ACCIDENT ANALYSIS BEYOND DESCRIPTIVE STATISTICS

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Degree of Master of Science

Department of Civil Engineering

University of Moratuwa

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Thesis submitted in partial fulfilment of the requirements for the degree

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DECLARATION

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ABSTRACT

Worldwide, more than 1.2 million people die annually from road accidents and now it is the 8th leading cause of death in the world. In the context of Sri Lanka, road traffic injury is also a leading cause of mortality and morbidity. In year 2014, 35,967 crashes were reported where 6% of them are fatal contributing to 2,440 deaths. Providing effective countermeasures for the identified safety issues and proper policy developments are vital in mitigating the issue of road traffic accidents.

Under this study, a comprehensive analysis of road traffic crashes of the country in terms of descriptive statistics was carried out using 'Sri Lanka Police Accident Database' to find the road safety condition of the country with the objective of providing a basis to encourage concentrated and in depth studies in road safety of the country. Over the decade 2005 – 2014, on an average, 6 people have died every day in Sri Lanka form road traffic crashes. According to the accident details of the last five years, age group 15-29 accounted for 33% of the total casualties in the country and 23% of the total fatalities due to road crashes. Pedestrians accounted for 21% of those who died from 3W related crashes. Promotion of public transport, strict law enforcement on helmet usage, design change of three-wheelers to limit sharp turns and more road safety education are among the suggestions made that can improve the road safety condition.

However, only with descriptive statistics it is not possible to carry out an in depth review of the causes of accidents. Therefore, statistical methodologies have been improving which have enabled better safety design and policy improvements. In this study, a stepwise binary logistic regression was used for heavy vehicle related crashes to show the importance of accident analysis. Among the identified contributory factors, heavy vehicle crashes occurring during 03:00 – 06:00 hours, occurring at Batticalo, Chilaw and Jaffna DS Divisions and crashes involving intercity busses, semi government heavy vehicles are some of the factors that have a higher chance of becoming a fatal crash.

DEDICATION

To

My Loving Younger Brother

Who Passed Away from a Motorcycle Accident at the Age of 17.

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1. Problem Statement and Background

Worldwide, more than 1.2 million people die annually from road accidents and now it is the 8th leading cause of death in the world, the leading cause of death for the people in the age category of 15-29 years and projected to be the 5th leading cause of death in 2020 unless otherwise any action is taken to mitigate these effects. Developing countries contributes largely towards this number. Among them 80% of the road traffic deaths occurring in middle income countries (WHO, Global Status Report on Road Safety 2013: Supporting a Decade of Action, 2013) where majority of the road users are found to be vulnerable road users (motorized two or three wheeled vehicle users and pedestrians). As a mitigating measure, a long term project called "Decade of Action for Road Safety" was started in 2011 and runs up to 2020.

Road safety is always a critical issue in the developing world due to the fast industrialization and motorization taking place. Performance of the vehicle, person and the environment interaction is not creating a safe situation for the road users. Rapidly increasing numbers of motorcyclists or three wheelers (vulnerable road users) together with lagged behind road infrastructure development contribute to intensify the issue of road traffic crash related mortality and morbidity. Thus, providing effective countermeasures for the identified safety issues and proper policy developments can help mitigating this issue successfully. Identification of safety related issues and contributory factors using available data, plays a major role in this regard. Under this study, the effort was taken to identify such major issues and trends of the road traffic accidents in Sri Lanka, a lower-middle income country.

Sri Lanka is an island nation which belongs to the lower-middle income category. The island has a total land area of about 65,000 km^2 and an estimated total road network of 28,000km with a total adult literacy rate of 91.2% and under 5-yr mortality rank of 136 by 2012 (UNICEF, 2012). Although the literacy and morbidity uplifts the country, status of road safety of the country degrade this position. With the end of 20 years old civil war in 2009, the country has experienced a rapid period of economic development, mainly supported by an increased popularity as a tourist destination. The country has much to offer as a tourist destination with a wide range of climate conditions ranging from misty hills to sunny beaches and number of archeologically important destinations all concentrated within the relatively small geographic constraints of the island nation. However, until the end of civil conflict, the country's road network had not been paid due attention and these relatively small distances were bridged by substandard roads that were both uncomfortable and time consuming to travel. In spite of the significant road improvement made during the last 10 to 15 years, the existed majority of the roads which were of substandard nature, affected the country's ability to attract investors and has a significant negative impact on the daily lives of the general population too.

Since the end of the civil conflict, the country has paid special attention to upgrade the country's road network with the hope of increasing both tourist and industry related income. However, the impact of these improvements upon the road safety and road-traffic accident related mortality and morbidity has not been fully explored. Even prior to the improvements to the road network, the country had a relatively high number of road-traffic accident related deaths. While it may be argued that improved road standards can lead to a reduction in such incidents, it must be noted that such improvements also allow for a change in driving dynamics such as an increase in the average driving speeds which again can have a significant impact on the accident probability, as well as increased the severity. In addition, the economic improvements have also increased the percentage of vehicle owners in the general population with an 11.75% growth in the Per capita gross domestic product from 2013 to 2014 amounting to value of 473,261 LKR with a corresponding increase in the number of vehicles on Sri Lankan roads, with available poor public transportation system. With these changes, road safety characteristics of the local road network have become more relevant than ever.

Over the decade 2005 to 2014, an average 2,247 number of people died annually in Sri Lanka from road accidents. In year 2014, 35,967 crashes were reported where 6% of them are fatal followed by 2440 fatalities. Motorcycles individually accounts for more than 50% of the vehicles registered in the country and has involved over 50% of the total fatalities in the year 2014. Three wheelers, being the second highest vehicle category in the country, have contributed for 16% of the fatalities in the same year. Therefore, finding the causes for these accidents and taking proactive counter measures have become of great importance. To assess the road safety and to find the possible reasons for crashes, accident data is a must and a detail analysis would enable to propose possible counter measures to reduce crashes in future. Thus, the analysis of traffic crash data has long been used as a basis for influencing highway designs and directing implementations of regulatory policies with the aim of road safety improvement. However, only with inferential statistics it is not possible to obtain a lot of information regarding the causes of accidents. Therefore, statistical methodologies have been improving which have enabled better safety design and policy improvements. Here in this study, effort is taken to derive descriptive statistics regarding the road safety status of the country and derive more useful information through statistical methodologies to help identifying causes and future trends in accidents. As such a stepwise binary logistic regression analysis has been carried out for heavy vehicle related crashes in Sri Lanka to point out the potential of such statistical methods in finding out the causes and safety related issues.

1.2. Objectives of the Study

Sri Lanka Police maintains a comprehensive database of road traffic crashes taking place in the country since 2003. But, there has not been any possibility of extracting the required data easily to analyse due to the absence of a virtual database for the outside entities. Therefore, this database has not long been used by any entity other than Sri Lanka Police. Recently, according to a programme initiated by World Health Organization (WHO), the Department of Civil Engineering, University of Moratuwa and Sri Lanka Police had to work together to introduce several improvements to the prevailing accident database. Therefore, the Department of Civil Engineering has the database now and has received the permission to analyse it in order to derive valuable information to improve the road safety condition in Sri Lanka.

Therefore, this study tries to address the lack of literature based on accident data analysis regarding road safety in Sri Lanka, a lower-middle income country through a basic analysis of 'Sri Lanka Police Accident Database' using descriptive statistics so that more follow up studies are encouraged to identify the patterns, contributory factors and propose preventive strategies. On the other hand, it investigates the potential of other statistical methods beyond descriptive statistics in finding out causative factors and other safety issues. It points out the advantages of statistical methods over descriptive statistics.

1.3. Scope of Work

Study utilizes a basic analysis of 'Sri Lanka Police Accident Database' using descriptive statistics. A brief analysis was done using the accident data from 2004 to 2014 and a more specific analysis was carried out using the accident details, vehicle registration data, and population data of the last five years of the country. An in depth review of these details and analysis results identified several safety related issues and suggestions were made accordingly to reduce the huge economic loss due to motor-vehicle related fatalities and injuries. Special attention has been paid on the vulnerable road users who are motorcyclists, three wheelers and pedestrians.

Different categories of accidents were considered under chapter 3 and heavy vehicle crashes were selected to investigate using an advanced statistical method. As per the statistical methods other than descriptive statistics, the stepwise binary logistic regression analysis and multiple regression were selected to be considered in analyzing heavy vehicle crashes among the available methods through literature review. Out of these two methods, stepwise binary logistic regression was selected to be used in analyzing heavy vehicle crashes.

2. LITERATURE REVIEW

2.1. Road Safety Issue

2.1.1. Developing Countries and Vulnerable Road Users

An estimated 1.2 million people die from road traffic accidents every year in the world. In 2013, it was ranked as the leading cause of death for young people aged 15-29 worldwide and the 8th overall. Motor vehicle related fatalities is expected to become the 5th leading cause of the death worldwide by 2030 unless remedial action is taken to reverse this unfavourable trend (WHO, Global status report on road safety 2013: supporting a decade of action., 2013). Surprisingly 80% of these deaths are occurring in the middle income countries (WHO, Global status report on road safety 2013: supporting a decade of action., 2013) and they have become the largest contributors to this growing problem. It is justifiable to at least partly attribute this disproportionate number of fatal road-traffic accidents seen in the middle income countries to the dramatic transportation infrastructure development and rapid increase in the number of vehicle owners in them. Motorization of the community increases the number of vehicle users (probably in the form of motorcycle and three wheeler users in low-middle income countries) and decreases the number of pedestrians and public transport users. With that there are fewer pedestrians who observes a road traffic accident risk from higher number of vehicles than before. At the same time, increased number of motorcycles and three wheelers are also subjected to accident risk from higher number of vehicles. As a result, the probability of a vulnerable road user (Pedestrians, Cyclists and motorized 2 or 3 wheelers) encountering a vehicle has increased with a resultant increase in the risk of pedestrian and vulnerable road user casualties through accidental means.

Adverse effects of this situation were evident with comparatively higher number of pedestrian casualties in middle and low income countries as depicted in Global Status Report on Road Safety 2013 (WHO, Global status report on road safety 2013: supporting a decade of action., 2013). According to the same source, pedestrian casualties are higher in low income countries than middle income countries. This could be due to the comparatively higher number of non-motorized road users (pedestrians) in low income countries and comparatively higher number of motorized road users in middle income countries which increases the number of pedestrians at risk in the roads of low income countries. Some studies suggest that driver's attitudes have a crucial effect on the road accident involvement (Mirzaei, et al., 2014). The same study reveals that the socio economic status of a certain region correlates with road traffic accident involvement as well. And the road safety attitude was also found to be influenced by regional development (Şimşekoğlua, Nordfjærn, & Rundmo, 2012). These sources altogether suggest that having a middle income in developing countries has influenced the high road accident rates. It doesn't necessarily imply that road safety status of those countries cannot be uplifted by any other means. Chorlton and Conner, who were studying the long term impact of intervening an Intelligent Speed Adaption (ISA) system on drivers' cognition and behaviour of speeding found that, enforced behaviour, if sustained, can change the attitude of people (Chorlton & Conner, 2012). Evidence from France suggests that gradual improvement of driver's attitude can be achieved through strict law enforcement (Constant, Salmi, Lafont, Chiron, & Lagarde, 2008).

Another important fact revealed from the Global Status Report on Road Safety 2013 by WHO is that, about 33% of the road traffic deaths in South East Asia are from motorized 2 or 3 wheel users. It further depicts that low income countries have higher numbers of vulnerable road users (pedestrians, cyclists and motorized 2 or 3 wheelers). Injuries from motorcycles accounts for more than 50% of road traffic injuries in low and middle income countries (Hyder, Waters, & Rehwinkel, 2007). In low and middle income countries, the majority cannot afford to have motorized 4 wheel vehicles which are safer compared to cycles and motorized 2 or 3 wheels. As a result, it increases the number of vulnerable road users on road and degree of risk when on the road which in turn paves the path for increased number of fatalities in these regions. This overall picture gives a sense of strong relationship between road safety status of a country and the income level of it. However, on the other hand, some high income countries such as Oman, Saudi Arabia and United Arab Emirates have reported higher fatality rates than some middle income countries like Malaysia and Thailand

(Mohan, 2011). This brings forward the fact that high national incomes do not always produce a good road safety environment. Therefore, this goes against the strong belief that road traffic fatalities have a strong relationship with per capita income (Kopits & Cropper, 2005). However, there are evidence from many countries about dramatic successes in reduction of road traffic accidents as a result of national level efforts and interventions towards identified issues (WHO, Global status report on road safety 2013: supporting a decade of action., 2013). Therefore, as a mitigating measure, a long term project called "Decade of Action for Road Safety" was started in 2011 and runs up to 2020 by United Nations (UN).

2.1.2. Road Safety in Sri Lanka

As a developing nation, many of the above findings are applicable to Sri Lankan road users. Road accidents, congestion and emission (air quality) in Sri Lanka are becoming a major social, economic and health hazard with the increasing number of road kilometers, vehicles and vehicle kilometers. With the dramatic road infrastructure development in recent years, the total number of vehicles increased at a decent rate but motorized 2 or 3 wheelers increased at an accelerated rate. As a result, the probability of a vulnerable road user encountering a vehicle has increased giving way to the increased risk of vulnerable road user casualties from road accidents.

In order to address this issue, the government took the necessary steps to implement seat belt laws and motorcycle helmet laws. Under the seat belt law, every person travelling in the driving seat or the front passenger seat of every motor vehicle which was registered after the year 2000 was made mandatory to wear seat belt and this law was implemented with effect from 1st of October 2011. The helmet law was implemented in 1991 where all the riders were made mandatory to wear a helmet. However, problems remain regarding extent of implementation of the law and the proper use of helmets by the local riders with most preferring to leave their helmets unclasped. On an average 2,426 number of people died annually from road accidents over the past decade giving evidence for the extent of the road safety problem in Sri Lanka as a serious health issue. Adverse effects of this were evident by comparatively higher number of pedestrian, motorcycle and motorized three wheeler casualties. Accordingly, this study tries to understand the accident patterns in Sri Lanka using “Sri Lanka Police Accident Database” which can pave the path for better road safety policy developments and effective countermeasure implementations.

2.2. Accident Analysis for Road Safety

2.2.1. Overview

Accidents were perceived as the consequence of complex interactions rather than simple incidents of causes and effects until recently. Now it is widely accepted that these can be prevented if correctly understood and investigated in detail. The widely available and practiced method is analysing the routinely maintained police accident databases with descriptive statistics.

With descriptive statistics, it can be summarized what the data sample shows and describe the basic features in an effective way. With the use of simple graphics, they can supply the basics for quantitative analysis of data. Descriptive statistics however does not help us to do any estimations beyond the data we have analysed. Inferential statistics are used to meet that requirement (LUND & LUND, 2016).

With the evolution of mathematics and statistics, the quantitative analysis of accidents has gone well beyond just descriptive statistics. They can be categorized into three basic levels.

- Inferential statistics which enables us to assess the statistical significance of the dataset and the results obtained
- Simple inter relationships which enables us to measure the relationship of two variables in the data set
- Assessment of inter relationship between three or more variables in the data set: Multivariate analysis

Such analysis methods are used to determine the circumstances of the accidents and both direct and underlying contributory factors.

Most of the police accident databases are maintained manually with the use of police officers. Hence it involves the human error for some extent. Due to the inaccuracies and reliability issues associated with such kind of accident databases, the accident analysis has further evolved to incorporate more reliable methodologies. Two such major developments are the Accident Investigation and Conflict Studies. In the accident investigation, a multidisciplinary team conduct a thorough in-depth and on-spot investigation of an accident. Conflict studies on the other hand observe the behaviour of near accidents or accidents of a certain pre identified location to find out the causes and underlying factors.

2.2.2. Accident Analysis beyond Descriptive Statistics

The road accident data can be divided in to two basic types when it comes to the analysis. They are "Frequency Data" and "Severity Data". Frequency data denotes the number of accidents occurred (count data) in a road or area entity over a specified interval of time. Categorical modelling techniques are inappropriate for frequency modelling (Lee & Mannering, 2002) while Poisson regression analysis has been widely used by the scholars as a basis for initial research effort in finding causative factors for crash frequencies (Mannering & Bhat, 2014) (Lee & Mannering, 2002). Due to the problem of over dispersion of crash data (few data points have unusually high number of crash data), the simple Poisson Regression analysis became less promising and Poisson variants (for example, negative binomial model) became dominant (Mannering & Bhat, 2014). Multiple regression analysis has also been used to find out relationships between fatalities and different explanatory variables through frequency modelling (Ameena & Najib, 2001). It could be seen that there are many observations with no observed crashes in these databases. Zero-inflated poisson regression and negative binomial regressions were considered to overcome this issue (Mannering & Bhat, 2014).

For severity data, the models have evolved from simple binary discrete outcome models (binary logit and probit models) to multiple discrete outcome models (Mannering & Bhat, 2014). Multiple discrete outcome models used simple multinomial models to the nested Logit models. Logistic Regression models and ordered Probit models have been used most commonly for severity analysis. Some studies have used Bayesian Networks to classify accidents according their injury severity. Bayesian Networks are capable of making predictions without the need for pre assumptions (Juan de O˜na, Mujalli, & Calvo, 2011). Accident type, driver age and lighting were found to be some of the contributory factors for accident severity by inference (Juan de O˜na, Mujalli, & Calvo, 2011).

The theoretical frontier of statistical modelling has evolved well beyond the practical usage by the practitioners in the field. Yet it is not encouraged to slow the methodological advances since they can produce more effective inferences and methods to find out underlying causes (Mannering & Bhat, 2014).

2.3. Binary Logistic Regression Analysis for Heavy Vehicle Crashes

2.3.1. Heavy Vehicle Crashes

Identification of contributory factors associated with Heavy Vehicle crashes is vital in aiding the development of prevention strategies. In Australia, the majority of the work related deaths are occurring in the field of Transportation. Heavy vehicle drivers accounts for the vast majority of this (Harrison, Mandryk, & Frommer, 1993). Not abiding the law of seatbelt was found to be a common practice among the truck drivers than the other fatally injured working drivers. The speed, on the other hand, was found to be one of the major issues of heavy vehicle related road crashes. It is suggested that in Australia 29% of the Heavy Vehicle crashes can be reduced if all the Heavy Vehicles can comply with the existing speed limits (Commision, 2005). Fatigue was found to be another more prevalent issue in heavy vehicle drivers than all work related fatal crashes (Boufous & Williamson, 2006). Although the majority are concerned with the alcohol usage of drivers of any sort of vehicle type to affect the safety significantly, a study in Australia revealed that alcohol is not a significant contributory factor for Heavy Vehicle crashes (Drummer, et al., 2003). The consequences of truck crashes are more serious than car accidents due to weight, size, and manoeuvring limitations of the bigger and heavier vehicles.

Major causes for truck crashes can be classified in to three categories. They are, Driver factors (fatigue, misjudgement, carelessness, drug and alcohol use, speeding, age, gender, height, weight and employment stability), Vehicle factors (vehicle type, breakdown and failure of some components such as tires and brakes) and Environmental factors (poor road conditions, adverse weather conditions, structural and engineering difficulties). 87.2% of all truck crashes are caused by driver related factors, 10.1% are due to the vehicle related factors and 2.3% are related to the environmental factors (Cantor, Corsi, Grimm, & Ozpolat, 2010). Heavy vehicle drivers younger than 27 years of age demonstrated higher rates of accident/fatality involvement which decline and plateau until the age of 63 years where increased rates were again observed. Other contributing factors to heavy vehicle accidents include: long hours and subsequent sleepiness and fatigue, employer safety culture, vehicle configuration particularly multiple trailers, urbanization and road classification (Duke, Guest, & Bogess, 2010). American Transportation Research Institute's study (Alexandria, 2005) points out that if a truck driver had a crash in the previous year, his/her likelihood of having a crash in the following year is almost twice as high as a driver with no crashes in the previous year. Examining the circumstances of death where other road users have died in a heavy vehicle crash would provide a more comprehensive depiction of heavy vehicle fatal crashes and associated risks (Lisa, Lyndal, & Elias, 2009).

A study which was done incorporating two government maintained databases, suggests that following driver specific factors significantly influence the likelihood of a crash occurrence. They are: driver age, weight, height, gender, and employment stability as well as previous driver out-of-service violations rates and past crashes. They also found that poor maintenance of vehicles contributes to poor safety performance (Cantor, Corsi, Grimm, & Ozpolat, 2010). On the other hand, a new concept being developed is that, a road transport safety system designed to be forgiving of human error is ideal, though preventing human failures within such a system is complex. Hence suggests increased recognition of heavy vehicle safety beyond individual driver responsibility is necessary (Lisa, Lyndal, & Elias, 2009). Truck crashes depend not only on environmental factors but also on vehicle and driver factors. These theoretical considerations suggest that vehicle and driver related variables should be included in a truck crashes model. However, the Sir Lanka Police Accident database does not contain driver related variables as described above and thus they are not included in the current study.

Around 2,250 number of people die annually in Sri Lanka from road accidents. In 2013, the heavy vehicle percentage of the country is 8% but its involvement in fatal crashes is 21%. Therefore, it is evident that heavy vehicles are playing a major role in fatal crashes. Finding the causes for these accidents and finding proper engineering and other solutions to minimize them have become of great importance. The goal of this study is to inform scholars and public policy makers of the most critical factors of heavy vehicle crashes and improving the Sri Lankan safety literature.

2.3.2. Binary Logistic Regression Analysis

Specifically, in safety sciences, logistic regression has shown to deliver a realistic modelling and is of the widely utilized methods. Numerous studies have adopted logistic regression models in extracting the risk factors of road traffic crashes which are rooted in human behavior, including the use of cell phones (Wilson, Fang, Wiggins, & Cooper, 2003), smoking (Ryb, Dischinger, Kufera, & Soderstrom, 2007) and drunk driving (Mirzaei, et al., 2014).

Logistic regression allows us to control the effect of confounding variables. Previous studies have proposed age, gender (Turner & McClure , 2003), drivers' education and licensing (Sivak, Soler, Tränkle, & Spagnhol, 1989); (Blows, Ameratunga, Ivers, Lo, & Norton, 2005), smoking (Ryb, Dischinger, Kufera, & Soderstrom, 2007) and wearing medical glasses (Sagberg, 2006) as potential confounders of contributory factors on RTC (Mirzaei, et al., 2014).

Selection bias is one of the main drawbacks which can be involved in logistic regression modeling (Steyerberga, Bleekerb, Moll, Grobbeec, & Moons, 2003); (Nemes, Jonasson, Genell, & Steineck, 2009). However, this can be eliminated by acquiring a large sample size. Increasing the sample size reduces the analytically induced bias and protects against extreme value estimates (Mirzaei, et al., 2014).

Cantor (Cantor, Corsi, Grimm, & Ozpolat, 2010) has used a Poisson regression model as well since their dependent variable was defined in terms of non-negative count data. The calibration of each logistic regression model is in means of concordance between the model's predictions and the observed probabilities. Technically, it can be estimated by the Hosmer–Lemeshow X^2 test for the goodness of fit (Mirzaei, et al., 2014).

3. ACCIDENT ANALYSIS WITH DESCRIPTIVE STATISTICS

3.1. Source of Data

Two decades ago, there was no proper mechanism to record and store accident related data in the country. Transport Research Laboratory of United Kingdom (TRL-UK) has been involved in an Official Development Assistance (ODA) funded project to introduce Microcomputer Accident Analysis Package (MAAP) on a trial basis in parts of Colombo and then the whole country adopted this as the official way of recording and storing road traffic accident data. Sri Lankan Police is responsible for collecting and recording of accident data as per the directive which has been a success so far.

With the introduction of MAAP, the accident fact sheet where the details of the accidents are recorded at the time of accident was introduced. It mainly consists of three sections, namely, (1) Attendant Circumstances where the basic details related to accident and accident environment is recorded, (2) Vehicle Details, where details of all vehicles involved in an accident are recorded, (3) Casualty Details, where details of all people who were injured at an accident are recorded. Even though the accident data being recorded in three different tables a unique number is given for each accident named as "Accident Key" in order to link respective accident information.

Data collection sheet, known as B 249, are filled out by a Police officer who happen to be on duty at the time of a particular accident. Although, vast majority of these police officers are not specially trained for filling the fact sheet, the form maintains the accuracy of data to an acceptable level by reducing the degree of freedom given to a police officer by providing multiple choices to any given variable. All these data sheets are entered either at police divisions or at the police headquarters throughout the year and transferred to a main system established at headquarters in Colombo. These data are stored in an MS ACCESS database. The relevant data can be extracted from the database directly through MS ACCESS.

3.2. Methodology

Attendant circumstances, vehicle details and casualty details were analyzed separately. An overall analysis using descriptive statistics was carried out to identify the critical factors and issues. First, overall trends were observed using the data over a decade to get an idea of the safety situation as a whole. A more specific analysis was then done using accident data of the most recent 5 years at the time of this study to derive more specific and useful information which can help the authorities to direct their future programs to improve road safety in Sri Lanka. Since it could be seen that the fraction of vulnerable road users (pedestrians, cyclists, motorized 2-3 wheelers) is comparatively higher than other motorized vehicle users, more attention has been paid towards the accidents where vulnerable road users are involved and affected during further analysis.

3.3. Results and Discussion

3.3.1. Overall Safety Situation of the Country

Table 1 - Registered Vehicle Population in Sri Lanka

	Cumulative Vehicle Population of the country			New registrations in 2014		Operating vehicle fleet in 2013	
Class of Vehicle	**2013**	**2014**	**2014%**	**Number**	**Percentage**	**Number**	**Percentage**
Motor cars	528,094	566,874	10.06%	38,780	9.03%	392,398	11.11%
Three Wheelers	850,457	929,495	16.50%	79,038	18.40%	743,054	21.04%
Motorcycles	2,715,727	2,988,612	53.05%	272,885	63.53%	1,763,976	49.96%
Buses	93,428	97,279	1.73%	3,851	0.90%	44,314	1.26%
Dual purpose vehicles	304,746	325,545	5.78%	20,799	4.84%	275,588	7.81%
Lorries	329,648	334,769	5.94%	5,121	1.19%	211,885	6.00%
Land vehicles	381,578	390,660	6.93%	9,082	2.11%	99,684	2.82%
TOTAL	**5,203,678**	**5,633,234**	**100.00%**	**429,556**	**100.00%**	**3,530,899**	**100.00%**

(Source –Department of Motor Traffic, Central Bank Sri Lanka)

Table 1 clearly indicates that MCs followed by 3Ws govern the registered vehicle population in the country, which is over 69% cumulatively. At the same time data shows that operating vehicle fleet composition is also more or less similar to cumulative vehicle registration data. Furthermore, when last year vehicles registration is considered, percentage of MCs and 3Ws registered shows a significant increase compared to population percentage and thus depicts the growing trend in MC and 3W population in the country.

On an average, 6 people die every day in Sri Lanka from road traffic accidents. 35,967 road traffic accidents were recorded during the year 2013 where 6% of them were found to be fatal accidents. 31,850 casualties were recorded with 7.6% of them being fatalities, 7,071 grievous accidents and 12,782 non grievous accidents were recorded in 2014 with 6,909 pedestrians met with accidents. Figure 1 shows the variation of number of accidents in each severity level for the previous decade in Sri Lanka.

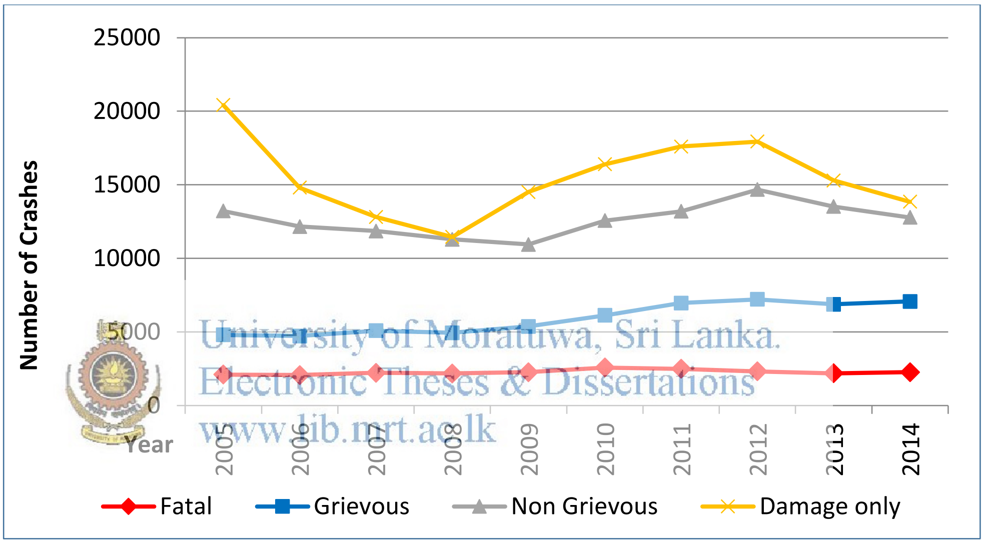

Figure 1- Overall Accident Trend by Severity Type.

There is a significant reduction of damage only accidents from 2004-2008 period and more or less the same variation in non-grievous accidents as well. The numbers of grievous and fatal accidents in fact has been rising up to 2008. Grievous accidents have more or less same gradient afterwards where the variation of fatal accidents cannot be seen clearly in this figure, which therefore, has been depicted separately in Figure 2.

The drastic reduction in damage only accidents cannot necessarily be classified as an improvement in road safety situation in Sri Lanka due to the fact that no such reduction could be observed in total number of accidents. However, the most possible reason behind this reduction of damage only accidents was the introduction of "on the spot" insurance schemes where the affected parties were paid damages on the spot (at accident scene itself) and thus eliminated the necessity of Police interference or reporting. This method became very popular since it is much more convenient to settle damages, just at the presence of insurance agent rather than seeking Police assistance (mainly due to the reduced time consumption and convenience). As a result, many 'Damage Only' accidents started disappearing (not reported) from the database and thus numbers went down over the years. However, this pattern is not exhibited in the 'Grievous' and 'Fatal' accidents due to the fact that these accidents are mandatory to be reported. This is a common trend which can be seen everywhere in the world and thus 'Damage Only' accident related data analysis may not produce reliable and accurate results.

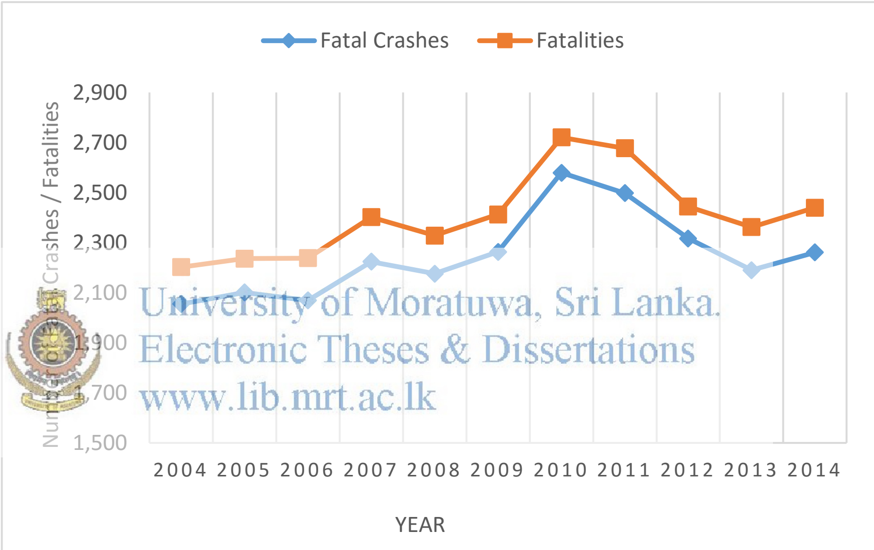

Figure 2 - Trend of Fatal Accidents and Fatalities.

According to the Figure 2, the number of fatal accidents has been increasing until 2010 and then decreasing afterwards till 2013 and again a slight increase in 2014. It can be seen that there had been an improvement in road safety situation in the country after 2010 despite the increasing number of motorcycles and three wheelers on roads. The same trend can be seen in the fatalities as well.

Urban percentage of accidents has been reducing during the last few years. This can be accounted for the recent development of roads in rural areas. Many roads were rehabilitated and many new rural road kilometers were added to the system increasing the number of vehicles in the rural road environment and increasing the speeds of the vehicles.

When possible reasons for increasing numbers of private transport modes as MCs, motor car, dual purpose vehicles and para transit modes like 3Ws as opposed to the public transport was explored, it was found that there is a degrading trend of public transport usage (mainly bus service). When operating vehicle fleet in the country is considered, busses show a percentage reduction of about 15% while MCs and 3Ws show an increment of about 15% and 27% respectively from 2011 to 2013 (central bank sources, Sri Lanka). These facts collectively suggest more or less the inadequacy and inefficiency of the public transportation system, which has compelled the road users to shift in to more convenient yet vulnerable transport modes like MCs and 3Ws. A study carried out in Sri Lanka concludes that 40% of the three wheel users can be transferred back, provided a better public transport system is available (Kumarage, Bandara, & Munasinghe, 2010). Literature also suggests that implementing public transport projects is a solution to reduce MC deaths in low income countries (Nishitateno & Burke, 2014). Therefore, it can be suggested to improve the quantity and quality (access and mobility) of public transportation system as a viable countermeasure for the betterment of road safety in Sri Lanka.

Table 2 - Number of Vehicles Involved in Crashes over the Last Five Years

CLASS OF VEHICLE	2010	2011	2012	2013	2014	2014 Percentage
Motor cars	11,094	12,306	12,881	11,464	10,793	18.7%
Three wheelers	7,927	9,455	11,224	10,416	9,938	17.1%
Motorcycles	16,240	16,990	18,013	16,624	15,938	27.6%
Buses	5,989	6,414	5,983	5,363	5,193	8.9%
Dual purpose vehicles	10,054	10,217	10,111	9,330	8,805	15.2%
Lorries	7,924	8,284	8,116	7,009	6,606	11.4%
Land Vehicles-Tractors	630	616	654	559	540	0.9%
TOTAL	**59,858**	**64,282**	**66,982**	**60,765**	**57,813**	**100%**

Considering the vehicles involved in crashes, MC as well as 3W shows a significant contribution. In year 2014 it is about 28% and 17% respectively despite the fact that actual number of MC and 3W on roads are comparatively lower than registered number of vehicles (*Table 1*) in each category. Operating vehicle fleet in *Table 1* depicts the vehicle classification data based on MCC surveys carried out on number of roads in the country which indicates the general proportions of vehicle types on roads. Accordingly, the proportion of motorcycles are less than that of new registrations and cumulative population.

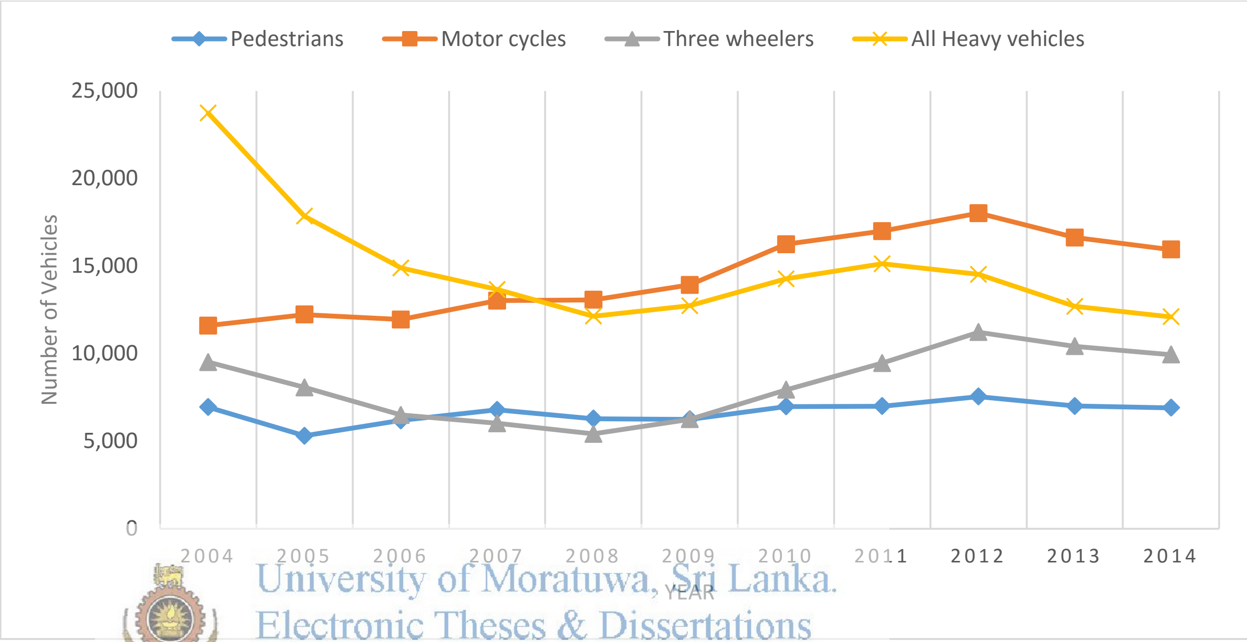

Figure 3 - The trend of number of pedestrians, motorcycles, three wheelers and heavy vehicles involved with road traffic accidents.

The number of pedestrian accidents has not increased significantly after 2010 despite the sudden increase in 2012 and is being decreasing after 2012 although the number of vehicles on road and the populations has been increasing over the last few years. This positive pattern of pedestrian casualties can be accounted for the recent development of pedestrian facilities such as (pedestrian walkways and crossings) with the road developments recently carried out, mostly in urban areas.

The number of motorcycle accidents has been increasing over the last decade until 2012 as it can be seen in the Figure 3 and been decreasing afterwards after 2012 despite the continuous growth of motorcycle population of the country (Table 1).

More or less the same pattern after 2008 in Motorcycles and Three Wheelers met with accidents can be seen in the figures. There are several reasons behind this.

The "Decade of Action for Road Safety" implemented by United Nations commenced in 2011. As a result, more attention was paid upon the vulnerable road users in developing countries and accordingly several steps were taken to mitigate this issue in those countries with the involvement of UN and WHO. Following their interference, several awareness and training programs were conducted for the safety professionals and officials at related authorities to come up with better safety environment and policies. As a result, the measures such as increased fines, increased vigilance of law enforcement officers at accident prone locations, making some safety related features mandatory in vehicles (helmets, seat belts and etc.), posting speed limits and incorporating safety features in to design of road environment and intersections have paved the path to the above success of reducing motorized 2 and 3 wheel accidents after 2012 despite the growth of motorized 2 and 3 wheel vehicles in the country.

Similarly, when heavy vehicle accidents are taken in to account, the same pattern as motorized 2 or 3 wheels that showed after 2008 can be seen in the figure along with the gradual drop in number of accidents after 2011. The above mentioned pattern suggests that the same reasons which influenced the motorcycle and three wheeler accident reduction may have influenced the reduction of heavy vehicle accidents as well.

When talking about the safety situation of a country, the youngsters come to the light for their significant involvement in road traffic accidents. Especially under the section of motorcycle related accidents they are significant (Woratanarata, Ingsathitb, Chatchaipanb, & Suriyawongpaisalc, 2013). WHO declares that the road traffic accidents is the leading cause of death for the age group 15-29 years in their Global Status Report on Road Safety 2013 (WHO, Global status report on road safety 2013: supporting a decade of action., 2013). During the last five years, this age group accounted for 33% of the total casualties in the country and 23% of the total fatalities giving clues for its significance with respect to the road safety situation in the country. While the significance of the age group is evident, the number of casualties have been decreasing after the year 2012 revealing the same pattern as the number of pedestrians and vehicles met with accidents.

In the preceding sections, further analysis was carried out by considering accident data, vehicle registration data and population data of last five years (2010-1014) in to account. A chi-square analysis was done between the vehicle type and severity of the involved accidents to check whether there is a significant relationship between vehicle type and severity of accidents. For this analysis, the damage only accidents were excluded due to its issue of under reporting which could lead to some biasness in the analysis. The obtained chi-square value was fairly high, while the test value for 95% confidence interval was 31.4, proving that there exists a strong relationship between vehicle type and severity. Therefore, the vehicle types in the country and vehicles involved in the accidents were further analyzed.

A grasp of *Table 1* gives an idea of how big the proportion of motorcycles in the country now and few years back. From the total vehicle population in the country in 2014, motorcycles accounted for about 53% while Three Wheelers accounted for 16% and the other categories are less than that. This depicts the typical situation of a developing country which has an average low per capita income where the people cannot afford to have safer motor cars, eventually making the majority of road users vulnerable road users while worsening the safety situation. Then a question arises about busses or public transportation. Increasing number of Motorcycles, Three Wheelers and the significant proportion of them despite the ability of general public to use public transportation without any trouble suggest the inadequacy and inefficiency of the prevailing public transportation system. Motorcycles being the major type of vehicle possesses the highest rate of increase of the number and this has increased compared to previous year. The rate of increase of Three Wheelers has the second highest value and both these values are greater than the rate of increase in total vehicle population. This alarming trend suggest that increase in the quantity and quality (access and mobility) of public transport system is necessary to avoid worsening of safety situation of the country.

Considering the vehicles involved in accidents (*Table 2*) the number of motorcycles is clearly significant. In 2014, the accident involvement of motorcycles is about 28%. When comparing the proportion of vehicle population and accident involvement percentage of each vehicle type, motor cars, dual purpose vehicles and busses had higher accident involvement percentage than their respective proportions of total vehicle population. This measure of obtaining an idea of safety behaviour by type of vehicle is subjective since the fault of the vehicle is not assessed. Therefore, a better way to get a rough idea about the safety behaviour of a certain type of vehicle is to compare them with respect to an exposure level. Such an accident rate can be developed by dividing the number of vehicles involved in accidents by the number of vehicles in the country. This provides comparatively a better value to compare. The following chart displays the variation of that accident rate over previous five years for each vehicle type.

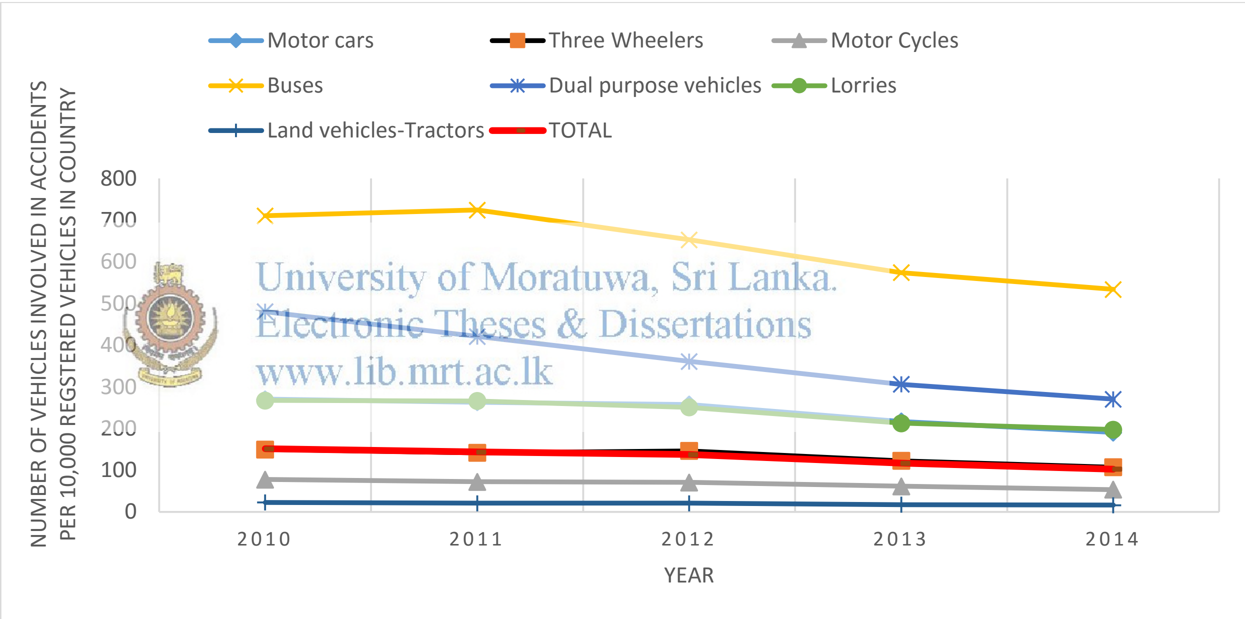

Figure 4 - Vehicles Involved in Accidents per 10,000 Registered Vehicles in Country.

All the vehicle types have reduced their involvement in accidents per 10,000 vehicles in country over the course of last five years. Interestingly the busses show a significantly higher involvement in accidents compared to the other vehicles and motorcycles on the other hand show an unexpected low rate. For busses, the reason may be their need to be on roads on most of the time of day engaging in turns. Therefore, the real exposure of busses is higher than the other vehicles. Although this rate of busses can be justified for some extent, the significantly higher rate of busses can still be accounted for some other reasons as well. The experience of being a pedestrian and a bus passenger of main roads suggests the aggressive and negligence behaviour of bus drivers. This can be avoided by strict law enforcements and by giving a proper training for these drivers.

The motorcycles on the other hand shows a smaller rate of accidents (lesser than the rate for total vehicles) compared to the other vehicles. Although the rate is less, since the number of vehicles are high, the number of vehicles involved in accidents are also high. As motorcycles are categorized under vulnerable road user category (the injury severity is high when in an accident) the impact of this for the fatalities is high. Still the attention for these accidents is necessary.

Table 3 - Five Most Significant Collision Types for Urban and Rural Conditions

Urban	**No of Accidents**	**Rural**	**No of accidents**
Rear end accident	22,924	Other head on accident	15,153
Other head on accident	6,350	Rear end accident	10,113
Pedestrian entering the road from left sidewalk/shoulder	5,040	Travelling straight ahead leaving the road to the left	6,899
Vehicles intersecting without turning off	3,957	In conjunction with overtaking	4,043
Overtaking to the right	3,540	Pedestrian entering the road from left sidewalk/shoulder	3,745

Apart from the basic details of accidents, the collision types give us a bit more in detail insight as of how that accident occurred, possible causes and approximate behaviour just before the accident. Therefore, accident details of the last five years were analyzed in terms of collision type and urban rural condition in which the accident took place.

Table 3 shows the significantly large number of rear end accidents which occurred in urban context whereas in rural context as well it has obtained the second place. Behaviour of traffic flow and traffic mix in the roads of the country in urban context have collectively contributed towards this alarming rate of rear end accidents. Here in Sri Lanka, the traffic flow has abrupt variations of speed very often where at most of the times speed tend to reach zero within a very short period of time. Since the country is in developing stage and being a middle income country, the smaller light vehicles (motorized 2-3 wheels) which has a high manoeuvrability are high in the roads, lacks a proper design layout for the minor roads connecting to major roads and lacks infrastructure facilities like pedestrian fences that separates the pedestrian walkway and carriageway. These motorized 2-3 wheels in combination with unhealthy attitudes towards road safety has paved the path towards aggressive and negligence behaviour of driving (sudden turns, sudden stops at inappropriate places, inappropriate lane changes and etc.) causing the main stream traffic to undergo abrupt and unexpected changes of traffic speed. The poor design layout of minor roads (minor roads connects to major roads directly without connecting to a collector road first) keep adding vehicles to the major traffic at times making the major traffic speed obstructed. The lack of physical separation of pedestrian walkway and carriageway allow pedestrians to get into the carriageway as required. Normally the pedestrians even tend to get into the carriageway due to the lack of sufficient width of walkway. The same reason has contributed towards the collision type "Pedestrians entering the left side walk/shoulder" to become the third most significant collision type at urban context. These facts collectively discourage the smooth functioning of traffic flow at urban context.

The vehicle mix on the other hand plays a major role with related to rear end accidents. Normally in a developing country like Sri Lanka, the goods and material transportation has no separated modes (such as special trains, roads and etc.), separated times and separated paths. This paves the path for heavy vehicles (which are mostly used for goods and material transportation in Sri Lanka) to occupy the same roads at same times with light vehicles. Therefore, in Sri Lanka, the traffic mix has a high diversity on major roads. This fact when combined with often abrupt changes in traffic flow encourages rear end accidents. More significantly, when there is a sudden drop down of speed in the traffic flow where there is a heavy vehicle and a light vehicle consecutively, the heavy vehicle may not be able to stop at a shorter time period as a light vehicle do. When this happens, when the maintained headway is not enough to make the velocity zero, it results in a rear end accident. On the other hand, the tail lights of the heavy vehicles are not working most of the times and people have become careless about the functioning of these lights since there is no law enforcement being applied to address these issues although there are rules addressing the requirement of tail lights. Given that the heavy vehicle population in country in 2014 is 7.67% (Land vehicles were included neither in light vehicles nor heavy vehicles in this analysis) yet the heavy vehicle versus light vehicle accidents accounted for 31%of the rear end accidents occurred in last five years. This provides clues for the significance of rear end accidents between light vehicles and heavy vehicles. The other significant reason behind this is the habit of not maintaining a proper and sufficient headway distance. Since there are no sufficient laws to enforce drivers to maintain a proper headway, it is typically neglected by the drivers. Therefore, these facts have collectively caused the increased number of rear end accidents at urban context.

Reduction of heavy vehicles from the main roads and main traffic would seems to be a viable option but it is not an easy task to do since they drive the economy in a developing country like this. Among the measures that we can undertake, short term measures would be to deviate the operating times of heavy vehicles from the main traffic and eliminate the contributory driving behaviours like sudden, abrupt speed variations, not maintaining suitable headways and reckless behaviour driving behaviour through conducting driving etiquette classes at the licensing process. Promotion of other transport modes such as railway and water transport modes for materials and goods transportation would be a long term measure since it needs the railway network developed and a proper water transport mode introduced.

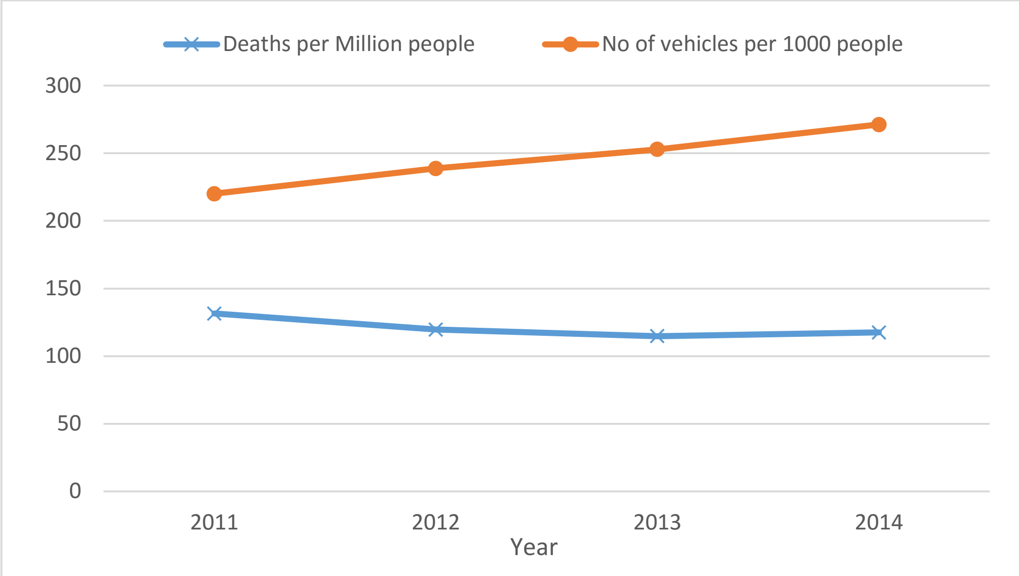

Figure 5 - Comparison of Road Accident Related Deaths per Million People and Number of Registered Vehicles per 1000 People in the Country

The vehicle ownership rate of a country is known to have a positive relationship with its road safety situation in terms of fatality and casualty rates (Jacobs & Cutting, 1986). Therefore, number of vehicles per 1,000 people in the country provides a way to roughly estimate the safety situation. Deaths per million people on the other hand with an exposure condition provides a fairer assessment of the safety performance of the country. Comparing these two rates gives an idea of the safety performance as a country. Although “Number of vehicles per 1000 people” has been increasing over the last five years, “Deaths per million people” in country has been decreasing slightly. Therefore, it is evident that the overall road safety situation of the country is getting better but with a very low rates.

3.3.2. Pedestrian Related Accidents

Table 4 - The Location Significance of Pedestrian Related Accidents

Pedestrian Location	Urban	Urban %	Urban fatal	Rural	Rural %	Rural Fatal
On pedestrian crossing	4286	23.81%	358	1873	10.30%	201
Pedestrian crossing within 50metres	3304	18.36%	372	1684	9.26%	236
Pedestrian crossing beyond 50 metres	5219	29.00%	575	7232	39.78%	906
Pedestrian overpass bridge or under pass tunnel within 50 metres	271	1.51%	27	330	1.81%	35
Hit outside sidewalk	804	4.47%	73	514	2.83%	55
Hit on sidewalk	947	5.26%	87	1270	6.98%	149
Hit on road without sidewalk	2841	15.79%	310	4616	25.39%	644
Other	326	1.81%	41	663	3.65%	71

Pedestrian related accidents are always important to pay attention since the consequences are severe in such accidents. Therefore, a further analysis can help the development of effective preventive measures. Table 4 shows the significance of locations of pedestrian related accidents. At urban context, "Pedestrian crossing beyond 50 meters" has scored the highest rate signifying the lack of pedestrian crossings at required locations. The rural context conveys the same message more significantly and effectively. Here the "Pedestrian crossing beyond 50 meters" category had a significantly large rate of accidents and secondly the location "Hit on road without sidewalk" had a large rate of accidents. Both locations can be accounted for lack of infrastructure facilities. Although there had been a development in rural areas in terms of roads, sufficient attention has not been paid to related infrastructure facilities like pedestrian walkways and pedestrian crossings. In rural condition, only about 0.3 meters of hard shoulder has been provided from the edge of carriageway in which the lane width only be around 3.5 meters. Therefore, most of the times, the pedestrians have no other way than occupying the carriageway of the road at times. Eventually the speed increment which results due to the uplift of road condition has caused the increment of pedestrian related accidents. This sudden infrastructure development at rural areas did not give enough time for an accompanied attitude change within people. Simply the road users did not have time to get adopted for this situation. So, they act as they were acting in their day to day lives despite the speed increment of vehicles accommodated by recent developments. Although the government was paying attention only on essential major developments, failing to pay due attention on related other infrastructure facilities (pedestrian crossings and walkways) along with the development of roads, has caused serious problems in the country.

There was a recent pedestrian infrastructure development funded by the World Bank by the end of 2013, at a stretch of A002 road from ‘Maliban Junction’ to ‘Nalluruwa’ which had been identified for its significance for pedestrian related accidents. A lot of location specific issues were addressed including introducing staggered pedestrian crossings, separating pedestrian walkways with safety fences near junctions, pedestrian barriers at center median in a way that pedestrians cannot cross at any location, provision of pedestrian activated signalling, proper lane markings and signs after a road safety audit. A before and after study was done using pedestrian related accident data for that specific road stretch. The number of pedestrian related accidents in that 12 km long stretch of road has been reduced to 41 from 62 in 2014 with respect to 2013.Therefore, illustrates the need for resource allocation for pedestrian related infrastructure development which in turn can save many lives a year.

3.3.3. Motorcycle Related Accidents

Crashes associated with motorized two wheelers are noted to be prominent in the country according to the overall crash trends in the basic analysis. This is an identical scenario compared to trends observed in other developing countries with low and middle level income, where the MC proportion in the vehicle fleet is high (Hyder, Waters, & Rehwinkel, 2007). Annual average fatal crashes related to MCs were recorded to be 1,048 during the period of 2003 – 2013 in Sri Lanka while MC related crashes caused 47% of the fatalities in year 2013. Among the fatalities related to MC related crashes, 67% was recorded to be MC occupants and they accounted for 26% of the annual fatalities in Sri Lanka during the same year while pillion riders accounted for 6% from the total. Above figures clearly depict the gravity of the safety issues associated with MCs.

On an average, 4 people died every day from MC and 3W related crashes in the year 2013 whereas it is about 6 for all types of vehicle related crashes. Youngsters have a significant contribution towards the road safety condition of a country. Especially regarding MC related crashes (Woratanarata, Ingsathitb, Chatchaipanb, & Suriyawongpaisalc, 2013). From 2010 to 2014, 33% of the total casualties in the country and 23% of the total fatalities belongs to age group 15-29 years as highlighted in WHO report (WHO, Global status report on road safety 2013: supporting a decade of action., 2013). An in depth analysis was then carried out by utilizing the crash data, vehicle registration data and population data of last five years. A chi-square analysis was carried out to check whether there is a significant relationship between the vehicle type and severity of the crashes, and thus proven significant. (Damage only crashes were excluded from analysis due to under reporting issue). Hence, vehicle types and vehicles involved in the crashes were further analyzed.

Most of the low and middle income families in developing countries possess a MC and this can be backed by the Kuznets curve relationship of MC ownership and economy (Nishitateno & Burke, 2014). With this high availability, a trend of MC riding has grown up even among the young community who are below the legalized age (18 years) to obtain a license. Crash records of last five years show that 29% of the MC riders was not been able to produce a valid driving license upon a crash incident and these youngsters (below 18 years of age) represented a significant proportion (9%) of MC drivers who failed to produce license at a crash. They are much prone to encounter with a crash of high severity due to obvious reasons such as lack of proper training, experience, awareness of road rules and regulations, etc. When collision types are concerned in the urban context, rear end crashes had the highest percentage of 19% (5,935) followed by 'other head on' crashes with 10% (2,974). In rural context, 'other head on' crashes found to be the highest crash type 21% (9,321) followed by rear end crashes with 10% (4,554).

Drivers in the age of 21-25, have been recorded to be the most significant group that has involved in most MC crashes (20%). 48% of the drivers encountered with a crash were recorded with "Aggressive or negligent driving" as the major contributory factor. Upon consideration of above two facts, it can be seen that the aggressiveness and negligence of young people in age group of 21-25 are more liable for road crashes and the chance for such a crash being a fatal one is relatively higher than other crashes. As far as the severity of such crashes are concerned, a crash being a rolled over one was recorded as the major contributory factor for severity. In 2013, 21% of the single vehicle MC crashes are fatal whereas it is 6% for multi vehicle MC crashes. The two most significant element types met with fatal MC crashes are pedestrians (232) and Lorries (185).

An analysis of MC rider fatalities and number of MCs involved in crashes before and after the implementation of helmet law in 1991 showed that the ratio of number of MC rider fatalities per 1,000 MCs involved in crashes, reduced by 43% with respect to 1990 (Data – Police Head Quarters, Colombo, 2006) proving the importance of wearing helmets. Although, the trend among the general public towards wearing helmets is not healthy, as they have identified it as something imposed on them, despite of its importance for driver safety. The undesirable effect of that attitude is their tendency to avoid wearing it if possible.

Nevertheless, it is recorded that 99% of the drivers and 87% of the (first) pillion riders in Sri Lanka are wearing the helmet (WHO, Global status report on road safety 2013: supporting a decade of action., 2013). The percentage is far less (20%) when it comes to the second pillion rider (Amarasinghe, 2014) who, most of the times are children. Still helmet usage at rural areas were recorded to be low (Amarasinghe, 2014) due to lack of frequent law enforcement. Mostly, the parents are wearing the helmets but the children travelling with them are not equipped with helmets. Due to negative attitude towards wearing helmets and low probability of being caught by law enforcement officers, people don’t perceive the necessity of helmets for their children. And also the children show a rapid physical growth up to age of 16, therefore a frequent change of helmet is required. Issues like un-affordability and availability at the market are encouraging such practices. In 2013, 37% of the children (under 19 years MC occupants) who died in road crashes did not wear a helmet.

According to past research and police sources, the tendency of neglecting the chin strap fastening increases the severity of a crash as the helmet tends to jump off from the head during crash if the chin strap is not fastened, making him vulnerable for major head injuries. It is recorded that 22.5% of the motorcyclists who went through fatal injuries, during last five years, did not wear a helmet. Also it is recorded that 10% of the drivers went through any MC injury did not wear a helmet. Observing above two figures, the crucial effect of helmets on fatalities can be seen. Pillion riders with a helmet has accounted for 15% of the MC fatalities while the pillion riders without the helmet has accounted for 30% (>22.5%) which is double the percentage of pillion rider fatalities with helmets. This shows that the pillion riders have a higher tendency of encountering a fatality in a crash if they have not worn a helmet. The above mentioned facts highlight the urgency of taking necessary measures to encourage users to comply with helmet wearing rules. Usage of attractive strategies such as advertisements, public campaigns and educational programs would be effective in driving the community towards complying with safety measures.

During the basic analysis of overall accident trends as well, motorized two wheel accidents were found to be dominating like in other low and middle income developing countries of which they have a large proportion of motorcycles in vehicle fleet (Hyder, Waters, & Rehwinkel, 2007). From 2003 to 2013, an average number of 1048 motorcycle related fatal accidents occurred every year. During the year 2013, 47% of the total fatalities of the country were from motorcycle related accidents and 67% of them were found to be motorcycle occupants. On the other hand, these motorcycle riders accounted for 26% of the total fatalities of the country in 2013 and pillion riders accounted for 6% of the total fatalities in the same year. The facts provided above clearly bear witness for the magnitude of the safety problem related with motorcycles. Drawing due attention for this issue in order to come up with better policies and effective programs can reduce the accidents in numbers and will come in handy for the improvement of overall road safety.

During the analysis of accident details of last five years, it was found that, 29% of the motorcycle drivers did not have a valid driving license at the time of the accident. It seems to be a common practice in developing world that the governments are keen on eliminating unlicensed riding due to its impact on road safety in terms of fatalities. Most of the time the children gain the ability to ride motorcycles in their childhood since there are motorcycles owned by most of the low and middle income families. When they are at young age, not having a driving license is not necessarily enough to avoid them using it for their personal and immediate requirements specially when the required distant to travel is less and within their neighbourhood. However, not having a proper driving training and unawareness of the road rules and circumstances of accidents make them more vulnerable for accidents. This set of people accounts for the majority of the motorcycle drivers who did not have valid license at the time of an accident. The age group of 21 – 25 yrs. had the maximum number of motorcycle accidents (20%). And the "Aggressive or negligent driving" was recorded as the most common contributory factor from 48% of the motorcycle riders. This fact together with the most significant age group relates a story where the youngsters of age group 21 – 25 with aggressive and negligence driving behaviour is more susceptible for road accidents and the probability of such an accident being a fatal one is higher than the other accidents. Another fact revealed was that for majority of accidents, the accident factor contributing to severity has been recorded as the accident being a rolled over accident.

Wearing helmets has drawn the attention of many professionals and authorities for its importance in safety. Thus, the attitude of majority of the people towards wearing helmets as a safety measure is not unhealthy and most seem to regard it as a nuisance that must be avoided where possible. 99% of the riders and 87% of the pillion riders wore helmets in Sri Lanka (WHO, Global status report on road safety 2013: supporting a decade of action., 2013) where the helmet usage was low on rural areas compared to urban areas due to lack of frequent law enforcement. The helmet usage among children was found to be as low as about 20%. Most of the times when children are travelling with their parents, only the parents are wearing helmets while the most susceptible and vulnerable children are not wearing helmets. Among the reasons behind this situations, the attitude towards wearing helmets has contributed for some extent. Most of the times, the children are travelling in between their parents and the law enforcement officers cannot easily see them since they are smaller in size. Therefore, they don’t perceive that it is necessary for their children to wear helmets. The more promising reason is the rapid physical growth of children in under 16 years of age and the previous helmets become unusable within a short period of time and it is inconvenient and unaffordable for parents to buy helmets regularly. The majority of the motorcycle users, being low income community of the country, can’t afford to buy helmets frequently for their children and manage to travel without a helmet paving the way for increased child casualties.

The other fact with related to these helmets is that a lot of people avoid fastening the chin strap. In such cases when involved an accident, the helmet is thrown away making the motor cyclist vulnerable for major head injuries. As a result, they have a significant influence on motorcycle fatalities of the country. According to the accident details of the last five years, 22.5% of the motorcycle users with fatal injuries did not wear a helmet, where as it is 10% for all the motorcycle user injuries. This provides us clues for its effect on fatalities than other injuries. Out of motorcycle user fatalities that wore a helmet at the time of an accident, pillion riders accounted for 15% whereas it is double that value (30%) for pillion riders that did not wear a helmet at the time of an accident. This provides us a sense that pillion riders are in more danger when they are not wearing a helmet. These facts suggest that immediate measure are necessary to make motorcycle users comply with helmet wearing rules. Reinforcing the attitude of people towards helmet usage as a safety measure should be done using creative methods such as advertisements, public campaigns, education programs and etc.

3.3.4. Three Wheeler Related Accidents

3Ws have become popular among people in developing countries for short distance journeys such as travelling from home to bus stop, bus stop to railway station, etc. where there is no any public transport mode (could available, but inefficient) to meet the requirement. Drivers of these vehicles mostly are below 50 years of age and running their own vehicle or running someone else's vehicle for hire (Kumarage, Bandara, & Munasinghe, 2010). There is a good demand for these vehicles as taxis and there exists a good supply as well. In order to meet this demand, people without a proper educational background tend to start driving a 3W as a taxi to make their own living. Many banks provide loans to buy these vehicles and majority tend to buy it due to its comparatively low price and easy payment schemes. As discussed above, majority of these drivers being young and middle aged people coming from an area with a comparatively low socio economic status have paved the path for increased number of 3W related crashes (Mirzaei, et al., 2014).

Average annual fatalities due to 3W related crashes are recorded to be 277 during the period of 2003 to 2014. In year 2013 alone, 383 fatalities accounting for 16% of the total fatalities were caused by 3W related crashes and 65% of them were 3W occupants. 43% of died victims among 3W occupants are drivers. 3Ws involved in crashes accounted for 17% from the total vehicles encountered with crashes in 2014 while motorized two wheeled vehicles and motor cars accounted for the 28% and 19% from the total vehicles respectively. The statistics of the 3W crashes does not highlight a severe impression as in the case of MCs, but its' significance can't be neglected due to its higher involvement in fatal crashes. 21% of the people who died from 3W related crashes were pedestrians. For the fatal crashes where 3Ws met with pedestrians, the most significant collision type was 'With pedestrian entering the road section from the left sidewalk, shoulder etc.' (23%)

14% of the 3W drivers have failed to produce a valid driving license upon a crash incident according to data records of last five years. This is relatively a low value compared to the case of MCs, but it still needs proper attention as reduction of 3W crashes have the potential to make a significant reduction in fatal crashes in the country. "Aggressive or negligent driving" was recorded as the contributory factor for 50% of the 3W drivers associated with the crashes, and this percentage is higher compared to that of the MCs. Low socio economic status can be identified as a main reason behind the attitude issues of the 3W drivers. Most of them being teenagers they related naturally inherit aggressive and neglecting behaviors to a certain level. Age26-30 (17%) and 31-35 (16%) were recorded as the most significant age groups for 3W crashes nevertheless 26-30 age group accounted only for 7.5% out of the population of the country. Similarly, to the crashes associated with MCs, being a rolled over crash was identified as the most significant crash factor contributing towards the crash severity. 3Ws are prone to overturning in obstacle avoidance attempts and easy turns (Raman, Rao, & Kale, 1995). With the vehicle size and high manoeuvrability, 3W drivers tend to crawl through the traffic taking sudden movements and turns affecting the other road users in the periphery.

3.3.5. Heavy Vehicle Related Accidents

Looking at the Sri Lankan road safety context through descriptive statistics draws the attention towards several key areas where attention is necessary. Motorcycle related crashes, three wheeler related crashes and heavy vehicle related crashes were found to be significant. According to the Department of Motor Traffic, Sri Lanka, the heavy vehicle percentage of the country in 2013 is 8% while the percentage heavy vehicle involvement in fatal crashes in 2013 according to Sri Lanka Police Accident Database is 21%. This is an outstanding figure compared to the other vehicle types. Finding out the contributory factors for the severity of these heavy vehicle crashes can lead the respective authorities to take necessary actions to control for the severity. Reduction of the severity can result in the reduction of fatal crashes leading to less loss of lives. Therefore, this study utilizes a binary logistic regression analysis to find out the factors that has an effect on the severity of heavy vehicle crashes in Sri Lanka. An in depth analysis on heavy vehicle related crashes was carried out and is presented in detail in the next chapter.

4. ACCIDENT ANALYSIS BEYOND DESCRIPTIVE STATISTICS

Advanced statistical methods are frequently used in the field of accident analysis because of the associated advantages they have over the descriptive statistics. An analysis done using a statistical method going beyond descriptive statistics is discussed in this chapter to elaborate on the uses statistical methods other than descriptive statistics. In this regard, an application of such a statistical method on Heavy Vehicle Crashes of Sri Lanka was carried out. A detailed description of the selection of a statistical method and the analysis carried out is presented in the rest of this chapter.

4.1. Data source

The data source is the same as in the previous chapter which is “Accident Analysis with Descriptive Statistics’. Sri Lanka Police Accident Database has been used here. Heavy vehicle related crash data for the most recent three years (2014, 2013, 2012) were obtained from the accident database.

4.2. Methods Considered

As discussed in the literature (2.2.2. Accident Analysis beyond Descriptive Statistics), different methods were possible and out of them two main methods were considered. They are, multiple regression and logistic regression. The database contains mainly, two types of data. Namely, Categorical (Light condition, Weather condition, Severity, Urban rural condition, Road surface condition, Location type, Element type, Vehicle ownership, Crash factor for severity) and Discrete and Continuous (Time of accident, Age of vehicle, Driver age, Number of years since issue of license). For categorical data analysis, it was found that the logistic regression has been widely utilized in safety science whereas for discrete and continuous data, the most popular method was multiple regression.

In order for a multiple regression analysis to be carried out, it needs at least more than 15 data points (for a rich model fit) where each data point contain number of crashes as the dependent variable with frequencies of other independent variables. As far as the independent variables are concerned, only the counts of categorical variables can be included in the model. One of such analysis can be carried out by taking the number of accidents taken place at each province. Since each province is formed with several DS divisions, provinces can be identified using the DS divisions in the database. But, the problem arising here is that there are only 9 provinces in the country and it needs at least 15 data points for a multiple regression to be reliable. This problem can be eliminated by taking DS Divisions or Stations (in the database) as data points. The issue with these data points is that they consist of small number of crashes or no crashes and other independent variables since the study takes only the heavy vehicle crashes into account.

Multiple regression model can deliver the variables which affects the number of crashes. Whereas logistic regression delivers the probability of the effects of variables to the severity of crashes. Two positive features in logistic regression is that it can incorporate both discrete and categorical data in the model and every accident record becomes a data point which increases the number of data points in the model increasing the reliability and accuracy of the model.

4.3. Binary Logistic Regression

Binary logistic regression model is a regression model where the dependent variable is a binary categorical variable. It is used to estimate the binary response depending on one or more independent variables (predictors). If the concerned dependent variable consists of several categories, it can be recoded in to a dichotomous variable. There are several assumptions which needs to be satisfied for the model to be a reliable one. They are;

- There should be one or more independent variables and they can be either continuous or categorical
- Independence of observations
- Categories of the dependent variable being mutually exclusive and exhaustive
- The independent variables need to have a linear relationship with the logit transformation of the dependent variable

The multicollinearity of independent predictor variables should be investigated before incorporating them directly in to the model. The multicollinearity between independent variables in a logistic regression model can produce erroneous results and hence should be avoided. This can be done through a chi-square test among independent variables. Assessing the goodness of fit of the model needs a considerable effort. Normally, the goodness of fit is evaluated using the R-squared value of a regression model. But, here in logistic regression, R-squared value is of less use and hence the Hosmer and Lemeshow test value is used dominantly. If the test value is greater than 0.05, then the model is said to have a good fit (Hosmer, Lemeshow, & Archer, 2007). Higher the value, higher the goodness of fit.

All the variables that we consider to be a part of the model might not necessarily be a part of the model with the best fit. Different variables are capable of describing the dependent variable in different scales. Adding some variables into the model does not improve the goodness of fit of the model with a statistically significant amount and yet can degrade the goodness of fit. Finding out these variables and eliminating them from the model helps to achieve a better goodness of fit for the model. In order to accommodate this, logistic regression can be conducted in a stepwise manner.

Stepwise regression consists of two methods known as forward and backward. In forward stepwise method, the variables are kept adding to the model according to the descending order of the difference it can create to the model goodness of fit. It terminates adding variables when the possible change in goodness of fit of the model is not statistically significant. Backward stepwise method does this in the other way round by keep removing variables with minimal impact to the goodness of fit until the model undergoes a statistically significant change in the model goodness of fit.

It is evident that logistic regression analysis has been widely used by the scholars for accident severity modelling. Apart from frequency analysis, the logistic regression modelling has been used to distinguish between single and multivehicle crashes and to find out the explanatory factors (Martensen & Dupont, 2013). In a study done in Iran, logistic regression modelling has been utilized to estimate the contribution of Knowledge, Attitude and Practice towards the highway crashes (Mirzaei, et al., 2014).

One of the main drawbacks in logistic regression as perceived by the scholars is this technique being selectivity bias. It is possible for logistic regression analysis to produce erroneous results due to this issue when the sample size is small. This can be eliminated by utilizing larger sample sizes (Mirzaei, et al., 2014).

When modelling the accident trends, there are some confounding factors which avoids some statistical methods to produce reliable results about the trends. Logistic regression is capable of eliminating this problem by allowing to control the effects of confounding variables such as age, gender, licensing, smoking and wearing medical glasses (Mirzaei, et al., 2014).

4.3.1. Analysis Procedure Using SPSS

Normally, a certain accident has three main involving parties at the time of an accident. They are location, vehicle and casualty. The location (environment) include the specific details of the crash and location such as date, time, east and north coordinates, road number, weather condition, light condition, collision type and other crash specific details. Vehicle denotes the details and conditions of the affected vehicles such as vehicle type (element type), age of vehicle, pre-crash factors from vehicles, validity of driving license and other vehicle related factors. Casualty denotes the details and conditions of the people who has been affected by the accident such as gender, age, category of casualty (driver, pedestrian etc.) and other casualty specific details. Therefore, an accident contains a unique set of crash related details with different sets of vehicle related details and casualty related details. Due to this reason, a group of entries can contain a unique set of environmental details with different vehicle and casualty details which includes duplicate entries if taken in to account in the analysis. Therefore, it is not possible to analyze all the factors related to these three environments at the same time. Hence those factors related to different parties of accidents were analyzed separately to find out the contributory factors towards the severity of heavy vehicle accidents in Sri Lanka. Since the important casualty details are included in the vehicle details table itself (eg. Driver age, gender and etc.) developing a separate model for casualty related details was not necessary.

In binary logistic regression analysis, the dependent variable should be a binary variable. Since we are assessing the severity of the accidents, the severity was taken to be considered as the dependent variable. According to the severity of the accidents, there are four categories as Fatal, Grievous, Non Grievous and Damage Only. But in Sri Lankan context, majority of the damage only crashes are not being reported to the police and hence to the police accident database as a result of the interference of insurance companies (people get their issues settled through insurance agents since they perceive it as more convenient and time saving than reporting to police). Therefore, including these accidents may create erroneous results. In order to avoid that, those accidents were excluded from the analysis. Then the remaining three levels of severity of accidents were converted to a binary variable as follows.

Fatal ➔ "Crucial" ➔ "1"

Grievous, Non Grievous ➔ "Not Crucial" ➔ "0"

It is also possible to consider Fatal and Grievous as one category (Crucial) and Non grievous as the other category (Not Crucial). When the model is developed according to this scenario, it was found that the model fit is poor so that this was not considered in the further analysis.

In logistic regression, we can use both continuous and categorical data as independent variables. Some of the continuous variable are possible to use as it is in the analysis while some of them have to be converted (re coded) as a categorical variable in order to obtain more meaningful results.

Accordingly, two binary logistic regression models were developed for crash environment related factors and vehicle environment related factors. **SPSS 16.0** software package was used to develop these models.

A sample analysis procedure in the SPSS is described in the **Appendix A**.

4.3.2. The Model Developed for Crash Data

Several models were developed using the available variables and applying different changes to different variables so as to see what models give more accurate results. The measures undertaken will be described later in this chapter.

In this model, a variable was recoded apart from excluding DS Divisions. The number of vehicles involved in the crash was converted to a categorical variable under the same name by making number of vehicles up to 9 as 9 different categories (1 – 9) and any crash where more than 9 vehicles involved falls into 10^{th} category of the same variable.

Following are the analysis results as given by the SPSS software package.

-2 Log likelihood = 14,121.836

Hosmer and Lemeshow test value = 0.269

-2 Log likelihood value can be used to compare different models. Lesser the value, better the model describes the dependent variable. Hosmer and lemeshow test value on the other hand is the limiting value to decide whether goodness of fit of the particular model is enough to take it as a reliable model. When the Hosmer and Lemeshow test value is greater than 0.05 (as referred in the literature) the model is said to have a good fit.

The following are the statistically significant results of the model as given by the SPSS software package.

Table 5 - Statistically Significant Results from crash data related model

Variable Code	Variable/Category Name	B	Sig.	Exp(B)
NU_OF_CASU	Number of Casualties	0.065656	0	1.067859
NU_OF_VEH	Single Vehicle Crash		0.0001	
NU_OF_VEH(1)	Two vehicle involved Crash	0.349841	0	1.418842
NU_OF_VEH(2)	3 vehicle involved Crash	0.536952	0	1.710784
TIME	00:00 - 03:00		0.0001	
TIME(2)	06:00 - 09:00	-0.56348	0.0002	0.569226
TIME(3)	09:00 - 12:00	-0.44349	0.0029	0.641793
TIME(4)	12:00 - 15:00	-0.52627	0.0004	0.590806
TIME(5)	15:00 - 18:00	-0.4605	0.0016	0.630966
URB_RUR(1)	Rural	0.166409	0.0004	1.181057
DAYOF_WE(2)	Tuesday	-0.17947	0.0341	0.835711
LO_TY(6)	Entrance By road	-0.4961	0.0318	0.608899
Constant		-1.90157	0	0.149334

The logistic coefficient (B) in the above table denotes the expected amount of change in the logit (what is being predicted) for each one unit change in the predictor. Closer the logistic coefficient to zero, lesser the influence it has in predicting the dependent variable (or what's being predicted). **Exp(B)** is the odds ratio associated with each predictor. In explaining the influence of a categorical variable (Categories of it) on the dependent variable, the Exp(B) used more often since it is easy to describe the results.

The "Enter" method (the normal method) of logistic regression in SPSS includes all the variables in the model. There can be some variables that reduces the accuracy and goodness of fit and those cannot be identified through this method. Hence, the elimination of such variables is not possible. The stepwise logistic regression accommodates this necessity and hence capable of creating a model with a btter fit and accuracy.

4.4. Stepwise Logistic Regression

There are two main methods in stepwise logistic regression. They are forward stepwise method and backward stepwise method. SPSS refers to them as 'Forward: LR' method and 'Backward: LR' method where 'LR' stands for 'Likelihood Ratio'. Forward and backward methods are performed depending on the log likelihood ratio of the model. In forward stepwise method, the model consists only the constant and dependent variable. Then, the most significant variable that can create the biggest positive change in log likelihood ratio which is at the same time statistically significant is added to the model first. Then again the next most significant variable according to the same criteria is added to the model. Likewise, this procedure keeps adding variables to the model until the next available variable which causes the biggest change in model but not statistically significant (significance of the change in model log likelihood greater than 0.05). At this point, the stepwise procedure terminates.

In backward stepwise analysis procedure, the model has all the variables first and keep removing the variables with lowest statistically insignificant change in model log likelihood until the next variable with the biggest change in model log likelihood becomes statistically significant. Here, the backward stepwise process terminates and remaining variables form the model.

4.4.1. Logistic Regression Model for Crash Related Details

The following table shows the analysis results (order of inclusion of variables) of the forward stepwise regression model for crash data.

Table 6 - Stepwise inclusion of variables in to the crash data model

Variable		Model Log Likelihood	Change in -2 Log Likelihood	Sig. of the Change
Step 1	DSD_NEW	-7200.597	217.804	.000
Step 2	DSD_NEW	-7145.090	209.434	.000
	TI_RA_NEW	-7091.695	102.645	.000
Step 3	NU_OF_CASU	-7040.372	47.782	.000
	DSD_NEW	-7119.939	206.916	.000
	TI_RA_NEW	-7066.002	99.040	.000
Step 4	NU_OF_CASU	-7026.018	51.056	.000
	DSD_NEW	-7100.945	200.911	.000
	TI_RA_NEW	-7052.569	104.158	.000
	NU_VE_CODED	-7016.482	31.983	.000
Step 5	NU_OF_CASU	-7020.967	48.974	.000
	DSD_NEW	-7098.451	203.943	.000
	WETH	-7000.490	8.021	.046
	TI_RA_NEW	-7047.510	102.062	.000
	NU_VE_CODED	-7012.640	32.321	.000

This way, the analysis has excluded the statistically insignificant variables from the model in five iterations.

The logistic regression compares the categories of each variable with its first category. The categories of variables that were used in the crash data analysis are presented below.

Table 7 - Categories of the variable 'DS Division"

Number	DS Division		Number	DS Division		Number	DS Division
6	Ampara		21	Kegalle		36	Tangalle
7	Anuradhapura		22	Kelaniya		37	Trincomalee
8	Badulla		23	Kuliyapitiya		38	Vavuniya
9	Bandarawela		24	Kurunegala		39	Hatton
10	Batticalo		25	Matale		40	Mannar
11	Chilaw		26	Matara		41	Mankulam
12	Colombo		27	Monaragala		42	Seethawaka
13	Elpitiya		28	Mt. Lavinia		45	Kilinochchi
14	Galle		29	Negambo		46	Kankasanthurai
15	Gampaha		30	Nikaweratiya		47	Mullativ
16	Gampola		31	Nugegoda		48	Puttalam
17	Jaffna		32	Nuwara Eliya			
18	Kalutara		33	Panadura			
19	Kandy		34	Polonnaruwa			
20	Kantale		35	Ratnapura			

Table 8 - Categories of the other variables used in the crash data related model

Urban/Rural
1 - Urban
2 - Rural

Weather
1 - Clear
2 - Cloudy
3 - Rain
4 - Fog/Mist
9 - Other
0 - Not known

Road surface condition
1 - Dry
2 - Wet
3 - Flooded with water
4 - Slippery surface (mud, oil, garbage, leaves)
9 - Other
0 - Not known

Light condition
1 - Daylight
2 - Night, no street lighting
3 - Dusk, dawn
4 - Night, improper street lighting
5 - Night, good street lighting
0 - not known

Day of week
1 - Sunday
2 - Monday
3 - Tuesday
4 - Wednesday
5 - Thursday
6 - Friday
7 - Saturday

Type of location
1 - Stretch of road, no junction within 10metres
2 - 4-leg junction
3 - T-junction
4 - Y- junction
5 - Roundabout
6 - Multiple road junction
7 - Entrance by-road
8 - Railroad Crossing
9 - Other
0 - Not Known/NA

Time Range

Category	**Coding**
00:00-03:00	1
03:00-06:00	2
06:00-09:00	3
09:00-12:00	4
12:00-15:00	5
15:00-18:00	6
18:00-21:00	7
21:00-24:00	8

The output of the logistic regression analysis compares the probability of occurrence (odds ratio) of each category with respect to the first category in the variable (numerically). For example, when the 'Weather Condition' is taken into account, the output gives that, an accident occurring at clear weather (category 3) is 'x' times more probable to become a 'crucial' accident than an accident occurring at 'Not Known' (category 0). Because, '0' is the first (numerically) category in that variable. In such cases, the categories of the variable are being compared with an unknown or unusable category making the results not fruitful.

In order to overcome this issue, these variables (where the numerically first category is not feasible to compare with) have to be recoded in a way that the most preferable category to be compared with, becomes the first category. The next problem raised was what category to be selected to compare the other categories with. In order to provide the basis for that, the categories with the maximum percentage in the database was chosen to be made (recoded) the first category where possible. In cases where it is not possible (again the category with the maximum percentage is 'unknown' or 'Not Applicable'), the next highest category was made (recoded) to be the first category.

The variable re-codings are as presented below. Only the variables included in the model by the stepwise procedure are re coded. Hence the percentages of only those variables and interventions made (On the right hand side of the variable) to them are presented below.

Table 9 - Frequency, Percentage and the Selected category (Bold) for the variable 'DS Division'

DS Division	Frequency	Percentage
12	**1104**	**6.17**
31	1080	6.04
19	1046	5.85
35	1033	5.77
15	1012	5.66
22	1000	5.59
24	921	5.15
7	670	3.74
25	593	3.31
21	593	3.31
26	574	3.21
28	537	3.00
18	537	3.00
14	522	2.92
36	477	2.67
23	466	2.60
29	464	2.59
13	450	2.51
33	444	2.48
27	383	2.14
34	334	1.87
11	334	1.87
42	324	1.81
6	324	1.81
9	256	1.43
32	241	1.35
10	238	1.33
48	237	1.32
8	227	1.27
17	225	1.26
30	219	1.22
16	136	0.76

DS Division 12 was made the first category

45	133	0.74
39	133	0.74
38	129	0.72
41	128	0.72
37	109	0.61
20	96	0.54
46	64	0.36
40	56	0.31
47	45	0.25
Total	**17,894**	**100.00**

Table 10 - Frequency, Percentage and the Selected category (Bold) for the variable 'Time Range'

Time Range	Frequency	Percentage
15:00-18:00	**3723**	**20.81**
12:00-15:00	3244	18.13
09:00-12:00	2797	15.63
06:00-09:00	2781	15.54
18:00-21:00	2662	14.88
21:00-24:00	1229	6.87
03:00-06:00	881	4.92
00:00-03:00	577	3.22
Total	**17,894**	**100.00**

15:00 – 18:00 was made the first category and 00:00 – 03:00 was made the second category and the numbering kept according to the previous order.

Table 11 - Frequency, Percentage and the Selected category (Bold) for the variable 'Weather'

Weather	Frequency	Percentage
1	**16592**	**92.72**
3	705	3.94
2	541	3.02
4	56	0.31
Total	**17,894**	**100.00**

Already the first category has the highest frequency

Table 12 - Frequency, Percentage and the Selected category (Bold) for the variable 'Number of Vehicles new'

Number of Vehicle new		
Category	**Frequency**	
1	2579	
2	**13987**	This category was made the first category by changing "1" to "4"
3	1328	
Total	**17,894**	

Results of the Crash Data Model

After re-coding the variables, the analysis was carried out using 'Forward: LR' stepwise logistic regression. The statistically significant results are as follows. The variable categories that has a significant effect on the severity of heavy vehicle crashes are highlighted (Bold Letters).

Table 13 - Statistically significant results of the crash data model

Variable	**Statistical Significance**	**Logistic Coefficient (B)**	**Exp(B)**
NU_OF_CASU	**0**	**0.07**	**1.072**
DSD_NEW	0		
DSD_NEW(1)	0.004	0.598	1.819
DSD_NEW(2)	0	1.053	2.867
DSD_NEW(3)	0.008	0.632	1.882
DSD_NEW(4)	0.007	0.616	1.851
DSD_NEW(5)	**0**	**1.129**	**3.093**
DSD_NEW(6)	**0**	**1.266**	**3.547**
DSD_NEW(7)	0	0.98	2.663
DSD_NEW(8)	0.004	0.524	1.689
DSD_NEW(9)	0	0.739	2.094
DSD_NEW(10)	0.036	0.605	1.831
DSD_NEW(11)	**0**	**1.272**	**3.57**
DSD_NEW(12)	0	0.711	2.036
DSD_NEW(13)	0.019	0.373	1.452
DSD_NEW(14)	0.045	0.65	1.915
DSD_NEW(15)	0.001	0.555	1.742

DSD_NEW(16)	0	0.631	1.879
DSD_NEW(17)	0	0.996	2.709
DSD_NEW(18)	0	0.696	2.006
DSD_NEW(19)	0	0.738	2.092
DSD_NEW(20)	0	0.83	2.294
DSD_NEW(21)	0.002	0.61	1.84
DSD_NEW(23)	0.001	0.623	1.865
DSD_NEW(24)	0	0.939	2.557
DSD_NEW(25)	0.014	0.388	1.474
DSD_NEW(27)	0	0.702	2.018
DSD_NEW(28)	**0**	**1.179**	**3.251**
DSD_NEW(29)	0	0.824	2.281
DSD_NEW(30)	**0**	**1.26**	**3.525**
DSD_NEW(31)	0.001	0.989	2.69
DSD_NEW(32)	0.011	0.725	2.065
DSD_NEW(34)	0.041	0.822	2.276
DSD_NEW(35)	**0**	**1.171**	**3.225**
DSD_NEW(36)	0	0.753	2.123
DSD_NEW(37)	**0**	**1.438**	**4.214**
DSD_NEW(38)	**0**	**1.246**	**3.477**
DSD_NEW(39)	**0.002**	**1.233**	**3.43**
DSD_NEW(40)	**0**	**1.152**	**3.164**
WETH	0.038		
WETH(2)	0.006	0.286	1.331
TI_RA_NEW	0		
TI_RA_NEW(1)	0	0.551	1.734
TI_RA_NEW(2)	**0**	**0.643**	**1.902**
TI_RA_NEW(6)	0	0.299	1.349
TI_RA_NEW(7)	0	0.362	1.436
NU_VE_CODED	0		
NU_VE_CODED(1)	**0.001**	**0.264**	**1.303**
NU_VE_CODED(2)	0	-0.291	0.748
Constant	0	-2.772	0.063

4.4.2. Interpretation of the Crash Data Model Results

The information in the Table 13 is used to predict the probability of an event occurring based on a one-unit change in an independent variable when all other independent variables are kept constant.

According to the results, 'NU_OF_CASU' which represents the 'number of casualties' reported in an accident has an effect on the severity of the accident. Addition of one casualty makes an accident 1.072 times more probable to become a crucial accident.

According to the SPSS variable coding, 'TI_RA_NEW (2)' represents the 'Time Range New Coded 3' which represents the time range "03:00 – 06:00" and is compared with "TI_RA_NEW " in the SPSS which represents the 'Time Range New Coded 1' which is '15:00 – 18:00'. The Exp(B) value for TI_RA_NEW (2) is 1.902 and it denotes that, an accident occurring during '03:00 – 06:00' is 1.902 times probable to become a 'Crucial' one than an accident occurring during '15:00 – 18:00'.

In the same way, DSD_NEW (5), DSD_NEW (6) and DSD_NEW (11) represents the DS Divisions 10, 11 and 17 which represents the Batticalo, Chilaw and Jaffna DS Divisions. Accidents occurring in these DS Divisions are respectively 3 times, 3.5 times and 3 times more probable to become a 'Crucial' accident than an accident occurring in DS Division 1 in the input data which actually represents the DS Division 12 (Colombo). In the same way, the other DS Divisions are also can be interpreted.

According to the SPSS variable coding, NU_VE_CODED (1) represents the Number of Vehicle New Coded 3 which actually represents the accidents where 3 vehicles are involved in a heavy vehicle involved crash. Such crashes are 1.3 times more probable to become a 'Crucial' accident than a two vehicles involved heavy vehicle accident. That is, 1.3 time more probable to become a fatal accident than a grievous or non-grievous accident.

Likewise, all the other statistically significant results can be interpreted. The categories of each statistically significant variable that has a significant effect on the severity of the heavy vehicle accidents are highlighted.

4.4.3. Logistic Regression Model for Vehicle Related Details

For this model as well, the same stepwise logistic regression analysis (Forward:LR) was carried out. Here, the steps of variable introduction for the SPSS package is not described since it was described earlier. Only the variable coding and results achieved are presented here. Following are the variables considered under the analysis.

Table 14 - Variables Considered under Vehicle Related Crash Data Model

Variable	Variable Name
Element Type	ELEL_TYP
Vehicle Ownership	VEH_OWN
Driver Gender	DRI_GEN
Validity of License	VAL_LICE
Ag of Vehicle Category	VEH_AGE
Driver Age Category	DRI_AGE
Number of Years of License Category	LICE_YRS
Human Pre Crash factor 1 new	HU_FACT
Pedestrian Pre Crash factor new	PED_FACT
Road Crash Factor new	RD_FACT
Vehicle Pre Crash Factor New	VEH_FACT
Crash Factor for Severity New	SEV_FACT
Other Crash Factor New	OTH_FACT
Alcohol Test	ALCOHOL
Dependent Variable	DEPENDENT

In Table 14, some of the categories are named as "….new". A new variable was formed from the same variable. These variables had a category denoted by "0" which represented "not known" condition. When that category is in the variable, during the analysis, when the contrast is set to "Indicator(first)", the first category ("0" in these variables) is set as the reference category where the other categories are compared to. When the other categories are compared with a non-informative category like this, it is less likely to derive useful information out of the analysis results. Therefore, in those variables, the category "0" was combined with its last category which denotes "other". As a result, the reference category of each variable becomes the category "1".

In the same way as in the crash data related model, the next problem raised was what category to be selected to compare the other categories with. In order to provide the basis for that, the categories with the maximum percentage in the database was chosen to be made (recoded) the first category where possible same as in the crash data related model. In cases where it is not possible (again the category with the maximum percentage is ‘unknown’ or ‘Not Applicable’), the next highest category was made (recoded) to be the first category. In that case, only the variables included in the model by the stepwise analysis were recoded. The frequencies and percentages of categories of such variables are listed down here and the selected category with which the other categories of the variable are compared with is highlighted (in bold letters).

Table 15 - Frequency and Percentage of the categories of variable 'Element Type'

Element type		
Category	Frequency	Percent
10 – Intercity Bus	97	1
9 – Private Bus	6389	33
8 – SLTB Bus	1932	10
7 – Articulated Vehicle	366	2
3 - Lorry	**10487**	**54**
Total	19271	100

Table 16 - Frequency and Percentage of the categories of variable 'Vehicle Ownership'

Vehicle Ownership		
Category	Frequency	Percent
6 – Police Vehicle	34	0
5 – Service Vehicle	202	1
4 – Semi Government Vehicle	155	1
3 – Government Vehicle	1727	9
2 – Private Company Vehicle	382	2
1 – Private Vehicle	**16549**	**86**
0 – Not known	222	1
Total	19271	100

Table 17 - Frequency and Percentage of the categories of variable 'Validity of License'

Validity of License		
Category	Frequency	Percent
5 – International License	1	0
4 – Probation License	334	2
3 – Learner Permit	21	0
2 – No Valid License for Vehicle	1470	8
1 – Valid License for Vehicle	**16861**	**87**
0 – Not known/NA	584	3
Total	19271	100

Table 18 - Frequency and Percentage of the categories of variable 'Driver Age'

Driver Age		
Category	Frequency	Percent
11 – More than 50 years	2855	15
10 – 45-50 yrs	1978	10
9 – 40-45 yrs	2662	14
8 – 35-40 yrs	3398	18
7 – 30-35 yrs	**4299**	**22**
6 – 25-30 yrs	2823	15
5 – 20-25 yrs	890	5
4 – 15-20 yrs	98	1
1 – 0-5 yrs	268	1
Total	19271	100

Table 19 - Frequency and Percentage of the categories of variable 'Human pre Crash Factor'

Human Pre Crash Factor		
Category	Frequency	Percent
19 – Other/Not known	5388	28
9 – Blinded by another vehicle/sun	5	0
8 – Sudden Illness	1	0
7 – Poor eye sight	2	0
6 – Distracted/Inattentiveness	41	0
5 – Fatigue/Fall asleep	148	1
4 – Influenced by Alcohol/Drugs	276	1
3 – Error of Judgement	276	1
2 – Aggressive/Negligent Driving	**11587**	**60**
1 – Speeding	1547	8
Total	19271	100

Table 20 - Frequency and Percentage of the categories of variable 'Pedestrian Pre Crash Factor'

Pedestrian Pre Crash Factor		
Category	Frequency	Percent
9 – Other/Not Known	**18855**	**98**
4 – Poor Visibility (Clothing)	79	0
3 – Influenced by Alcohol	22	0
2 – Disobey designated crossing	38	0
1 – Unexpected Pedestrian Movement	277	1
Total	19271	100

Table 21 - Frequency and Percentage of the categories of variable 'Vehicle Pre Crash Factor'

Vehicle Pre Crash factor new		
Category	Frequency	Percent
9 – Other/Not known	**18708**	**97**
6 – Overloaded or wrongly loaded vehicle	33	0
5 – Poor mechanical condition	74	0
4 – Lights, Lamps	30	0
3 – Steering	5	0
2 – Tyres/Wheels	115	1
1 – Brakes	306	2
Total	19271	100

Table 22 - Frequency and Percentage of the categories of variable 'Other Crash Factor New'

Other crash factor new		
Category	Frequency	Percent
9 – Not known/NA	**18563**	**96**
4 – Post Crash Violence	41	0
3 – Road works	20	0
2 – Hit and run	450	2
1 – Avoiding Maneuver	197	1
Total	19271	100

Table 23 - Frequency and Percentage of the categories of variable 'Alcohol Test'

Alcohol Test		
Category	Frequency	Percent
3 – Not tested	**12942**	**67**
2 – Over Legal Limit	374	2
1 – No alcohol/Below legal limit	5955	31
Total	19271	100

The interventions made for the variables are shown in Table 24 below.

Table 24 - The interventions made for the variables

Variable	**Category with Highest Frequency**	**Interventions Made**	
Element type	3	Already the first category	
Vehicle Ownership	1	"0" made to "9"	
Validity of License	1	"0" made to "9"	
Driver Age	7	"4" made "7" and vice versa	
Human Pre Crash Factor new	2	"01" made "10"	
Pedestrian Pre Crash Factor new	1	Choose the category with the second highest frequency Since the category with highest frequency was "Other" or "Not applicable"	
Vehicle pre-crash factor new	1		
Other crash factor new	2		"1" made "5"
Alcohol Test	1		

However, the variables entered in to the SPSS is recoded by the software itself for the analysis purposes and the results are also given according to that format. A sample parameter coding by SPSS for a particular variable is shown below.

Table 25 - A sample parameter coding by SPSS

			Parameter Coding				
Variable	**Category**	**Frequency**	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Validity of Licence new	1	16860	0	0	0	0	0
	2	1464	1	0	0	0	0
	3	21	0	1	0	0	0
	4	333	0	0	1	0	0
	5	1	0	0	0	1	0
	9	324	0	0	0	0	1

According to the Table 10 and 11, the variable 'Validity of License new' is referred to as 'VAL_LICE_NEW' in the SPSS interface and this variable is again recoded by the SPSS during the analysis. For example, 'VAL_LICE_NEW(1)' in table 15 denotes the 'Validity of License new 2' in Table 10 which is 'No Valid License for Vehicle' according to the police definition in Police data base. The full parameter coding by SPSS for the vehicle details related model is given in the **Appendix B.**

Table 26 below shows the model parameters of the Forward stepwise model for heavy vehicle details.

Table 26 - Model Parameters of Forward Stepwise Procedure

Variable		Model Log Likelihood	Change in -2 Log Likelihood	Significance of the Change
Step 1	PED_FACT	-7596.082	48.560	.000
Step 2	PED_FACT	-7571.513	46.712	.000
	HU_FACT_NEW	-7571.802	47.291	.000
Step 3	ELE_TYP	-7548.156	32.100	.000
	PED_FACT	-7555.372	46.531	.000
	HU_FACT_NEW	-7555.259	46.304	.000
Step 4	ELE_TYP	-7541.180	39.926	.000
	VEH_OWN_NEW	-7532.107	21.778	.001
	PED_FACT	-7543.919	45.402	.000
	HU_FACT_NEW	-7544.724	47.013	.000
Step 5	ELE_TYP	-7536.796	39.719	.000
	VEH_OWN_NEW	-7527.859	21.844	.001
	DRI_GEN	-7521.218	8.562	.014
	PED_FACT	-7539.691	45.509	.000
	HU_FACT_NEW	-7540.547	47.221	.000
Step 6	ELE_TYP	-7524.871	36.953	.000
	VEH_OWN_NEW	-7517.410	22.030	.001
	DRI_GEN	-7510.625	8.461	.015
	VAL_LICE_NEW	-7516.936	21.083	.001
	PED_FACT	-7529.415	46.040	.000
	HU_FACT_NEW	-7530.020	47.250	.000
Step 7	ELE_TYP	-7518.040	36.637	.000
	VEH_OWN_NEW	-7510.590	21.738	.001

	DRI_GEN	-7503.972	8.502	.014
	VAL_LICE_NEW	-7510.181	20.920	.001
	PED_FACT	-7521.980	44.517	.000
	OTH_FACT_NEW	-7506.395	13.348	.010
	HU_FACT_NEW	-7523.189	46.935	.000
Step 8	ELE_TYP	-7511.144	36.612	.000
	VEH_OWN_NEW	-7503.537	21.397	.002
	DRI_GEN	-7497.121	8.565	.014
	VAL_LICE_NEW	-7503.262	20.846	.001
	PED_FACT	-7514.597	43.517	.000
	VEH_FACT	-7499.721	13.765	.032
	OTH_FACT_NEW	-7498.435	11.192	.024
	HU_FACT_NEW	-7515.454	45.230	.000
Step 9	ELE_TYP	-7504.294	36.634	.000
	VEH_OWN_NEW	-7496.607	21.261	.002
	DRI_GEN	-7490.266	8.578	.014
	VAL_LICE_NEW	-7496.473	20.993	.001
	PED_FACT	-7507.373	42.791	.000
	VEH_FACT	-7492.006	12.059	.061
	SEV_FACT	-7492.839	13.723	.056
	OTH_FACT_NEW	-7491.162	10.371	.035
	HU_FACT_NEW	-7508.611	45.269	.000

According to the above order, the analysis has added the statistically significant variables to the model. The variables in step 9 shows all the variables included in the model. The analysis has terminated adding any more variables to the model since there are no other variables that can be added to the model which can do a statistically significant change to the log likelihood of the model.

Following are the analysis results of the stepwise binary logistic regression model developed for crash involved heavy vehicle related data.

Table 27 - Model Summary for each step in Stepwise procedure for vehicle related details model

Step	-2 Log likelihood
1	15143.604
2	15096.313
3	15064.213
4	15042.435
5	15033.873
6	15012.790
7	14999.442
8	14985.677
9	14971.954

Table 27 shows that, the -2 Log likelihood value has gone down with the addition of new variables. Which in turn depicts that, addition of variables has made the model better in terms of its ability to predict the dependent variable successfully. The stepwise procedure has terminated the procedure of adding variables to the model since the addition of any other variables did not make any statistically significant difference to the -2 Log likelihood value.

Table 28 - Hosmer and Lemeshow Test Results

Step	Chi-square	Significance
1	.000	.
2	.027	.987
3	4.659	.324
4	5.328	.503
5	5.420	.609
6	4.290	.637
7	6.528	.367
8	5.731	.571
9	7.602	.473

The analysis has terminated the model in the 9th step (Table 28). At the final step the Hosmer and Lemeshow test value is 0.473 which is greater than 0.05. This denotes the model has a good fit.

Table 29 - Classification table of the results

			Predicted		
			Dependent Variable		Percentage Correct
Observed			0	1	
Step 9	Dependent Variable	0	16392	5	100.0
		1	2599	7	.3
	Overall Percentage				86.3

a. The cut value is .500

The percentage of correct classification by the model is **86.3%**

The statistically significant results of the vehicle detail related model as given by the SPSS software package are listed below in the Table 30.

Table 30 - Statistically significant results of the model

Variable	**Sig.**	**B**	**Exp(B)**
ELE_TYP	0		
ELE_TYP(2)	0	-0.556	0.573
ELE_TYP(3)	0.008	-0.127	0.88
ELE_TYP(4)	**0.001**	**0.787**	**2.197**
VEH_OWN_NEW	0.001		
VEH_OWN_NEW(1)	0.002	0.407	1.502
VEH_OWN_NEW(2)	0.002	0.456	1.578
VEH_OWN_NEW(3)	**0.02**	**0.534**	**1.707**
VAL_LICE_NEW	0.002		
VAL_LICE_NEW(1)	**0.008**	**0.201**	**1.222**
VAL_LICE_NEW(3)	**0.001**	**-0.716**	**0.489**
PED_FACT	0		
PED_FACT(4)	**0**	**-0.83**	**0.436**
VEH_FACT	0.04		
OTH_FACT_NEW	0.021		
OTH_FACT_NEW(1)	**0.016**	**1.234**	**3.434**
HU_FACT_NEW	0		
HU_FACT_NEW(1)	0.012	-0.536	0.585
HU_FACT_NEW(3)	0.001	0.659	1.933
HU_FACT_NEW(7)	**0.019**	**2.166**	**8.72**
HU_FACT_NEW(8)	0	0.296	1.345

The categories with a significant effect on the severity of heavy vehicle accidents are highlighted in the Table 14.

4.4.4. Interpretation of the Vehicle Data Model Results

Depending on the model results obtained from the Table 30, below interpretations were possible.

According to the SPSS variable coding, 'ELE_TYP(4)' represents the 'Element Type 10' (Appendix B) which represents the vehicle type 'Intercity Bus' and is compared with 'ELE_TYP' in the SPSS which represents the 'Element Type 3' which is Lorry. The Exp(B) value for 'ELE_TYP(4)' is 2.19 and it denotes that, an accident which involves an intercity bus is 2.19 times probable to become a 'Crucial' (fatal other than grievous and non-grievous) one than an accident involving a lorry. In the same way it shows that the 'SLTB Bus' involved crashes are less severe than lorry involved crashes (Exp (B) value of ELE_TYP(2) is 0.57)

VEH_OWN_NEW(3) represents the 'Vehicle ownership new 4' (Appendix B) which is a semi government vehicle is compared with VEH_OWN_NEW which is a private vehicle (Appendix B). The Exp (B) value of VEH_OWN_NEW(3) 1.7 which denotes that a 'semi government heavy vehicle' (Appendix B) involved accident is 1.7 times probable to become a 'Crucial' (a fatal crash over grievous and non-grievous crashes) accident than a private heavy vehicle involved crash.

VAL_LICE_NEW(3) represents the 'Validity of license new 4' (Appendix B) which represents the heavy vehicles with drivers who had a probationary driving license is compared with heavy vehicles where the drivers had a valid license. The Exp (B) value of VAL_LICE_NEW(3) is 0.49 which denotes that the heavy vehicle involved crashes where the driver of the involved heavy vehicle in the crash had a probationary driving license was found to be 2 times less probable to become a 'Crucial' accident than the heavy vehicle involved crashes where the drivers had a valid driving license. In other words, the heavy vehicle crashes where the drivers have a valid driving license are approximately 2 times (1/0.49) probable to become a fatal crash over grievous and non-grievous crashes than the heavy vehicle involved crashes where the drivers have a probationary license.

PED_FACT(4) denotes the 'pedestrian pre-crash factor new 9' (Appendix B) which denotes the other/not known category is compared with the PED_FACT which denotes the 'Unexpected pedestrian movement'. Since the statistically significant category from the analysis has to be compared with the 'not known/other' category, this result is not capable of providing a productive idea regarding the severity of heavy vehicle crashes.

OTH_FACT_NEW(1) represents the 'other crash factor 3' (Appendix B) which is the 'road works' compared with OTH_FACT_NEW which is the 'Hit and Run' crash factor. The Exp (B) value of OTH_FACT_NEW(1) is 3.4 which denotes that when the heavy vehicle involved accident is associated with the crash factor 'Road Works' it is 3.4 times probable to become a 'Crucial' (a fatal crash over grievous and non-grievous crashes) accident than a heavy vehicle involved crash which is associated with the crash factor 'Hit and Run'. Since this variable is an aggregate of several other factors associated with crashes, it is not possible to derive a useful information regarding the factors affecting the severity of heavy vehicle crashes.

HU_FACT_NEW(7) represents the 'Human pre-crash factor new 9' (Appendix B) which denotes the human pre-crash factor for the crash 'Blinded by another vehicle/sun' is compared with 'Aggressive/Negligent Driving'. The Exp (B) value of HU_FACT_NEW(7) is 8.72. That is, a heavy vehicle crash occurring due to the human crash factor 'Blinded by another vehicle/sun' is 8.7 time more probable to become a 'Crucial' accident than a heavy vehicle crash occurred due to the human crash factor 'Aggressive/Negligent Driving'.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Road Safety Situation of Sri Lanka

Some of the main points obtained through the study are as follows;

- Under reporting of damage only accidents is a significant disadvantage for the process of safety improvement since it reduces the ability to understand accident patterns and contributory factors. Therefore, steps are necessary to eliminate this issue and further studies are needed on improved mechanisms that take the new information in to account during the policy and decision making processes.

- The number of motorized two and three wheeled vehicles (responsible for over 60% of the road traffic fatalities in the country during the year 2013) which form a significant proportion of all vehicles in the country creates a considerable impact on the road safety situation. Improvement of quantity and quality of public transportation can be used as a counter measure by motivating motorized two or three wheeled vehicle users to adopt public transport. However economic implications on those who earn a living through these modes of transportation also needs to be considered.

- Significant amount of youngsters below the legal age to ride a MC was found to be using MCs and it (lack of practice and experience) could increase the crash severity.

- Single vehicle MC crashes were severe than multi vehicle crashes.

- Lack of proper helmet usage was found to be an important contributor towards increased morbidity and mortality in motorized two wheeled crashes and the negative attitude towards helmet usage of children is a critical issue. In the short term, strict enforcement of laws mandating helmet usage especially for children can mitigate this issue to an acceptable limit

- The diversity of traffic mix, together with traffic behaviour in Sri Lankan context (Ex. abrupt speed variation) seems to contribute extensively to the rise in rear end accidents. One of the suggested proposals to overcome this issue include an attempted reduction of heavy and long vehicles at least during peak periods. This can be done by allowing goods and materials transporting heavy vehicles on roads at different time periods where main traffic is less on roads or can allocate different routes or else other transport modes such as railway and water can be encouraged for goods and material transportation as a long term measure. On the other hand, the quality of ridership of heavy vehicle drivers can be improved by introducing mandatory driving etiquette classes at the licensing procedure.

- Resource and attention allocation for pedestrian related infrastructure mainly in rural areas can benefit the road safety situation of the country.

- Age group 21-25 years found to be most susceptible for motorcycle related accidents. Strict enforcement of helmet laws should be done together with accompanied attitude improvement towards helmet usage through creative means like media advertisements and public campaigns. This would be more effective if safety education can be included as a part of primary school education.

- 26-35 age group was significant for motorized three wheel accidents. If these motorized three wheels can be designed to limit the high maneuverability to reduce sudden maneuvers, the severity could have been reduced

5.2. Accident Analysis Beyond Descriptive Statistics

Due to the inaccuracies and reliability issues associated with accident databases, the accident analysis has further evolved to incorporate more reliable methodologies. Two such major developments are the Accident Investigation and Conflict Studies.

Road traffic data basically consist of two types. Namely "Frequency Data" and "Severity Data". Poisson regression analysis has initially been used for the frequency modeling and then Poisson variants became dominant. Multiple regression analysis has also been used to find out relationships between fatalities and different explanatory variables through frequency modeling.

For severity data, the models have evolved from simple binary discrete outcome models (binary logit and probit models) to multiple discrete outcome models. Logistic Regression models and ordered probit models have been used most commonly for severity analysis. Specifically, in safety sciences, logistic regression has shown to deliver a realistic modeling and is of the widely utilized methods.

5.2.1. Logistic Regression Analysis Related

Heavy Vehicle Crash Data utilized model

Through the analysis it was found that,

- There is 1.9 times chance for a heavy vehicle crash occurring during 03:00 to 06:00 hours to become a fatal crash than a crash occurring during 15:00 to 18:00 hours
- The heavy vehicle crashes occurring at Batticalo, Chilaw and Jaffna DS Divisions have a 3 times, 3.5 times and 3 times chance respectively to become a fatal crash than the crashes occurring at Colombo DS Division
- Although the number of vehicles involved in a crash is not well known to influence the severity of a crash, it was found through the model that, the heavy

vehicle crashes where 3 vehicles are involved has a 1.3 times chance to become a fatal crash than the heavy vehicle crashes involved with 2 vehicles

Heavy Vehicle (involved in crashes) Data Utilized Model

- The crashes where Intercity Busses are involved have 2.19 times chance and the crashes where SLTB busses are involved has a 0.57 times lower chance of becoming a fatal crash than the crashes involved with lorries
- A semi government heavy vehicle related crash have 1.7 times higher chance of becoming a fatal crash than a private heavy vehicle related crash
- Heavy vehicle involved crashes where the drivers have a valid driving license have a 2 times higher chance to become a fatal crash than the heavy vehicle involved crashes where the drivers have a probationary license
- Heavy vehicle crashes occurring due to 'blinded by sun or another vehicle' have a 8.7 times higher chance of becoming a fatal crash than a heavy vehicle crash occurring due to 'aggressive/negligent driving'

5.3. Overall Conclusion

When comparing the descriptive statistics with the logistic regression modelling, identification of more qualitative and quantitative finer details about the contributory factors for a certain type of crashes is possible whereas by using descriptive statistics, the obtainable results are quite general. Therefore, in order to gain an in depth understanding or assessment of road crashes, the statistical methodologies are of much use and to gain a wider and a more general overview of a set of data, the descriptive statistics are useful.

The logistic regression modelling carried out for heavy vehicle related crashes found out several latent factors affecting the severity of heavy vehicle crashes in Sri Lanka which if properly addressed is able to reduce the significant road crash fatality rate due to the heavy vehicle crashes. Through descriptive statistics of the overall crashes in the country, it was evident that vulnerable road user related crashes such as MC and 3W related crashes are crucial with regard to the overall road safety situation of the country. Therefore, it can be recommended to carry out logistic regression modelling for MC and 3W related crashes as well to find out the factors affecting the severity of such crashes so that the mitigations can be found out.

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Appendix A – A Sample Analysis Procedure Using SPSS 16.0

The following figure shows the variable view of the SPSS software. The variables used for developing the above said models can be seen here.

Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure
NU_OF_CASU	Numeric	8	0	Number of Casualties	None	None	9	Right	Scale
NU_VE_N	Numeric	8	0	Number of Vehicle New	None	None	8	Right	Nominal
DSD_NEW	Numeric	8	0	DSD New coded	None	None	8	Right	Nominal
URB_RUR	Numeric	8	0	Urban Rural	None	None	8	Right	Nominal
DAYOF_WE	Numeric	8	0	Day of Week	None	None	8	Right	Nominal
RO_SUR	Numeric	8	0	Road Surface	None	None	8	Right	Nominal
WETH	Numeric	8	0	Weather	None	None	8	Right	Nominal
LI_COND	Numeric	8	0	Lighting Condition	None	None	8	Right	Nominal
LO_TY	Numeric	8	0	Location Type	None	None	8	Right	Nominal
NU_VE_CODED	Numeric	8	0	Number of vehicle new coded	None	None	8	Right	Nominal
TI_RA_NEW	Numeric	8	0	Time Range new coded	None	None	8	Right	Nominal
DEPNDNT	Numeric	8	0	Dependent	None	None	8	Right	Nominal

Figure 6 - SPSS Interface for Varible Moode

Here the DSD is a location specific information (DS Division – District Secretariat Division). Time of the accident was converted to a categorical variable known as "Time Range" which has time intervals of three hours starting from mid night. The dependent variable was coded as described above. Some of the other categorical variables were also recoded to ease the analysis and interpretation of results. Those are described later in detail.

The following step shows the way from which the independent and dependent variables are introduced to the analysis interface of the SPSS.

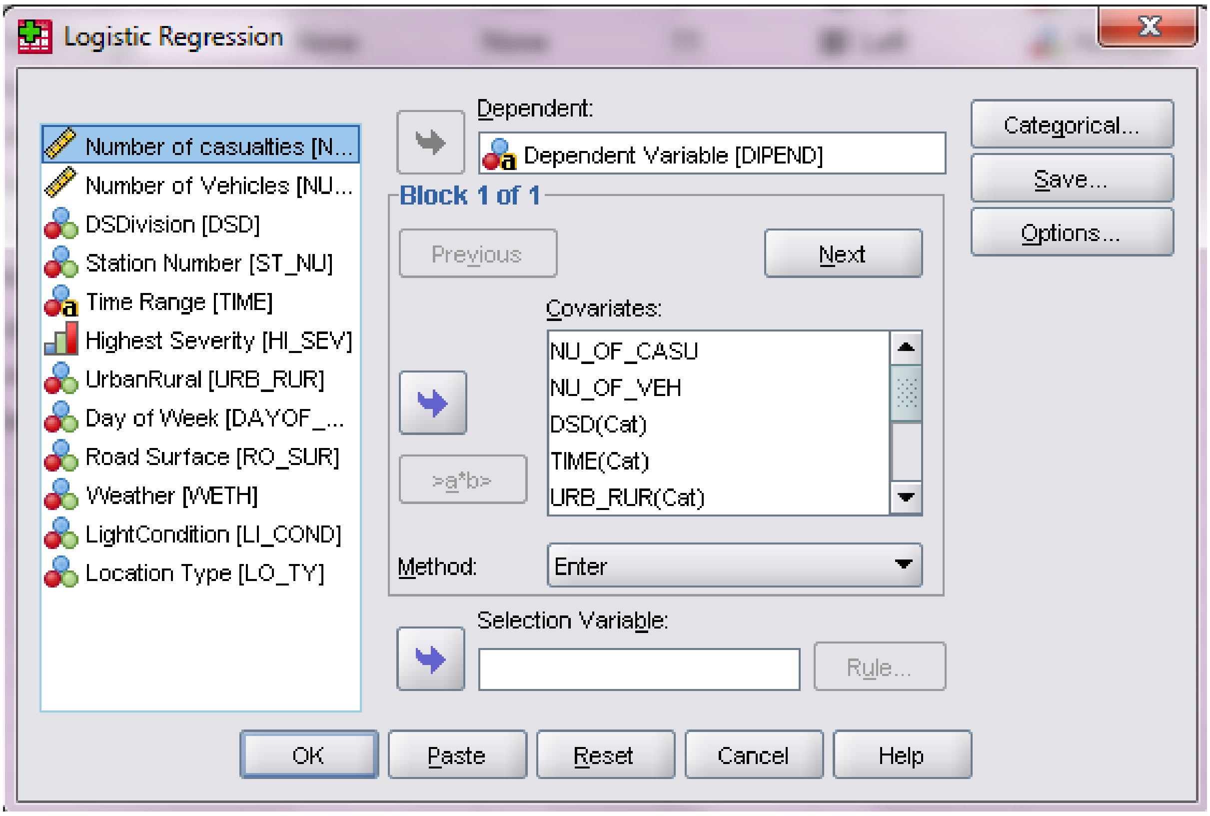

Figure 7 - Logistic Regression dialog box in SPSS Interface

The dependent variable was moved to the “Dependent” box while all the indicator (independent) variables were moved to the “covariates” box. The “Method” was kept “Enter”.

As the next step, the categorical variables among the indicator variables have to be introduced into SPSS from the “Categorical” button appearing in the above shown dialog box. The view of that interface is shown below.

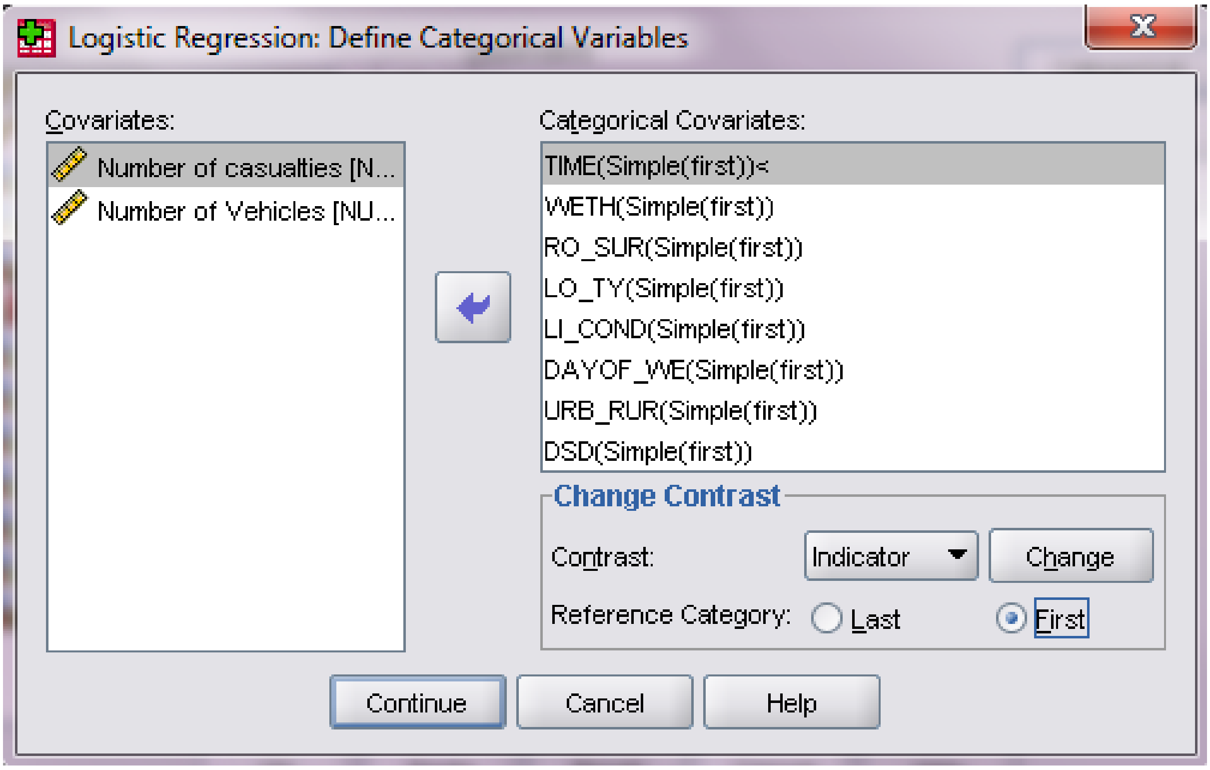

Figure 8 - Defining Categorical Variables dialog box in SPSS Interface

All the categorical variables have to be moved from the covariates box to categorical covariates box. When a certain variable is inside the box we can change the contrast of that variable (as of how will the variable be used to contrast in between the categories of its own) from “Change Contrast”. When the contrast is set to “Indicator” and reference category to “First” of a certain variable and click “Change”. The variable will be changed as “Variable(Indicator(first))” in the “Categorical Covariates” box. Which means the SPSS then compares the other categories of a certain variable with the first category of that variable. For example, in the “Urban Rural” variable, there are two categories named as “1 – (Urban)” and “2 – (Rural)”. When it is introduced to SPSS in the above mentioned way with Indicator Contrast, the SPSS compares the contribution of Rural condition (2nd category) with Urban condition (1st category) as the basis towards the severity of the accident. Here for this analysis, the “Indicator” contrast was used. There are other ways of contrast as well. They are introduced as follows.

Change Contrast. Allows you to change the contrast method. Available contrast methods are:

- **Indicator.** Contrasts indicate the presence or absence of category membership. The reference category is represented in the contrast matrix as a row of zeros.
- **Simple.** Each category of the predictor variable (except the reference category) is compared to the reference category.
- **Difference.** Each category of the predictor variable except the first category is compared to the average effect of previous categories. Also known as reverse Helmert contrasts.
- **Helmert.** Each category of the predictor variable except the last category is compared to the average effect of subsequent categories.
- **Repeated.** Each category of the predictor variable except the first category is compared to the category that precedes it.
- **Polynomial.** Orthogonal polynomial contrasts. Categories are assumed to be equally spaced. Polynomial contrasts are available for numeric variables only.
- **Deviation.** Each category of the predictor variable except the reference category is compared to the overall effect.

After selecting continue, we can select the types of results we need from "Options" and continue. Then the analysis can be performed using SPSS and it will give analysis results in another interface of the software.

Appendix B – Parameter Coding by SPSS for Crash Involved Heavy Vehicle related Crashes

Categorical Variables Codings are as follows

		Frequency	Parameter coding (1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Nu of Yrs of licnse catgry	1	10458	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	2	3205	1.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
	3	1927	.000	1.000	.000	.000	.000	.000	.000	.000	.000	.000
	4	1033	.000	.000	1.000	.000	.000	.000	.000	.000	.000	.000
	5	855	.000	.000	.000	1.000	.000	.000	.000	.000	.000	.000
	6	662	.000	.000	.000	.000	1.000	.000	.000	.000	.000	.000
	7	630	.000	.000	.000	.000	.000	1.000	.000	.000	.000	.000
	8	132	.000	.000	.000	.000	.000	.000	1.000	.000	.000	.000
	9	66	.000	.000	.000	.000	.000	.000	.000	1.000	.000	.000
	10	18	.000	.000	.000	.000	.000	.000	.000	.000	1.000	.000
	11	17	.000	.000	.000	.000	.000	.000	.000	.000	.000	1.000
Human Pre crash factor 1 new new	2	11416	.000	.000	.000	.000	.000	.000	.000	.000	.000	
	3	273	1.000	.000	.000	.000	.000	.000	.000	.000	.000	
	4	276	.000	1.000	.000	.000	.000	.000	.000	.000	.000	
	5	148	.000	.000	1.000	.000	.000	.000	.000	.000	.000	
	6	41	.000	.000	.000	1.000	.000	.000	.000	.000	.000	
	7	2	.000	.000	.000	.000	1.000	.000	.000	.000	.000	
	8	1	.000	.000	.000	.000	.000	1.000	.000	.000	.000	
	9	5	.000	.000	.000	.000	.000	.000	1.000	.000	.000	
	10	1510	.000	.000	.000	.000	.000	.000	.000	1.000	.000	
	19	5331	.000	.000	.000	.000	.000	.000	.000	.000	1.000	
Cr Fct Sev New	1	98	.000	.000	.000	.000	.000	.000	.000			
	2	148	1.000	.000	.000	.000	.000	.000	.000			

	3	22	.000	1.000	.000	.000	.000	.000	.000			
	4	47	.000	.000	1.000	.000	.000	.000	.000			
	5	51	.000	.000	.000	1.000	.000	.000	.000			
	6	214	.000	.000	.000	.000	1.000	.000	.000			
	7	544	.000	.000	.000	.000	.000	1.000	.000			
	9	17879	.000	.000	.000	.000	.000	.000	1.000			
Driver Age Category New	4	4299	.000	.000	.000	.000	.000	.000	.000			
	5	890	1.000	.000	.000	.000	.000	.000	.000			
	6	2823	.000	1.000	.000	.000	.000	.000	.000			
	7	98	.000	.000	1.000	.000	.000	.000	.000			
	8	3398	.000	.000	.000	1.000	.000	.000	.000			
	9	2662	.000	.000	.000	.000	1.000	.000	.000			
	10	1978	.000	.000	.000	.000	.000	1.000	.000			
	11	2855	.000	.000	.000	.000	.000	.000	1.000			
Vehicle Ownership new	1	16459	.000	.000	.000	.000	.000	.000				
	2	382	1.000	.000	.000	.000	.000	.000				
	3	1721	.000	1.000	.000	.000	.000	.000				
	4	155	.000	.000	1.000	.000	.000	.000				
	5	201	.000	.000	.000	1.000	.000	.000				

	6	34	.000	.000	.000	.000	1.000	.000
	9	51	.000	.000	.000	.000	.000	1.000
Veh pre fact new	1	304	.000	.000	.000	.000	.000	.000
	2	115	1.000	.000	.000	.000	.000	.000
	3	5	.000	1.000	.000	.000	.000	.000
	4	30	.000	.000	1.000	.000	.000	.000
	5	74	.000	.000	.000	1.000	.000	.000
	6	33	.000	.000	.000	.000	1.000	.000
	9	18442	.000	.000	.000	.000	.000	1.000
Rd crsh fact new	1	195	.000	.000	.000	.000	.000	
	2	91	1.000	.000	.000	.000	.000	
	3	21	.000	1.000	.000	.000	.000	
	4	146	.000	.000	1.000	.000	.000	
	5	50	.000	.000	.000	1.000	.000	
	9	18500	.000	.000	.000	.000	1.000	
Validity of Licence new	1	16860	.000	.000	.000	.000	.000	
	2	1464	1.000	.000	.000	.000	.000	
	3	21	.000	1.000	.000	.000	.000	
	4	333	.000	.000	1.000	.000	.000	

	5	1	.000	.000	.000	1.000	.000					
	9	324	.000	.000	.000	.000	1.000					
Age of veh categry	1	5244	.000	.000	.000	.000						
	2	7531	1.000	.000	.000	.000						
	3	2276	.000	1.000	.000	.000						
	4	1543	.000	.000	1.000	.000						
	5	2409	.000	.000	.000	1.000						
Othr Cr fact new new	2	197	.000	.000	.000	.000						
	3	20	1.000	.000	.000	.000						
	4	41	.000	1.000	.000	.000						
	5	196	.000	.000	1.000	.000						
	9	18549	.000	.000	.000	1.000						
ped pre fact new	1	276	.000	.000	.000	.000						
	2	38	1.000	.000	.000	.000						
	3	22	.000	1.000	.000	.000						
	4	79	.000	.000	1.000	.000						
	9	18588	.000	.000	.000	1.000						
Element Type	3	10310	.000	.000	.000	.000						
	7	366	1.000	.000	.000	.000						

	8	1920	.000	1.000	.000	.000						
	9	6310	.000	.000	1.000	.000						
	10	97	.000	.000	.000	1.000						
Driver Gender	0	2	.000	.000								
	1	18986	1.000	.000								
	2	15	.000	1.000								