many varieties of traffic and traffic congestion leads to more pedestrian. Those are some macro level difference of developed and developing nation's pedestrian –vehicle crash factor.

There has been a constant debate about which procedure at grade, grade separation or underpass will be best in the intersections at Dhaka city for the safety and comfort of the pedestrians. But for this consideration, further detailed study is needed.

6.1.2 Objective and Scope of Research

In order to develop a mathematical model that correlates accident frequencies to the intersection approach geometric, traffic and regulatory control characteristics and exposure variables, 54 intersections of Dhaka City is selected as theses representative set of intersections that possess a wide variety of geometric and traffic characteristics and high amount of vehicle-pedestrian number. Accident data is the central resource used for the identification of causal factors and evaluation of safety performance. Now while analyzing and getting result, it can be said that developed country parameters are far different than developing countries. While developed countries have different roads for cycling, developing countries even don't have the proper width for mainstream vehicle maneuver. Even developed countries have electrical VMS, whereas developing countries don't have the normal regulatory or informatory sign for directing vehicle. The most important thing is pedestrians of developing countries have little knowledge about safety of themselves. They pass roads scatter and randomly, drivers have to face many road side friction while driving. So overall the pedestrian-vehicle crashes at intersection in developed countries is less than the crashes, death and causality rate of developing countries.

There is many scope for further researching taking into the drivers-pedestrians mentality and other factors for crash severity analysis.

6.1.3 Conclusion

Our study found out that waste deposit facility, vehicular volume, presence of over bridge or underpass, law enforcement and solar power system near intersections increases the possibility of pedestrian-vehicle crashes. On the other hand we have found approach road similarities, presence of nearby office area, speed breaker, rail crossing, maximum number of lanes in any individual approach road, absence of bus stop, signalized intersection and pedestrian volume are the factors that contribute in decreasing pedestrian-vehicle crashes.

6.1.4 Recommendations

The results of this study will provide policy makers as well as transportation engineers and planners with important information for predicting the possibility of crashes due to the significant or critical factors that we got from our result for the development communities. Some recommendations from our findings are provided below for future research and consideration. Crash possibility will be decreased at the selected intersections if –

- All the signals are maintained automatically.
- Lane number is increased.
- Similar roads are made so that drivers can easily identify the points from which people tend to cross the road.
- Office area is designed properly near intersections.
- Dependencies on automated signal is increased rather than relying on manual control.
- Speed breakers are constructed following the rules.
- Railway crossings are provided efficiently.
- Proper maintenance of overhead bridges or underpasses.
- Solar panel system is present at safe distance from the intersections to provide security and sufficient power for the signals and street lights.
- Waste deposit facilities are removed if located very near to the intersection.
- Less number of bus stoppage near intersections.

- Traffic volume is controlled.
- Random movement of pedestrians are restricted.

6.2 Limitations and Future Research

This study is not without limits. Out of the 54 intersection's data, we were able to cover only the 45 intersections to get all the geometric characteristics, regulatory characteristics and exposure variables. In fact there must be some human error while taking the data on spot as not all the distances were calculated exactly. Some of distances were taken qualitatively. Pedestrian number might be less than actual number and same goes for vehicular data. So, this may cause some sort of bias in the main result. Again while taking data, some information was not obvious, like- the presence of waste deposit facility. At some places it was temporarily present, so we had to take the decision whether to take it or not.

We didn't take any traffic characteristics such as AADT, ADT, average speed these data need long time evaluation. Even driver's characteristics are not taken into consideration.

Crash frequency is only analyzed. Crash severity is not analyzed, so the logit model is not needed for our study purpose.

For future research, too many crash factors can be taken like- driver's age, gender, mentality and other critical mental characteristics, weather condition, temperature change, advanced VMS sign implementation, public survey on different socio-demographic-economic matters.

As the resident of the communities are the stakeholders and sufferers of the road accidents, their views are really important on choosing the particular type of intersection approach along with different grade separation facilities, roadside and median barriers. Their responses actually reflect that how much trade-off they are ready to consider among safety and network reliability.

However, the overall study and recommendations should be helpful in future research and in policy makers' decision making about any long or short term policy or proposal making.

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