MOTORCYCLE ACCIDENT ANALYSIS IN SRI LANKA

Sulaima Labbie Ahamed Shajith

(148315V)

Degree of Master of Engineering in Highway & Traffic Engineering

Department of Civil Engineering

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Thesis submitted in partial fulfillment of the requirements for the degree
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DECLARATION

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ABSTRACT

Motorcycles comprise nearly 30% of the traffic flow in most highways in Sri Lanka. The rapid increase in motorcycle usage has led to a significant increase in the number of motorcycle related accidents and fatalities. The objective of this study is to identify the risk factors involved in motorcycle accidents.

In this study, Motorcycle related accidents data were analyzed under four categories. Such as, Motorcycle accident with motor vehicles, pedestrian, cyclist and self-accidents. Risk to motorcyclist with respect different types of vehicles also estimated. Other than descriptive statistics, the stepwise binary logistics regression was selected to be used in analyzing accidents.

Motorcycle related accidents accounts for nearly 40% of total road accidents. Motorcyclist in Sri Lanka face approximately 1.60 times more fatal risk compare to motorcyclists all over the world. Motorcycle accidents with Lorries and Buses have more chance to become fatal compare with other vehicles.

Nearly 29% of the pedestrian fatalities and 9% of cyclist fatalities involved motorcycles. Furthermore, pedestrians - motorcycle fatal accidents were at greatest risk at mid block sections of the road and pedestrian aged 60 above were at the highest risk of sufferring a fatality during a motorcycle accident compared to other age groups.

For single vehicle accidents, more than 57% of accidents occur during the night time and the risk ratio increase by over 20% during the night time on road segments without street lightings.

Involvement of younger riders in accidents are high and fatal risk to riders increase with their age. The study also evaluates other risk factors associated with motorcycle related accidents. Findings of the study would be useful to identify appropriate measures to improve the motorcycle rider safety in Sri Lanka.

Keywords: Accident analysis, Motorcycle, road safety, risk analysis

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1 INTRODUCTION

1.1 Background

Motorcycles (**MCL**) are the most common mode of transportation in Sri Lanka and other developing countries. In the absence of sufficient road networks and inadequate public transport, motorcycles provide good solution to urban and rural commuters. It is a popular mode of transport of the lower middle income families as well as youths due to lower transportation cost. However, the rapid increase in motorcycle usage has led to significant increase in the motorcycle related accidents and fatalities. This has resulted in motorcycle riders being amongst the most vulnerable road users on roads as they have lack of protection in case of crash.

The number of registered motorcycles in Sri Lanka in year 2016 was 3,699,630 which is 55% of the total registered vehicle population for the year (Department of Motor Traffic, 2016). From 2012 to 2016, the number of registered motorcycles increased by 45% with the growth rate of 11% per year, which shows the significant growth of motorcycle population in the country. There are 355 motorcycles per 1,000 households and 911 per 10,000 population available in Sri Lanka (National Transport Commission [NTC], 2015). As the number of motorcycles increase so does the probability of their being involved in crashes also increases.

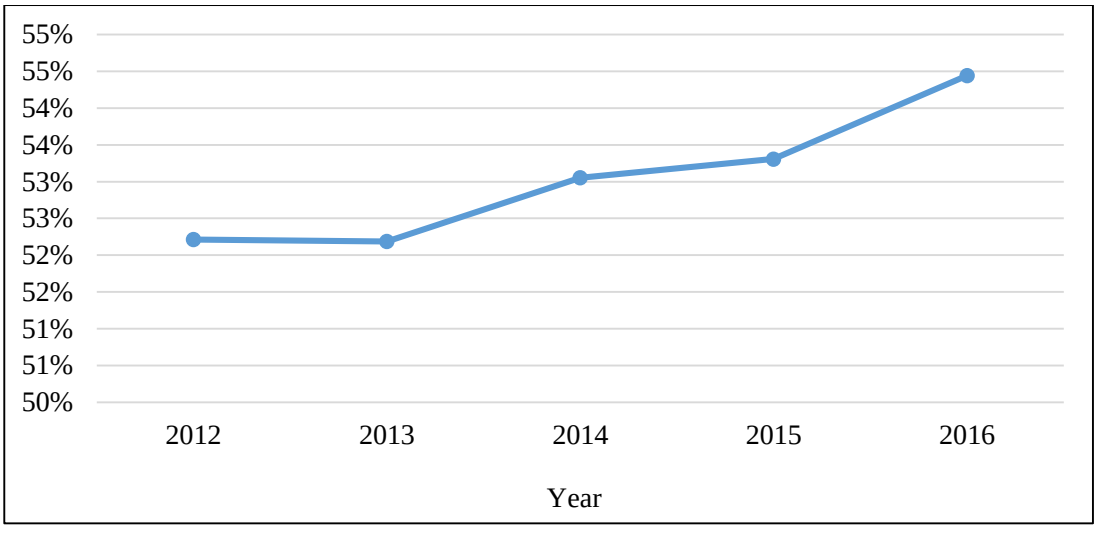

Figure 1.1: Percentage of Motorcycles in Total Registered Vehicle Population

On an average, four people die every day from motorcycle related crashes in the year 2015 whereas it is little above eight for all types of vehicle related crashes as per the available records at police headquarters. Involvement of youngsters in motorcycle accidents are very significant. Riders in the age of 21 to 25, involved mostly in the motorcycle crashes and major contributory factor for accident was aggressive or negligent driving (Devasurendra, 2016). The same study revealed that youngsters (bellow 18 years) represented 9% of the proportion of riders failed to produce license at the time of crash.

The above facts show that trend of riding motorcycle has grown up among the younger community who are below the legalized age to obtain license. In most cases, motorcyclist do not undergo proper training since riding motorcycle is easier compared with other motor vehicles and easy accessibility to motorcycles. Use of motorcycle without proper training has become one of the major threat to the road safety in this country. In a report published by World Health Organization (WHO), most of the youth are killed by road traffic injuries in low-income and middle-income countries are vulnerable road users such as pedestrian, cyclist, motorcyclist etc… (WHO, 2007).

With the upgrading of the engine capacity and other modern features of the motorcycles, motorcyclists tend to ride with very high speed and accelerations. Being a 'single track vehicle', a motorcycle can easily become unstable when either break is applied suddenly or slippery road surface causes a wheel to loose adhesion. Other than the motorcycles, other types of motor vehicles are not so vulnerable to accident due to incorrect or inappropriate brake application in most circumstances.

Rapidly increasing number of motorcycle population, rider dynamics such as increase in speed and negligent driving, increasing motorcycle related mortality and morbidity emphasize the need for pay immediate attention on the motorcycle related accidents which accounts for nearly 40% of total accidents reported every year. Increasing numbers of road accidents specially related to motorcycles have created a big challenge to the country to meet the Sustainable Development Goals (SDG) launched by the United Nation (UN) in the year 2015. One of the SDG implies to halve the number of global deaths and injuries from road traffic accidents by the year 2020.

Therefore, finding the causes of motorcycle related accidents and taking counter measures have become the prime important by considering the safety of motorcyclists and other vulnerable road users.

1.2 Objective of the Study

The objective of this study was to identify the risk factors related to motorcycle accidents in Sri Lanka. Both descriptive analysis and statistical analysis were done to find out causative factors and other safety issues related to motorcycle accidents.

1.3 Scope of Work

This study uses "Sri Lanka Police Accident Database" from year 2012 to 2014. Motorcycle accidents were separated from the general database and further analyzed. Other than the accident data, vehicle registration, operating vehicle population and census data also were considered.

Special attention was paid on vulnerable road users involved in motorcycle related accidents such as cyclist and pedestrian. Here, Motorcycle (MCL) related accidents data were analyzed under four categories. Such as, MCL accident with motor vehicles, pedestrian, cyclist and MCL-Self accidents. Other than this, risk to motorcyclist with respect different types of vehicles also estimated.

Other than the descriptive statistics, the stepwise binary logistics regression was selected to be used in analyzing accidents. The analysis identified several safety related issues regarding to MCL related accidents and suggestions were made accordingly to reduce the number of fatality and loss to the economy due to accidents.

2 LITERATURE REVIEW

There is a positively significant relationship between human factors, environmental factors, legal factors and vehicle factors contributing to the motorcycle related accidents. These factors are discussed below.

2.1 Human Factors

2.1.1 Speed and Loss of Control

The majority of motorcycle collisions continue to occur at relatively low speed and, although injury severity increases with impact speed (Elliott et al., 2003). The study on motorcycle safety by Elliott et al (2003) reported that a substantial proportion of serious injuries and fatalities occur at modest speed.

A naturalistic study on motorcycle accidents resuts indicates that excessive speed is the factor for 45% of accidents observed in curves (Williams, McLaughlin & Atwood, 2016). A study reveled that the median pre-crash factor speed was 29.8 mph, and the median crash speed was 21.5 mph, and the one-in-a-thousand crash speed is a apporoximately 86 mph (Hurt, Ouellet & Thom, 1981).

Rider losing control of the vehicle is one of the major factors in motrcycle crashes. According to Ministry of Transport – Newzeland (2013), 30% of head-on crashes resulted from a rider lossing cotrol of the motorcycle. A large proportion of 'loss of control' accidents took place in built-up areas and non-built-up areas where speed limit was 30 mph and 60 mph subsequently (McCarthy, Walter, Hutchins, Tong & Keigan, 2007). Aggressive or negligence of young people in age group 21-25 are more liable for road crashes and the chance of being a fatal one is relatively heigher than other crashes (Devasurendra, 2016). The above studies reveal that more motorcycle related accidents occur at the modest speed.

2.1.2 Age and Gender

In-depth investigation of motorcycle accident results shows that the majority of accidents involved male riders under the age of 25 (European Association of Motorcycle Manufacturers (EAMM), 2003).

A comprehensive study on motorcycle fatalities in South Delhi reported that in 93.6% cases victims were male as compared to female victims of 6.4%. Commonest age group involved was 21 to 30 years (44.67%) followed by 31 to 40 years (27.66%) (Behera, Rautji, Lalwani & Dogra, 2009). Another study in Tanzania disclosed that majority of motorcycle accident victims are younger (male) motorcyclist (Ndunguru, 2016). Motorcycle operators in the 17 to 25 age range have almost 100 times greater risk to operator of other vehicles (Paine, Paine, Haley & Cockfield, 2004).

The conclusion from the above studies is, majority of victims are younger male riders, the productive force of the country. To the economic this is double effect; incresed medical expenditure and loss of man power.

2.1.3 Risk Taking, Traffic Scan Errors and Attention Failure

A motorcyclist is overtaking another vehicle is considered as a main safety issue. McCarthy et al (2007) reported that motorcycle riders was considered to have made a trafficc scan error in 28% of motorcycle accidents. The same study revealed that attention failure was considered to have contrributed to accident causation in 20% of accidents.

2.1.4 Alcohol Consumption

Albalate & Villadangos (2009) revealed that speed violations and alchocol consumption provide the worst health outcomes in motorcycle accidents. A study in cameron reported that over 16% using a motorbike always or ocasionally under the influence of alcohol or drugs (Nyagwui, Fredinah, Che & Yulia, 2016).

When people drink and ride, they are at much greater risk of crashing and dying. Twenty-eight percent of motorcycle riders who died in 2010 had a blood alchcol

concentration that was at or above the legal limit of 0.08 g/dl (National Center for Injury Prevention and Control [NCIPC], 2016).

2.1.5 Helmet Uasge

The only significant protective equipment is the qualified safety helmet, and it is capable of a significant reduction of head injury severity and frequency.

A comprehensive study on motorcycle fatalities in South Delhi reported that most of the diseased on motorcycle accidents were riders, among them only 54.05% wore a helmet at the time of accident (Behera et al., 2009). The United States saved $ 3.0 billion in 2010 and could have saved an additional $ 1.4 billion if all motorcyclists had worn helmets (NCIPC, 2016). The above studies reveal that wearing helmets reduces injury severity and saves economic burden from crash related injuries. The majority of motorcycle users, can not effort to buy helmet for their children because of their rapid physical growth, mange to travel without helmet lead the way for increased child casualties (Devasurendra, 2016).

Hurt, et al (1981) reported that helmeted riders and passengers show significantly lower head and neck injury for all types of injury, at all levels of injury severity. The same study revealed that increased coverage of the full facial helmet increaes protection, and significantly reduces face injuries. 99% of the riders and 87% of the pillion wore helmet in Sri Lanka. This is very close to helmet wearing rate of United States of America which is 99% (Dharmaratne, Jayatilleke, Abeyrathna, Mabharana & Kumbukgolle, 2013). But, still helmet usage at rural areas were recorded to be law due to lack of law enforcement (Amarasingha, 2014). In 2013, 37% of childern who died in road crashes did not wear a helmet (Devasurendra, 2016).

A recently published study revealed that wide-spread use of non-standard helmets in low-and-middle-income countries may limit the potential gain of the motorcycle helmet use programms. A scoping study by Elliott et al (2003) on motorcycle safety suggested that helmets work should continue on the deveopment of helmet standards, to improve energy absorbing capacity, minimize induced rotational motion, and improve the evaluation of the complete helmet including chin-guard.

2.1.6 Training and Experience of Riders

Giving riders the skills, rules and knowledge necessary to identify and avoid critical situations and maximizing control of motorcycle is the challenge for training based interventions. The control skills needed for motorcycling are inherently more demanding than those needed for car driving, especially in emergencies. Motorcyclists receive relatively little formal training, and opportunities for supervised on road-riding are limited.

A scoping study (Elliott et al., 2003) disclosed that emphasizing skill limitations, coverage of higher order cognitive skills, providing information on risk levels , and communicating a rules and knowledge base for safe riding will improve the safety of motorcyclist.

The Hurt's Report (Hurt et al., 1981) indicated that the motorcycle riders involved in accidents are essentially without training; 92% were self-taught or learned from family or friends. The same study disclosed that motorcycle rider taining experience reduces accident involvement and related injuries in the event of accidents.

2.1.7 Impairement through Stress and Fatigue

The discomfort felt by psychological stress can increase accident risk. Because it increases reaction times, impair motor responses, increase fatigue and impair peception. Robertson and Porter (1987) found that 60% of motorcycle riders reported muscular stress, 33% thermal stress, 27% noise stress and 22% vibration stress. The affect of stress may be quite differnt for different individuals.

A study by Karmegam et al (2009) indicated that motorcyclists mainly experienced discomfort on their upper body parts (neck or head, shoulder, upper back, arm and hand, low back and buttock) and whereas majority expressed no discomport in their lower body parts.

Strees can increase fatigue which is a silent killer (Horberry, Hutchins & Tong, 2008). Fatigue is also been associated with squinting of the eyes, heavy helmets and long journey time (Travers & Jennings, 1980). Fatigue can cause reaction time and decision making ability to detoriate as distance travelled increased.

Napping for motorcyclists is not easy to achieve.The best option for motorcyclists to reduce fatigue is to is to take break, but not to nap. Elliott et al (2003) suggessted that long journeys should be planed to include frequent rest.

2.2 Environmental Factors

2.2.1 Road Environment

Road site environment is one of the main factor contributes to motorcycle accidents. It includes road surface, road furniture, roadway defects etc. In addition to these, road site vegetation and unexpected movement of animals also contribute to accidents.

A scoping study on motorcycle safety (Elliott et al., 2003) revealed that longitudinal riding or grooving of the road surface, and raised road marking, can lead to instability of motorcycles. Slippery road surfaces, drain covers, roadway defects, gratings and unevenness road marking also the environmental factors contribute to motorcycle accidents. The above study concluded following facts,

- When wet, bitumen surface has low friction of coefficient and can therefore cause motorcycle to become unstable.
- Parallel longitudinal grooves in the road surface can also induce instability and are therefore additional hazard to motorcycling.
- The crossing of profiled road marking causes strong steering impulses leading to deviations from the normal track of about 100 mm especially to motorcycles which leads to sustained weaving.

Slippery or wet road surfaces are more dangerous for riding motorcycles. The crossing of wet bitumen while leaning leads to the speed deviation of 20^0/s (Elliott et al., 2003). The typical or average riders cannot respond to rapid unexpected movements of the motorcycle. It leads the motorcycle to slide either into opposing lane or possibly into road site furniture. For an emergency stop from 50 km/h, the stopping distance on wet bitumen is more than double the distance on wet tarmac while one meter wide of patch of bitumen can increase the stopping distance by 45% (Elliott et al., 2003).

Ndunguru (2016) concluded that envirnmental factor is the cause for 13.5% of motorcycle accidents.The reported environmental factors in his study were poor road

design, slippery road and lack of road signs (8.1%), vegetation (3.4%) and animals (2%). Unexpected movement of animals sch as cows and dogs crossing the road also do cause motorcycle accidents. Riders maneuver to avoid (such as pedestrian, cyclist, animal, or other objects) increases the crashor near-crash risk by nearly 12 times (Williams et al., 2016).

Thickness of road marking and profilled marking also produce steering instability to riders. Thickness of road marking should be limited to a maximum height of 2 mm above the road surface and profille marking should be no more than 7 mm above the road surface (Ndunguru, 2016).

Steep slopes, potholes and road bumps also affecting the speed and stability of the motorcycles. Roadway defects (Pavement ridges, potholes, etc.) were the accident cause in 2% of the accidents (Hurt et al., 1981). McCarthy et al (2007) concluded that only 11% of accidents occuring on roads with surface defects recorded.

Paved roads enable motorcyclists to ride with high speed. As a result, motorcycles end up colliding with other vehicles since such roads are used by all kind of motorised transport hense congested.

2.2.2 Accident Location

Accident locations are normally classified as road sections, without junctions, junctions, by roads, railway crossing etc. At the same time based on land development, it can be categorized as accident occurred at urban and rural areas. While, it can be further classified based on road geometry and type of road pavement.

Intersections are the most likely place for the motorcycle accident, with the other vehicle violating the motorcycle right-of-way, and often violating traffic controls. Looked but failed to see accidents are very much predominant at junctions. These accidents occur due to conspicuity, driver behavior, experience and highway issues.

Considering the junction type, 72% of junction accidents occur at T-Junction (McCarthy et al., 2007). Motorcycle crashes reported from 2008-2012 in Sri Lanka revealed that 27% of accidents reported are intersection related where accidents at

T-Junctions are significant. Hernández (2008) reported that almost one-third of motorcycle accidents reported in Portugal happended inside intersections.

In Sri Lanka, most frequent crash conditions for motorcycle crashes occurred while driving on rural roadways.

Road way alignment factor is also plays an important role in motorcycle related accidents. On the spot study of motorcycle accidents (McCarthy et al., 2007) revealed that 70% of accidents recorded in straight section of roads. Most of the accidents occur in bends caused by loss of control took place in bends. Riding in a right curve doubles the risk of crash or near-crash compared to riding on a straight roadway (Williams et al., 2016).

Improved road surfaces allow for a change in driving dynamics such as increase in the average driving speed which again can have a significant impact on the accident probability, as well as increased the severity. A study in Tanzania (Ndunguru, 2016) disclosed that there was a high rate of motorcycle accidents in paved roads than on unpaved roads.

2.2.3 Day of the Week and Time of the Day

A comprehensive study on motorcycle fatalities in South Delhi (Behera et al., 2009) reported that maximum number of accidens (34%) occurred between 6.00 am to 12.00 noon when people are hurry to reach their work places. Another study (Hernández, 2008) indicated that dangerous period of the day is 5.00 pm to 8.00 pm where people go back home.These two findings reveal that the most dangerous period for riding motorcycle is morning and evening peaks of the time where peole are in hurry.

Motorcycle crash studies revealed that more than 70% of motorcycle crashes occurred while driving during week days, clear weather and dry road in heavy traffic (Amarasingha, 2015; Hernández, 2008). Hurt et al (1981) disclosed that most motorcycle accidents involve a short trip associated with shopping, errands, friends, entertainment or recreation, and the accident is likely to occur in a very short time close to the trip origin.

2.3 Legal Factors

2.3.1 Licensing and Enforcement

More effective enforcement of licensing and registration for motorcycles could serve as a potential measures to reduce crashes. In Sri Lanka, the minimum age limit for getting license is 18 years. Devasurendra (2016) indicated that 29% of motorcycle riders in Sri Lanka were not been able to produce a valid driving license at the time of accident where 9% represented the age below 18 years.

More stringent panalties, including the temporary impounding of motorcycles driven by riders who are invalidly licensed should be implemented. This statergy not only prevent unlicensed riders but also owners from allowing unlicensed riders to operate their motorcycles.

Countries like UK, USA, Canada, Newzealand and some other countries have been practicing gratuated licensing system. In the UK, Compulsary Basic Training (CBT) is must for all learner drivers (Huang et al., 2004). After the succesfull completion of the CBT training only, riders are allowed to ride with L- Plates for a period of maximum two years.

There are two types of licenses issued for motorcycle riders in the UK based on motorcycle type. One is, Light motorcycle license and another one is standard motorcycle license (Huang, 2004). But, in Sri Lanka there is no such system is in practice. Basically, license are issued in three stages. The learner permit is issud after passing the written examination conducted by Motor Traffic Department. Then the probational licence is issued after the completion of trial and with in three months period permenant licence is issued.

But, when considering the increasing number of motorcycle accidents, it is time to reconsider the method of licensing and training given by Motor Traffic Department.

2.4 Vehicle Factors

2.4.1 Breaking Problem and System

In many vehicles, incorrect or inappropriate breaking is not critical in most circumstances. However, in case of motorcycle, a mistake by the rider that leads to wheel being over-braked will cause the vehicle to skid, become unstable and capsize even an experience driver over brake the front wheel due to the stress situation. The incidence of skidding in personal injury accidents is substantially greater for motorcycles than for other vehicles.

An in-depth study of fatal motorcycle collisions revealed that the cause of accidents is incorrect breaking in many circumstances (Sporner & Kramlich, 2003). Shepard, Hester, Gatfield and Martin (1985) by observing the behaviour of riders at road junction reported that 36% of riders used only the rear breake and 11% of used only the front breake. Even in an emergency, 19% still used the rear breake and 35% used the front breake.This study shows that in efficent breaking system and breaking problem are one of the major reasons for accidents.

At present, with the advances in vehicle technology, breaking system of motorcycles have improved. One of the recently introduced improved breaking system is Anti-lock brake system. An Anti-lock brake is a closed-loop system that reduces wheel locking during breaking, resulting in improved vehicle stability and control during stopping maneuver (Fildes, Newstead, Rizzi, Fitzharris & Budd., 2015). The same study indicates that the effectiveness of ABS in reducing crash risk for motorcycle is higher than for passenger car. ABS are designed to use brakes up to the limit of the friction available, without fear of falling to the ground (Elliott et al., 2003).

Recent studies demonstrate that ABS fitment reduces motorcycle injury crashes in Europe up to 39 %, 37% in US and 33% in India (Fildes et al., 2015). As a result, fitment of ABS for motorcycles now been mandated in major markets such as all 28 member states of the European Union (EU), Japan, Taiwan, Brazil and announced in India too (Sporner & Kramlich, 2003). Howver, in Sri Lanka, number of vehicles with

ABS techonology is very less. One of the reasons is, motorcycles with ABS are expansive in Sri Lankan market compared with the cost of motorcyles without ABS.

2.4.2 Vehicle Age and Maintenance

Analysis of accident data in Sri Lanka from 2008 to 2012 indicate that 65% of motorcycles involved in accident are less than five years old (Amarasingha, 2015). It shows that nearly two-third of vehicles involved in accidents are new vehicles driven by younger riders.

Many motorcycle riders belive that they can make mechanical repairs or adjusments themselves because they can see the components. It leads to the poor repairing or maintanance of the bike. A study by Hurt, Ouellet and Thom (1981) reported that vehicle related to accident causation are rare and likely to be due to deficient or defective maintenance. Technical fault contribute only 3% of accidents (Norwegian Public Roads Administration and Norwegian Motorcycle Union (NMCU), 2014).

2.4.3 Engine Size

There is no scientific evidence that engine size is a major factor in motorcycle accidents and does not emerge as a sereious risk factor (Honk, Klootwijk & Ruijs., 1997). Riders of bikes over 125 CC had accident liabilities (for ‘all accidents’) that were 15% lower than riders of smaller bikes (Sexton, Baughan, Elliott & Maycock., 2004). The same study revealed that however, there appeared to be an effect of bike size on accident severity.

Recently in Sri Lanka too, the usage of bikes over 100 CC has been becoming very popular among younger riders. As the engine size increases, sensation seeking motives, lessiure seeking motives and risk taking behaviour also increases since the increased engine capacity support the riders to achieve high accelaration.This will further worsen the road safety situation of the country.

2.4.4 Day Time - Conspicuity of Motorcycles

Not seeing a motorcycle has been reported to be a common cause of accidents during the both hours of day light and at night. Difficulties in identifying motorcycles occur as a result of poor conspicuity of motorcycle due to their smaller size and lower fequency than other road vehicles, as well as the visual limitations of other road users. Conspicuity is an important factor with respect to the interaction of morcycles with other taffic (McCarthy et al., 2007; Hawrath & Schulze, 1996).

One way of increasing increasing interaction of motorcycles with other traffic is, Day time Running Lights (DRL). The use of head lamps during the day time is compulsary for powered two wheelers in Australia, Belgium, Switzerland, Germany and Spain for motorcycles with the capacity greater than 125 cc (Paine, Haley & Cockfield, 2004).

The UK on the spot motorcycle accident study (McCarthy et al., 2007) showed that 40% of cases head lights were off at the time of accident. Smither & Torrez (2010) concluded that use of high and low beam head lights drecresase the crash involvement. Many researches recommended to use head lights and running lights to improve day time conspicuity (Hawrath & Schulze, 1996; Huang & Preston, 2004).

2.4.5 Night Time – Conspicuity of Motorcycles

A motorcycle has only one head lamp which as a provider of visual cues, has several draw backs. At night ‘not seen’ may be interpreted in diffeent ways. These can be classified as;

- Inefficent bright to attract attention perticularly when competing with other vehicles which have powerful pairs of lights.
- A single light may not be identified as belonging to motorcycle in a comlex traffic.
- A single light provides poor cues compared with two lights as spaced on four-wheeled vehicles.

When lightning system is out of order, it causes short vision to the motorcyclist especially during the night (Ndunguru, 2016). In depth investgation of motorcycle

accidents by EAMM (2003) reported that 19% of accidents took place at night in areas where there was street lightning and 3.7% in area without street lightning.

A 55 W quartz halogen headlamp was the simplest and most effective aid to night-time conspicuity (Elliott et al., 2003). A study by Olson, Halstead-Nussloch & Sivak (1980) disclosed that night time-conspicuity is aided by retro reflective garments and running lights. However, in Sri Lanka, the usage of reflective garments among riders at night time is very rare. At the same time, proper maintanace of tile lights and breaking lights also very important as they contribute very much to the night time conspicuity.

2.5 Injury Patterns and Severity

The likelihood of injuries are extremely high in motorcycle accidents. The cost of motorcycle crashes is not just measured in bodies, loss and grief. Motorcycle crashes creates a burden to society, consuming public funds for emergency response, and insurance premiums. NCIPC (2016) reported that economic burden from motorcycle related injuries and death in one year alone totalled $12 billion.

Injury severity increases with collision speed, and the lack of head protection. Head protection accounts for the most severe but preventable injuries. Elliott et al (2003) revealed that serious injuries produced when the motorcycle impacted another vehicle, either at roughly 90 degrees to the face, or at a relatively small angle.

A comprehensive study of motorcycle fatalities by Behera et al (2009) disclosed that head injury, including cervical spine injuries, was the common cause of death (74%) and heavy motor vehicles were the offender in maximum number of cases (34%). Ministry of Transport - Newzeland (2013) reported that on average, the risk of being killed or injured in road crashes is 22 times higher for motorcyclist than for car drivers over the distance travelled.

The increase in the number of casualties is mainly due to increased nmber of motorcycles and the increase in the distances being tavelled. Elliott et al (2003) reported that 12 motorcyclist are killed per 100 million vehicle kilometers comparred with car it is 0.3.

2.6 Motorcycle Safety in Low – and – Middle Income Countries

Low and middle income countries are badly affected by traffic- related injuries and fatalities. This is largely because they don't have the national structure in place to promote and enforce quality road safety laws and regulations.

Vulnerable road users represents the most significant group of victims of road crashes in low and middle income countries. Because of the greater variety and intensity of traffic mix and lack of separation from other road users. Vulnerable road users include motorcyclist, cyclist and pedestrians.

Powered Two - Wheelers (PTW) play a very important role in the mobility and transport system of the low - and - middle income countries. Among 1.24 million people killed every year on road, 90% of casualties live in low - and - middle income countries, and depending on the country, up to 74% casualties are PTW riders (OECD, 2015).

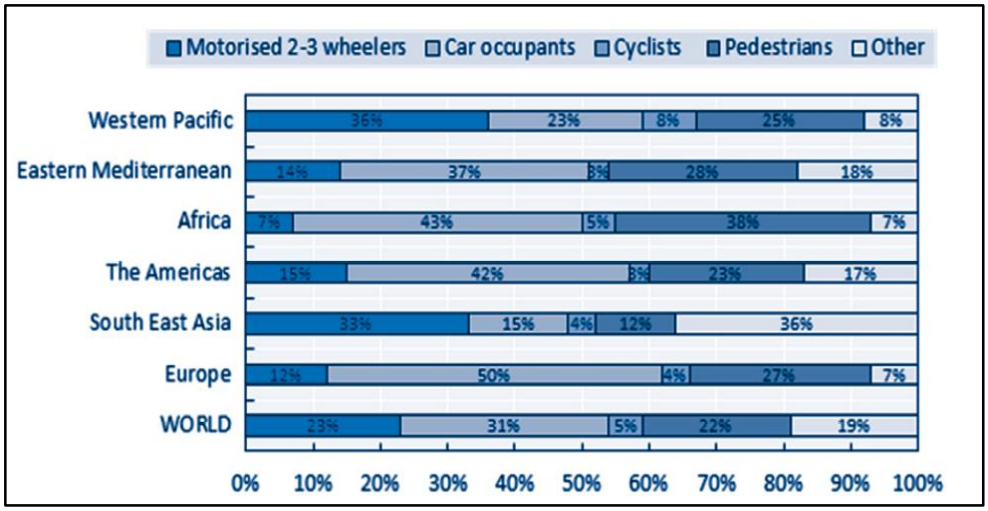

Figure 2.1: Road Traffic Death by Road User (2012)

Source: WHO (2013)

The figure 2.1 shows that there is high fatal risk to motorized 2-3 wheelers in Western Pacific region followed by South East Asia where the percentage of 2-3 wheelers passengers died in road accidents was 33%.

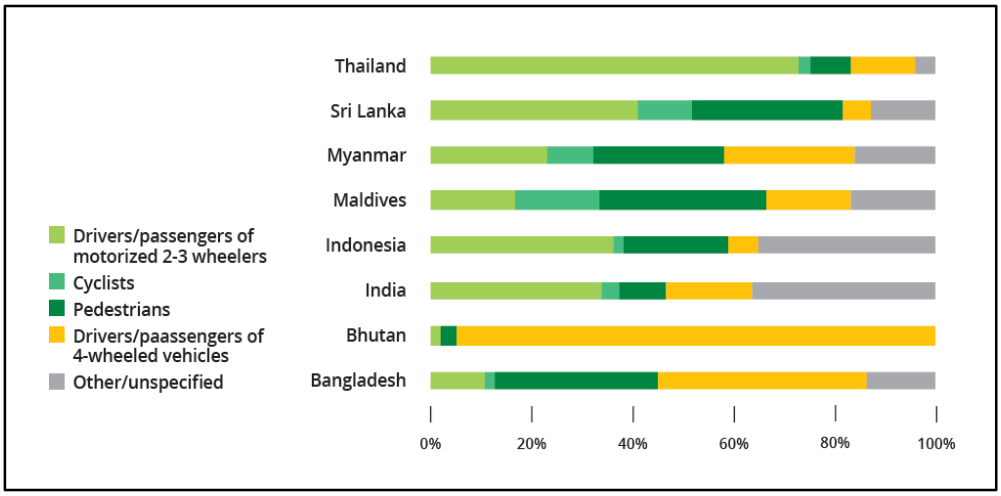

Figure 2.2: Distribution of Road Traffic Death by Road User (2015)

Source: WHO (2016)

The Figure 2.2 briefly give the idea about the distribution of road traffic death by road user in year 2015. It shows that nearly 75% of passengers of motorized 2-3 wheelers died in Thailand. Sri Lanka is the second front runners in the death of passenger of motorized 2-3 wheelers which accounts for nearly 43%. In year 2015, 1,025 motorcyclists died out of 2,816 over all fatality recorded which accounts for 36% of the total fatality. When compared to other countries in the region like India, Indonesia and Bangladesh, this figure is very much high.

The Figure 2.3 explains about the distribution of powered two wheeler (PTW) users killed in 2010 across many countries in the world. As discussed above, more fatal occurred in Thailand. The percentage of PTW users killed in Pakistan was 39%, Indonesia 36% and India 32%. In the same year, 906 motorcyclist killed in Sri Lanka which accounts for 34% of total fatalities (2721) recorded. When compared with India this is little higher.

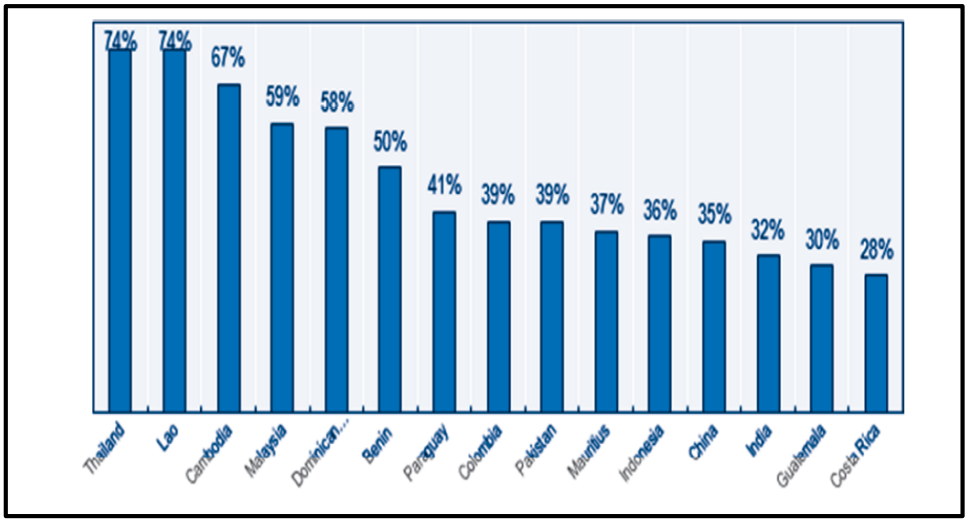

Figure 2.3: Low-Middle-Income Countries with highest Percentage of Powered Two Wheeler Users Killed in 2010

Source: WHO (2013)

2.6.1 Motorcycle Safety in India

In 2011, there were 100 million motorizes two-wheelers in India, representing 70% of motor vehicle fleet in the country (OECD, 2015). In year 2016, Motorcycles contributed to 34% (162,280) of total accidents and 31% (41,608) of fatal accidents. Around 29% (44,366) of road users killed in motorcycle related accidents and 31% (153,060) sustained injuries (Ministry of Road Transport & Highways Transport Research Wing [MRT&HTRW], 2017).

In India, there were 52,500 motorcyclist died in road accidents which is 34.8% of total fatal accidents. This figure was 31.5% in year 2015. It shows a 3.3% (6,430) incresae in an year. Motorcycle riders are front runners in road accidents in India also (MRT&HTRW, 2017).

2.6.2 Motorcycle Safety in Malaysia

Motorcycle is the most preferred, convenient and affordable mode of transport in Malaysia also. In 2013, there were 10 million Powered Two Wheeler (PTW), representing the half of the total registered vehicle population of the country. 90% of the fleet has an engine capacity of 250 CC or less with the majority of motorcycles between 100 and 250 CC. In 2012, PTW accounted for 61% of the total road deaths

(OECD, 2015). In year 2001, Motorcycle ownership per 1,000 Malaysians was 230, Taiwan 523, Vietnam 107, but in Sri Lanka this figure was just 91 even in year 2014 (Hsu, Pen, Sadullah & Dao, 2003). Exclusive motorcycle lanes are provided in some highways in Malaysia to reduce motorcycle accidents. A study revealed that 14 km length of exclusive motorcycle lane installed along Federal Highway (F02) had led to a 25% reduction of the motorcycle crashes (OECD, 2015).

2.6.3 Motorcycle Safety in Bangladesh

In a report on 'Road Safety in Bangladesh Ground Realities and Action Imperatives' revealed that motorcycles share 12% in total accidents followed by bus 38%, trucks 30% , car 11% and baby taxis 9% in year 2013 (Power and Participation Research Center [PPRC], 2014). In 2015, there were approximately 1.5 million registered motorcycles in the country out of 2.6 million registered motor vehicles fleet which accounts for 57% (Ahamed, 2016). In the same year, registered motorcycle population in Sri Lanka was 3.6 million and which was 53% of the total registered vehicle population. But, contribution of motorcycles to accidents in Bangladesh is very much less compared to Sri Lanka. According to WHO (2016), in the year 2015, passenger of 2-3 wheelers died in accidents in Bangladesh was close to 10% (240) out of 2376 fatal recorded. But, in Sri Lanka it was around 43%.

2.6.4 Motorcycle Safety in Vietnam

In 2011, motorcycle population in Vietnam was 34.0 million which was 95% of total vehicle (35.8 million) fleet of the country (Tuan, 2015). Motorcycle ownership rate was 400 MC/ 1000 population. In year 2011, motorcycles contributed to 75% of total accidents 68% of fatal accidents . In year 2014, road traffic death in Vietnam was 10,950 and serious injuries accounted for 48,356 (Tuan, 2015). When compared with Sri Lanka, motorcycle population and fatality is very much high in Vietnam.

2.6.5 Motorcycle Safety in Indonesia

A study on road accidents in Indonesia revealed that most of the people who were killed in road accidents were riders of two or three wheel vehicles , which is about 61% and motorcycle population account for 83% of total vehicle fleet followed by passenger cars 10% and commercial vehicles 7% (Soehodho, 2015).

2.6.6 Motorcycle Safety in Thailand

In most countries of South-East Asia, especially Thailand, motorcycles are the most widely used mode of transportation and the main source of road traffic injury risk. A report indicate that 67% of traffic related morbidity and mortality among individuals younger than 15 years were related to motorcycles (WHO, 2015). Alcohol use was a key factor in Bangkok accidents. Roadway design and maintenance problem were contributory factors in 13% of accidents (WHO, 2015).

According to the World Health Organization's (WHO) Global status report on road safety 2015, almost half of the estimated 1.25 million deaths of the world's roads per year are among those with least protection. That is vulnerable road users which include motorcyclists (23%), pedestrian 22% and cyclist 4%. As per the available records at police headquarters little over 8 deaths are reported every day in Sri Lanka due to road traffic accidents in which nearly 3 are motorcyclist. Promoting public transport will reduce accidents due to motorcycles (Per & Haji, 2005).

Lack of institutions responsible for road safety and lack of laws, Lack of knowledge of traffic rules and lack of enforcement, Lack of proper infrastructure, including poor or low maintenance, sale of low-cost PTWs and Lack of data to properly asses safety issues in general and of PTW in particular are identified as specific challenges in general, including PTW safety in low-middle-income countries (OECD, 2015).

3 METHODOLOGY AND DATA COLLECTION

3.1 Source of Data

Accident data was retrieved from the Police Accident Database (2012-2014) and accident related statistics retrieved from the web site of the Ministry of Transport and Civil Aviation, Sri Lanka for the years 2015 and 2016 also were used for the analysis. Traffic Police is responsible for collecting and recording of accident data received from different police stations in Sri Lanka. Police accident database consists of three main sections, namely, Attendant Circumstances, Vehicle Details and Casualty Details. Attendant Circumstances provide details about accident environment, severity of accident and basic details related to accident. Vehicle Details provides basic information about Vehicle, Driver or Pedestrian involved in accident and crash pre-crash factors contributed to accident interns of driver, vehicle and road. Casualty details, where details of people involved in accident and accident severity are recorded. All these three information are recorded separately in MS ACCESS database linked by a unique ID. This unique ID is called 'Accident Key' which is very useful in extracting required information from data base.

All these information in Police Accident Database are initially entered by police officers in respective police division in a 'Road Accident Report Sheet' which consists of four pages. A sample of 'Road Accident Report Sheet' is shown in annex – I. Devasurendra (2016) mentioned that multiple choices given to any given variable in the data sheet helps to maintain the accuracy of data to an acceptable level by reducing the degree of freedom given to police officers.

Curently, there are 41 Police Divisions in all over the Island. All the accident reported to police are entered in road accident report sheet in the relevent police divisions and transferred to the main system established in Colombo.

3.2 Methodology

Accident data was retrieved from the Police Accident data base (2012-2014). Two traffic elements involved, or two vehicles only involved, Motorcycle - Motor vehicle,

Motorcycle – Pedestrian, Motorcycle – Bicycle and Motorcycle self-accidents was used to develop the database for the study. Damage only accidents were not considered in this analysis because of their under-reporting issues (Devasurendra, 2016).

Here, accident severity is considered as the dependent variable; others are independent variables. Human factors, Environmental factors, vehicle factors are some of the independent variables considered in this analysis. Some variables were converted as a categorical variable in order to obtain more meaningful results (age, time of accident occurred). The response is binary variable, which represents two levels: '**0**' represents the accidents which result '**no fatality but at least have one injury**', '**1**' represents the accidents which result '**at least one fatality'**. The binary logistics method was used for analysis.

Other than the accident data, vehicle registration, operating vehicle population and census data also were used to be incorporated in the analysis.

3.2.1 Logistic Regression

Logistic regression is generally used to study relationship between a binary response variable and a group of predictors can be either categorical or continues. This method has been widely used by scholars for accident severity analysis. In Sri Lanka, the logistic regression modelling carried out for heavy vehicle related crashes to find out the factors affecting the severity of accident (Devasurendra, 2016). Other than this numerous studies have adopted logistic regression models in identifying risk factors involved in road traffic accidents (Wilson, Fang, Wiggins & Cooper, 2003; Mirzaei et al , 2014)

Binary data in this model are numerically represented by combination of zeros (0) and ones (1). The logistics formulas are stated in terms of the probability that Y=1, which is referred to as P. The probability that Y=0 is 1-P.

For an example,

> $P_{MCL\text{-}Lorry}$ (Y=1) means that probability of motorcycle accident with lorry is being fatal.

$P_{MCL\text{-}Lorry}$ (Y=0) means that probability of motorcycle accident with lorry is being non -fatal.

The 'Odds' of an event is defined as the probability of the outcome event occurring divided by the probability of the event not occurring (Long, 1997).

$$\text{Odds}_{MCL\text{-}Lorry} = \frac{P_{MCL\text{-}Lorry}\ (Y = \text{Fatal})}{P_{MCL\text{-}Lorry}\ (Y = \text{Non-Fatal})}$$

$$\text{Odds}_{MCL\text{-}3Wheeler} = \frac{P_{MCL\text{-}3Wheeler}\ (Y = \text{Fatal})}{P_{MCL\text{-}3\ Wheeler}\ (Y = \text{Non-Fatal})}$$

In this study, relative risk factors are evaluated using odds ratio method. The odds ratio (**Exp(B)**) is the relative risk of an occurrence of fatal accident when compared to non-fatal accidents (grievous and non-grievous accidents), when a given variable was present.

The odds ratio or fatal risk ratio for MCL-Lorry accidents is calculated with respect to MCL-Three wheelers accidents as shown below.

$$\text{Odds Ratio (OR)} = \frac{\text{Odds}_{MCL\text{-}Lorry}}{\text{Odds}_{MCL\text{-}3Wheeler}}$$

The OR gives the relative amount by which the odds a variable increase (OR > 1.0) or decrease (OR < 1.0) when the value of one of the predictor variables is increased by one unit.

When considering vehicle type involved in accident with motorcycles, three wheelers represented the highest percentage. Therefore, fatal risk ratio or odds ratio (fatal) for motorcycle accidents with other vehicle types was estimated based on motorcycle accidents occurring with three wheeler. Likewise, the categories with maximum percentage in the database was chosen to be made the first category where possible and odds ratio or fatal risk ratio was calculated.

In cases where the category with the highest percentage is 'unknown' or 'not applicable', the next highest category was chosen to find out the relative risk. For example, when the 'human pre-crash factors' contributed to motorcycle-motor vehicle accidents is taken to account, 55% of occasions the human pre-crash factor is recorded as 'Other or Not known, Therefore, comparing relative risk with respect to this will not give any meaningful results. Therefore, the variable with the next highest category in the same group 'Aggressive or negligent driving (35%)' was recoded in SPSS software in order to become the first category and selected to compare the relative risk factor. Likewise, relative risk factors in between the other variables were calculated. Variable coding and re-coding are explained clearly in Appendix-D.

Significance of each factor contributed to accident severity is tested by using likelihood ratio test. Likelihood ratio test is a test of the significance of the difference between the likelihood ratios for the researcher's model minus the likelihood ratios for a reduced model. Factors with P-values < 0.05 are identified as significant and considered as most influential factors on the accident severity.

This analysis is also called univariate analysis, is based on the assumption that the dependent variable is influenced by only one independent variable, while keeping all other variables constant.

3.2.2 Hosmer – Lemeshow Test

The Hosmer and Lemeshows' (H-L) goodness of fit test divides subjects into categories based on predicted probabilities and then computes a Chi-square from observed and expected frequencies. Then a probability value is computed from the Chi-square distribution to test the fit of the logistic model. If the H-L goodness-of-fit test statistics is greater than 0.05 as we want for well-fitting models, fail to reject the null-hypothesis that there is no difference between observed and model-predicted values, implying that the model fits the data at an acceptable level.

3.2.3 Maximum Likelihood

Maximum Likelihood (ML) is a way of finding the smallest possible deviance between the observed and predicted values. In SPSS statistical package, computer

uses different “iterations” in which it tries different solutions until it gets smallest possible deviance or best fit. Once it has found the best solution, it provides the final value for the deviance, which is usually referred to as “negative two log likelihood” shown as “-2 Log Likelihood” in SPSS.

3.3 Preparing Motorcycle Accident Database from the Base Data

Using the SPPS 23.0 statistical package, Motorcycle (**MCL**) involved fatal, grievous and non-grievous accidents with Motor Vehicle, Pedestrians, Cyclists and Motorcycle self-accidents were analyzed. As discussed in the Chapter 3.1, accident database consists of three main data sets such as Attendant Circumstances, Vehicle Details and Casualty details. Casualty related details mainly consist of details included in the Vehicle Details Sheet. Therefore, data in Attendant Circumstances and Vehicle Details were used for the further analysis.

Initially, all the data in MS ACCESS accident data base were directly imported to MS-EXCEL. Vehicle data sheet consists of details of vehicles involved in the accident. Vehicle details are entered in the “Element Type” column. Initially, accidents related to MCL were filtered which is denoted by “5” in Element type column.

Finally, a database was prepared which consists of MCL related two traffic elements involved fatal, grievous and Non-Grievous accidents. Damage only accidents were not considered in this analysis because of the under reporting issue (Devasurendra, 2016).

From the MCL related accident database, MCL - Motor vehicle, MCL- Pedestrian, MCL-Bicycle and MCL self-accidents data were developed in the same way as described above. Likewise, for each year from 2012 to 2014 the data was prepared.

Thereafter, for each type of accident, these three years of data files were merged carefully and a final data base was prepared. Unnecessary data to the analysis such as Station No, East, North coordinates, link, Nod etc were removed.

Now, the final data base consist of two types of variables. Namely, categorical and continuous variables. Highest severity of accident, township accident occurred (urban

or rural), day of week, collision type, second collision, road surface condition, weather condition, light condition, accident location, and pedestrian location accident occurred are categorical variables. Time of accident, vehicle age, driver or pedestrian age, number of years license issued are continues variables. To get meaningful results these continues variables were converted to categorical variable. For example, time of accident occurred divided in to time interval of three hours starting from mid night.

After that, descriptive analysis was performed for each variable in the accident database to get basic idea about the contribution of each parameter to accident severity.

4 RESULTS AND DISCUSSION

4.1 Overview of Motorcycle Accidents in Sri Lanka

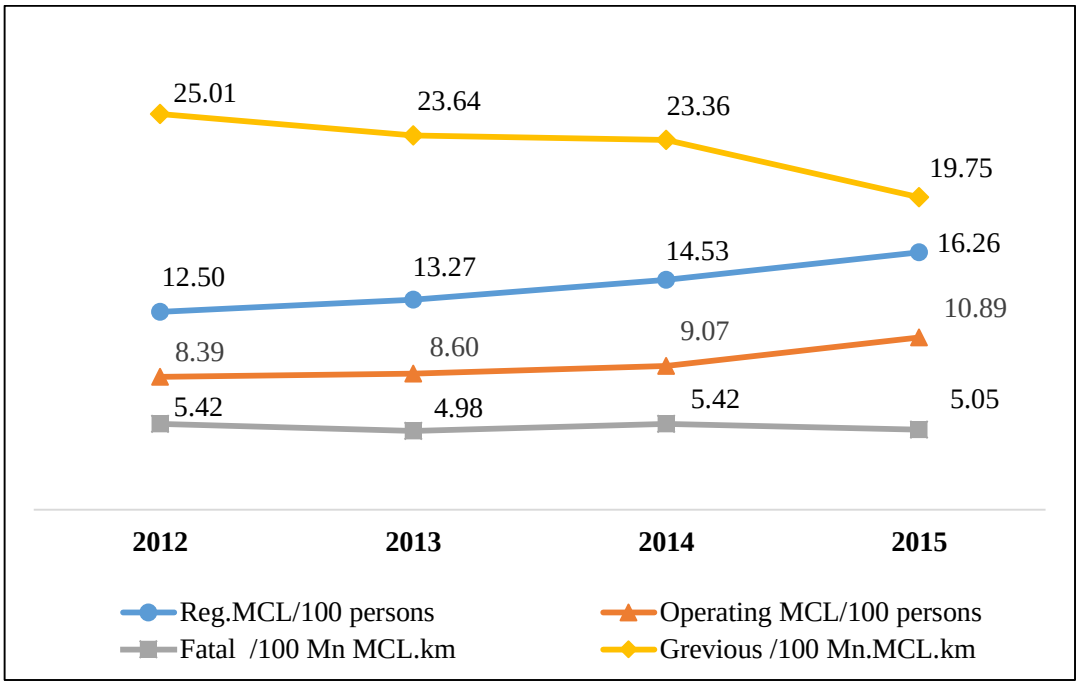

Figure 4.1: Comparison of Registered, Operating MCL Population per 100 Persons, Fatal, Grievous Injuries to Motorcyclist per 100 Million MCL kilometers

Sources: Census Data, Sri Lanka Socio Economic Data, www.motortraffic.gov.lk

The figure 4.1 gives the overall view about registered and operating motorcycle (**MCL**) population, fatal and grievous injuries to motorcyclist per 100 million motorcycle kilometer travelled with in the country. It shows that registered and operating MCL population has been increasing every year. But, grievous injuries per 100 Mn/MCL.km shows the decreasing trend whereas the fatal risk is averaged to 5.22 fatal per 100 Mn /MCL.km travelled. Accident rate per unit of exposure (travel) can be reduced by improving rider skills, proper training, education and giving attention on vehicle performance, maintaining road standards, legislation and enforcement (Per & Haji, 2005).

Figure 4.2 shows the comparison between all accidents reported in a year verses motorcycle accidents. It shows that MCL related accidents accounts for nearly 40% of total accidents and approximately half of the total fatal, grievous, non-grievous

injuries recorded throughout the last three years. It is a very serious safety and health related issue in Sri Lanka which need to be attended immediately.

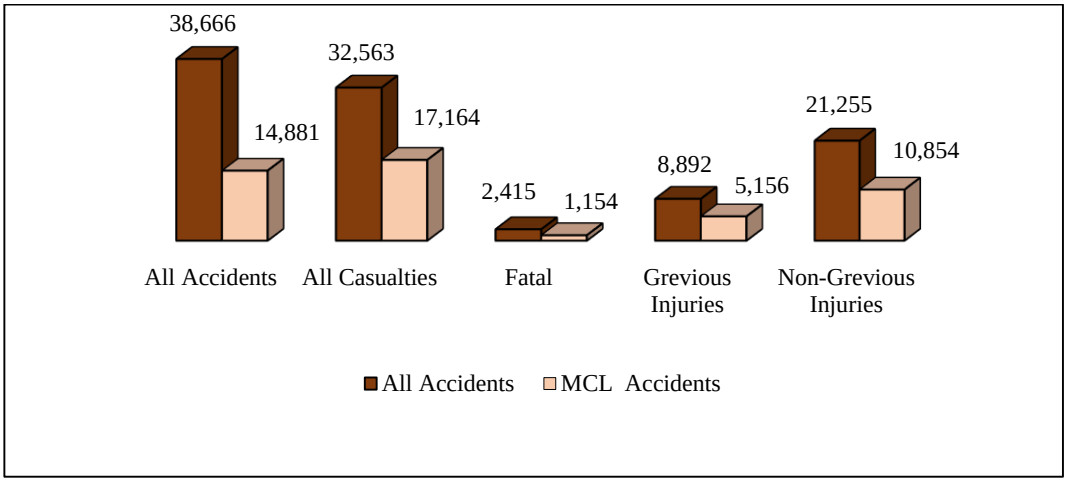

Figure 4.2: Comparison of Total Road Accidents and Motorcycle Accidents

Figure 4.3 shows the fatal injuries to motorcyclists (Rider and Pillions) in roads and all road users killed in road accidents every year. In the year 2012, 835 motorcyclists killed in road accidents which has increased to 1227 in the year 2016. This is approximately 98 fatal injuries increase per year within a 4 years period. When total fatal injuries in all accidents are concerned, it is increased by 125 per year with in the same period. It shows that MCL accidents contribute significantly to the growth rate of accidents and fatality which is nearly 50% to the growth rate of accidents as a single traffic element.

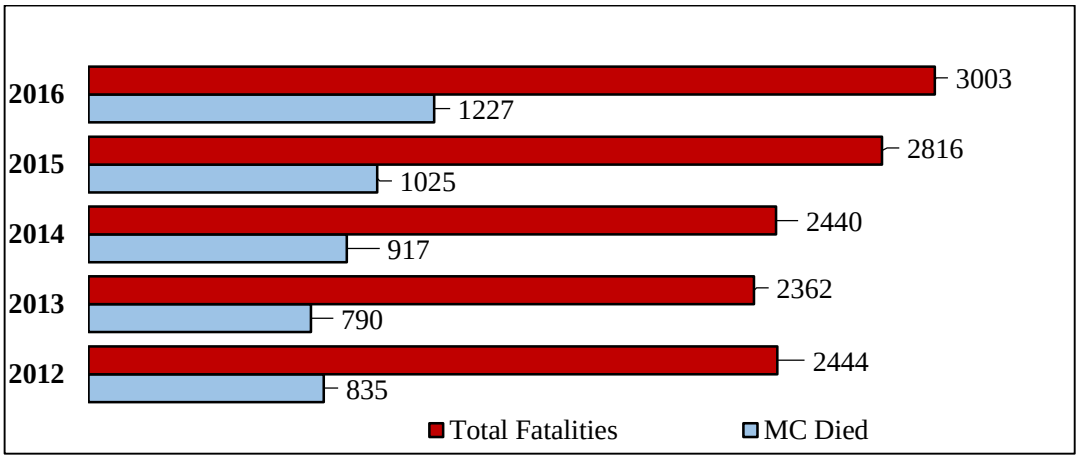

Figure 4.3: Comparison of All Fatalities in Road Accidents verses Motorcyclist Died

Figure 4.4 shows the distribution of different road users involved in fatal accidents in year 2015. Accordingly, the major categories which contributed to fatal are motorcyclists (36%), 29% of pedestrian and 9% of cyclist.

When compared with the figures published by the WHO, Global Status Report on Road Safety 2015, Motorcyclist in Sri Lanka face approximately 1.60 times more fatal risk compare to motorcyclists in all over the world. Likewise, other vulnerable road users such as pedestrians and cyclists face 1.32 times and 2.25 times more risks respectively.

Figure 4.5 illustrate the type of traffic element sustained fatal injuries in MCL related accidents. It shows that nearly 73% of motorcyclists were killed in MCL related accidents followed by pedestrians 19% and cyclist 7%. Further, motorcyclists are at great risk at MCL related accidents and they create significant risk to other vulnerable road users such as pedestrians and cyclist.

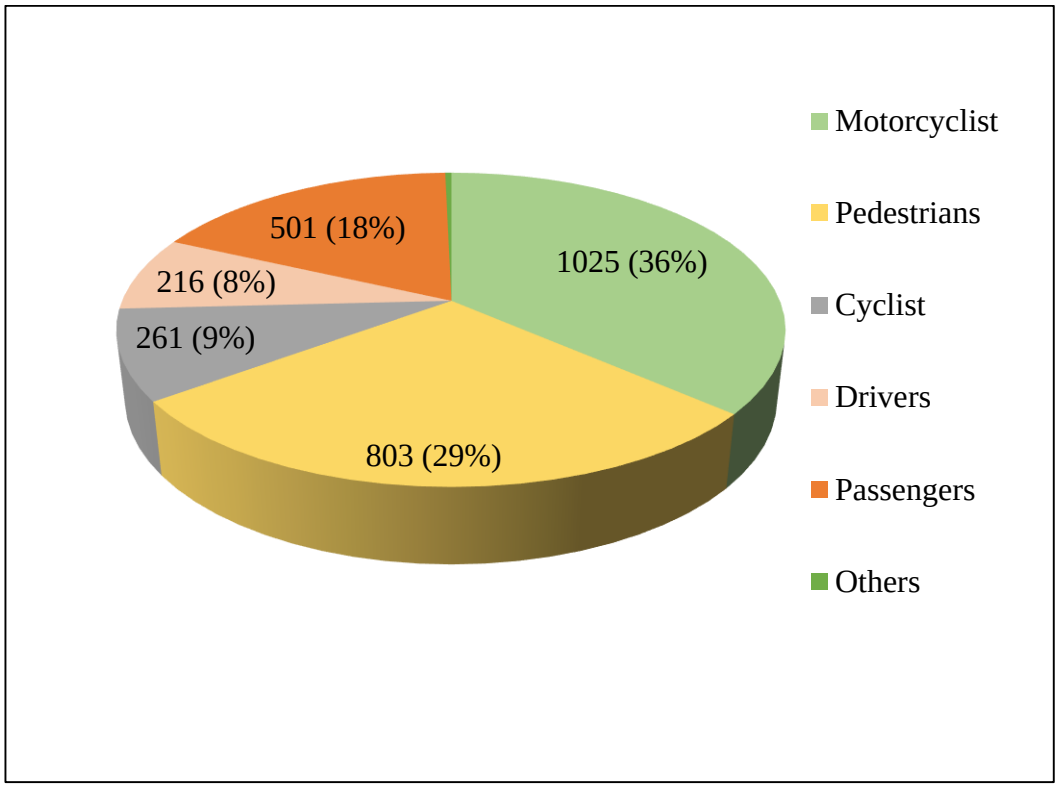

Figure 4.4: Fatality in Road Accidents in Year 2015

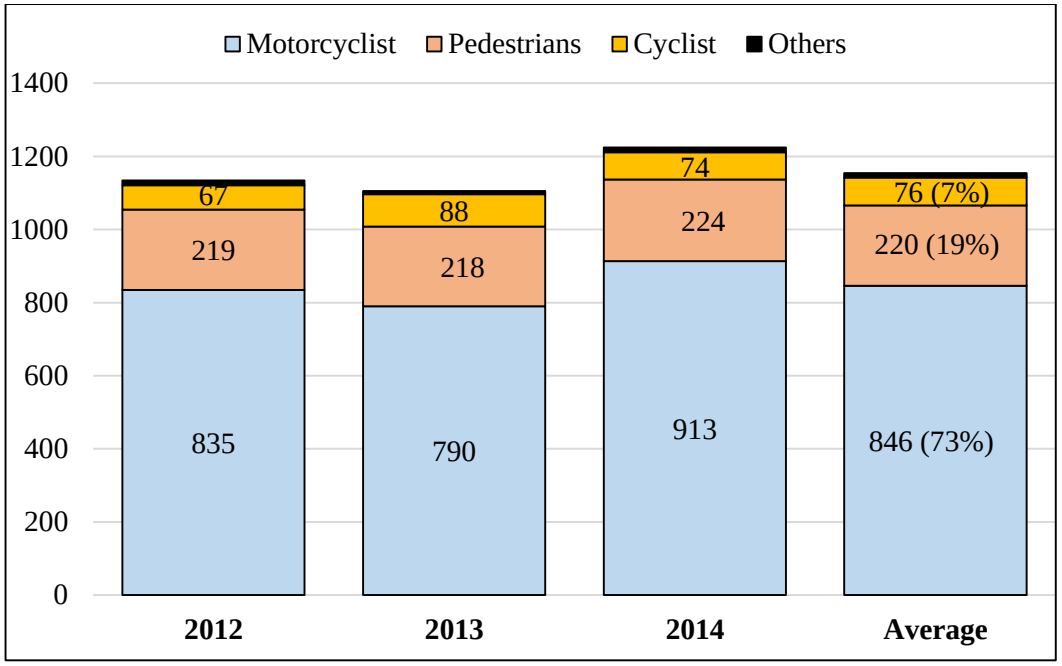

Figure 4.5: Traffic Elements Sustained Fatal Injuries in MCL Related Accidents

Motorcycle users consist of two components; rider and pillions. Figure 4.6 shows the comparison of rider and pillion deaths in road accidents. Rider and Pillion fatality accounts for nearly 80% and 20% respectively. Figure 4.7 describes the grievous injuries to both rider and pillion in motorcycle accident. The percentage of riders and pillion sustained grievous injuries is approximately same as in the fatal accident. Children under age six (preschoolers) and seven to twelve accounts for nearly 1.5% of casualties in motorcycle accidents.

When this is assessed with percentage of pillion ridership in motorcycles, an observation study on four locations: two locations entering and leaving the city of Kandy, a rural area in the Kandy district, and the high way (A1) leading to Colombo from Kandy indicate that riders accounts for 70% (883) and Pillions accounts for 30% (371) (Dharmaratne, Jayatilleke, Abeyrathna, Mabharana & Kumbukgolle, 2013). In addition to this, an observation study was done along CRWB (A004) road from (363+000 to 424+000) revealed that, in 2,547 observations made, 1,797 (70%) were riders and 750 were pillions (30%). It also gave the same figure revealed in the study.

It can be concluded that pillion ridership in motorcycles is around 30% to 35% and fatal and grievous risk is about 20% and 22%.

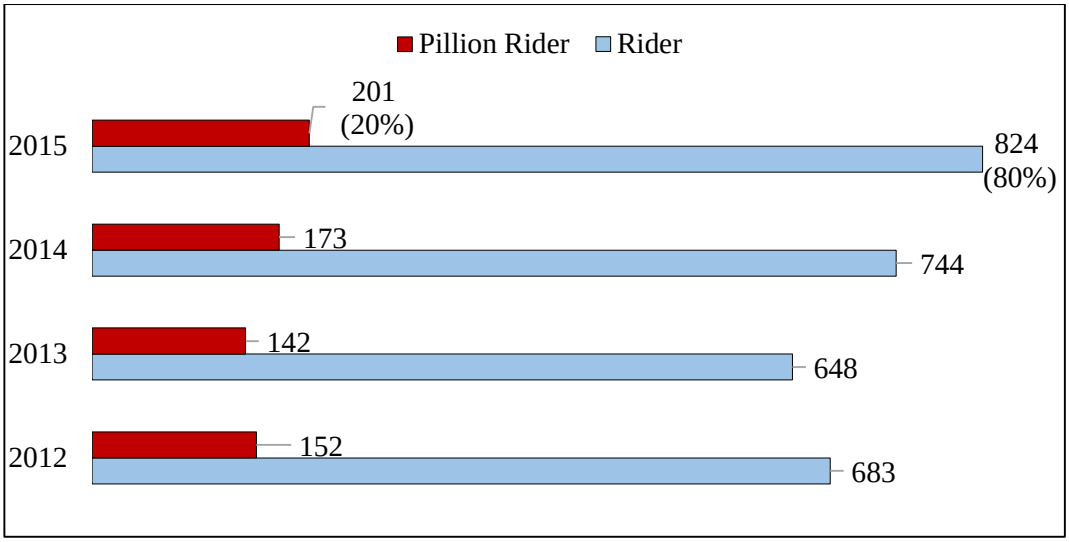

Figure 4.6: Comparison of Rider and Pillion Fatality in Road Accidents

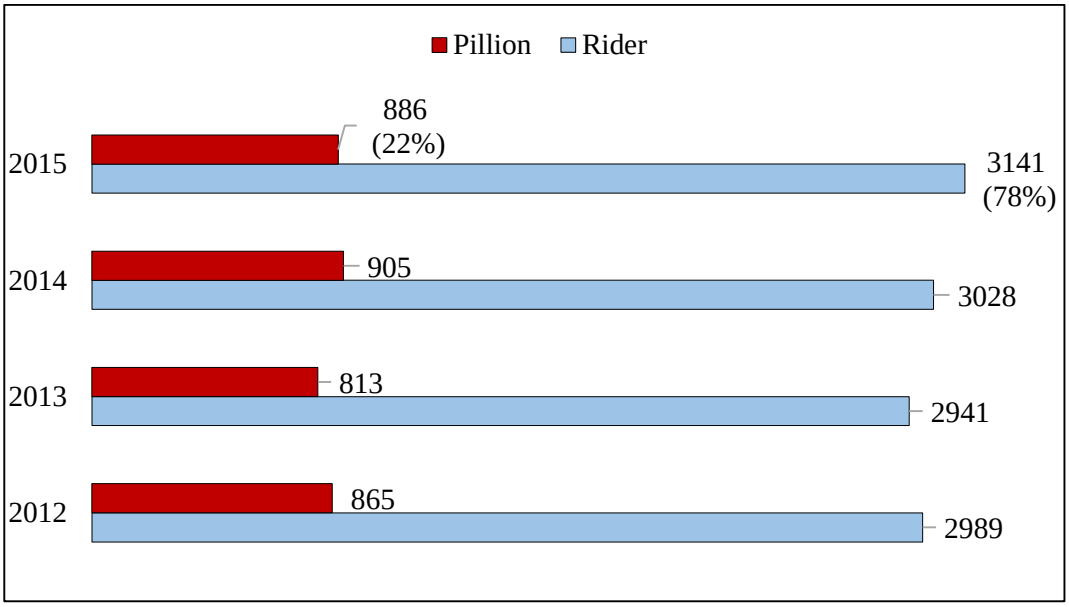

Figure 4.7: Comparison of Rider and Pillion Grievous Injuries in Road Accidents

Table 4.1 shows the fatality of motorcyclists in road accidents per 10,000 operating motorcycles in each province in Sri Lanka. It reveals that there is more fatality per 10,000 operating motorcycles in Sabragamuva Province and less in Central province. Though numbers of operating MCLs are high in Western province, fatality per 10,000 operating motorcycles is less. Overall fatality to 10,000 operating MCL fleet in Sri Lanka is 4.76 and grievous injuries is 21.63.

Table 4.1: Motorcycle Accident Summery, Province-wise, Since 2012-2014

Risk to Motorcyclists							
No	**Province**	**No of accidents/ year**	**Number of fatalities / Year**	**No of grievous injuries/ Year**	**Operating MCL population /Year**	**Fatality / 10,000 operating MCL**	**Grievous Injuries / 10,000 operating MCL**
1	Sabragamuba	965	71	307	94,572	7.47	32.46
2	North Central	978	96	363	140,197	6.87	25.89
3	Southern	1,804	119	482	240,461	4.93	20.04
4	Northern	732	63	192	129,829	4.83	14.79
5	North Western	1,729	135	612	288,360	4.69	21.22
6	Uva	567	31	166	67,280	4.66	24.67
7	Eastern	1,111	67	299	154,843	4.35	19.31
8	Western	5,958	227	1,169	569,830	3.98	20.51
9	Central	1,038	37	256	93,189	3.97	27.47
Total / Average		**14,881**	**846**	**3,847**	**1,778,560**	**4.76**	**21.63**

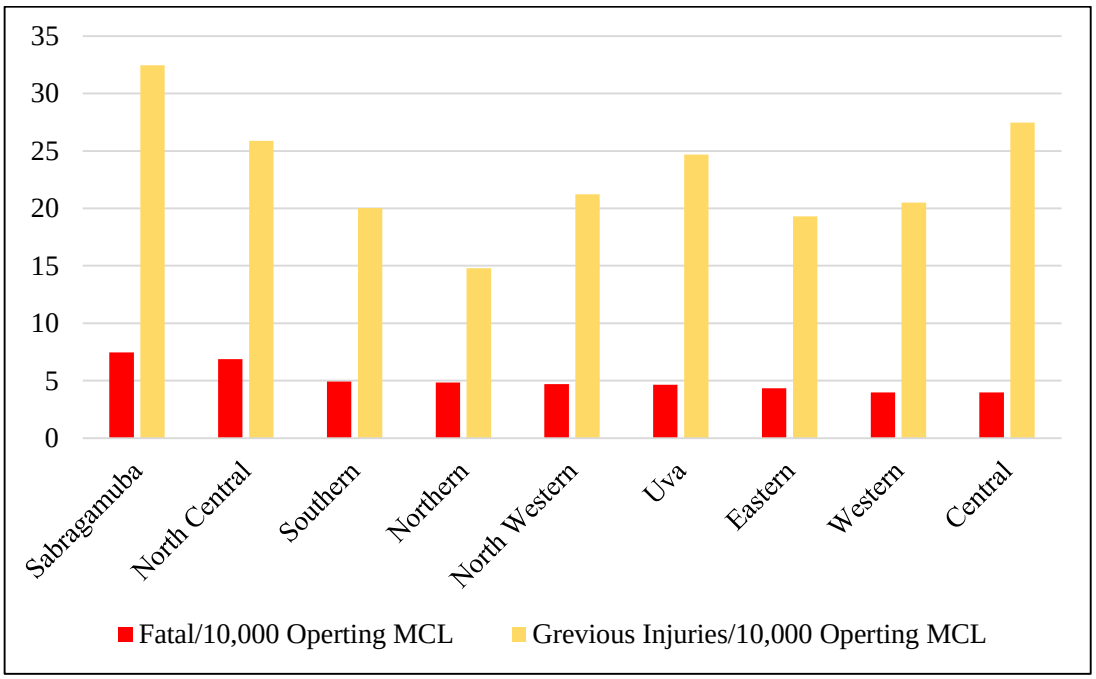

Figure 4.8: Fatal and Grievous Injuries to Motorcyclists per 10,000 Operating Motorcycles in Each Province

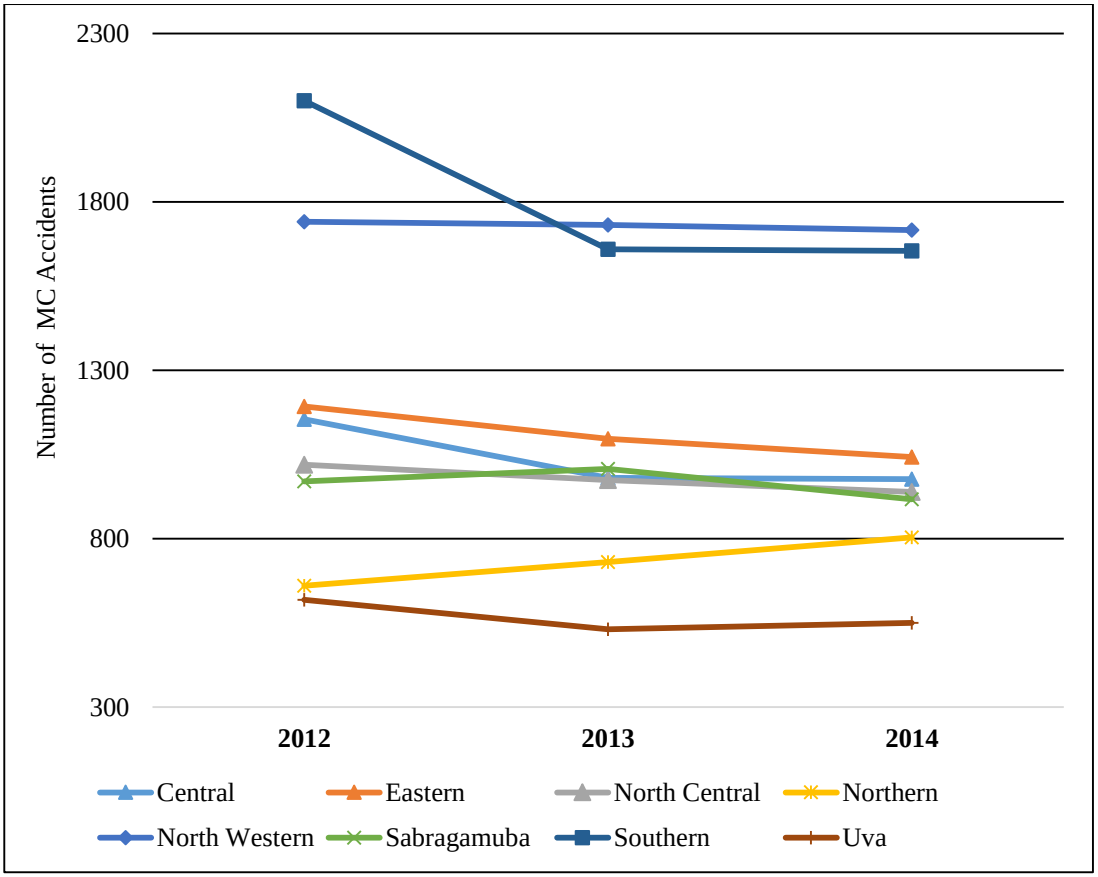

Figure 4.9: Number of Motorcycle Accidents in Each Provinces

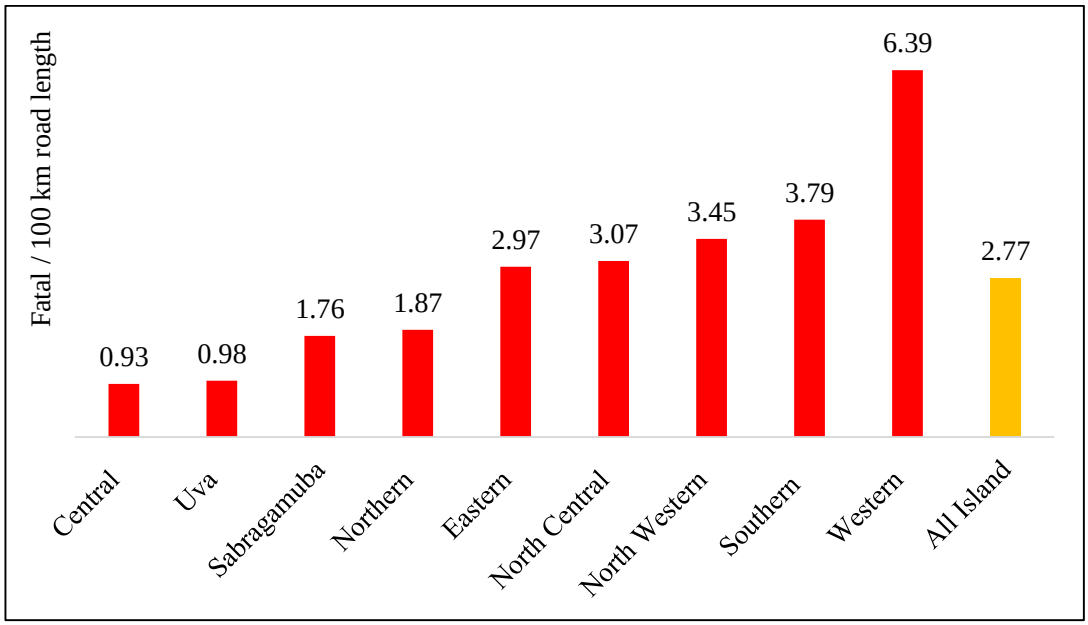

Figure 4.10: Fatal Injuries to Motorcyclist per 100 km Road Length in Each Province

The Figure 4.10 shows the MCL fatal rate per 100 km road length in each province. The road length include all A, B, C & D class roads excluding expressways. MC population is high in Western province where fatality rate of motorcyclists is 6.39 per 100 km. In the meantime, total length of road network is high in North Western province where fatality rate per 100 km road length is only 3.45. The national figure is 2.77 fatal per 100 km road length.

Therefore, by considering above results, motorcycle accidents are analyzed under four categories which includes MCL – Motor Vehicle Accidents, MCL-Pedestrian accidents, MCL-Bicycle accidents and MCL- Self accidents.

4.2 Motorcycle – Motor Vehicle Accidents

Motorcyclist are in great danger in Motorcycle – Motor Vehicle accidents compare to other vehicles users. Because, Motorcycle is a two wheel vehicle, it becomes unstable during accidents and motorcyclist sustain severe injuries. Compare to other vehicles, there is no or less protection to motorcyclist during accidents. This results in loss of lives and permanent disabled of thousands of motorcyclists. Because of its smaller size and easy maneuvering, it is easy for motorcyclist to filter the road traffic and overtake. It results in severe accidents.

Motorcycle – Motor vehicle accidents can be classified as Motorcycle accident with Car, Dual Purpose vehicle, Lorry, Three-wheeler, Articulated vehicle or Prime mover, Bus and Land vehicle. A Chi-square analysis was done between the vehicle type and severity of accidents. The damage only accidents were excluded in this analysis due to under reporting issues. The obtained Chi-square value was 689.153 at 0.05 significance level. It exposes that there is a strong relationship vehicle type and severity of accidents.

Fatality in motorcycle accidents with different types of vehicles were estimated with respect to the operating vehicle fleet. Estimating risk based on registered number of each type of vehicle will not give meaningful results. Therefore, the risk to motorcyclist was estimated based on operating vehicle fleet of each types of vehicles.

Table 4.2 shows that motorcycles share more than half of the total operating vehicle fleet in this country. Three wheelers contributes to 21% followed by motor cars 11%, dual purpose vehicles 7.75% and lorry 5.99%. During the period from 2012 to 2014, the operating vehicle fleet of motorcycle increased by 9.25% and for three-wheelers it is 16.84% which indicates significant growth of motorcycles (**MCL**) and three-wheelers within a short period of time. The growth rate of these small vehicles on roadways has created significant safety related issues.

Table 4.3 indicates the number of motorcyclists killed in road accidents with different types of motor vehicles. It shows that more than one third (34.63%) of motorcyclist are killed in MCL – lorry accidents followed by 18.48% in bus related accidents, 17.12% in dual purpose vehicle related accidents and 15.95% in MCL-MCL related accidents. MCL population growth rate of 9.25% within three years has increased the fatality to motorcyclists by 38% whereas increase of three-wheeler population of 16.84% has increased the fatality by 78%. Further, 14.24% increase of dual purpose vehicles population has increased the same by 76%. Accordingly, fatality to motorcyclist increase significantly with the growth rate of above vehicles.

Table 4.2: Details of Operating Vehicle Fleet in the Country

Vehicle Type	**Operating Vehicle Fleet in 2012,2013 & 2014**				**Percentage (%)**
	2012	**2013**	**2014**	**Average**	
Motorcycle	1,708,611	1,760,356	1,866,714	1,778,560	50.17
Three-Wheeler	688,249	744,860	804,179	745,763	21.04
Motor Cars	368,047	390,056	418,459	392,187	11.06
D.P.Vehicle	256,176	275,454	292,661	274,764	7.75
Lorry	214,939	211,625	210,155	212,240	5.99
Land Vehicle	98,904	99,107	93,642	97,218	2.74
Bus	43,281	43,784	46,246	44,437	1.25
Total	**3,378,207**	**3,525,242**	**3,732,056**	**3,545,169**	**100.00**

Sources: Sri Lanka Socio - Economic Data 2013, 2014, 2015

Table 4.3: Motorcyclists Death in Motor Vehicle Accidents

MC collision with	Number of motorcycle users died in 2012, 2013 & 2014				Per (%)
	2012	2013	2014	Average	
Lorry	186	174	175	178	34.63
Bus	93	86	105	95	18.48
D.P.Vehicle	67	79	118	88	17.12
Motorcycle	71	76	98	82	15.95
Land Vehicle	25	27	23	25	4.86
Three-Wheeler	18	22	32	24	4.67
Motor Cars	19	24	24	22	4.28
Total	**479**	**488**	**575**	**514**	**100.00**

Sources: Police Accident Database 2012, 2013, 2014

Table 4.4: Motorcyclists Grievous Injuries in Motor Vehicle Accidents

MC collision with	Number of motorcycle users sustained grievous injuries in 2012, 2013 & 2014				Per (%)
	2012	2013	2014	Average	
Lorry	590	535	572	566	18%
Bus	304	257	302	288	9%
D.P.Vehicle	458	516	551	508	16%
Motorcycle	792	805	824	807	26%
Land Vehicle	115	96	117	109	4%
Three-Wheeler	498	500	525	508	16%
Motor Cars	352	298	313	321	10%
Total	**3109**	**3007**	**3204**	**3107**	**100.00**

Sources: Police Accident Database 2012, 2013, 2014

Fatalities and grievous injuries to Motorcyclist per 10,000 operating vehicles was estimated using the data shown in table 4.2, 4.3 and table 4.4. Table 4.5 shows the results of the analysis. Fatality to motorcyclist per 10,000 operating buses is very high. Even though, Buses shares the 1.25% of the total operating vehicle fleet in this

country, it creates more fatalities to MCL users. Lorries contribute to 6% of the total operating vehicle fleet. Fatalities to MCL users per 10,000 operating Lorries is 8.39. This is 2.5 times lesser than the fatality from buses. This data is very much useful in advising drivers and motorcycle riders regarding the road safety and take possible countermeasures to reduce accidents.

Table 4.5: Fatality to Motorcyclist per 10,000 Operating Vehicles

Motorcycle Collision with	**Average vehicle fleet in operation**	**Average number of motorcyclist died**	**Average number of motorcyclist sustained grievous injuries**	**Fatality to motorcyclist / 10,000 operating vehicles**	**Grievous injuries to MCL / 10,000 operating vehicles**
Bus	44,437	95	288	21.38	64.81
Lorry	212,240	178	566	8.39	26.67
D.P.Vehicle	274,764	88	508	3.20	18.49
L.Vehicle	97,218	25	109	2.57	11.21
Motor Cars	392,187	22	321	0.56	8.18
Motorcycle	1,778,560	82	807	0.46	4.54
3 Wheeler	745,763	24	508	0.32	6.81
Total	**3,545,169**	**514**	**3107**	**1.44**	**20.10**

Table 4.6: Vehicle Kilometer Travelled (VKT) by Different Vehicles

Vehicle Type	**VKT (Millions)**	**Vehicle Classification**	**VKT (Millions)**			
	2012		**2012**	**2013**	**2014**	**Average**
Motorcycle	15,410.79	Motorcycle	15,410.79	15,873.11	16,797.76	16,027.22
3Wheelers	9,767.52	3Wheelers	9,767.52	10,548.92	11,428.00	10,581.48
Cars & S/Wagons	4,416.52	Motor Cars	5,413.34	5,738.14	6,171.20	5,774.23
Jeep & Pajero	481.03					
Pick up	515.79					

Light Truck	1,284.61	Lorry	4,272.61	4,486.24	4,785.32	4,514.72
Medium Truck	1,403.30					
Large Truck	1,117.99					
SUV	466.70					
Passenger Van	2,253.68	D.P.Vehicle	2,253.68	2,366.36	2,479.04	2,366.36
Tractors	125.67	Tractors	125.67	131.95	133.21	130.27
SLTB Bus	337.83	SLTB Bus	337.83	343.69	371.24	350.92

Source: National Transport Statistics (2015), Estimation of VKT (Jayasekera – 2014)

Table 4.7: Fatal and Grievous injuries to Motorcyclist per 100 Million VKT by different vehicles

Vehicle Type as per accident data sheet	**Average VKT (Millions) (2012-2014)**	**Average Fatality (2012-2014) (MCL)**	**Average grievous injuries (2012-2014) (MCL)**	**Fatal of MCL /100 Million VKT**	**Grievous Injuries to MCL /100 Million VKT**
Motorcycle	16,027.22	81.67	807	0.51	5.04
3Wheelers	10,581.48	24.00	508	0.23	4.80
Cars	5,774.23	22.33	321	0.39	5.56
Lorry	4,514.72	178.33	566	3.95	12.54
D.P.Vehicle	2,366.36	88.00	508	3.72	21.47
Land Vehicle	130.27	25.00	109	19.19	83.67
SLTB Bus	350.92	25.67	68	7.31	19.38

Table 4.7 illustrate the fatal and grievous injuries to motorcyclist with respect 100 million vehicle kilometers travelled by different types of vehicle. Presence of tractors or land vehicles are less in road, fatality to motorcyclists per 100 million VKT by tractors is significantly high compared with other motor vehicles. For each 10 million VKT by Tractors kill approximately two motorcyclists. Fatal and Grievous injuries to motorcyclist by SLTB bus per 100 million VKT is 7.31 and 19.38 respectively.

4.2.1 Descriptive Analysis of Motorcycle – Motor Vehicle Accidents

Motorcycle - motor vehicle accidents are usually complicated events normally contributed by a number of various types of interactions. Examining the characteristic of crash data provides a fairly decent inference at some underlying aspects of the motorcycle - motor vehicle accidents and thus can assist the analysts in devising possible safety counter measures. For the objective of the study, a total of 17,670 observations of complete data points retrieved from police accident database (2012-2014) were used whereby, 7% (n=1,252) fatal accidents, 34% (n=6,072) was grievous injury accidents and 59% (n=10,346) non-grievous injury accidents. The damage only accidents were omitted to maintain the accuracy of database and to avoid probable insufficient data due largely to under reporting.

4.2.1.1 Descriptive Analysis Results of Crash Related Details of MCL-MV Accidents

The main objective of the descriptive results is to provide a better view of characteristics of motorcycle - motor vehicle accidents.

Table 4.8: Gender of Motorcyclist Involved in MCL-MV Accidents

Gender	**Frequency**	**Percentage**
Male	17,059	97.00
Female	611	3.00
Total	**17,670**	**100.00**

Table 4.9: Involvement in MCL-MV Accidents since Numbers of Year License Issued

No of years license issued at the time of accident	**Frequency**	**Percentage**
0 - 2	4,379	25.00
3 - 5	2602	15.00
6 - 10	1694	9.00
10>	2091	12.00
Not Known	6,904	39.00
Total	**17,670**	**100.00**

Table 4.9 indicate the involvement of motorcycle riders in accidents since numbers of year license issued. Number of year's license issued indicates the experience of a rider at the time of accident. In all reported accidents, 39% of cases numbers of year license issued is not known. Among that, 32% of cases riders not have valid license and 7% of cases validity of license is not known. This 7% of population consist of riders not having license, have license but forgot to bring, lost license and police failed to get the record by mistake or not possible for them to get that data due to accident severity of motorcyclist at the scene. These figures indicate the major regulation issues in the country regarding the strict enforcement of licensing system.

Apart from this, nearly 40% of riders involved in accidents with in within 5 years after getting license among them 25% within two years after getting license. It indicates that involvement of new riders in accidents is high. Therefore, it is recommended to implement more training programs to riders before issuing license. But, in Sri Lanka, riders receive less formal training before getting license and most of them are self-learned.

Table 4.10: Motorcycle Accident with other Vehicle Types

Motor vehicle type	**Frequency**	**Percentage**
Three Wheeler	4803	27.00
Lorry	3716	21.00
Dual Purpose Vehicle	3613	20.00
Car	2778	16.00
Private Bus	1541	9.00
Land Vehicle/Tractor	582	3.00
SLTB Bus	486	3.00
Articulated Vehicle	120	0.82
Intercity Bus	31	0.18
Total	**17,670**	**100.00**

Table 4.10 shows the motor vehicle accidents with motorcycle. In total accidents, three wheeler related accidents accounts for 27% followed by Lorry (21%) and Dual purpose vehicle (20%).

In a study, it is recommended that, truck drivers should watch for motorcycles at intersections and those who behind other vehicles (Fagnant & Kockelman, 2015).

Because of the increased seat height, lorry riders face difficulties in seeing motorcycles and competition among lorry drivers in increasing number of trips per day induced them to drive at high speed. Not like dual purpose vehicles, Lorries especially with loads cannot be controlled immediately during accidents.

Operating three wheeler fleet in the country is nearly 3.5 times higher compared to operating lorry fleet. At the same time, vehicle kilometers travelled by three wheelers are 2.40 times higher compared with Lorries. But, percentage of accidents of Lorries with motorcycle is approximately equal to three wheelers. Therefore, immediate measures to be taken to identify the risk factors in motorcycle – lorry accidents.

Motorcycle (**MCL**) accident with SLTB Bus, Private Bus, InterCity Bus accounts for 3%, 9% and 0.18% respectively. Altogether, Buses involve in nearly 12% of motorcycle related accidents. Operating Bus fleet is approximately 6 times less compared with dual purpose vehicles. But, bus accident with motorcycle is 12% where for dual purpose vehicles 20%.

Table 4.11: Age Group of Motorcyclist Involved in MCL-MV Accidents

Age group of MCL riders	**Frequency**	**Percentage**
12-17	227	1.00
18-23	3547	20.00
24-29	3903	22.00
30-35	3319	19.00
36-41	2336	13.00
42-47	1619	9.00
48-53	1218	7.00
54-59	747	4.50
60>=	754	4.50
Total	**17,670**	**100.00**

Table 4.11 indicate the age group of riders involved in MCL-MV accidents. Rider age group between 24 to 29 involved in 22% of accidents and age group 18-23 (20%) and 30-35 (19%) respectively. Riders' age below 41 accounts for 75% of total accidents. It shows that involvement of younger riders in MCL-MV accidents are high in proportion who are productive force of this country.

Table 4.12: Rider Pre-Crash Factors Contributed to MCL-MV Accident

Human pre-crash factor -01	**Frequency**	**Percentage**
Aggressive/negligent driving	6130	35.00
Speeding	1146	6.00
Influenced by alcohol	409	2.00
Error of Judgment	183	1.00
Distracted/In attentiveness	20	0.11
Fatigue / Fall asleep	16	0.09
Blinded by another vehicle	9	0.05
Poor eye sight	1	0.01
Sudden illness	1	0.01
Other/Not known	9755	55.00
Total	**17,670**	**100.00**

Table 4.12 indicates that aggressive or negligent driving of motorcyclists is the casuals' factor for 35% of accidents followed by speeding (6%) and Influenced by alcohol (2%). In 55% of accidents, human pre-crash factor contributed to accident severity is un-known. It is one of the short coming in the police accident recording method. Therefore, necessary steps has to be taken to identify other human factors contribute to accidents and accommodate in accident record sheet. Because, human factor is the major cause for road accidents. Table 4.13 shows that rolled over is the factor for accident severity in recorded 13% of accidents. Here also, in 86% of reported accidents, crash factor contributed to accident severity is not known.

Table 4.13: Crash Factor Contributed to Accident Severity to Motorcyclist in MCL-MV Accidents

Crash factor contributing to accident severity	**Frequency**	**Percentage**
Rolled Over	2303	13
Hitting other fixed objects	72	0
Hitting pole/post	20	0
Hitting barrier	15	0
Hitting road island	13	0
Hitting Tree	12	0
Hitting stone/boulder	7	0
Not Known	15,228	86
Total	**17,670**	**100.00**

4.2.1.2 Descriptive Analysis Results of Crash Environment Related Details of MCL-MV Accidents

Table 4.14 shows the road surface condition at the time of accident occurred. It indicates that 95% of MCL-MV accidents occur in dry road surface condition. Since, Sri Lanka has dry climate throughout many months of a year, it is possible for more accidents to occur in dry road surface condition. Only 4% of accidents recorded in wet surface condition.

Table 4.14: Road Surface Condition in MCL-MV Accident

Road surface condition	**Frequency**	**Percentage**
Dry	16831	95.00
Wet	719	4.00
Flooded with water	85	0.68
Slippery Surface	35	0.32
Total	**17670**	**100.00**

Table 4.15 indicates that more MCL-MV accidents reported in Nugegoda, Colombo, Keleniya and Gampaha police divisions which comes under the Western province and where motorcycle and motor vehicle population are highest in Sri Lanka. Few numbers of accidents are reported in Kankasenthurai, Mannar, Mulaitivu and Hatton Police Divisions.

Table 4.15: Police Division MCL-MV Accident Occurred

DS Division	**Frequency**	**Percentage**
Nugegoda	1416	8
Colombo	1122	6
Keleniya	1047	6
Gampaha	1028	6
Kurunagalle	868	5
Ratnapura	831	5
Kandy	760	4
Anuradapura	734	4
Galle	645	4
Mt.Lavinia	611	3
Negombo	604	3

Panadura	582	3
Matara	572	3
Tangalle	546	3
Kuliyapitiya	544	3
Kalutura	520	3
Elpitiya	497	3
Ampara	465	3
Matale	426	2
Kegalle	384	2
Monaragala	380	2
Polonnaruwa	354	2
Chilaw	338	2
Batticaloa	297	2
Nikaweratiya	274	2
Jaffna	260	1
Puttalam	235	1
Seethawaka	187	1
Badulla	181	1
Vavuniya	141	1
Bandarewela	128	1
Trincomalee	126	1
Kilinochi	123	1
Nuwer Eliya	82	0
Gampola	63	0
Kantale	62	0
Mankulam	59	0
Kankasenthurai	53	0
Mannar	47	0
Mulaitivu	40	0
Hatton	38	0
Total	**17670**	**100**

Table 4.16: Time Range MCL-MV Accident Occurred

Time Range	**Frequency**	**Percentage**
Midnight – 3.00 am	351	2
3.00 am - 6.00 am	358	2
6.00 am -9.00 am	2415	14
9.00 am – 12 Noon	2637	15
12.00 Noon - 3.00 pm	3034	17
3.00 pm - 6.00 pm	4050	23
6.00 pm - 9.00 pm	3341	19
9.00 pm - Midnight	1484	8
Total	**17670**	**100**

Table 4.16 shows that highest number of accidents occurred in between 3.00 pm to 6.00 pm, accounts for 23% of total accidents. Followed by 19% of accidents recorded between 6.00 pm to 9.00 pm. Likewise, 17% of accidents occurred in time period from 12.00 noon to 3.00 pm. In summary, 88% of accidents occurred from 6.00 am to 9.00 pm, at 15 hours interval and only 12% of accidents occurred after 9.00 pm.

Table 4.17: Township MCL-MV Accident Occurred

Town	**Frequency**	**Percentage**
Rural	10723	61
Urban	6947	39
Total	**17670**	**100**

In total number of MCL-MV accidents reported, 61% occurred in rural areas and 39% in urban areas.

Table 4.18: Light Condition at the Time of MCL-MV Accident Occurred

Light Condition	**Frequency**	**Percentage**
Daylight	12136	69
Night, No Street Light	2694	15
Night improper Street Light	1211	7
Night / Good Street Light	965	5
Dusk, Dawn	664	4
Total	**17670**	**100**

When considering the light condition at the time of accident, 69% of accidents occurred in day light condition and 27% occurred in night time and 4% in dusk or dawn. Among 27% of accidents occurred in night time, 22% occurred in roads where no street lights or improper street lights available.

Table 4.19 indicates the collision patterns in MCL-MV accidents. Head on collisions (0120) are more dominant in motorcycle – motor vehicle accidents which contributed to 26% of total accidents followed by rear end collisions (0310) 17%. Motorcycle coming straight collide with vehicle taking U-Turns accounts for 4% of total accidents. It can be reduced by closing additional U-Turn openings provided in national highways, maintaining correct number of U-turn openings and providing

rumble strips ahead of U-turn openings. Because of small in size of motorcycles, it is not possible for drivers to see motorcycles when they suddenly take U-turn and merge with traffic. This situation is further worsen when large trees, flower pots and any other objects placed in center median close to U-turn. Therefore, necessary precautions should be taken to avoid accidents due to these factors.

Table 4.19: Collision Types in MCL-MV Accidents

Collision Type	**Frequency**	**Percentage**
0 120	4653	26
0 310	3040	17
0 110	1232	7
0 210	1017	6
0 411	889	5
0 521	722	4
0 130	668	4
Others	5449	31
Total	**17670**	**100**

- 0120 – Head On collision.
- 0310 – Rear end collision.
- 0110 - Vehicle overtaking to the right Hit MC.
- 0210 – 90^{o} angle collision at intersection.
- 0411 – Side swept
- 0521 - MC travelling straight ahead from other direction crash at 90^{0} angle with vehicle taking right-turn at the junction.
- 0130 – MC travelling straight ahead crash with vehicle taking U-turn to the other side of the road.

4.2.2 Analysis of MCL-MV Accidents 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. As discussed in methodology, logistics regression method is used here to analyze accident severity in order to get more insights about risk factors associated with motorcycle accidents in Sri Lanka.

4.2.2.1 Data Source, Selection and Description

The data set contained a total of 17,670 two vehicle accidents that is one motorcycle struck one vehicle occurred throughout the Island. Out of the figure, 7% (n=1,252) contributed to fatal cases, 34% (n=6,072) was grievous injury cases and non-grievous injury cases comprised of 59% (n=10,346).

The study focus on fatal and non-fatal accidents to analyses the factors contributed to the accident severity. The accident severity level was divided into two categories which are 'Fatal' coded as '1' and 'Not-Fatal' (Grievous and Non-grievous) coded as '0' in SPSS.

Two binary logistics regression models were prepared separately for vehicle details related factors and crash environment related factors. Analysis procedure using SPSS 23.0 software package has been clearly explained in Chapter: 03.

4.2.2.2 Logistics Regression Analysis for Crash Details Model of MCL-MV Accidents

The dependent variable in this analysis is Highest Severity of accident. The independent variables considered are age of MCL, rider gender, validity of license at the time of accident, number of years license issued, road pre-crash factors, vehicle pre-crash factors, other crash factors, alcohol test to rider, vehicle collided with MCL, rider age, human pre-cash factor contributed to accident and crash factor for accident severity. Altogether, 12 independent variables included in the model.

The Table 4.20 shows the results of the forward stepwise Likelihood Ratio (**LR**) regression model for vehicle related details of Motorcycle-Motor Vehicle accidents.

Table 4.20: Stepwise Inclusion of Variables into the Crash Details Model (MCL – MV Accidents)

Variable		Model Log Likelihood	Change in- 2 Log Likelihood	Sig.of the change
Step 1	MV_TY_NEW	-4520.760	721.012	.000
Step 2	NU_YR_LIC_ISS	-4160.254	196.382	.000
	MV_TY_NEW	-4389.608	655.089	.000
Step 3	NU_YR_LIC_ISS	-4114.069	190.964	.000
	MV_TY_NEW	-4340.472	643.770	.000
	RID_AGE_NEW	-4062.063	86.952	.000
Step 4	NU_YR_LIC_ISS	-4079.118	169.760	.000
	MV_TY_NEW	-4307.904	627.331	.000
	RID_AGE_NEW	-4042.935	97.393	.000
	HU_PRE_FAC_NEW	-4018.587	48.697	.000
Step 5	NU_YR_LIC_ISS	-4065.590	170.633	.000
	MV_TY_NEW	-4290.009	619.472	.000
	RID_AGE_NEW	-4028.157	95.767	.000
	HU_PRE_FAC_NEW	-4001.823	43.099	.000
	CRA_SEV_NEW	-3994.239	27.931	.000
Step 6	NU_YR_LIC_ISS	-4056.199	169.824	.000
	RD_FAC	-3980.273	17.973	.003
	MV_TY_NEW	-4279.001	615.429	.000
	RID_AGE_NEW	-4020.066	97.558	.000
	HU_PRE_FAC_NEW	-3991.705	40.837	.000
	CRA_SEV_NEW	-3983.899	25.225	.001

Step 7	RID_GEN	-3971.287	8.964	.003
	NU_YR_LIC_ISS	-4052.227	170.845	.000
	RD_FAC	-3975.626	17.643	.003
	MV_TY_NEW	-4274.813	616.017	.000
	RID_AGE_NEW	-4014.401	95.192	.000
	HU_PRE_FAC_NEW	-3985.927	38.245	.000
	CRA_SEV_NEW	-3979.515	25.420	.001

Insignificant variables in the model were removed in seven iterations in this way. Finally, the model identified rider gender, number of years license issued, road pre-crash factors, vehicle involved in accident with MCL, rider age, human pre-cash factor contributed to accident and crash factor for accident severity are the seven factors significantly related to injury severity of accidents.

The stepwise procedure has terminated the adding of variables to the model since the addition of any other variables did not make any statistically significant difference to the -2 Log likelihood values. Table 4.21 shows the model summery for each step in forward stepwise LR method.

Table 4.21: Model Summery of Crash Details Model in Each Step in Forward Stepwise LR Method

Step	**-2 Log Likelihood**
1	8320.508
2	8124.126
3	8037.174
4	7988.477
5	7960.547
6	7942.573
7	7933.609

Table 4.22: Hosmer and Lemeshow Test Results of Crash Details Model (MCL-MV Accident)

Step	**Chi-square**	**Significance**
1	0.000	1.000
2	7.730	.460
3	9.155	.329
4	2.776	.948
5	4.259	.833
6	4.164	.842
7	6.037	**.643**

At the final step, Hosmer and Lemeshow test value is greater than 0.05. This indicates that the model has a good fit.

Table 4.23: Classification Table of the Results

Observed			**Predicted**		
			Highest Severity		**Percentage Correct**
			0	**1**	
Step 7	Highest Severity	0	16409	9	99.9
		1	1242	10	0.8
	Overall Percentage				**92.9**
a. The cut value is .500					

The overall percentage of the correct classification by the model is 92.9%.

The statistically significant results of the Motorcycle-Motor Vehicle crash model given by the SPSS software package are given bellow.

Table 4.24 shows the statistically significant results of the crash details model of MCL-MV accidents

Table 4.24: Statistically Significant Results of the Crash Details Model (MCL – MV Accidents)

Variable Coding in SPSS	Description	Sig	B	Exp(B)
Accident severity with motorcyclists gender				
RID_GEN	**Male**	0		
RID_GEN(1)	Female	.006	-0.616	0.540
Accident severity with vehicle involved in accident with motorcycle				
MV_TY_NEW	**Three wheeler**	0		
MV_TY_NEW(1)	Dual Purpose Vehicle	**0**	1.302	3.678
MV_TY_NEW(2)	Lorry	**0**	1.990	7.313
MV_TY_NEW(4)	Articulated Vehicle	**0**	2.420	11.247
MV_TY_NEW(5)	SLTB Bus	**0**	2.001	7.398
MV_TY_NEW(6)	Private Bus	**0**	1.914	6.783
MV_TY_NEW(7)	Intercity Bus	**0**	2.960	19.291
MV_TY_NEW(8)	Land Vehicle / Tractor	0	1.847	6.340
Accident severity with riders' age group involved in accident				
RID_AGE_NEW	**Age 24-29**	0		
RID_AGE_NEW(6)	Age 48-53	0	0.538	1.712
RID_AGE_NEW(7)	Age 54-59	0	0.708	2.029
RID_AGE_NEW(8)	Age 60 or above	0	0.960	2.611
Accident severity with riders pre-crash factor contributed to accidents				
HU_PRE_FAC_NEW	**Aggressive or Negligent driving**	0		
HU_PRE_FAC_NEW(2)	Influenced by Alcohol	0.009	0.421	1.523
HU_PRE_FAC_NEW(3)	Fatigue / Fall asleep	0.002	1.815	6.140
HU_PRE_FAC_NEW(8)	Speeding	0.004	0.324	1.382
Accident severity with crash factors contributed to accident severity				
CRA_SEV_NEW	**Rolled Over**	0		
CRA_SEV_NEW(1)	Hitting Pole / Post	0.001	1.840	6.294

- **B** in the above table denotes the logistic coefficient.
- **Exp(B)** is the odds ratio or fatal risk ratio associated with each predictor.
- Variables bolded in each category are used as base variables to calculate odds ratio or fatal risk ratio.

4.2.2.2.1 Accident Severity with Motor Vehicle Type

Fatal accident risk of motorcycles with Lorries is 7.313 times more compared to accidents with three wheelers. In the same way, motorcycle accident with dual purpose vehicle was compared and it is found to be 3.678 times more probable to become fatal.

MCL accident with SLTB Bus has 7.398 time more fatal risk ratio compared with three wheelers. Fatal accident risk of motorcycles with Private Bus is nearly 1.1 times (7.398/6.783) less compared with MCL accident with SLTB Buses.

4.2.2.2.2 Accident Severity with Age Group of Riders

Accidents where rider age group 48 to 53 involved are 1.712 times more probable to become fatal compared to age group 24 to 29. Likewise, fatal risk of accidents where rider age group 54 to 59 and more than 60 years involved are 2.029 and 2.611 times more probable to become fatal compared to age group 24 to 29.

Comparison of risk to riders in terms of their age group shows that involvement of younger riders in MCL-MV accidents are high in proportion compared to older riders. But, fatal risk to older riders in accidents are more than twice compare to younger riders.

4.2.2.2.3 Riders Pre-Crash Factors Contributing to Accident Severity

Accidents due to ‘fatigue or fall asleep’ is 6.140 times more probable to become fatal compared with the accident due to human pre-rash factor ‘Aggressive or negligent driving’. Elliott, et al (2003) suggessted that long MCL journeys should be planed to include frequent rest.

It is concluded that percentage of accidents occur due to Rider pre-crash factor ‘aggressive or negligent driving’ is high. But, when accidents due to rider pre-crash factors such as ‘influenced by alcohol’, ‘speeding’ is compared with this highest category, it is revealed that those accidents are more probable to become crucial though numbers of accidents reported are less.

4.2.2.2.4 Crash Factor Contributed to Accident Severity of Motorcyclist

The Exp(B) value for crash factor contributed to accident severity 'Hitting pole or post' is 6.294. It denotes that accident severity due to 'Hitting pole or post' is 6.294 times more probable to become fatal compared with crash severity to motorcyclists due to 'rolled over'.

Road Development Authority and Highway designers should take necessary measures to reduce accident severity due to hitting road side objects and road furniture.

4.2.2.3 Logistics Regression Analysis for Crash Environment Model of MCL-MV Accidents

The dependent variable in this analysis is Highest Severity of accident. The independent variables considered are second collision, road surface condition, weather, light condition at accident location, accident location type, police division accident recorded, time of accident, urban rural condition, day of week accident occurred, collision type, traffic control and speed limit enforcement . Altogether, 12 independent variables included in the model.

Table 4.25: Stepwise Inclusion of Variables into the Crash Environment Model (MCL – MV Accidents)

Variable		Model Log Likelihood	Change in- 2 Log Likelihood	Sig. of the change
Step 1	DS_DIV_NEW	-4520.760	307.600	.000
Step 2	DS_DIV_NEW	-4477.994	315.711	.000
	TIME_RAN_NEW	-4366.960	93.644	.000
Step 3	DS_DIV_NEW	-4427.133	300.496	.000
	TIME_RAN_NEW	-4322.391	91.012	.000
	COLL_TY_NEW	-4320.138	86.507	.000
Step 4	DS_DIV_NEW	-4394.688	247.760	.000
	TIME_RAN_NEW	-4317.310	93.004	.000

	URV_RUR_NEW	-4276.885	12.153	.000
	COLL_TY_NEW	-4308.877	76.136	.000
Step 5	SEC_COL	-4270.808	14.865	.002
	DS_DIV_NEW	-4385.967	245.182	.000
	TIME_RAN_NEW	-4309.883	93.014	.000
	URV_RUR_NEW	-4269.427	12.103	.001
	COLL_TY_NEW	-4301.294	75.837	.000
Step 6	SEC_COL	-4264.437	14.201	.003
	RD_SUR	-4263.376	12.078	.007
	DS_DIV_NEW	-4381.108	247.543	.000
	TIME_RAN_NEW	-4301.250	87.827	.000
	URV_RUR_NEW	-4263.436	12.199	.001
	COLL_TY_NEW	-4294.073	73.472	.003
Step 7	SEC_COL	-4252.675	13.237	.004
	RD_SUR	-4252.054	11.995	.007
	LOC_TY	-4257.337	22.561	.004
	DS_DIV_NEW	-4368.310	244.508	.000
	TIME_RAN_NEW	-4289.601	87.089	.000
	URV_RUR_NEW	-4250.917	9.722	.002
	COLL_TY_NEW	-4276.274	60.435	.000

This way insignificant variables in the model were removed in seven iterations. Finally, it is found that second collision, road surface condition, location of accident occurred, police divisions accident recorded, time of accident, urban rural condition and collision types are the seven factors significantly related to injury severity of accidents

At the final step Hosmer and Lemeshow test value is 0.654 which is greater than 0.05. This indicates that model has a good fit. The table shows the statistically significant results of the MCL-MV accident environment related model.

Table 4.26: Statistically Significant Results of the Crash Environment Model (MCL – MV Accidents)

Variable Coding	Description	Sig	B	Exp(B)
Accident severity with road surface condition at the time of accident				
RD_SUR	**Dry**	.005		
RD_SUR(1)	Wet	.005	0.359	1.432
RD_SUR(2)	Flooded with water	.037	0.680	1.973
Accident severity with police divisions accident occurred				
DS_DIV_NEW	**Nugegoda**	0		
DS_DIV_NEW(2)	Anuradhapura	0	1.284	3.611
DS_DIV_NEW(5)	Batticaloa	0	1.202	3.328
DS_DIV_NEW(7)	Colombo	.021	-0.674	0.510
DS_DIV_NEW(12)	Jaffna	0	1.138	3.120
DS_DIV_NEW(28)	Polonnaruwa	0	1.305	3.687
DS_DIV_NEW(30)	Tangalle	0	1.229	3.419
DS_DIV_NEW(34)	Mannar	0	1.591	4.906
DS_DIV_NEW(35)	Mankulam	0	1.655	5.232
DS_DIV_NEW(37)	Kilinochi	0	1.590	4.904
DS_DIV_NEW(38)	Kankasenthurai	0	1.812	6.121
DS_DIV_NEW(39)	Mulaitivu	.002	1.472	4.359
Accident severity with time period accident occurred				
TIME_RAN_NEW	**3.00 pm – 6.00 pm**	0		
TIME_RAN_NEW(1)	3.00 am – 6.00am	**0**	**1.032**	**2.806**
TIME_RAN_NEW(5)	Midnight - 3.00 am	**0**	**0.931**	**2.538**
TIME_RAN_NEW(7)	9.00 pm – Midnight	**.001**	**0.371**	**1.449**
Accident severity with township accident occurred				
URV_RUR_NEW	**Rural Area**	0		
URV_RUR_NEW(1)	Urban Area	.002	-0.225	0.798
Accident severity with collision pattern				
COLL_TY_NEW	**0 120**	0		
COLL_TY_NEW(1)	0 130	**0**	**-0.727**	**0.483**
COLL_TY_NEW(2)	0 210	.010	-0.453	0.635
COLL_TY_NEW(3)	0 310	**0**	**-0.515**	**0.597**

- **B** in the above table denotes the logistic coefficient.
- **Exp(B)** is the odds ratio or fatal risk ratio associated with each predictor.
- Variables bolded in each category are used as base variables to calculate odds ratio or fatal risk ratio.

4.2.2.3.1 Accident Severity to Motorcyclist with Road Surface Condition

MCL-MV accident occurring in wet road surface is 1.432 times probable to become fatal compared with accidents occurring in dry road surface. The Exp(B) value for road flooded with water is 1.973. This also can be interpreted in the same way.

It is concluded that 95% of MC-MV accidents occur in dry road surface condition. But, accidents occurring in wet roads and road flooded with water are more probable to become fatal compared with accidents occurring in dry road surface condition.

4.2.2.3.2 Accident Severity in Various Police Divisions across the Country

MCL-MV accidents occurring in Mannar, Mankulam and Kankasenthurai are compared with accident occurring in Nugegoda Police division. Accident occurring in these divisions are 4.906 times, 5.232 times and 6.121 times more probable to become fatal compared with accident occurring in Nugegoda where more numbers of accidents recorded.

These Mannar, Mankulam and Kankasenthurai police divisions are in Northern Province of the country. In meantime, accidents occurring in Killinochi and Mullathivu areas also very much severe. It may be due to difficulties in access to ambulance or health services or vehicle and people movement in these area may be less. Anyhow, further research has to be conducted to ascertain the factors behind this.

Accidents occurring in Colombo was compared with accidents occurred in Nugegoda Police division. Because, vehicle population is very much high in Colombo. Accident occurring in Colombo is 0.510 times less probable to become fatal than accidents occurring in Nugegoda area. It shows that fatal risk to motorcycle riders in Colombo police division is approximately 2 times (1/0.510) less compared with riders in Nugegoda Police division.

It was concluded that MCL-MV accidents are very much crucial in Mannar, Mankulam and Kankasenthurai police divisions whereas, in Colombo police division, fatal risk in MCL-MV accidents are 2 times less compared with accidents in Nugegoda Police division where the highest numbers of accident recorded.

4.2.2.3.3 Accident Severity with Time Period of Accident Occurred

Accidents occurring at night times, 9.00 pm to midnight, midnight to 3.00 am, 3.00 am to 6.00 am are 1.449 times, 2.538 times and 2.806 times probable to become fatal compared with accident occurring between 3.00 pm to 6.00 pm.

It is concluded that MCL-MV accidents are high in percentage between 6.00 am to 9.00 pm. It is because of higher number of vehicle presence in roads during that time. But, when accident severity is concerned, accidents occurring at night time from 9.00 pm to 3.00 am are more probable to become fatal than accidents occurring at evening peak 3.00 pm to 6.00 pm. It may be due to high speed of vehicles during that time due to less traffic in roads. At the same time, access to emergency services and help from other people are probably less during this period.

Therefore, it is suggested that it is better to avoid motorcycle journeys at late night or take necessary precautions to increase the conspicuity during night time including wearing illuminating jackets and light color helmets. In WHO, Global Status Report on Road Safety (2015), it is recommended to use illuminating jackets and protective clothing to enhance the MCL rider safety at night time.

4.2.2.3.4 Motorcycle Accidents in Urbn and Rural Areas

Accident severity of MCL-MV accidents occurred in rural areas compared with the urban areas. It shows that accidents occurring in rural areas are 1.253 (1/0.798) times crucial compared with accidents in urban areas. Shaheed (2007) in a study reported that highway millage in rural roads increases the motorcycle fatalities.

4.2.2.3.5 Accident Severity with Collision Pattern

Collision pattern of motorcycles with other vehicles such as, MCL coming straight collision with vehicle taking U-turn, 90^{o} angle collision at 4-Leg intersection and rear end collision were compared with head on collision in which the highest numbers of accident reported. Accident occurring in these pattern of collisions are 0.483 times, 0.635 times and 0.597 times probable to become fatal compared with head on collision. It reveals that fatal risk in accidents with those collision patterns are less

compared to accidents with head on collisions. Fatal risk in head on collisions are 1.675 (1/0.597) times high compared to rear end collisions.

It can be concluded that head on collision are more dominant and the most risky in MCL-MV accidents. Even though, rear end collisions contributed to 17% of total accidents, fatal risk in this collision pattern 1.675 times less compared with Head on collisions.

4.3 Motorcycle – Pedestrian Accidents

4.3.1 Over View of Motorcycle – Pedestrian Accidents

According to the WHO Global Status report on road safety 2015, pedestrian's deaths of the world's roads per year are 22% and in the total traffic fatalities more than 270,000 are pedestrians. In Sri Lanka, this figure was 31% (762) in the year 2012 and 29% (803) in the year 2015. Though it shows a 2% reduction within three years span, no of death is increasing every year. The comparison of international accident statistics indicate that pedestrian safety has highly improved in developed countries while the situation in developing countries is still serious (Hausmann, 2006).

Fatality of pedestrian in Sri Lanka roads are 1.32 times higher compare to deaths in world roads. At the same time, nearly 30% of pedestrians suffer fatal and 45% suffer grievous injuries due to accident with motorcycles. The figure 4.11 illustrate the pedestrians killed in other road accidents and MCL accidents.

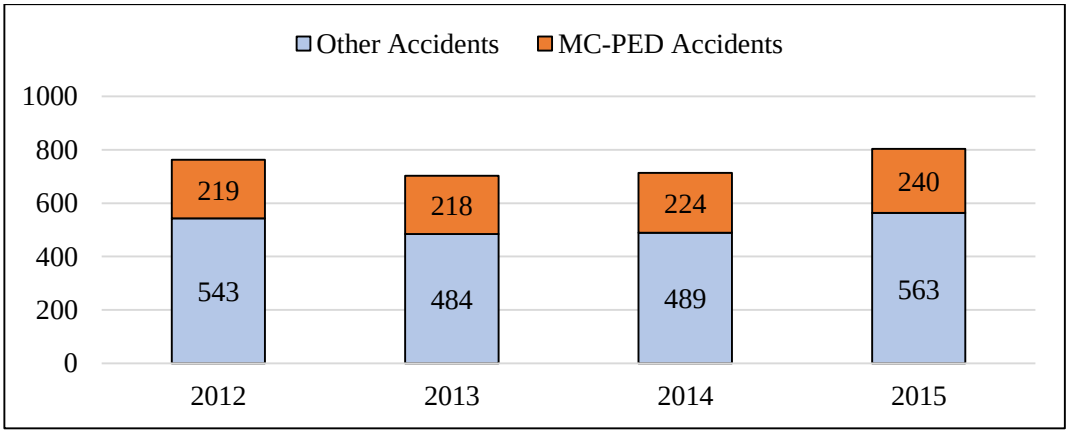

Figure 4.11: Comparison of Pedestrians Killed In Other Accidents and MCL-Pedestrian Accidents

In the year 2014, 723 pedestrians died in road accidents. Out of which, 589 (82%) were killed in two vehicle related accidents. That is one pedestrian and single vehicle accident. The figure 4.12 shows the distribution of pedestrian fatal two vehicle accidents with different vehicle types. Pedestrian fatal accident with MCLs accounts for 38% of total pedestrian accidents followed by dual purpose vehicle 17% and three wheelers 13%.

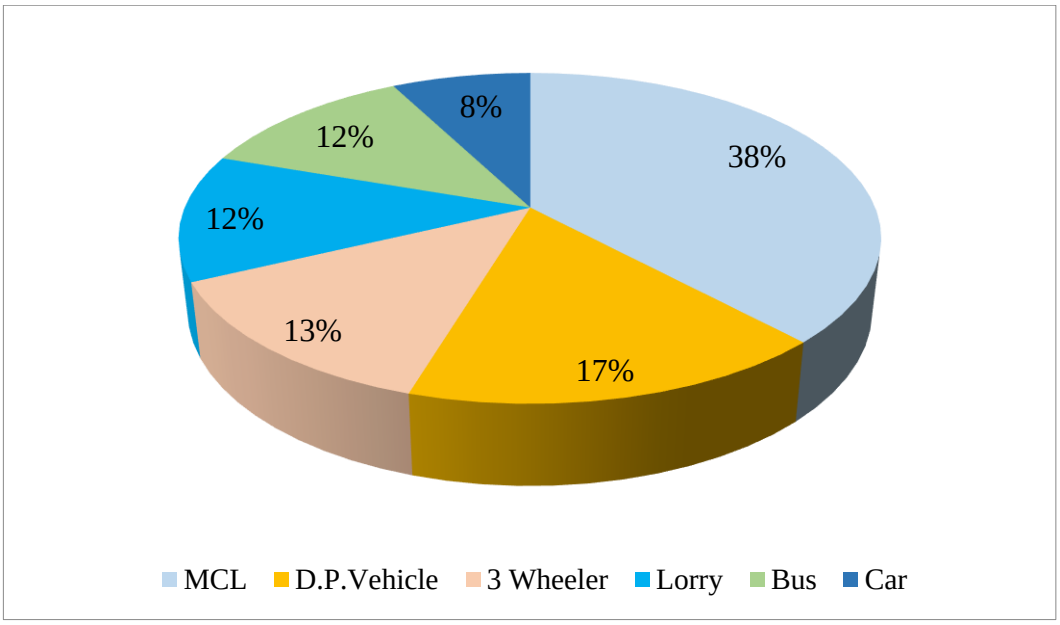

Figure 4.12: Pedestrian Fatal Accidents with Different Vehicle Types

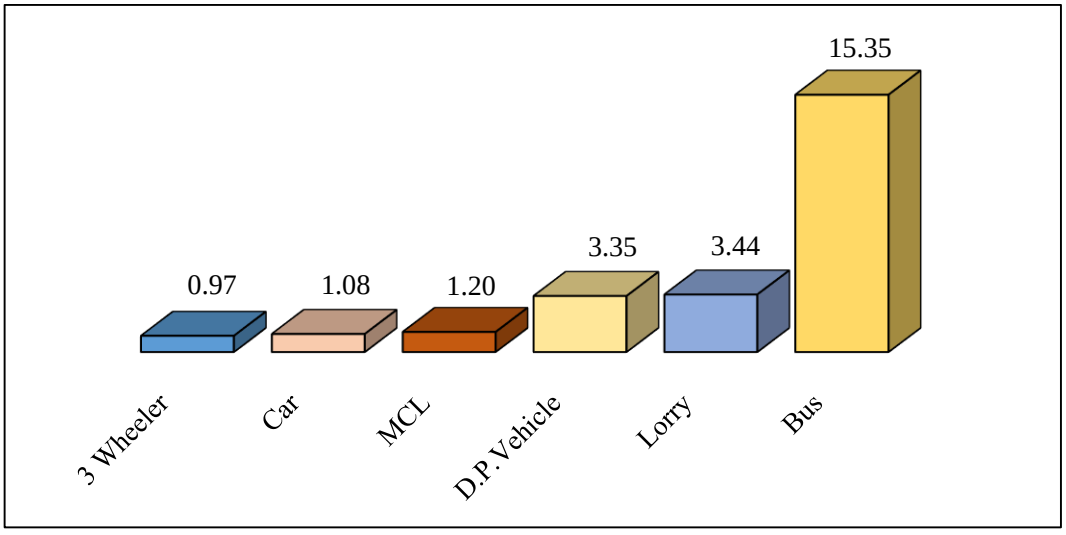

Figure 4.13: Fatality to Pedestrians per 10,000 Operating Vehicles

When fatality of pedestrians per 10,000 operating vehicle is concerned, there is more risk from buses. It accounts for nearly 16 pedestrians killed by 10,000 operating Buses. But, for MCL it's only 1.20. This less value is due to the higher population of MCLs compared to Buses.

When MCL only accidents are concerned, nearly 20% killed in MCL related accidents are pedestrians followed by cyclists 7%.

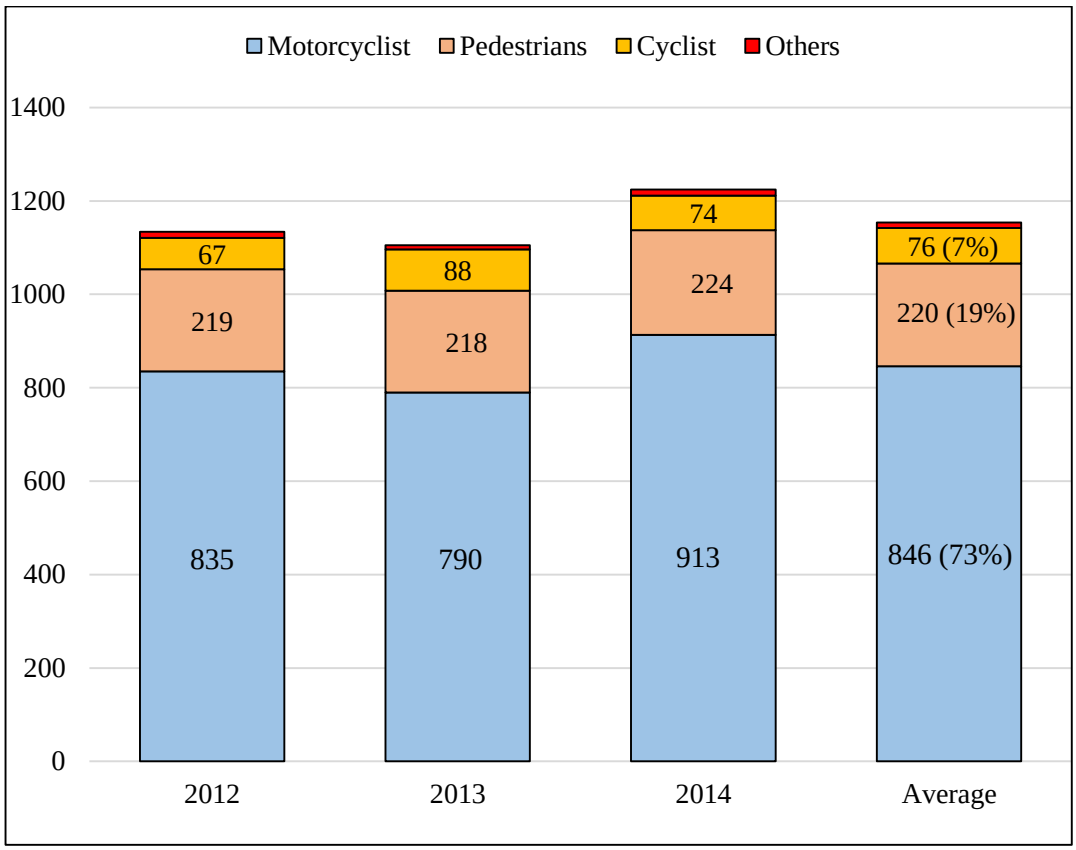

Figure 4.14: Different Road Users Died in Motorcycle Related Accidents

Fatality to 100,000 population from motorcycles are nearly little more than the half of the total fatality to 100,000 population from overall road related accidents. According to the analysis, in the year 2015, fatality of pedestrians in all road accidents per 100,000 population is 3.89 and from MCL related accidents is 1.19. Fatality of pedestrians per 100 Million MCL.km travelled is around 1.21.

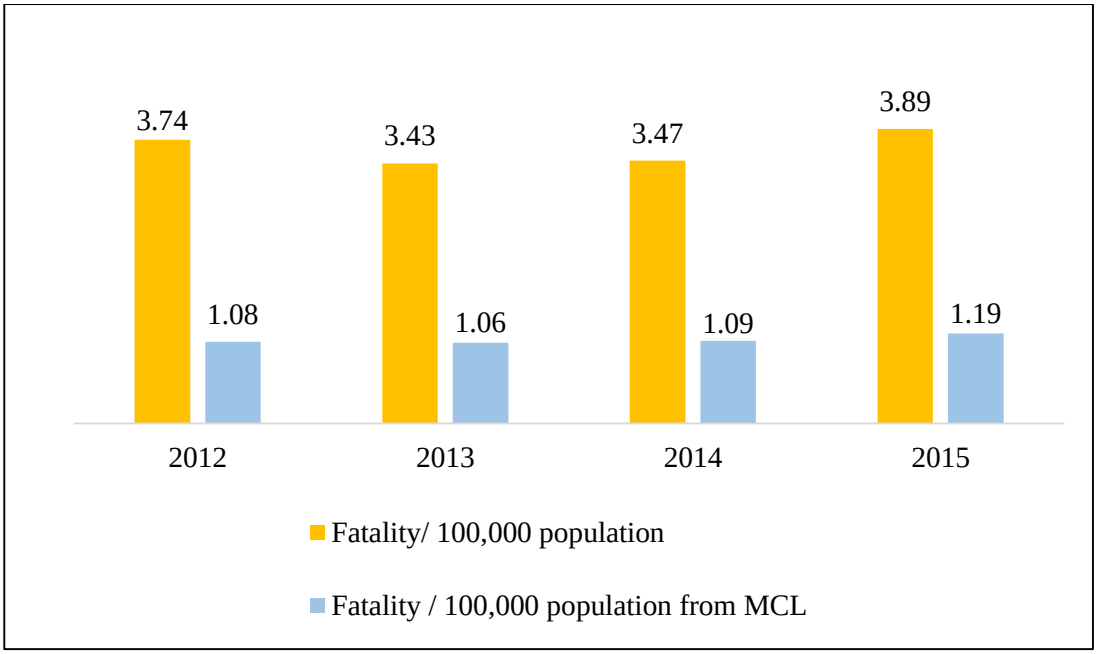

Figure 4.15: Fatality of Pedestrians in Road Accidents per 100,000 Population, Fatality of Pedestrians in MCL Accidents per 100,000 Population

The above results show that MCL - Pedestrian accidents are relatively high in Sri Lanka. Therefore, it is good to understand the associated risk factors in this type of accidents.

4.3.2 Descriptive Analysis of Motorcycle – Pedestrian Accidents

The data set considered for the analysis consist of a total of 7,637 motorcycle-pedestrians only involved single vehicle accidents. That is one pedestrian struck by single motorcycle. Out of the figure, 8% (n=626) contributed to fatal cases, 33% (n=2,524) was grievous injury cases and non-grievous injury cases comprised of 59% (n=4,487). The damage only accidents were omitted to maintain the accuracy of database and to avoid probable insufficient data due largely to under reporting.

4.3.2.1 Descriptive Analysis Results of Crash Environment Related Details of MCL - Pedestrian Accidents

Table 4.27 shows the time where period motorcycle – pedestrian accidents occurred. 91% of total accidents occurred between 6.00 am to 9.00 pm. Among these, the highest number of accidents recorded between 6.00 pm to 9.00 pm accounts for 27%.

This is nearly two folds high compared with accidents occurred in morning and evening peak hours.

Table 4.27: Time Period MCL – Pedestrian Accidents Occurred

Time Range	**Frequency**	**Percentage**
Midnight -3.00 am	70	1
3.00 am - 6.00 am	116	2
6.00 am - 9.00 am	1155	15
9.00 am -12.00 noon	1142	15
12.00 noon - 3.00 pm	1176	15
3.00 pm - 6.00 pm	1433	19
6.00 pm - 9.00 pm	2074	27
9.00 pm - Midnight	471	6
Total	**7637**	**100**

Table 4.28 shows the pedestrian locations where MCL-Pedestrian accidents occurred. Highest number of accidents occurred 50 meters away from pedestrian crossings. That means mid-block section of the road.

In total MCL-Pedestrian accidents, 19% of accidents occurred on roads without side walk. It indicates the lack of pedestrian walk ways on many roads in Sri Lanka or even walkways are available, they are not in the position to use by pedestrians due to lack of maintenance or occupied by street vendors. By considering these facts, Government has to take measures to construct new pedestrian walkways simultaneously, pay attention on maintaining existing walkways and remove obstructions on that.

Hit on sidewalk accidents account for 6% of total MCL-Pedestrian accidents. It is a very pathetic safety situation regarding the safety of pedestrians using walkways. In congested town areas motorcycle riders use walkways to filter the traffic or overtaking purpose. Because of the small in size of MCL, motorcyclists share walkways with pedestrians. Therefore, necessary precautions such as providing safety fences, increasing the level difference between walkways and road surface will reduce this problem.

Table 4.28: Pedestrian Locations MCL – Pedestrian Accidents Occurred

Pedestrian Location	**Frequency**	**Percentage**
PC beyond 50 m	3150	41
Hit on road without side walk	1467	19
On PC	1285	17
PC within 50 m	987	13
Hit on side walk	426	6
Hit outside sidewalk	187	2
Pedestrian Over/Under Pass	100	1
Others /Not Known	35	0
Total	**7637**	**100**

Table 4.29 shows the police divisions where accidents occurred. More MCL - Pedestrian accidents recorded in Nugegoda, Kandy, Keleniya and Colombo and less in Killinochi, Mannar, Mankulam, Hatton and Mulaitivu areas.

Table 4.29: Police Division of MC – Pedestrian Accidents

DS Division	**Frequency**	**Percentage**
Nugegoda	573	8
Kandy	427	6
Keleniya	422	6
Colombo	418	5
Gampaha	411	5
Ratnapura	343	4
Kurunagalle	328	4
Anuradapura	299	4
Matara	288	4
Mt.Lavinia	283	4
Galle	279	4
Panadura	274	4
Ampara	253	3
Elpitiya	233	3
Batticaloa	231	3
Kalutura	216	3
Matale	201	3
Negombo	198	3
Kuliyapitiya	176	2
Monaragala	173	2
Kegalle	168	2

Tangalle	155	2
Nikaweratiya	139	2
Polonnaruwa	131	2
Chilaw	112	1
Badulla	106	1
Seethawaka	98	1
Jaffna	96	1
Trincomalee	88	1
Puttalam	76	1
Bandarewella	75	1
Vavuniya	71	1
Nuwer Eliya	54	1
Gampola	46	1
Kankasenthurai	42	1
Kantale	41	1
Kilinochi	31	0
Mannar	29	0
Mankulam	20	0
Hatton	17	0
Mulaitivu	16	0
Total	**7637**	**100**

When considering the light condition at the time of accident, 64% of accidents occurred in day light condition and 32% occurred in night time and 4% in dusk or dawn. Among 32% of accidents occurred in night time, 18% occurred in roads where no street lights or improper street lights available.

Table 4.30: Light Condition at the Time of MCL-Pedestrian Accidents

Light Condition	**Frequency**	**Percentage**
Daylight	4906	64
Night, No Street Light	1384	18
Night improper Street Light	581	8
Night / Good Street Light	426	6
Dusk, Dawn	340	4
Total	**7637**	**100**

4.3.2.2 Descriptive Analysis Results of Pedestrian Related Factors of MCL-Pedestrian Accidents

Not like any other kind of accidents, involvement of females is significant in pedestrian accidents. In MCL-Pedestrian accidents involvement of female accounts for 44% which is only 12% less compared with male pedestrians involved in accidents.

Table 4.31: Gender of Pedestrians Involved in MCL – Pedestrian Accidents

Pedestrian Gender	**Frequency**	**Percentage**
Male	**4264**	**56**
Female	3369	44
Not Known	4	0
Total	**7637**	**100**

Pedestrian pre-crash factors contributed to accidents is one of the key element to find out the causes of accidents and to take mitigation measures. But, for 94% of MCL-Pedestrian accidents, pedestrian pre-crash factor contributed for accident is not known. It is one of the major drawback in Police accident data collection process. Therefore, measures has to be taken to identify other factors as much as possible and should be included in data sheet.

Table 4.32: Pedestrian Pre – Crash Factor for MCL-Pedestrian Accidents

Pedestrian Pre-crash factors	**Frequency**	**Percentage**
Unexpected pedestrian movement	223	3
Disobey designated crossing	123	2
Poor visibility	79	1
Influenced by alcohol	21	0
Other/Not Known	7,191	94
Total	**7,637**	**100**

Table 4.33 shows the age group of pedestrians involved in accidents. Pedestrians age group 60 and above represents highest percentage of population involved in MCL-Pedestrian accidents accounts for 27%. Children (Age bellow 18) involved in nearly

21% of total accidents recorded. Pedestrian age group 6 to 11, 48 to 53 and 54 to 59 involved in 11%, 11% and 10% of accidents respectively.

Table 4.33: Age Group of Pedestrians Involved in MCL-Pedestrian Accidents

Age Group of Pedestrians	**Frequency**	**Percentage**
0-5	330	4
6-11	843	11
12-17	449	6
18-23	407	5
24-29	353	5
30-35	477	6
36-41	471	6
42-47	642	8
48-53	832	11
54-59	743	10
60>=	**2090**	**27**
Total	**7,637**	**100**

Table 4.34 indicate that nearly 61% of MCL-Pedestrians accidents occurred when pedestrians cross the road from left to right in straight road sections without any visibility obstructions.

Table 4.34: Top Five Collision Patterns in MCL – Pedestrian Accidents

Collision type	**No of accidents**	**Percentage**
Pedestrian entering the road from left side walk or shoulder hit by motorcycle travelling straight	2358	31
Pedestrian entering the road from right side walk or shoulder hit by motorcycle travelling straight	1058	14
Rear end accident	970	13
MC overtaking to the right hit pedestrian entering the road from left side walk or shoulder	703	9
Pedestrian entering the road from right side walk or shoulder hit by motorcycle travelling straight due to visibility obstruction due to parked vehicle on the right side	513	7

4.3.2.3 Descriptive Analysis Results of Rider Related Factors of MCL-Pedestrian Accidents

The table 4.35 indicate that involvement of younger riders in MCL-Pedestrian accident is high. Nearly 68% of riders involved in accidents are age bellow 36 years.

Table 4.35: Age Group of Riders Involved In MC- Pedestrian Accidents

Age Group of Riders	**Frequency**	**Percentage**
12-18	235	3
18-24	1952	26
24-30	1703	22
30-36	1275	17
36-42	857	11
42-48	595	8
48-54	366	5
54-60	201	3
60>	128	2
Not Known	325	4
Total	**7637**	**100**

Like all kinds of accidents, aggressive or negligent driving was found to be the accident causing factor in MCL-Pedestrian accidents also. Speeding contributed to 15% of accidents.

Table 4.36: Rider re-Crash Factor for MCL-Pedestrian Accidents

Rider Pre crash factor	**Frequency**	**Percentage**
Aggressive or negligent driving	5,878	77
Speeding	1,147	15
Influenced by alcohol	228	3
Error of Judgment	103	1
Other/Not Known	281	4
Total	**7,637**	**100**

4.3.3 Analysis of MCL-Pedestrian Accidents Beyond Descriptive Statistics

4.3.3.1 Data Source, Selection and Description

The data set considered for the analysis consist of a total of 7,637 motorcycle-pedestrians only involved single vehicle accidents. That is one pedestrian struck by single motorcycle. Out of the figure, 8% (n=626) contributed to fatal cases, 33% (n=2,524) was grievous injury cases and non-grievous injury cases comprised of 59% (n=4,487).

This study focus on fatal and non-fatal cases to pedestrian only to analyses the factors contributed to the accident severity. The accident severity level was divided into two which are Fatal coded as '1' and "Non-Fatal (Grievous and Non-grievous) coded as '0' in SPSS.

Three binary logistics regression models were prepared separately for crash environment related factors, pedestrian related factors and MCL and rider related factors.

4.3.3.2 Logistics Regression Analysis for Crash Environment Model of MCL-Pedestrian Accidents

The dependent variable in this analysis is Highest Severity of accident. The independent variables considered are road surface condition, weather, light condition, road location, road pre-crash factors, time of accident, urban or rural category, day of week, pedestrian location, traffic control and police division accident record. Altogether, 11 independent variables included in the model.

In four iterations insignificant variables in the model were removed. Finally, it identified road surface condition, time of accident, pedestrian location accident recorded and police division accident occurred are the four variables significantly related to injury severity of MCL-Pedestrian accidents.

Table 4.37: Stepwise Inclusion of Variables into the Crash Environment Model (MCL – Pedestrian Accidents)

Variable		Model Log Likelihood	Change in- 2 Log Likelihood	Sig. of the change
Step 4	RD_SUR	-2069.309	9.458	.024
	TIME_RA_NEW	-2083.505	37.850	.000
	PED_LO_NEW	-2079.876	30.593	.000
	DS_DIV_NEW	-2118.909	108.658	.000

The Hosmer and Lemeshow test value for this model is 0.961 which is greater than 0.05. This indicates that model has a good fit. The table shows the statistically significant results of the MC-MV accident circumstances related detail model

Table 4.38: Statistically Significant Results of the Crash Environment Model (MCL – Pedestrian Accidents)

Variable Coding	Description	Sig	B	Exp(B)
Accident severity with time period of accident occurred				
TIME_RA_NEW	**6.00 pm to 9.00 pm**	0		
TIME_RA_NEW(2)	3.00 am to 6.00 am	.031	0.578	1.782
TIME_RA_NEW(5)	12.00 noon to 3.00 pm	0	-0.673	0.510
TIME_RA_NEW(6)	3.00 pm to 6.00 pm	.004	-0.379	0.685
Accident severity with pedestrian locations accident occurred				
PED_LO_NEW	**PC beyond 50 m**	0		
PED_LO_NEW(1)	On PC	0	-0.525	0.591
PED_LO_NEW(4)	Hit outside sidewalk	.046	-0.739	0.477
PED_LO_NEW(5)	Hit on side walk	.024	-0.497	0.608
Accident severity in Police Divisions accident occurred				
DS_DIV_NEW	**Nugegoda**	0		
DS_DIV_NEW(6)	Chilaw	.006	0.894	2.445
DS_DIV_NEW(7)	Colombo	.023	-0.803	0.448
DS_DIV_NEW(8)	Elpitiya	.002	0.809	2.245

DS_DIV_NEW(10)	Gampaha	.010	0.604	1.830
DS_DIV_NEW(13)	Kalutura	.007	0.736	2.088
DS_DIV_NEW(17)	Keleniya	.048	0.473	1.605
DS_DIV_NEW(36)	Seethawaka	**.001**	**1.126**	**3.085**

- **B** in the above table denotes the logistic coefficient.
- **Exp(B)** is the odds ratio or fatal risk ratio associated with each predictor.
- Variables bolded in each category are used as base variables to calculate odds ratio or fatal risk ratio.

4.3.3.2.1 Accident Severity with Time Period of Accident Occurred

Accidents occurring at time range from 3.00 am to 6.00 am are 1.782 times more fatal compare accident occurring from 6.00 pm to 9.00 pm. The reason for this may be high speed of MCL at night time due to less traffic in roads.

Fatal risk ratio of accidents occurring during evening peak from 3.00 pm to 6.00 pm are 1.343 times (0.685/0.510) crucial compare to afternoon peak from 12.00 noon to 3.00 pm.

It is concluded that MCL- Pedestrian accidents occurring during early morning 3.00 am to 6.00 pm are more probable to become fatal. In the meantime, accident during evening peak is 1.343 times crucial compare to afternoon peak period.

4.3.3.2.2 Accident Severity with Pedestrian Locations

Pedestrians have 1.692 times (1/0.591) less fatal risk on accidents occurring on pedestrian crossing compare to the accidents occurs 50 meters beyond pedestrian crossing (at mid – block section of roads).

Hit on sidewalk accidents are 0.608 times less probable to become fatal compare to accidents occur at mid – block section of roads. But, when it's compared with accident on PC, both places pedestrian have nearly the same probability for fatal risk.

It is concluded that accidents occurring at mid –block section of roads are high and have more fatal risk ratio compared with other pedestrian locations accident occurred.

4.3.3.2.3 Accident Severity in Various Police Divisions across the Country

MCL- Pedestrian accidents occurring in Chilaw and Seethawaka Police divisions are 2.445 times and 3.085 times more probable to become fatal compared with accidents occurring in Nugegoda police division.

Accidents occurring in police divisions in Western Province such as Kelaniya, Gampaha and Colombo were compared with accident occurring in Nugegoda police division. Fatal risk ratio of those accidents are 1.605, 1.830 and 0.448 respectively.

When the fatal risk ratio of accidents occurring in Kelaniya and Gampaha police division compared with accidents occurring in Colombo. Accidents occurring in those areas are 3.58 times and 4.08 times more probable to become fatal than accidents occurring in Colombo.

It shows that pedestrian in Colombo have less fatal risk in MCL-Pedestrian accidents compare to other police divisions though it is in fourth place where more MCL-Pedestrian accidents occurred.

4.3.3.3 Logistics Regression Model for Pedestrian Related Factors of MCL-Pedestrian Accidents

The independent variables considered in this model are pedestrian gender, pedestrian pre-crash factors, alcohol test for pedestrian, pedestrian age, crash factor for accident severity and collision type. Altogether, 6 independent variables included in the model.

Finally, out of 6 independent variables, it identified pedestrian gender, pedestrian pre-crash factors and pedestrian age are the three variables statistically significant in the model for pedestrian factors contributed to MCL-Pedestrian accident. The Hosmer and Lemeshow test value for this model is 0.501 which is greater than 0.05.This indicates that model has a good fit. Table 4.39 shows the statistically significant results of the Pedestrian related factors model.

Table 4.39: Stepwise Inclusion of Variables into the Pedestrian Model (MC – Pedestrian Accidents)

Variable		Model Log Likelihood	Change in-2 Log Likelihood	Sig. of the change
Step 3	PED_GEN	-1902.220	24.969	.000
	PED_FAC	-1896.199	12.926	.012
	PED_AGE_NEW	-2149.293	519.114	.000

Table 4.40: Statistically Significant Results of the Pedestrian Model (MCL – Pedestrian Accidents)

Variable	Description	Sig	B	Exp(B)
Accident severity with pedestrian gender				
PED_GEN	**Male**	0		
PED_GEN(1)	Female	**0**	**-0.439**	**0.645**
Accident severity with pedestrian age group				
PED_AGE_NEW	**60 or above**	0		
PED_AGE_NEW(1)	0 to 5	0	-2.555	0.078
PED_AGE_NEW(2)	6 to 11	0	-3.947	0.030
PED_AGE_NEW(3)	12 to 17	0	-3.548	0.029
PED_AGE_NEW(4)	18 to 23	0	-2.432	0.088
PED_AGE_NEW(5)	24 to 29	0	-2.187	0.112
PED_AGE_NEW(6)	30 to 35	0	-1.829	0.161
PED_AGE_NEW(7)	36 to 41	0	-1.786	0.168
PED_AGE_NEW(8)	42 to 47	0	-1.702	0.182
PED_AGE_NEW(9)	48 to 53	0	-0.954	0.385
PED_AGE_NEW(10)	54 to 59	0	-0.740	0.477

- **B** in the above table denotes the logistic coefficient.
- **Exp(B)** is the odds ratio or fatal risk ratio associated with each predictor.
- Variables bolded in each category are used as base variables to calculate odds ratio or fatal risk ratio.

4.3.3.3.1 Accident Severity with Pedestrian Gender

Female pedestrians are 0.645 times less probable to become fatal in MCL-Pedestrian accidents compared with male pedestrians. This means, compare to male, female pedestrians have at 1.550 times (1/0.645) less fatal risk in accidents.

4.3.3.3.2 Accident Severity with Pedestrian Age Group

When fatal risk to pedestrians with different age groups involved in accidents was compared with the age group greater than or equal to 60. The Exp (B) value is increasing from 0.029 to 0.477 with increasing pedestrian age group. It shows that with the increasing age, fatal risk to pedestrian is increasing.

Age group of pedestrians Six to Eleven represents the school children from Grade -1 to Grade-6. Fatal risk ratio to this age group in accidents was compared with the pedestrian age group greater than 60. It shows that children between the age group Six to Elven involved accidents are 33 times (1/0.033) less probable to become fatal compared with age group greater than 60 pedestrian involved accidents. Likewise pedestrian between age group 54 to 59 are 2 times (1/0.477) less probable to become fatal in accidents compared with age group greater than 60.

The reason for this may be slower movement, a decrease of muscular tone, decrease in fine coordination and particularly strong decrease in the ability to adapt to sudden changes in posture increase with aging.

It is concluded that involvement of older pedestrians in MCL-pedestrian accident are high. While fatal risk to pedestrian increases with their age. Pedestrian greater than 60 years involved in more accidents and those accidents are more probable to become fatal compared to other age group of pedestrian involved accidents. Because, their bones are less brittle and tissues are less elastic (EC,DGTE, 2009).

But, in a report published by WHO (2016), it is mentioned that in high-income countries older pedestrians are more risk at death but in low and middle-income countries, younger pedestrians are more at risk. But, though Sri Lanaka is a middle-income country, here the situation is otherway round.

4.3.3.4 Logistics Regression Analysis of Motorcycle and Rider Related Factors

The independent variables considered in this model are age of motorcycle, rider gender, number of years license issued, vehicle pre-crash factor, alcohol test for motorcyclist, rider age, validity of license at the time of accident, human pre-crash factors and other factors contributed to accident severity. Altogether, 9 independent variables included in the model.

After several iterations, vehicle pre-crash factor and alcohol test on motorcyclists were added to the model as motorcyclist related variables contribute statistically significant to the model fit.

Table 4.41: Stepwise Inclusion of Variables into the Rider and Motorcycle Related Factors Model (MCL – Pedestrian Accidents)

Variable	Model Log Likelihood	Change in- 2 Log Likelihood	Sig. of the change
Step 1 ALCOHOL	-2165.495	41.696	.000
Step 2 VE_FAC	-2144.647	12.228	.057
ALCOHOL	-2159.440	41.814	.000

Table 4.42: Statistically Significant Results of the Motorcycle and Rider Related Factors Model

Variable	Sig	B	Exp(B)
ALCOHOL	0		
ALCOHOL(2)	0	-0.562	0.570

Motorcycle-Pedestrian accidents with Riders ‘No alcohol or bellow legal limit’ are approximately 1.78 times more probable to become crucial compared with accidents riders ‘Not undergone Alcohol test’.

4.4 Motorcycle – Bicycle Accidents

Cyclist are amongst the one of the vulnerable road user in Sri Lanka and the world also. In total fatality occur in road accidents every year, cyclists' accounts for nearly 9%. According to the WHO Global Status report on road safety 2015, cyclist's deaths of the world's roads per year are 4%. In Sri Lanka, this figure was 9% (261) in the year 2015. Fatality of cyclists in Sri Lanka roads are 2.25 times higher compare to fatality of cyclists in world roads. Make walking and cycling safer will reduce number of traffic deaths and important for achieving the Decade of Action for Road Safety's aims to promote the non-motorized form of transport. But, the above statistics show that cyclist are not safe in roads. The objective of this study is to identify the risk factors to cyclist created by motorcycles in roads.

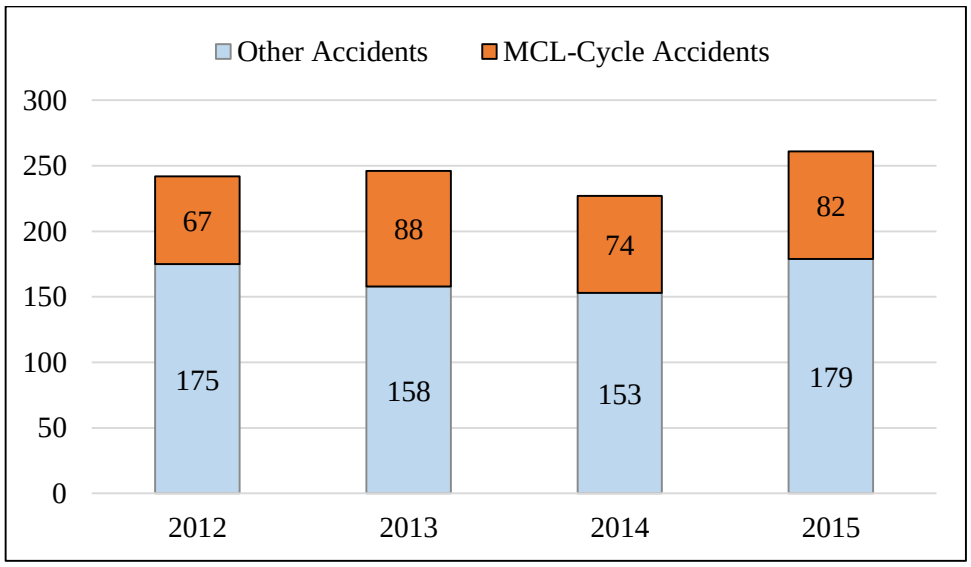

Figure 4.16: Comparison of Cyclist Death in Other Accidents and MCL-Cycle Accidents

In the year 2015, total 261 cyclist died in road accidents. Out of them 82 were died in MCL-Cycle accidents. It accounts for 31% of total fatalities. The death toll of cyclists has reached more than 250 in the year 2015. Likewise, in average nearly 45% cyclist suffer grievous injuries due to motorcycle-cycle accident.

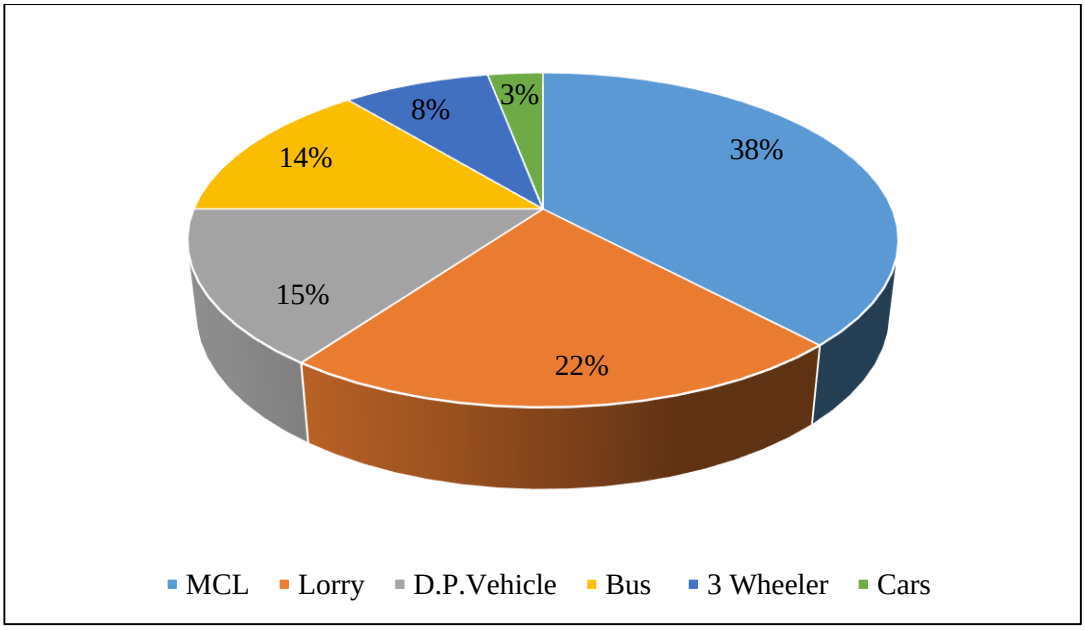

Figure 4.17: Cyclist Fatal Accidents with Different Vehicle Types

Figure 4.16 shows the fatality to cyclist from different types of vehicle operating in roads. Fatality to cyclist per 10,000 operating car is 0.17 and from Buses is 6.49. Though 38% of cyclist killed by MCL, fatality per 10,000 operating vehicle is less. It is because of the high population of motorcycles on roads.

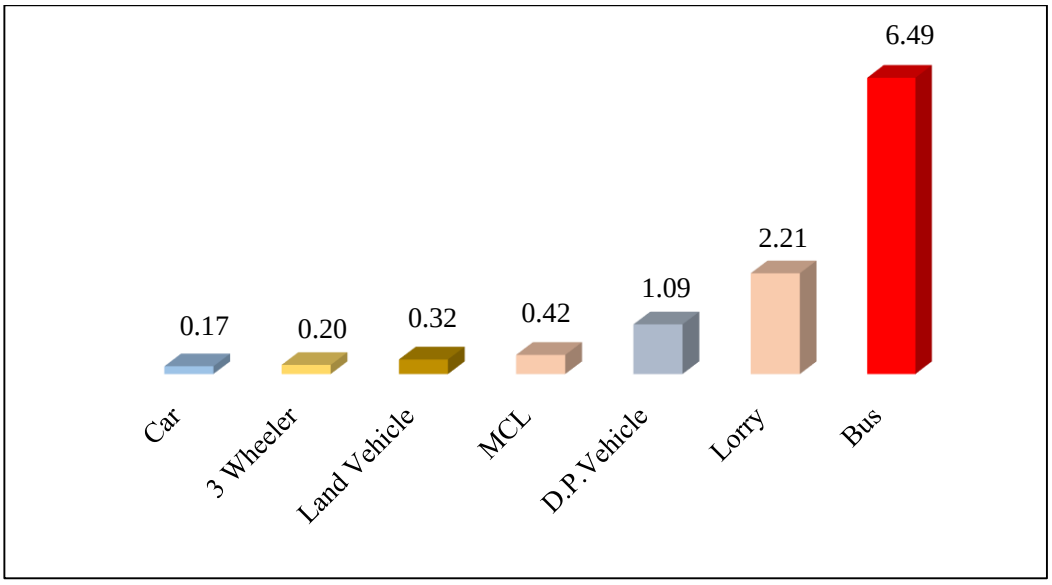

Figure 4.18: Fatality to Cyclist per 10,000 Operating Vehicles

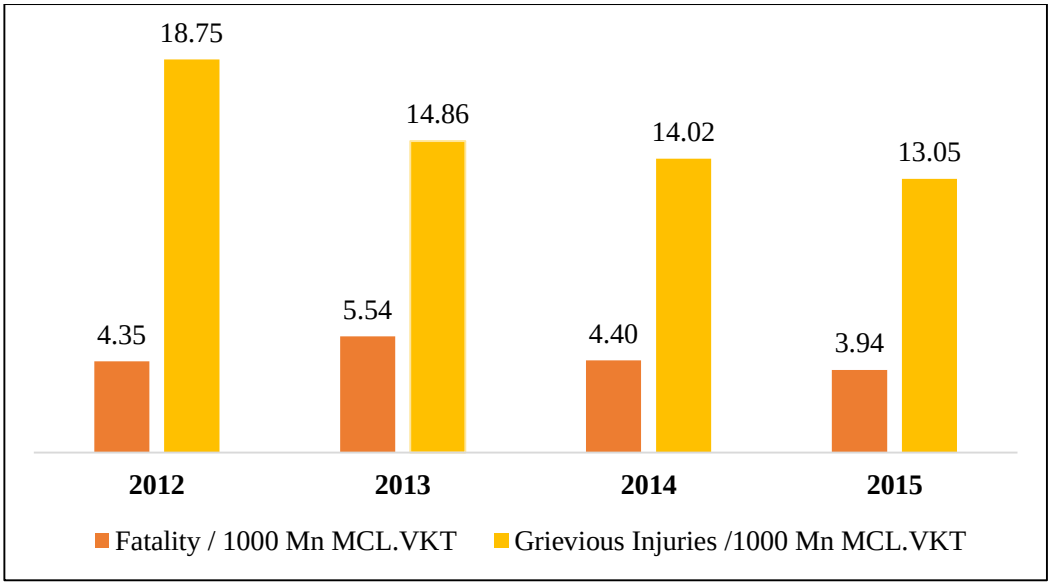

Figure 4.19: Comparison of Fatal and Grievous Injuries to Cyclist per 100 Million MCL km.

Because of the high vulnerability in usage of bicycles, young generation in Sri Lanka is not willing to use bicycles. If infrastructure facilities are not improved to enhance the safety of cyclist, population of bicycles users will go down with the time.

4.4.1 Descriptive Analysis of Motorcycle – Bicycle Accidents

A total of 5,237 motorcycle-bicycle single vehicle only involved accidents were analyzed for this purpose. That is one cyclist struck with single motorcycle. Out of the figure, 8% (n=427) contributed to fatal cases, 92% (n=4,810) were grievous and non-grievous injury cases.

4.4.1.1 Descriptive Analysis Results of Crash Environment Related Details of MCL-Bicycle Accidents

Table 4.43 shows that more MCL - Bicycle accidents recorded in Batticaloa, Anuradhapura, Ampara and Galle and less in Mullathivu, Badulla, Mannar, Mankulam and Kegalle police divisions.

Table 4.43: Police Divisions of MC-Bicycle Accidents Occurred

DS Division	Frequency	Percentage
Batticaloa	415	8
Anuradapura	400	8
Ampara	325	6
Galle	247	5
Jaffna	226	4
Elpitiya	209	4
Kuliyapitiya	201	4
Polannaruwa	199	4
Kalutura	199	4
Kurunagala	196	4
Panandura	189	4
Negambo	187	4
Gampaha	181	3
Matara	167	3
Nikawaratiya	162	3
Monaragala	155	3
Chilaw	155	3
Kelaniya	141	3
Tangalle	121	2
Puttalam	114	2
Vavuniya	111	2
Trincomale	98	2
Mountlavinia	95	2
Ratnapura	94	2
Nugegoda	92	2
Kankasenthurai	91	2
Matala	82	2
Kilinochi	68	1
Kantale	62	1
Colombo	59	1
Mullathivu	37	1
Badulla	36	1
Mannar	32	1
Mankulam	28	1
Kegalle	22	0
Kandy	20	0
Seethawakapura	9	0
Nuweraliya	5	0
Bandarewela	4	0
Gampola	3	0
Total	**5237**	**100**

Table 4.44: Time Period MCL-Bicycle Accidents Occurred

Time	**Frequency**	**Percentage**
Midnight – 3.00 am	36	1
3.00 am – 6.00 am	66	1
6.00 am – 9.00 am	640	12
9.00 am – 12.00 noon	692	13
12.00 noon - 3.00 pm	707	14
3.00 pm – 6.00 pm	990	19
6.00 pm – 9.00 pm	1771	34
9.00 pm - Midnight	335	6
Total	**5237**	**100**

Nearly 93% of MCL- Bicycle accidents recorded between 6.00 am to 9.00 pm. Among those, highest number of accidents recorded between 6.00 pm to 9.00 pm which accounts for 34% of all accidents.

Table 4.45 shows that, when considering the light condition at the time of accident, 58% of accidents occurred in day light condition and 38% occurred in night time and 4% in dusk or dawn. Among 38% of accidents occurred in night time, 25% occurred in roads where no street lights or improper street lights available.

Table 4.45: Light Condition at the Time of MCL-Bicycle Accidents Occurred

Light Condition	**Frequency**	**Percentage**
Daylight	3027	58
Night, No Street Light	1286	25
Night improper Street Light	393	7
Dusk, Dawn	341	6
Night / Good Street Light	190	4
Total	**5237**	**100**

4.4.1.2 Descriptive Analysis Results of Cyclists Related Factors, MCL-Bicycle Accident

Involvement of male older cyclists are high in MCL-Bicycle accidents. Nearly 59% of cyclists involved in accidents are above the age forty one. Among them riders above sixty years old accounts for 26%. In younger cyclist age group, age group of riders 12 to 17 represents 12%.

Table 4.46: Gender of Cyclist involved in MC-Cycle Accidents

Sex	**Frequency**	**Percentage**
Male	4,872	93
Female	365	7
Total	**5,237**	**100**

Table 4.47: Age Group of Cyclist Involved in MC-Cycle Accidents

Age of Cyclist	**Frequency**	**Percentage**
0-5	16	0
6-11	190	4
12-17	574	12
18-23	332	6
24-29	283	5
30-35	380	7
36-41	392	7
42-47	514	10
48-53	627	12
54-59	596	11
60>=	**1363**	**26**
Total	**5237**	**100**

Table 4.48 indicates the major collision patterns in MCL - Bicycle Accidents. Many accidents occurred in rear end collision which accounts for 35% of the total 5237 accidents. As vulnerable road users, most of the time cyclist use the hard shoulder or follow edge line of roads. In the meantime, 74% of accidents recorded in rural roads where in some stretches, road width only 3.5-4.5 m is. Because of this narrow road width, cyclist unable to segregate themselves from other vehicles. Therefore, when

constructing roads, it is necessary to provide exclusive cycle lanes and segregate cyclist from other traffic. This will further motivate the usage of cycles on roads and help to reduce motorized transport such as two wheelers.

Table 4.48: Major Collision Types in Motorcycle- Bicycles Accidents

Collision Type	**Frequency**	**Percentage**
1120	1815	35
1110	1282	24
1131	805	15
1140	298	6
1132	229	4
1133	121	2

- 1110 – Head on Collision.
- 1120 – Rear end Collision.
- 1131 – MC going straight crash with cycle taking right turn at junction.
- 1132 - Cycle going straight crash with MC taking right turn at junction at right angle.
- 1133 – MC going straight at junction crash with cycle taking right turn at junction
- 1140 – 90^{o} angle collision at junction.

4.4.2 Analysis of MCL - Bicycle Accidents Beyond Descriptive Statistics

4.4.2.1 Data Source, Selection and Description

The source of data used for this study is Police accident data during the period from 2010 to 2014. It includes fatal and non-fatal (Grievous and not grievous) accidents. The final data set consist of a total of 5,237 motorcycle-bicycle single vehicle only involved accidents. That is one cyclist struck with single motorcycle. Out of the figure, 8% (n=427) contributed to fatal cases, 92% (n=4,810) were grievous and non-grievous injury cases.

This study focus on fatal and non-fatal cases to cyclist only to analyses the factors contributed to the accident severity. The accident severity level was divided into two which are 'Fatal coded as '1' and "Non-fatal' (Grievous and Non-grievous) coded as '0' in SPSS.

Three binary logistics regression models were prepared separately for crash environment related factors, cyclist related factors and MCL and rider related factors. Each models were analyzed separately using SPSS 23.0 software.

4.4.2.2 Logistics Regression Analysis for Crash Environment Model of MCL-Bicycle Accidents

The dependent variable in this analysis is Highest Severity of accident. The independent variables considered are day of week, second collision, road surface condition, weather, light condition, road location, police division accident recorded , time of accident, urban or rural category, traffic control, speed limit of the environment and. road pre-crash factors. Altogether, 12 independent variables included in the model.

After several iterations, it found that police divisions accident occurred are only the significant variable improve the model fit of environmental related factors contributed to MCL-Bicycle accidents.

Table 4.49: Stepwise Inclusion of Variables into the Crash Environment Details Model (MCL – Bicycle Accidents)

Variable	**Model Log Likelihood**	**Change in- 2 Log Likelihood**	**Sig. of the change**
Step 1 DS_DIV_NEW	-1479.468	96.953	.000

Table 4.50 indicates that MCL-Bicycle accidents occurring in Kegalle and Kuliyapitiya Police divisions were compared with accident occurring in Batticaloa Police division. Accident occurring in these divisions are 5.518 times and 3.292 times more probable to become fatal compared with accident occurring in Batticaloa police division.

Table 4.50: Statistically Significant Results of the Crash Environment Model (MC – Bicycle Accidents)

Variable Coding	Description	Sig	B	Exp(B)
Accident Severity with Police Division				
DS_DIV_NEW	**Batticaloa**	0		
DS_DIV_NEW(2)	Anuradhapura	.009	0.735	2.085
DS_DIV_NEW(5)	Chilaw	0	1.133	3.103
DS_DIV_NEW(9)	Gampaha	.009	0.846	2.331
DS_DIV_NEW(11)	Jaffna	.001	0.976	2.653
DS_DIV_NEW(15)	Kegalle	.002	1.708	5.518
DS_DIV_NEW(17)	Kuliyapitiya	0	1.191	3.292
DS_DIV_NEW(18)	Kurunagala	.033	0.700	2.014
DS_DIV_NEW(20)	Matara	.008	0.879	2.409
DS_DIV_NEW(23)	Negombo	0	1.152	3.166
DS_DIV_NEW(29)	Ratnapura	.002	0.948	2.581

- **B** in the above table denotes the logistic coefficient.
- **Exp(B)** is the odds ratio or fatal risk ratio associated with each predictor.
- Variables bolded in each category are used as base variables to calculate odds ratio or fatal risk ratio.

4.4.2.3 Logistics Regression Analysis for Cyclists Related Factors of MCL-Cycle Accidents

The independent variables considered in this model are cycle ownership, rider gender, cycle pre-crash factor, other crash factors, alcohol test for cyclist, age of cycle, rider age , human pre-crash factors, crash factor for accident severity and collision type contributed to accident severity. Altogether, 10 independent variables included in the model.

The forward stepwise procedure included rider gender and cyclist age as statistically significant variables in the model consist of cyclist and cycle related factors.

Table 4.51: Stepwise Inclusion of Variables into the Cycle and Rider Related Factors Model (MCL – Bicycle Accidents)

Variable		Model Log Likelihood	Change in- 2 Log Likelihood	Sig. of the change
Step 2	CYC_GENDER	-1388.860	7.651	.006
	CYC_AGE_NEW	-1465.385	160.701	.000

Table 4.52: Statistically Significant Results of the Bicycle and Rider Related Factors Model (MCL – Bicycle Accidents)

Variable	Description	Sig	B	Exp(B)
Accident severity with cyclist gender				
CYC_GENDER	**Male**	0		
CYC_GENDER(1)	Female	.016	-0.942	0.390
Accident Severity with cyclist age group				
CYC_AGE_NEW	**60 or above**	0		
CYC_AGE_NEW (3)	12 to 17	0	-1.600	0.202
CYC_AGE_NEW (4)	18 to 23	0	-1.559	0.210
CYC_AGE_NEW (5)	24 to 29	0	-1.404	0.246
CYC_AGE_NEW (6)	30 to 35	0	-1.574	0.207
CYC_AGE_NEW (7)	36 to 41	0	-1.095	0.335
CYC_AGE_NEW (8)	42 to 47	0	-1.118	0.327
CYC_AGE_NEW (9)	48 to 53	.001	-0.518	0.596
CYC_AGE_NEW (10)	54 to 59	.008	-0.417	0.659

- **B** in the above table denotes the logistic coefficient.
- **Exp(B)** is the odds ratio or fatal risk ratio associated with each predictor.
- Variables bolded in each category are used as base variables to calculate odds ratio or fatal risk ratio.

4.4.2.3.1 Accident Severity with Cyclist Age

When fatal risk to children ages 12 to 17 involved in MCL-Bicycle accidents was compared with the age group greater than or equal to 60. It shows that children ages between 12 to 17 involved accidents are 5 times (1/0.202) less probable to become

fatal when compared with age group greater than 60 involved accidents. Likewise cyclist between age group between 54 and 59 are 1.5 times (1/0.477) less probable to become fatal when compared with age group greater than 60.

It's concluded that involvement of older cyclist in MCL-Bicycle accidents are high and fatal risk to cyclist increases with their age while cyclist above age 60 are facing highest fatal risk in MCL-Bicycle related accidents.

4.5 Motorcycle-Self Accidents

4.5.1 Descriptive Analysis of Motorcycle – Self Accidents

The source of data used for this study is Police accident data from 2012 to 2014. It includes fatal and non-fatal (Grievous and not grievous) accidents. The final data set contained a total of 3,110 MC-Self accidents. That is motorcycle by himself run off in roads. Out of 3110 accidents, 24% (n=738) contributed to fatal cases, 76% (n=2,372) were grievous and non-grievous injury cases.

4.5.1.1 Descriptive Analysis Results of Crash Related Details of MCL-Self Accidents

Table 4.53: Number of Years License Issued at the Time of Self Accident Occurred

No of years license issued	Frequency	Percentage
0-2	677	22
3-5	346	11
6-10	234	8
More than 10	220	7
Not Known	1,633	53
Total	**3,110**	**100**

Rider's accounts for 22% involved in self-accidents within two years since license is issued. In 53% of cases, numbers of year license issued is not known. Accident data reveals that 47% of people had valid license at the time of accident and 44% without valid license. It is nearly 50 to 50 situation. In MCL-MV accidents this figure is 60% and 30 % respectively. It is a major regulatory issue regarding the MCL safety.

Therefore, necessary steps has to be taken by the police to overcome this issue as soon as possible.

Table 4.54: Age Group of Riders Involved in MCL-Self Accidents

Age of MCL Rider	**Frequency**	**Percentage**
12-17	77	2
18-23	743	24
24-29	745	24
30-35	541	18
36-41	382	13
42-47	256	8
48-53	186	6
54-59	105	3
60 or more	75	2
Total	**3110**	**100**

Involvement of younger riders in MCL self-accidents ages 12 to 30 accounts for nearly 50% of total accident. Involvement of older drivers in self-accident over the age 42 accounts for 19% of total accidents.

Table 4.55: Rider Pre-crash Factors Contributed to MCL-Self Accidents

Rider Pre crash factor	**Frequency**	**Percentage**
Aggressive/negligent driving	2,019	65
Speeding	578	19
Influenced by alcohol	279	9
Fatigue / fall asleep	54	2
Error of Judgment	32	1
Sudden illness	10	0
Distracted/In attentiveness	8	0
Blinded by another vehicle/Sun	2	0
Other/Not Known	128	4
Total	**3,110**	**100**

When Riders pre-crash factor contributed to accident are analyzed, 'Aggressive/negligent driving' is a causing factor for 65% and followed by 'speeding '19%. Padmanaban & Eyges (2006) reported that run off road crashes occuring at speed more than 55 mph.

Table 4.56: Crash Factor for Accident Severity Contributed in MCL-Self Accidents

Crash factor for accident severity	**Frequency**	**Percentage**
Rolled Over	1,250	40
Hitting pole/post	306	10
Hitting other fixed objects	227	7
Hitting Tree	101	3
Hitting barrier/guard rail	89	3
Hitting road island	60	2
Hitting stone/boulder	19	1
Not Known	1,058	34
Total	**3,110**	**100**

'Rolled over' of rider is one of the common factor for accident severity. It a factor in 40 % of MCL-Self accidents followed by 'Hitting pole/post 10%. In nearly 26% of MCL-Self self-accidents reported, crash factor contributed to accident severity due to hitting road side objects such as tree, guard rail, island and boulders.

When riders collide with these rigid structures like post, barrier and other fixed objects, those accidents have more chance to become fatal. In general, it is observed in many rural roads and National Highways that service post (Electricity, Telecom) are located in a very close proximity to carriageway. Due to lack of coordination between the Utility Service Providing organizations and Road Development Organizations, still those posts remain adjacent to carriageway or in some places within carriageway.

Another issues regarding shifting of these service posts is, though those service poles located inside the Road Development Authority (RDA) reservation, when requested

for shifting, those Utility Service Providing Organizations send estimate which are very expansive or difficult to bear.

Likewise, trees at road site contributes very significantly to the fatality in accidents. RDA does not hold rights on trees on road site. RDA's authority is limited to only cutting branches in their routine maintenance schedule. Cutting trees which are hindrance to road users is a lengthy procedure where correspondence should go through Divisional Secretaries in that area to the Forest Department.

Therefore, inter organization level discussion should be initiated at higher management level as soon as possible regarding this issue and measures has to be taken to remove these hindrance from road as these contribute significantly for the fatal deaths.

Fixing illuminating stickers, white washing road site rigid objects frequently and construction of culvert parapet wall away from carriageway will reduce the accidents due to these fixed objects in roads.

Other than this, as a permanent solution to this problem, when designing roads, designers should think about accommodating error forgiving structures in roads. Though it is very expensive solution, it will save the lives and property of many peoples.

4.5.1.2 Descriptive Analysis Results of Crash Environment Related Details of MCL-Self Accidents

In MCL-Self accidents, collision types 0811, 0840 and 0812 accounts for 32%, 12% and 11% respectively. Motorcycle coming straight, run off the road to the left side is represented by 0811, run off the road straight is denoted by 0840 and motorcycle coming straight, run off the road, right side is represented by 0812.

MCL-Self accidents due to motorcycle entering in a curve run off straight in the same direction (0821) accidents accounts for 7% and MCL entering in a curve run off straight to other direction (0822) accounts for 3% respectively. Table 4.57 shows the major collision pattern in MCL - Self accidents.

Table 4.57: Major Collision Types in MCL-Self Accidents

Collision Type	**Frequency**	**Percentage**
0811	997	32
0840	386	12
0812	334	11
0821	227	7
1210	194	6
0899	179	6
1399	155	5
1220	129	4
1310	96	3
0822	81	3
Other	332	11
Total	**3110**	**100**

Note: Refer **Appendix-C** for collision pattern diagrams.

Like all other accidents, more than 90% of self-accidents also reported in dry and clear weather conditions.

Table 4.58: Road Surface Condition at MCL-Self Accidents

Road Surface Condition	**Frequency**	**Percentage**
Dry	2880	93
Wet	184	6
Slippery Surface	32	1
Flooded with water	14	0
Total	**3110**	**100**

In total 3,110 self-accidents analyzed, 43% (1,340) of accidents are recorded in ‘Day light condition’ and 57% (1,770) of accidents occurred at ‘Night Time’. Among 57% of accidents occurred at night time 68% (1,199) of accidents occurred at night, road without street light, 17% (301) occurred at night, roads with improper street light, 10% (173) at night with good street light and 5% (97) at dusk or dawn. In total, 85%

accidents occurred at roads at night time without street light or rods with improper street lights.

When compared with motorcycle accident with motor vehicles, pedestrians and bicycles, highest numbers of motorcycle self-accidents reported in night time and road with no street lights which accounts for 39% of total accidents. For MCL-MV and MCL-Pedestrians accidents occurred in night time and road with no street lights is only 15% and 18% respectively.

Table 4.59: Light Condition on Road at the Time of MCL- Self Accidents

Light Condition	**Frequency**	**Percentage**
Daylight	1340	43
Night, No Street Light	1199	39
Night improper Street Light	301	10
Night / Good Street Light	173	6
Dusk, Dawn	97	3
Total	**3110**	**100**

Like all other accidents, more motorcycle self-accidents also reported in rural areas.

Table 4.60: Township MCL Self Accidents Occurred

Town	**Frequency**	**Percentage**
Urban	694	22
Rural	2416	78
Total	**3110**	**100**

Highest numbers of MCL-Self accidents recorded in Anuradhapura police division followed by Ampara, Batticaloa and Ratnapura while less numbers of accidents occurred in Bandarewela, Gampola and Hatton police divisions.

Table 4.61: Police Divisions MCL- Self Accidents Recorded

DS Division	Frequency	Percentage
Anuradapura	253	8
Ampara	222	7
Batticaloa	193	6
Ratnapura	121	4
Polannaruwa	116	4
Tangalle	115	4
Monaragala	108	3
Kuliyapitiya	101	3
Matala	98	3
Kelaniya	95	3
Nugegoda	93	3
Gampaha	92	3
Kandy	92	3
Negambo	91	3
Elpitiya	90	3
Galle	88	3
Nikawaratiya	82	3
Jaffna	79	3
Kurunagala	73	2
Colombo	69	2
Kalutura	64	2
Puttalam	64	2
Matara	63	2
Mountlavinia	61	2
Kantale	55	2
Trincomale	53	2
Badulla	52	2
Chilaw	46	1
Panandura	46	1
Kegalle	45	1
Kilinochi	40	1
Mullathivu	40	1
Mannar	38	1
Vavuniya	30	1
Nuweraliya	28	1
Seethawakapura	28	1
Mankulam	26	1
Kankasenthurai	25	1
Bandarewela	13	0
Gampola	12	0
Hatton	10	0
Total	**3110**	**100**

4.5.2 Analysis of MCL - Bicycle Accidents Beyond Descriptive Statistics

4.5.2.1 Data Source, Selection and Description

The source of data used for this study is Police accident data from 2012 to 2014. It includes fatal and non-fatal (Grievous and not grievous) accidents. The final data set contained a total of 3,110 MC-Self accidents. That is motorcycle by himself run off in roads. Out of 3110 accidents, 24% (n=738) contributed to fatal cases, 76% (n=2,372) were grievous and non-grievous injury cases.

This study focus on fatal and non-fatal cases to cyclist only to analyses the factors contributed to the accident severity. The accident severity level was divided into two which are 'Fatal coded as '1' and "Non-fatal' (Grievous and Non-grievous) coded as '0' in SPSS.

Two binary logistics regression models were prepared separately for crash details model and crash environment related factors.

4.5.2.2 Logistics Regression Analysis for Crash Details Model, MCL-Self Accidents

The independent variables considered in this model are age of motorcycle, rider gender, validity of license at the time of accident, number of years license issued, road pre-crash factors, vehicle pre-crash factor, other factors contributed to accident severity, alcohol test for motorcyclist, rider age, human pre-crash factors and crash factor for accident severity. Altogether, 11 independent variables included in the model.

After five steps, number of years license issued, other factors contributed to accident severity, rider age, human pre-crash factors and crash factor for accident severity were included in the model as the variables statistically significant to the model fit.

Table 4.62: Stepwise Inclusion of Variables into the Crash Details Model (MCL – Self Accidents)

Variable		Model Log Likelihood	Change in- 2 Log Likelihood	Sig. of the change
Step 5	NU_YRS_LIC_ISS	-1596.630	23.600	.000
	OTH_FAC	-1596.197	22.735	.000
	RID_AGE_NEW	-1596.815	23.971	.002
	HU_PRE_FAC_NEW	-1595.526	21.393	.006
	CRA_SEV_NEW	-1649.026	128.393	.000

Table 4.63: Statistically Significant Results of the Crash Details Model (MCL – Self Accidents)

Variable Coding	Description	Sig	B	Exp(B)
Accident severity with riders age group				
RID_AGE_NEW	**24 to 29**	.002		
RID_AGE_NEW(7)	54 to 59	.003	0.710	2.034
RID_AGE_NEW(8)	60 or more	0	1.061	2.891
Accident severity with riders pre-crash factors				
HU_PRE_FAC_NEW	**Aggressive or Negligent driving**	0		
HU_PRE_FAC_NEW(7)	Blinded by another vehicle or Sun	0	0.436	1.547
Crash factor for accident severity				
CRA_SEV_NEW	**Rolled Over**	0		
CRA_SEV_NEW(1)	Hitting Pole or Post	0	1.173	3.231
CRA_SEV_NEW(2)	Hitting Stone or Boulder	.019	1.155	3.175
CRA_SEV_NEW(4)	Hitting barrier	0	0.989	2.690
CRA_SEV_NEW(5)	Hitting other fixed objects	0	0.761	2.141
CRA_SEV_NEW(6)	Hitting Tree	0	1.449	4.260

- **B** in the above table denotes the logistic coefficient.
- **Exp(B)** is the odds ratio or fatal risk ratio associated with each predictor.
- Variables bolded in each category are used as base variables to calculate odds ratio or fatal risk ratio.

4.5.2.2.1 Accident Severity with Rider Age

Age group of riders 54 to 59 and greater than 60 involved accidents are 2.034 and 2.891 times more probable to become fatal compared to accident where riders' age group 24 to 29 involved.

Comparison of fatal risk to riders in terms of their age group shows that involvement of younger riders in MCL-self accidents are high in proportion compared to older riders. But, fatal risk to older riders is more than two folds compared to younger riders.

4.5.2.2.2 Accident Severity with Riders Pre-Crash Factors

Accidents due to the human pre-crash factor 'Blinded by another vehicle or Sun' is 1.547 times probable to become fatal compared to accident caused by 'Aggressive/negligent driving'. In a study by Devasurendra, 2016 also concluded 'Blinded by another vehicle or Sun' have 8.7 times chance for becoming fatal crash in Heavy vehicle related crashes.

4.5.2.2.3 Crash Factor for Accident Severity

Accidents due to 'Hitting pole or post', 'Hitting barrier or Guard rail' 'Hitting other fixed objects' and 'Hitting Tree' are 3.231 times, 2.690 times 2.141 and 4.260 times more probable to become fatal compared with accident severity caused by 'Rolled over'.

4.5.2.3 Logistics Regression Analysis for Crash Environment Model of MCL-Self Accidents

The dependent variable in this analysis is Highest Severity of accident. The independent variables considered are day of week, collision type, road surface condition, weather, light condition, road location, time of accident, urban or rural category, second collision, traffic control, speed limit of the environment and. police division accident recorded. Altogether, 12 independent variables included in the model.

After five iterations, analysis has excluded the statistically insignificant variables from the model. The variables collision type, road surface condition, light condition, urban or rural category, second collision and police division accident recorded are included to the model out of 12 input variables.

Table 4.64: Stepwise Inclusion of Variables into the Crash Environment Model (MCL – Self Accidents)

Variable		Model Log Likelihood	Change in- 2 Log Likelihood	Sig. of the change
Step 6	COLL_TY	-1593.168	36.667	.000
	RD_SUR	-1579.252	8.834	.032
	LIG_COND	-1581.898	14.127	.007
	URV_RUR_NEW	-1579.624	9.579	.002
	SEC_COLL_NEW	-1597.646	45.623	.000
	DS_DIV_NEW	-1629.792	109.914	.000

Table 4.65: Statistically Significant Results of the Crash Environment Related Model (MCL – Self Accidents)

Variable	Description	Sig	B	Exp(B)
Accident severity with collision pattern				
COL_TY	**0811**	0		
COL_TY(2)	0821	**0**	**0.634**	**1.885**
COL_TY(7)	1220	.003	-0.974	0.378
Accident severity with road surface condition				
RD_SUR	**Dry**	.027		
RD_SUR(1)	Wet	**.003**	**0.531**	**1.700**
Accident severity with light condition on road				
LIG_COND	**Day Light**	.014		
LIG_COND(1)	Night No Street Light	**.044**	**0.203**	**1.225**
LIG_COND(2)	Dusk, Dawn	.015	-0.833	0.435

Accident severity with township accident occurred				
URV_RUR_NEW	**Rural**	**0**		
URV_RUR_NEW(1)	Urban	.002	-0.382	0.682
Accident severity with police division accident occurred				
DS_DIV_NEW	Anuradhapura	0		
DS_DIV_NEW(1)	Ampara	.049	-0.461	0.631
DS_DIV_NEW(4)	Batticaloa	.050	-0.471	0.624
DS_DIV_NEW(12)	Kalutura	**.016**	**0.735**	**2.086**
DS_DIV_NEW(19)	Matala	.004	-1.017	0.362
DS_DIV_NEW(24)	Nikawaratiya	.003	-1.211	0.298
DS_DIV_NEW(27)	Panandura	**.018**	**0.808**	**2.244**

- **B** in the above table denotes the logistic coefficient.
- **Exp(B)** is the odds ratio or fatal risk ratio associated with each predictor.
- Variables bolded in each category are used as base variables to calculate odds ratio or fatal risk ratio.

4.5.2.3.1 Accident Severity with Collision Pattern

Collision type 0821 represents accidents due to, motorcycle entering in a curve run off straight in the same direction. This type of accidents were compared with MCL coming straight, run off the road to the left side (0811). The Exp (B) value for collision type 0821 is 1.885. This means, accidents in collision pattern 0821 are 1.885 times more probable to become fatal compare to collision type 0811.

4.5.2.3.2 Accident Severity with Road Surface Condition

Accidents occurring in wet road surface are 1.700 times more probable to become fatal compare to accidents occurred in dry road surface. Therefore, it is advisable for motorcyclist to reduce speed during rainy season in order to reduce such type of accidents.

4.5.2.3.3 Accident severity with Light Condition on Road

Fatal risk ratio of motorcycle-self accidents occurred at ‘Night with no street light’ condition are 1.225 times higher compared with accidents occurring in ‘Day Light

condition'. In the meantime, accidents occurring in rural areas are approximately 1.5 times (1/0.682) probable to become crucial compare to accidents in urban areas.

It can be concluded that accidents occurring at night time in rural areas in roads without street lights and improper street lights are high and more probable to become fatal. Therefore, relevant Authorities should take necessary actions to fix street lights on roads where necessary.

4.5.2.3.4 Accident Severity in Various Police Divisions across the Country

Accidents occurring in Kalutura and Panandura police divisions are 2.086 times and 2.244 times more probable to become fatal compared with accidents occurred in Anuradhapura district. Likewise, accidents occurring in Ampara police divisions and Nikawaratiya are 0.631 times and 0.298 times less probable to become fatal than accidents occurred in Anuradhapura.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings from Literature Review

There is a positively significant relationship between human factors, environmental factors, legal factors and vehicle factors contributed to motorcycle related accidents. The majority of motorcycle collisions leads to serious injuries and fatalities occur at modest speed. The majority of victims in motorcycle accidents are young male riders, the productive force of the country.

Slippery road surfaces, drain covers, roadway defects, gratings and unevenness road marking, poor road design, lack of road signs and unexpected movement of animals also the environmental factors contribute to motorcycle accidents.

Emphasizing skill limitations, coverage of higher order cognitive skills, providing information on risk level, and communicating a rules and knowledge base for safe riding will improve the safety of motorcyclist. The discomfort felt by psychological stress can increase accident risk. Stress can increase fatigue which is a silent killer. Long journeys should be planned to include frequent rest. More stringent panalties, including the temporary impounding of motorcycles driven by riders who are invalidly licensed should be implemented. This statergy not only prevent unlicensed riders but also owners from allowing unlicensed riders to operate their motorcycles.

For motorcycle, a mistake by the rider during break leads to wheel being over-braked will cause the vehicle to skid, become unstable and capsize. Nowadays, the recently introduced improved breaking system is Anti-lock brake system. Fitment of Anti-lock brake system for motorcycles now been mandated in major markets such as all 28 member states of the European Union (EU), Japan,Taiwan, Brazil and announced in India too.

Vehicle related to accident causation are rare and likely to be due to deficient or defective maintenance. As the engine size increases, sensation seeking motives, lessiure seeking motives and risk taking behaviour also increases since the increased engine capacity support the riders to achieve high accelaration. This will further worsen the road safety situation of the country.

Not seeing a motorcycle has been reported to be a common cause of accidents during the both hours of day light and at night. One way of increasing increasing interaction of motorcycles with other traffic is, Day time Running Lights (DRL).

5.2 Summary of Research Methodology

Logistic regression analysis has been widely used by the scholars for accident severity modeling. It is possible for logistic regression analysis to produce erroneous results due to small sample size but this can be eliminated by using larger sample size. The logistic regression modelling gives finer details about the contributory factors for accidents. But, the results obtained from descriptive statistics are very general. Here, Forward-Stepwise-Binary-Logistic method was used for analyzing accidents.

According to severity, there are four categories of accidents as Fatal, Grievous Non-grievous and Damage only. But, due to under reporting issues, Damage only accidents were excluded from the analysis.

5.3 Summary of the Analysis of Risk to Motorcyclist in Sri Lanka

Motorcyclist are more vulnerable and the most dangerous road users in Sri Lanka. MCL related accidents accounts for nearly 40% of total road accidents and approximately half of the total fatal, grievous, non-grievous injuries are caused in MCL related accidents. Motorcyclists are front runners in road accidents in other low-middle-income countries also. In India, motorcyclist account for 35% in total deaths in road accidents in year 2016. Malaysia this figure is around 61% and Thailand 74%. Meanwhile, percentage of motorcyclist die in roads in Sri Lanka is very much high compared with Motorcyclist deaths of the world's road per year.

The details on 'Number of years license issued since the time of accident' has more than one third of record are 'not known'. It is one of the major drawback in Police accident data entering process. Because, it is an important parameter to measure rider experience and implement training programs based on rider's experience. Likewise, information on human pre – crash factors, crash factors contributing to accident severity, road pre-crash factors and vehicle pre-crash factors contributing to accident

severity details collection process need to be improved. Where, more cases are recorded under 'Not known' category.

Fatal risk per 10,000 operating MCL is very high in Sabragamuva Province and less in Central province which accounts for 7.47 and 3.97 respectively. This figure is averaged to 4.76 for fatal and 21.63 for grievous injuries when considering the all island. Fatality of motorcyclists per 100 km of road length in the Western Province is 6.39 and in the Central Province is 0.93. In Sri Lankan road, fatal risk to MCL per 100 km of road length is 2.77. Fatality of motorcyclist per 100 million VKT is averaged to 5.22 and grievous injuries is averaged to 22.94.

More than one third (35%) of motorcyclist are killed in accident with Lorries followed by 18% in collision with buses and 17% in accidents with dual purpose vehicles. Fatality of motorcyclist per 10,000 operating vehicles is high from Buses and Lorries which accounts for 21.38 and 8.39 respectively. Estimated fatality of motorcyclist per 100 million Vehicle Kilometers Travelled (VKT) by each types of vehicle indicate that Land vehicles cause more fatality to MCL per 100 million VKT which accounts for 19.19 and followed by SLTB Buses (7.31), Dual purpose vehicle (3.72) and Lorries (3.95) but for cars this this figure is 0.39.

Pillion ridership in motorcycles is around 30% to 35%. Pillion riders' accounts for nearly 20% of total fatality and 22% of grievous injuries recorded in motorcycle accidents. Preschoolers' and children between age group 12 to 17 accounts for nearly 1.5% sustained casualties in motorcycle accidents as pillion riders.

5.4 Summary of Descriptive Analysis of Motorcycle – Motor Vehicle Accidents

Motorcycle accident with three wheelers accounts for 27% of total accidents followed by Lorry, Dual purpose vehicle and Car are accounts for 21%, 20% and 16% respectively. Aggressive or negligent driving of rider is the cause for more than 35% of accidents followed by speeding which contributed to 6% of accidents.

Nearly 95% of accidents recorded on dry road surface and 4% recorded on wet road surface. 88% of accidents recorded between 6.00 am to 9.00 pm. Among this, 23% of crashes occurred between 3.00 pm to 6.00 pm which include the evening peak traffic.

Head on collision and Rear end collision are more prominent in MCL-MV accidents which accounts for 26% and 17% respectively.

5.4.1 Summary of Logistic Regression Analysis of Motorcycle – Motor Vehicle Accidents

MC accidents with Lorries have 7.313 times more probable to become fatal compared to accidents with three wheelers where accident with dual purpose vehicles has 3.678 times more chance to become fatal compare to the same. Motorcycle accidents with SLTB buses are nearly 1.1 times vulnerable to become fatal compared to accident with Private Buses.

Riders above the age of 60 years are 2.611 times vulnerable to become fatal compared to rider age group from 24 to 29. Fatal risk to older riders is high compare to the younger riders. Accident occur due to human pre-crash factor 'fatigue or fall asleep' have 6.140 time more probable to become fatal compared to accident occur due to 'aggressive or negligent driving'

Crash factor contributed to motorcyclist accident severity due to 'Hitting pole or post' is 6.294 times probable to become fatal compared with crash severity due to 'rolled over' which was major casual factor for crash severity. MCL-MV accident occurring in wet road surface is 1.432 times more probable to become fatal compared with accidents occurring in dry road surface. Fatal risk of crashes occurring at late night from 9.00 pm to 6.00 am have more chance to become fatal. Riding MCL in rural areas are 1.253 times have chance to become fatal than in urban areas.

Collision of MCL coming straight with vehicle taking U-Turn, 90^{o} angle collision at 4-Leg intersection and rear-end collision are 0.483 times, 0.635 times and 0.597 times have less chances to become fatal when compared with head-on collision. Head-on collisions are 1.675 times probable to become fatal than rear-end collisions.

5.5 Summary of Motorcycle – Pedestrian Accidents

Fatality of pedestrian in Sri Lankan roads are 1.32 times higher compared to deaths in world roads. Pedestrian fatal accident with MCL accounts for 38% of total pedestrian

accidents followed by dual purpose vehicle 17% and three wheelers 13%. Nearly 30% of pedestrians suffer fatal and 45% suffer grievous injuries due to accidents with motorcycles.

Fatality of pedestrians per 10,000 operating MCL population is 1.20, buses 15.35, Lorry 3.44 and from dual purpose vehicle is 3.35 respectively. When MCL only accidents are concerned, nearly 20% killed in MCL related accidents are pedestrians followed by cyclists 7%. In year 2015, fatality of pedestrians in road accidents per 100,000 populations was 3.89 and from MCL it was only 1.19. The fatality of pedestrians per 100 Mn.MCL.km travelled is around 1.21.

Nearly 91% of accidents occurred between 6.00 am to 9.00 pm. Among them, 27% of crashes occurred between 6.00 pm to 9.00 pm. More than 41% of accidents have been recorded at '50 m beyond pedestrian crossing', on Pedestrian Crossing (PC) 17% and 13% within 50 m of PC. In total, 19% crashes occurred on roads without side walk. Hit on sidewalk accidents account for 6% of total MCL-Pedestrian accidents.

Pedestrian pre-crash factor 'other or not known' is mentioned as a reason for 94% of accidents. It is one of the major drawback in police accident data collection process. Therefore, measures has to be taken to identify other factors as much as possible which will help to get good understanding of pedestrian pre-crash factors contributed to accidents.

Involvement of pedestrians above the age 47 and in between Six and Eleven is high and contributed to nearly two third of total accidents. Pedestrians entering the road from left side walk or shoulder hit by motorcycle travelling straight ahead on the left accounts for 31% of accidents, entering the road from right side walk or shoulder hit by motorcycle travelling straight ahead on the left accounts for 14% of accidents, rear end accident accounts for 13% and MCL overtaking to the right hit pedestrian entering the road from left side walk or shoulder accounts for 9%.

5.5.1 Summary of Logistic Regression Analysis of Motorcycle – Pedestrian Accidents

Accident occurred between 3.00 am to 6.00 am are 1.782 times more probable to become fatal than accident occurred between 6.00 pm and 9.00 pm. Accidents occurred during evening peak from 3.00 pm to 6.00 pm are 1.343 times more probable to become fatal compare to afternoon peak from 12.00 noon to 3.00 pm.

Pedestrians have 1.692 times less fatal risk on pedestrian crossing compared to the accident beyond 50 m of pedestrian crossing or 1.692 more fatal risk in mid-block section of roads. Compared to male, female pedestrians have 1.550 times less chance to die in accidents. With the increasing age, fatal risk to pedestrian is increasing. Pedestrian age group greater than 60 are more probable to become fatal than the other age groups of pedestrians involved in accidents.

5.6 Summary of Motorcycle – Bicycle Accidents

Fatality of cyclists in Sri Lanka roads are 2.25 times higher compared to global figure on fatality of pedestrians in world's road. In the year 2015, 31% cyclist died in road accidents with motorcycles. In an average nearly 45% cyclist suffer grievous injuries due to motorcycle-cycle accident. Fatality of cyclist per 10,000 operating car is 0.17, buses and motorcycle is 6.49 and 0.42 respectively. In year 2015, fatality of cyclist per 100 million motorcycle km travelled was 3.94 and grievous injuries was 13.05 for the same.

Involvement of cyclist above the age of 42 and between 12 and 17 is high and contributed more than two third (70%) of total accidents. This group of cyclist face threat from younger MCL riders between the age group 18 and 42 (79%) with aggressive or negligent driving.

From 6.00 pm to 9.00 pm, 34% of MCL-Cycle accidents recorded followed by accidents occurred from 3.00 pm to 6.00 pm (19%) and 12.00 noon to 3.00 pm (14%). Rear end collisions are more prominent which accounts for 35% of total accidents followed by 24% of head on collisions. Nearly 75% of accidents occurred in rural areas.

5.6.1 Summary of Logistic Regression Analysis of Motorcycle – Cycle Accidents

Cyclist between ages 12 to 17 represents the school children who involved crashes are 5 times less probable to become fatal when compared with age group greater than 60. Involvement of older cyclist in MCL-Cycle accident is high and fatal risk to cyclist increases with their age. Age group of cyclists sixty or above are the most vulnerable in MCL-Bicycle accidents.

5.7 Summary of Motorcycle – Self Accidents

Involvement of younger riders in MCL self-accidents from the age 18 to 42 accounts for nearly 77% of total accident. Involvement of older drivers in self-accident over the age 42 accounts for 19% of total accidents. Aggressive or negligent driving is a causing factor for 65% of self-accidents and followed by 19% due to speeding.

Highest numbers of motorcycle self-accidents reported in night time and road with no street lights which accounts for 39% of total accidents. MCL-MV and MCL-Pedestrians accidents occurred in night time and road with no street lights is only 15% and 18% respectively.

Rolled over of rider is one of the common factors for accident severity which accounts for 40 % of accidents followed by ‘Hitting pole or post of 10%. Major Collision patterns are MCL coming straight, run off the road to the left side is 32%, MCL coming straight, run off the road to the right side is 11% and run off the road straight is 12% respectively.

5.7.1 Summary of Logistic Regression Analysis of Motorcycle – Self Accidents

Riders in the age group from 54 to 59 and greater than 60 involved accidents are 2.034 and 2.891 times probable to become fatal than the riders in the age group between 24 and 29. Self-accidents due to human pre-crash factor ‘Blinded by another vehicle/Sun’ is 1.547 times probable to become fatal than accident caused by ‘Aggressive/negligent driving’.

Accident severity due to ‘Hitting pole/post’, ‘Hitting barrier or Guard rail’ ‘Hitting other fixed objects’ and ‘Hitting Tree’ are more severe. These accidents are 3.231 times, 2.690 times 2.141 and 4.260 times probable to become fatal than accident severity due to ‘Rolled over’.

MC entering in a curve, run off the road to the left side have 1.885 times chance to become fatal compared to MC coming straight, run off the road to the left side. Accidents occurring ‘wet road surface condition’ are 1.700 times more probable to become fatal than accidents in ‘dry road surface’. Crashes occurring in ‘Night or no street light condition’ are 1.225 time have chance to become fatal compared with accidents occurring in ‘Day Light condition’. At the same time, accidents occurring in ‘rural areas’ are approximately 1.5 times probable to become fatal compared with accidents occurring in ‘urban areas’.

5.8 Overall Conclusion

Motorcycles are involved in nearly 40% of the total road vehicle accidents in the country. Nearly 29% of the pedestrian fatalities and 9% of cyclist fatalities involved motorcycles. Therefore, Motorcyclist can be considered in the vulnerable road user category in Sri Lanka. The study evaluated the primary risk factors related to motorcycle accident in Sri Lanka.

Motorcycle fatal accident risk ratio increasing significantly for lorries and buses when compared to other vehicle types (risk ratio is more that 7 when compared to three-wheeler accidents). Similarly, fatal accident risk ratio increase by 40% and 70% for collision with other vehicles and single vehicle accidents during wet weather. With respect to the time of day, although accident volumes are highest during the period 3 PM to 6 PM (23% of the total accidents); fatal accident risk ratio increase 44% during the period 9 PM to midnight and by more than 2.5 times during midnight to 6 AM.

Single vehicle accidents more than 57% occur during the nigh time and the risk ratio increase by over 20% during the night time on road segments without street lightings. Similar findings were observed for time periods where motorcycle-pedestrian

accidents occur. Furthermore, pedestrians - motorcycle accidents were at the greatest risk at mid block sections of the road and pedestrian aged 60 above were at the highest risk of sufferring a fatality during a motorcycle accident compared to other age groups.

The accident severity analysis shows that the fatal accident risk ratio is significantly high when the motorcycle collision involves hitting a pole or tree or fixed object compared to other collision types (risk ratio over 3.0). Head on collision proved to be the one with the highest risk for motorcycle accidents with other vehicles.

The study provides, useful insights to identify the main causal factors with respect to motorcycle accidents. These are for some variable different to the causal factors present in majority of the accidents. Therefore, the findings can be incorporated into improving motorcycle rider safety in Sri Lanka.

5.9 Risk Factors in Motorcycle Accidents and Mitigation Measures

Accident rate per unit of exposure (VKT) can be reduced by improving rider skills, proper training, education and giving attention on vehicle performance, maintaining road standards, legislation and enforcement. Special attention need to be focused on motorcycle users in Sabragamuva and North Central provinces where fatal and grievous injuries risk is high per 10,000 operating motorcycles. Risk to motorcycles per 10,000 operating vehicle data is useful in advising vehicle drivers on motorcycle safety.

To make sure pillion safety, Countermeasures like, design of comfortable and safe seating position, not allowing infants and preschoolers under 6 years on motorcycle as passenger, strict enforcement of law against over loading of pillions (more than two), not allowing woman to keep their both leg on one side of the foot rest and travel, creating awareness to woman specially wearing sarees to make sure, sarees not trap into wheel, make sure weather foot rest damaged or possible to rest feet while travelling and compulsory enforcement of laws on child helmet and protective gear when being carried on motorcycle.

Involvement of younger riders in accidents are high. Proper training, education, strict enforcement of law, creating awareness on skill riding and motorcycle safety and implementation of graduated licensing systems will further improve the rider's safety.

Risk to motorcycles from motor vehicles are high. Countermeasures like, separating motorcycle from traffic composition especially from buses and Lorries will help to reduce this. In Malaysia exclusive motorcycle lanes provided in some highways helped to reduce motorcycle accidents significantly.

Older riders are more vulnerable in accidents. Proper medical checkups, special motorcycle training programs targeting older riders, design of new driving license permission targeting older riders, promoting safety kids (Jacket, Boots, Knee guards and Standard helmets) avoiding long journeys and night time trips will help to reduce numbers of accidents older riders involved. Accident occur due to human pre-crash factor 'fatigue or fall asleep' are probable to become fatal. It is better to avoid long journeys by MCL and suggested to plan long journeys with frequent rest.

Accident occurring in wet road surfaces have more chances to become fatal compared with accidents occurring in dry road surface. Therefore, it is advisable to riders and drivers to pay more attention on road safety during rainy days. Moreover, improved breaking system and vehicle technology to reduce slipping on wet surface will further improve the risk to riders on wet rod surface. Crashes occurring at late night from have more chance to become fatal. Therefore, it is better to avoid late night journeys using MCL or take necessary precautions to increase the conspicuity during night time such as wearing illuminating jackets and light color helmets.

Head-on collisions are more probable to become fatal than rear-end collisions. Counter measure like, crash reduction technology in vehicles and inter-vehicle communication technologies, design of Air bags in motorcycles will help to reduce these kind of accidents. Closing additional U-Turn openings provided in national highways, maintaining correct number of U-turn openings and providing rumble strips ahead of U-turn openings will reduce accidents due to U-turn.

In total, 19% of MCL-Pedestrian accidents occurred on roads without side walk. It indicates either lack of pedestrian walk ways on many roads in Sri Lanka or even

walkways available they are not in the position to use by pedestrians due to lack of maintenance or occupied by street vendors. By considering these facts, Government needs to take measures to construct new pedestrian walkways while paying attention on maintaining existing walkways and removing obstacles to pedestrians. Hit on sidewalk accidents account for 6% of total MC-Pedestrian accidents. In congested town areas motorcycle riders use walkways to filter the traffic or overtaking purpose. Because of the small in size of MCL, they share walkways with pedestrians. Therefore, necessary precautions such as providing safety fences, increasing the level difference between walkways and road surface will reduce this problem.

Involvement of pedestrians above the age 47 and in between 6 and 11 is high and contributed to nearly two third of total accidents. Therefore, when designing pedestrian facilities or take precautions, more attention need to be paid on this age group of riders and pedestrians. Specially, more attention need to be paid on school children safety.

Rear-end collisions accounts for 13% of total accidents. It indicates that wrong side walking behavior of pedestrians contribute to this type of accidents. Creating awareness on pedestrian safety and understanding motorcycle rider – pedestrian behavior will help to reduce these kind of accidents. Fatal risk to cyclist per 10,000 operating car is 0.17, buses and motorcycle is 6.49 and 0.42 respectively. In year 2015, fatal risk to cyclist per 100 million motorcycle km travelled is 3.94 and grievous risk is 13.05 for the same. Rear end collisions are more prominent which accounts for 35% of total accidents Countermeasures like, providing dedicated cycle lanes and segregating cycles from normal traffic will help to promote the cyclist safety

From 18.00 pm to 21.00 pm, 34% of MC-Cycle accidents recorded. Countermeasures like, increasing the visibility of cyclist at night by using illuminating jackets, strictly enforcing the usage of head lights, helmet, tile lights, and illuminating lights in paddles will help to reduce accidents at night due to poor visibility of cyclist to motorcyclist or other vehicles. Accident severity due to ‘Hitting pole/post’, ‘Hitting barrier or Guard rail’ ‘Hitting other fixed objects’ and ‘Hitting Tree’ are more severe. Initiatives should be taken to shift utility posts which are hindrance to road users. Fixing illuminating stickers, White washing road site rigid objects periodically and

construction of culvert parapet wall away from carriageway will reduce the accidents due to these fixed objects on roads. When designing roads, designers should think about accommodating error forgiving structures in roads. Though it is very expansive solution, it will save the lives and property of many people.

MCL entering in a curve, run off the road to the left side have more chance to become fatal compared to MC coming straight, run off the road to the left side. Improving curve radius at black spot, proper lane marking and rumble strip marking ahead of curves to alert drivers, training on riding at curves will help to reduce the severity of this kind of accidents. Self-accidents occurring at 'Night or no street light condition' are 1.225 time have chance to become fatal compared with accidents occurring in 'Day Light condition'. Priority should be given to fix street lights on roads passing through rural segments as roads passing through urban areas. Street light facilities and pavement marking will reduce conflicts and misjudgment in Motorcycle maneuvering.

More stringent panalties, including the temporary impounding of motorcycles driven by riders who are invalidly licensed should be implemented. This statergy not only prevent unlicensed riders but also owners from allowing unlicensed riders to operate their motorcycles.

5.10 Limitations of the Study

Major limitation of this study is details about cyclist pre-crash factor, cycle factor and age of cycle involved in accident, pedestrian, rider, road and vehicle pre-crash factors contributed to accident are most of the time not known. Likewise, details on 'number of years license issued since the time of accident' data has more than 30% of records are 'not known'. Measures has to be taken to properly record these factors in accident sheet.

5.11 Future Work and Recomendation

Field studies are highly recommended to understand the behaviors of Pedestrian and Motorcyclist, Cyclist and Motorcyclist on roads.

Fatal risk to motorcyclist from buses and Lorries are high. Therefore, some research need to be done to ascertain the casual factors of these accidents.

Further, it is recommended to carry out logistic regression modelling for Three-wheelers related accidents to find out the factors contributing to accident severity so that mitigations can be found out.

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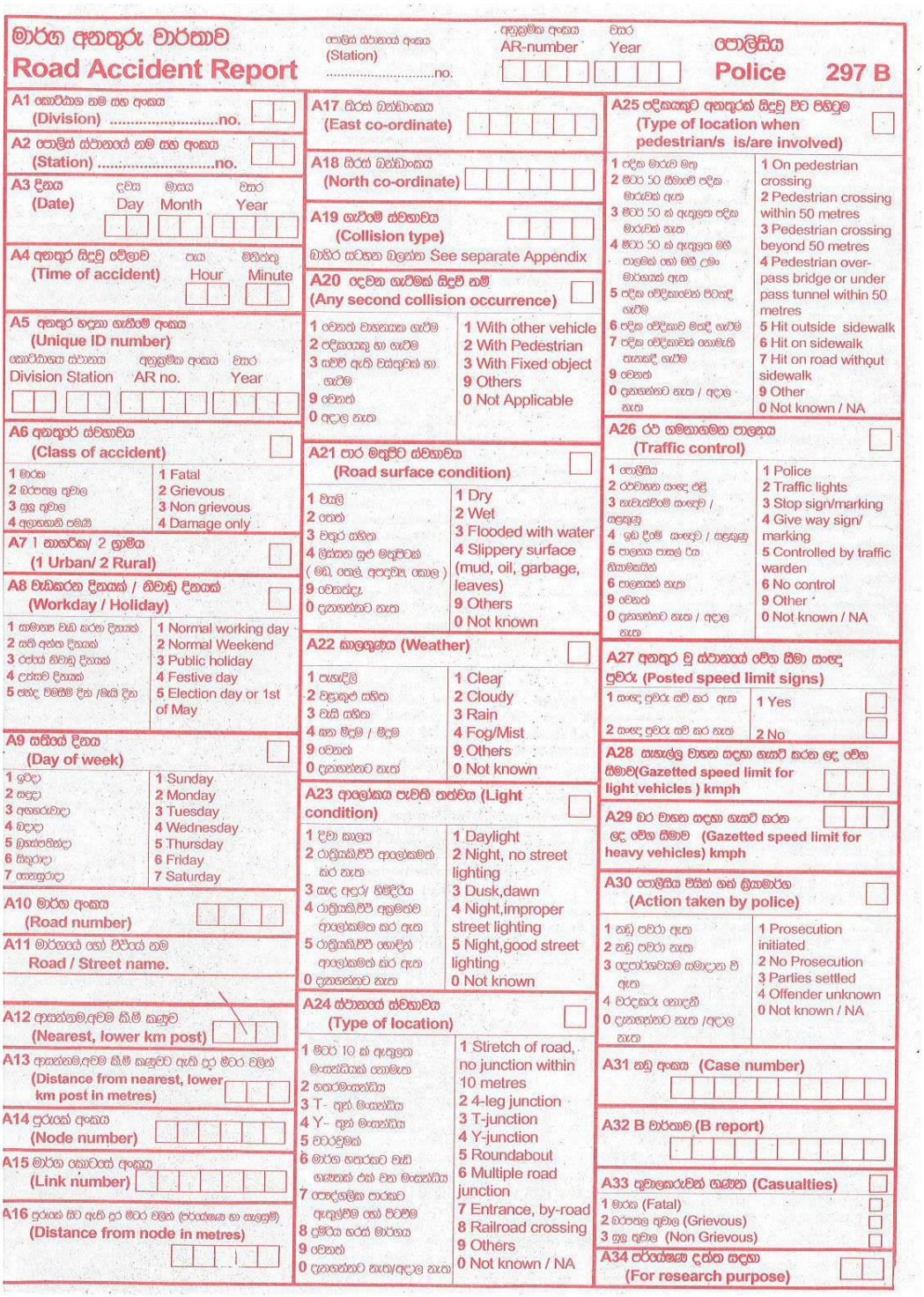
Appendix A – Sample of Road Accident Report Sheet



මාර්ග අනතුරු වාර්තාව
Road Accident Report

පොලිස් ස්ථානයේ අංකය (Station) .....no.
අනුක්‍රමික අංකය AR-number
වසර Year
පොලිසිය **Police** **297 B**

A1 කොට්ඨාශය නම සහ අංකය (Division) .....no.

A2 පොලිස් ස්ථානයේ නම සහ අංකය (Station) .....no.

A3 දිනය (Date) දවස Day මාසය Month වසර Year

A4 අනතුර සිදුවූ වේලාව (Time of accident) පැය Hour මිනිත්තු Minute

A5 අනතුර හඳුනා ගැනීමේ අංකය (Unique ID number)
කොට්ඨාශය ස්ථානය Division Station | අනුක්‍රමික අංකය AR no. | වසර Year

A6 අනතුරේ ස්වභාවය (Class of accident)
1 මාරක | 2 බරපතල තුවාල | 3 සුළු තුවාල | 4 අලාභහානි පමණි
1 Fatal | 2 Grievous | 3 Non grievous | 4 Damage only

A7 1 නාගරික/ 2 ග්‍රාමීය (1 Urban/ 2 Rural)

A8 වැඩකරන දිනයක් / නිවාඩු දිනයක් (Workday / Holiday)
1 සාමාන්‍ය වැඩ කරන දිනයක් | 2 සති අන්ත දිනයක් | 3 රජයේ නිවාඩු දිනයක් | 4 උත්සව දිනයක් | 5 ජන්ද විමසීම් දින /මැයි දින
1 Normal working day | 2 Normal Weekend | 3 Public holiday | 4 Festive day | 5 Election day or 1st of May

A9 සතියේ දිනය (Day of week)
1 ඉරිදා | 2 සඳුදා | 3 අඟහරුවාදා | 4 බදාදා | 5 බ්‍රහස්පතින්දා | 6 සිකුරාදා | 7 සෙනසුරාදා
1 Sunday | 2 Monday | 3 Tuesday | 4 Wednesday | 5 Thursday | 6 Friday | 7 Saturday

A10 මාර්ග අංකය (Road number)

A11 මාර්ගයේ හෝ වීථියේ නම Road / Street name.

A12 ආසන්නතම,අඩුම කිලී කණුව (Nearest, lower km post)

A13 ආසන්නතම,අඩුම කිලී කණුවට ඇති දුර මීටර වලින් (Distance from nearest, lower km post in metres)

A14 පුරුකේ අංකය (Node number)

A15 මාර්ග කොටස් අංකය (Link number)

A16 පුරුකේ සිට ඇති දුර මීටර වලින් (ප්‍රරාශය හා ඇණුම්) (Distance from node in metres)

A17 නිරස් බන්ධාංකය (East co-ordinate)

A18 සිරස් බන්ධාංකය (North co-ordinate)

A19 ගැටීමේ ස්වභාවය (Collision type)
බාහිර සටහන බලන්න See separate Appendix

A20 දෙවන ගැටීමක් සිදුවී නම් (Any second collision occurrence)
1 වෙනත් වාහනයක ගැටීම | 2 පදිකයෙකු හා ගැටීම | 3 ස්ථිර ඇති වස්තුවක් හා ගැටීම | 9 වෙනත් | 0 අදාල නැත
1 With other vehicle | 2 With Pedestrian | 3 With Fixed object | 9 Others | 0 Not Applicable

A21 පාර මතුපිට ස්වභාවය (Road surface condition)
1 වියලි | 2 තෙත් | 3 වතුර සහිත | 4 ලිස්සන සුළු මතුපිටක් (මඩ, තෙල්, අපද්‍රව්‍ය, කසල) | 9 වෙනත්ද. | 0 දැනගන්නට නැත
1 Dry | 2 Wet | 3 Flooded with water | 4 Slippery surface (mud, oil, garbage, leaves) | 9 Others | 0 Not known

A22 කාලගුණය (Weather)
1 පැහැදිලි | 2 වළාකුළු සහිත | 3 වැසි සහිත | 4 සෙ මීදුම / මීදුම | 9 වෙනත් | 0 දැනගන්නට නැත
1 Clear | 2 Cloudy | 3 Rain | 4 Fog/Mist | 9 Others | 0 Not known

A23 ආලෝකය පැවති තත්වය (Light condition)
1 දිවා කාලය | 2 රාත්‍රියකීවී ආලෝකමත් කර නැත | 3 සැදෑ අලු/ හිමිදිරිය | 4 රාත්‍රියකීවී අකුමවත් ආලෝකමත් කර ඇත | 5 රාත්‍රියකීවී ගොඩාක් ආලෝකමත් කර ඇත | 0 දැනගන්නට නැත
1 Daylight | 2 Night, no street lighting | 3 Dusk,dawn | 4 Night,improper street lighting | 5 Night,good street lighting | 0 Not known

A24 ස්ථානයේ ස්වභාවය (Type of location)
1 මීටර 10 ක් ඇතුලත මංසන්ධියක් නොමැත | 2 හතරමංසන්ධිය | 3 T- ආකාර මංසන්ධිය | 4 Y- ආකාර මංසන්ධිය | 5 වටරවුමක් | 6 මාර්ග හතරකට වැඩි ගණනක් එක් වන මංසන්ධිය | 7 පාසල්ගමික පාරකට ඇතුල්වීම හෝ පිටවීම | 8 දුම්රිය හරස් මාර්ගය | 9 වෙනත් | 0 දැනගන්නට නැත/අදාල නැත
1 Stretch of road, no junction within 10 metres | 2 4-leg junction | 3 T-junction | 4 Y-junction | 5 Roundabout | 6 Multiple road junction | 7 Entrance, by-road | 8 Railroad crossing | 9 Others | 0 Not known / NA

A25 පදිකයෙකුට අනතුරක් සිදුවූ විට පිහිටුම (Type of location when pedestrian/s is/are involved)
1 පදික මාරුව මත | 2 මීටර 50 සීමාවේ පදික මාරුවක් ඇත | 3 මීටර 50 ක් ඇතුලත පදික මාරුවක් නැත | 4 මීටර 50 ක් ඇතුලත මහ පාලමක් හෝ මහ උමං මාර්ගයක් ඇත | 5 පදික වේදිකාවෙන් පිටත් ගැටීම | 6 පදික වේදිකාව මතදී ගැටීම | 7 පදික වේදිකාවක නොමැති තැනකදී ගැටීම | 9 වෙනත් | 0 අනතුරට නැත / අදාල නැත
1 On pedestrian crossing | 2 Pedestrian crossing within 50 metres | 3 Pedestrian crossing beyond 50 metres | 4 Pedestrian over-pass bridge or under pass tunnel within 50 metres | 5 Hit outside sidewalk | 6 Hit on sidewalk | 7 Hit on road without sidewalk | 9 Other | 0 Not known / NA

A26 රථ ගමනාගමන පාලනය (Traffic control)
1 පොලිසිය | 2 රථවාහන සංඥා ලයිට් | 3 නැවැත්වීම සංඥාව / සලකුණු | 4 ඉඩ දීමේ සංඥාව / සලකුණු | 5 පාලනය පාසල් ළය නිලධාරීන් | 6 පාලනයක් නැත | 9 වෙනත් | 0 දැනගන්නට නැත / අදාල නැත
1 Police | 2 Traffic lights | 3 Stop sign/marking | 4 Give way sign/ marking | 5 Controlled by traffic warden | 6 No control | 9 Other | 0 Not known / NA

A27 අනතුර වූ ස්ථානයේ වේග සීමා සංඥා පුවරු (Posted speed limit signs)
1 සංඥා පුවරු සවි කර ඇත | 1 Yes
2 සංඥා පුවරු සවි කර නැත | 2 No

A28 සැහැල්ලු වාහන සඳහා ගැසට් කරන ලද වේග සීමාව(Gazetted speed limit for light vehicles) kmph

A29 බර වාහන සඳහා ගැසට් කරන ලද වේග සීමාව (Gazetted speed limit for heavy vehicles) kmph

A30 පොලිසිය විසින් ගත් ක්‍රියාමාර්ග (Action taken by police)
1 නඩු පවරා ඇත | 2 නඩු පවරා නැත | 3 පාර්ශවයන් සමාදාන වී ඇත | 4 වරදකරු නොදනී | 0 දැනගන්නට නැත /අදාල නැත
1 Prosecution initiated | 2 No Prosecution | 3 Parties settled | 4 Offender unknown | 0 Not known / NA

A31 නඩු අංකය (Case number)

A32 B වාර්තාව (B report)

A33 තුවාලකරුවන් ගණන (Casualties)
1 මාරක (Fatal)
2 බරපතල තුවාල (Grievous)
3 සුළු තුවාල (Non Grievous)

A34 පර්යේෂණ දත්ත සඳහා (For research purpose)

E1 අනතුරට හේතුවූ වූ දෑ (Element type)

01 කාරය	01 Car
02 ද්විත්ව කාර්ය වාහනය	02 Dual purpose vehicle
03 ලොරිය	03 Lorry
04 පාපැදිය	04 Cycle
05 ගතුරාසැදිය, මෝපෙඩ්	05 Motor cycle, Moped
06 ත්‍රිරෝද රථය	06 Three wheeler
07 ඇදුම් රථය, ට්‍රැක්ටර් ඇදගෙන යන වාහනය	07 Articulated vehicle, prime mover
08 ලංගම මහ ප්‍රවාහන බස්රථය	08 SLTB bus
09 පෞද්ගලික මහ ප්‍රවාහන බස්රථය	09 Private bus
10 ගුවන්විජයාගී මහ ප්‍රවාහන බස්රථය	10 Intercity bus
11 ඉඩම් වාහනය /ට්‍රැක්ටරය	11 Land vehicle/ Tractor
12 සතකු ඇදගෙන යන වාහනයක් හෝ සතකු පිටනැති පුද්ගලයෙක්	12 Animal drawn vehicle or rider on animal
13 පදිකයා	13 Pedestrian
19 වෙනත්	19 Others
00 දැනගන්නට නැත	00 Not known

E5 වාහනයේ අයිතිය (Vehicle ownership)

1 පෞද්ගලික වාහනයක්	1 Private vehicle
2 පෞද්ගලික ආයතනයක වාහනයක්	2 Private company own vehicle
3 රජයේ වාහනයක්	3 Government vehicle
4 අර්ධරාජ්‍ය, ආයතනයක වාහනයක්	4 Semi Government vehicle
5 සමුදා වාහනයක්	5 Service vehicle
6 පොලිස් වාහනයක්	6 Police vehicle
0 දැනගන්නට නැත	0 Not Known

E7 රියදුරාගේ/ පදිකරුගේ/ පදිකයාගේ ස්ත්‍රී පුරුෂ භාවය (Driver / Rider / Pedestrian Sex)

1 පුරුෂ	1 Male
2 ස්ත්‍රී	2 Female
0 දැනගන්නට නැත	0 Not known

E10 රියදුරු බලපත්‍රයේ වලංගුභාවය (Validity of driving license)

1 වාහනය සඳහා වලංගු බලපත්‍රයක් ඇත	1 Valid license for the vehicle
2 වාහනය සඳහා වලංගු බලපත්‍රයක් නැත	2 Without valid license for the vehicle
3 පුහුණුවීම් බලපත්‍රයක් ඇත	3 Learner permit
4 තාවකාලික බලපත්‍රය	4 Probation license
5 ජාත්‍යන්තර බලපත්‍රය	5 International license
0 දැනගන්නට නැත / අදාල නැත	0 Not known / NA

E13,E14 අනතුර සිදුවීමට රියදුරාගෙන් බලපෑ මූලික හේතු (Human pre crash factors contributing to accident)

01 අධික වේගය	01 Speeding
02 අවදානම් / නොසැලකිලිමත් රිය පැදවීම	02 Aggressive / negligent driving
03 වැරදි විනිශ්චය	03 Error of judgment
04 මධ්‍යසාර / මත්ද්‍රව්‍ය වල බලපෑම	04 Influenced by alcohol / drugs
05 විඩාව / නින්ද යෑම	05 Fatigue / fall asleep
06 අවධානයෙන් බැහැරවීම (ගුවන් විදුලිය ක්‍රියා කරවීම, ජංගම දුරකථන, මානසික ආතතික අවදි)	06 Distracted/ inattentiveness (handling radio, mobile phone, mental stress etc.)
07 අක් රෝහිමි දුර්වලතා	07 Poor eye sight
08 හදිසි රෝහි තත්වයක්	08 Sudden illness
09 වෙනත් වාහන වල ඒළි / හිරුරැස්	09 Blinded by another vehicle / sun
19 වෙනත්	19 Others
00 දැනගන්නට නැත / අදාල නැත	00 Not known / NA

E15 අනතුර සිදුවීමට පදිකයාගෙන් බලපෑ හේතුව (Pedestrian pre crash factor contributing to accident)

1 බලාපොරොත්තු නොවූ පදිකගමනක් සෑදීමක්	1 Unexpected pedestrian movement
2 නසන ඇති පදිකමාරුව නොසළකා හැරීම	2 Disobey designated crossing
3 මධ්‍යසාර / මත්ද්‍රව්‍ය වල බලපෑම	3 Influenced by alcohol / drugs
4 පහසුලිය නොපෙනීම	4 Poor visibility (clothing)
9 වෙනත්	9 Other
0 දැනගන්නට නැත / අදාල නැත	0 Not known / NA

E16 අනතුර සිදුවීමට මාර්ගයෙන් බලපෑ හේතුව (Road pre crash factor contributing to accident)

1 මතුපිට කඩ තොල සහිත මාර්ග, ලිස්සනසුළු මාර්ග, වතුර වලලු, මඩ කැබිලි, විශාල පැලෙන්, උස් හෝ පහත් කසළ කාණු ආවරණ ආදිය	1 Defective road surface, slippery road, pot holes, water puddles, large cracks, high or low sewer covers etc.
2 කැබිලු, කිසිසේදී නඩත්තු නොකරන ලද මාර්ග සලකුණු හෝ තාප්පු හෝ මාර්ග සලකුණු හෝ තාප්පු කිසිවක් දැකට නොපෙනීවීම	2 Defective, absent or badly maintained road markings or signs
3 තිබෙන රථ වාහන පාලන තාප්පු නොපෙනීව මාර්ගයේ වැඩ කරන අවස්ථා	3 Road works without adequate traffic control devices
4 කාලගුණ තත්වයක්	4 Weather conditions
5 දුර්වල ලෙස ආලෝකමත් වීම	5 Poor street lighting
9 වෙනත්	9 Other
0 දැනගන්නට නැත / අදාල නැත	

E17 අනතුර සිදුවීමට වාහනයෙන් බලපෑ හේතුව (Vehicle pre crash factor defects contributing to accident)

1 තිරිංග	1 Brakes
2 ටයර / රෝදු	2 Tyres, wheels
3 ඇදුකානම්	3 Steering
4 විදුලි එළි, ලාම්පු	4 Lights, lamps
5 දුර්වල යාන්ත්‍රික තත්වයක්	5 Poor mechanical condition
6 වැඩියෙන් බර පැටවූ හෝ වැරදි ලෙස බර පැටවූ වාහනයක්	6 Overloaded or wrongly loaded vehicle
9 වෙනත්	9 Other
0 දැනගන්නට නැත/අදාල නැත	0 Not known / NA

E18 අනතුර බරපතලකමට හේතුවූ සාධක (Crash factor contributing to accident severity)

1 ගහක හැපීම	1 Hitting tree
2 කණුවක හැපීම	2 Hitting pole / post
3 විශාල ගලක හැපීම	3 Hitting stone or boulder
4 මාර්ග හැඩයක් ඝෂා හැපීම	4 Hitting road island, curb etc.
5 බාධකයක හෝ ආරක්ෂක වැටක හැපීම	5 Hitting barrier or guard rail
6 සවිවී ඇති වෙනත් වස්තුවක් සමග හැපීම	6 Hitting other fixed object
7 පෙරළීම	7 Rolled over
0 දැනගන්නට නැත/අදාල නැත	0 Not known / NA

E19 වෙනත් හේතු (Other factors)

1 අනතුරක් වැළැක්වීමට ගැනීමේ	1 Avoiding maneuver
2 ගොනවත්වා පලාගිය	2 Hit and run
3 පාර වඩා කරමින් සිටීම	3 Road works
4 අනතුරත් පසු සිදුවිය කලබල	4 Post crash violence
5 කොරකම්කරන ලද වාහනයක්	5 Stolen vehicle
0 දැනගන්නට නැත/අදාල නැත	0 Not known / NA

E20 මධ්‍යසාර පරීක්ෂාව (Alcohol test)

1 මධ්‍යසාර භාවිතා කර නැත හෝ නීතිමය ප්‍රමාණයට අඩුවෙන්	1 No alcohol or below legal limit
2 නීතිමය ප්‍රමාණය ඉක්මවා ඇත	2 Over legal limit
3 පරීක්ෂා කර නැත	3 Not tested

E21 රියදුරු/පදිකරු/පදිකයා අනතුරට වගකිවයුතු (Driver/ Rider/ Pedestrian at fault)

1 ඔව්	1 Yes
2 නැත	2 No
0 දැනගන්නට නැත/අදාල නැත	0 Not known / NA

අනිවාර්යකරු පිළිබඳ විස්තර (CASUALTY DETAILS)

C1 අනතුරට හේතුවූ වූ දැයි අංකය (Traffic element number)

රියදුරෙක් හෝ මගියෙක් අනිවාර්ය අනතුරකට ලක් වූ නම් අනිවාර්යකරු ගමන්කළ වාහනයෙහි දැයි අංකය දක්වන්න	If a driver or passenger casualty indicate the vehicle's element number In which the casualty traveled.
පදිකයෙක් අනිවාර්ය වූ නම් පදිකයාගේ දැයි අංකය දක්වන්න	If a pedestrian casualty indicate the element number for the pedestrian

C2 දණ්ඩ නීති සංග්‍රහයට අනුව අනිවාර්යකරුගේ ගම්භීරතාව (Severity according to penal code)

1 මාරක	1 Fatal
2 බරපතල අනිවාර්ය	2 Grievous
3 සුළු අනිවාර්ය	3 Non grievous

C3 වර්ගය (Category)

1 රියදුරු /පදිකරු	1 Driver / Rider
2 පදිකයා	2 Pedestrian
3 මගියා / අතුරු පදිකයා හෝ පාපැදියක පිටුපස ගමන්කරු	3 Passenger / pillion rider
4 මගියා / අතුරු පදිකයා හෝ පාපැදියක පිටුපස ගමන්කරු වාහනයෙන් වැටීම	4 Passenger/pillion rider falling off vehicle
5 මගියා බාහනයට ඇතිම හෝ බහින්නේ බැසීම	5 Passenger entering or leaving bus
0 දැනගන්නට නැත	0 Not known

C4 ස්ත්‍රී පුරුෂ භාවය (Sex)

1 පුරුෂ	1 Male
2 ස්ත්‍රී	2 Female
0 දැනගන්නට නැත	0 Not known

C6 ආරක්ෂාව (Protection)

1 ආරක්ෂක බදාපටි පළඳා ඇත	1 Safety belt, worn
2 ආරක්ෂක බදාපටි පළඳා නැත	2 Safety belt, not worn
3 ආරක්ෂක හිස්වැසුම් පළඳා ඇත	3 Helmet, worn
4 ආරක්ෂක හිස්වැසුම් පළඳා නැත	4 Helmet, not worn
5 ළමා ආරක්ෂක ආසනය භාවිතාකර ඇත	5 Child restrain seat used
0 දැනගන්නට නැත/අදාල නැත	0 Not known / NA

C7 රෝහල් ගත කිරීම (Hospitalized)

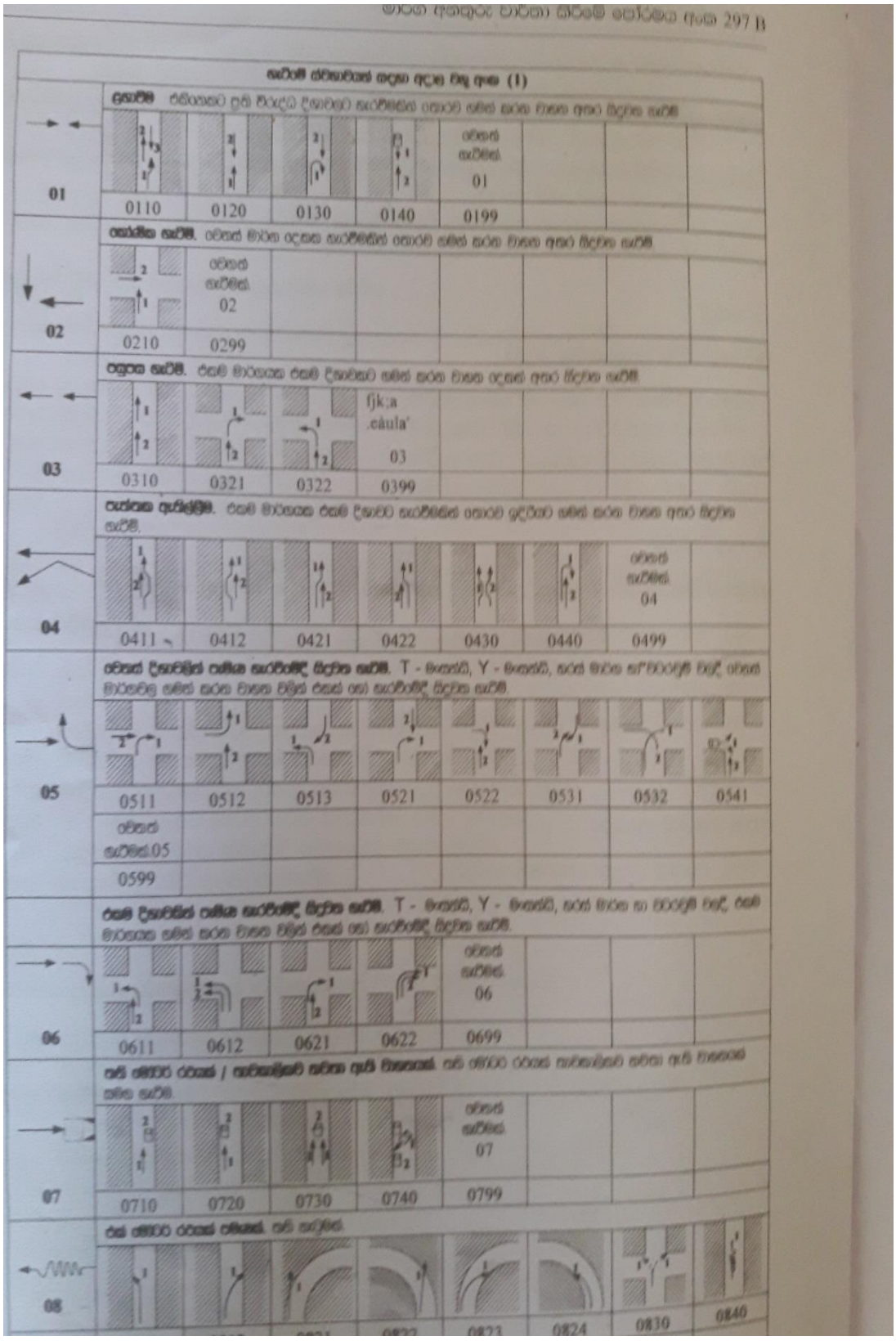
1 අවාල සිදුවීම හා අවම වශයෙන් එක් දිනක් හෝ රෝහල් ගත කිරීම	1 Injured and admitted to hospital at least 1 day
2 අවාල සිදුවීම. නමුත් රෝහලේ ඇතුල් නොකිරීම හෝ එක් දිනකට අඩු කාලයක් සඳහා රෝහල් ගත කිරීම	2 Injured but not admitted to hospital or admitted less than 1 day

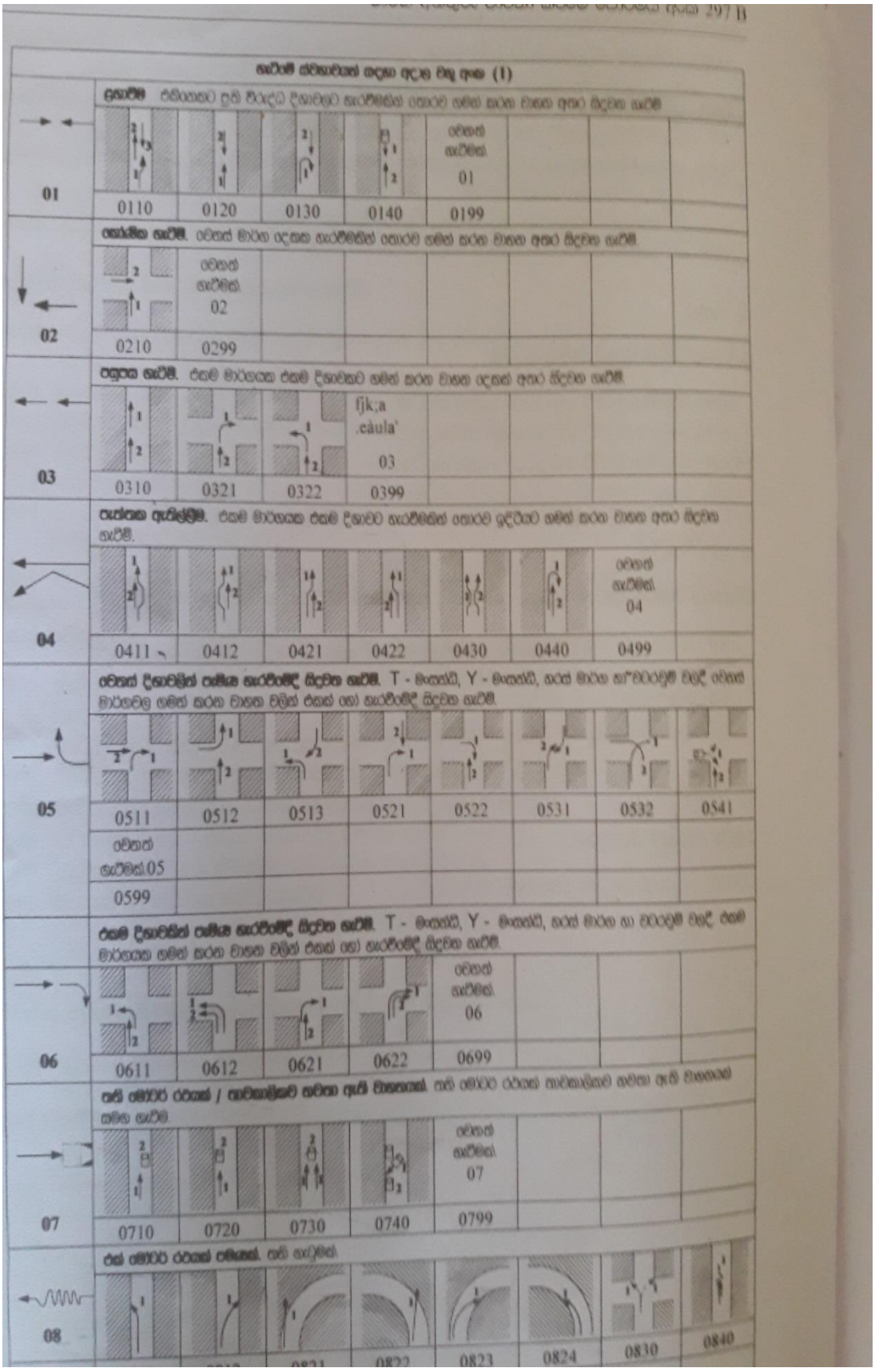
Appendix B – Estimation of Vehicle Kilometers Travelled in Sri Lanka

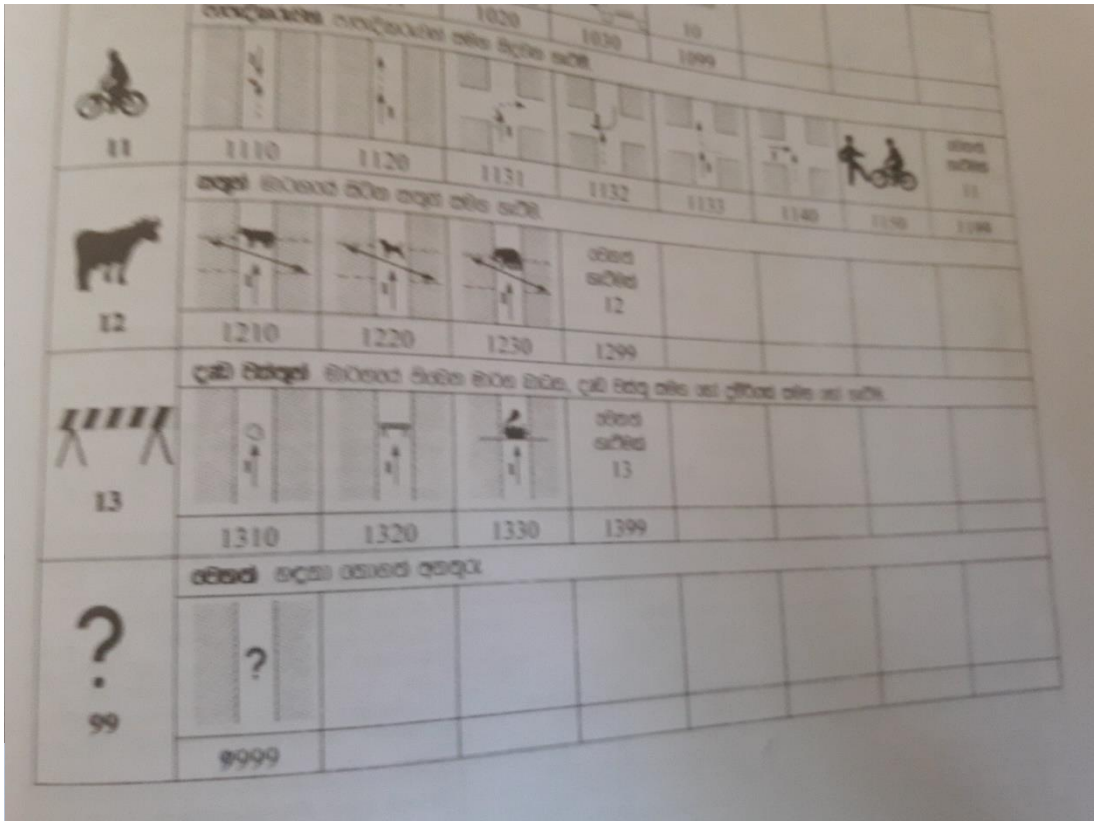
VKT Calculation for Petrol Vehicles - Island Wide 2012	
Vehicle Type	**Vehicle Kilometers Travelled (VKT)**
Motorcycles	15,410,788,711.18
Three Wheelers	8,103,267,002.94
Cars & S/Wagons	3,911,332,175.42
Jeep & Pajeros	481,026,800.44
Passenger Vans	706,940,547.67
VKT Calculation for Diesel Vehicles - Island Wide 2012	
Large Trucks	1,117,990,771.08
3 Axle Rigid Trucks	60,176,013.27
4 Axle Rigid Trucks	208,010,853.00
Tractors	125,666,475.00
Three Wheelers	1,664,253,619.54
Cars & S/Wagons	505,192,062.38
Pick Ups	515,785,961.44
SUV	466,700,992.30
Passenger Vans	1,546,734,865.44

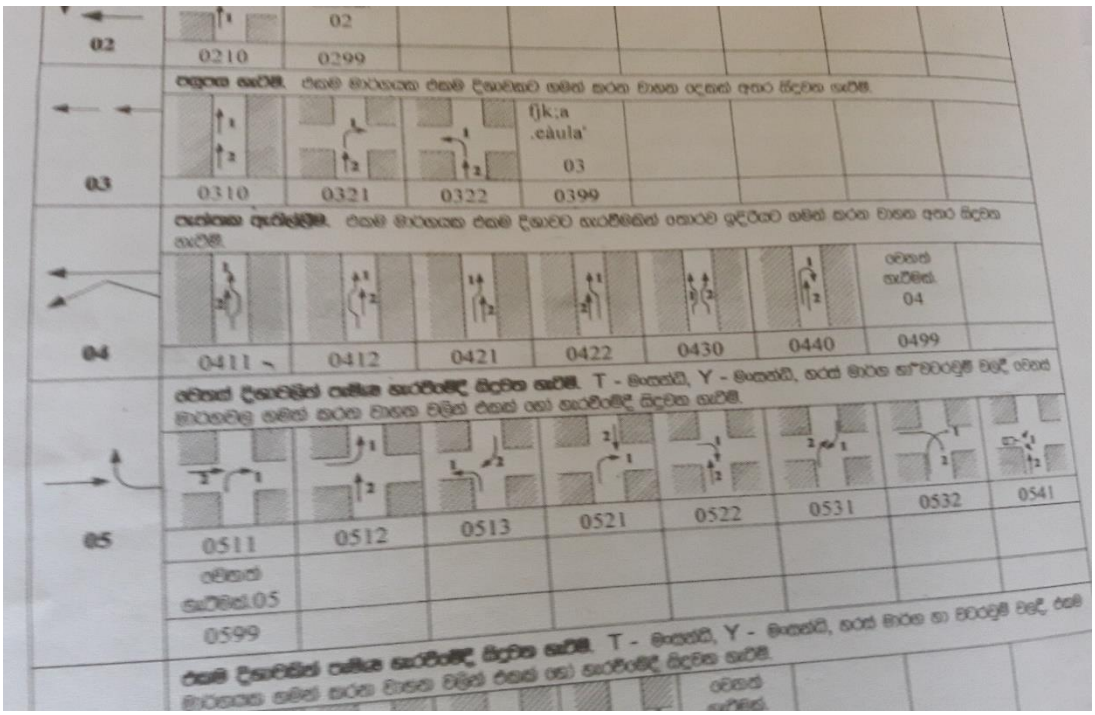
Source: Estimation of Vehicle Kilometers Travelled in Sri Lanka (2014), University of Moratuwa.

Appendix C - Crash Pattern Diagram






11
1110
1120
1131
1132
1133
1140
1150
1199
12
1210
1220
1230
1299
13
1310
1320
1330
1399
99
9999


02
0210
0299
03
0310
0321
0322
0399
04
0411
0412
0421
0422
0430
0440
0499
05
0511
0512
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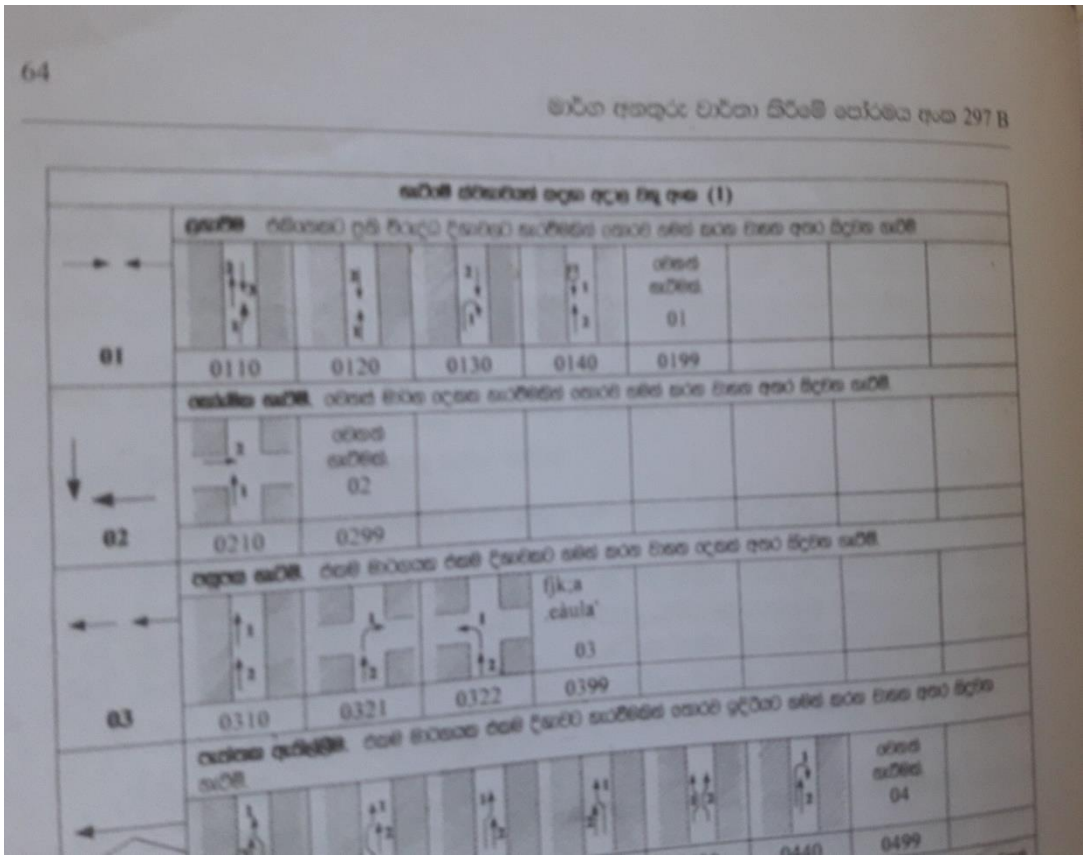
0521
0522
0531
0532
0541
0599



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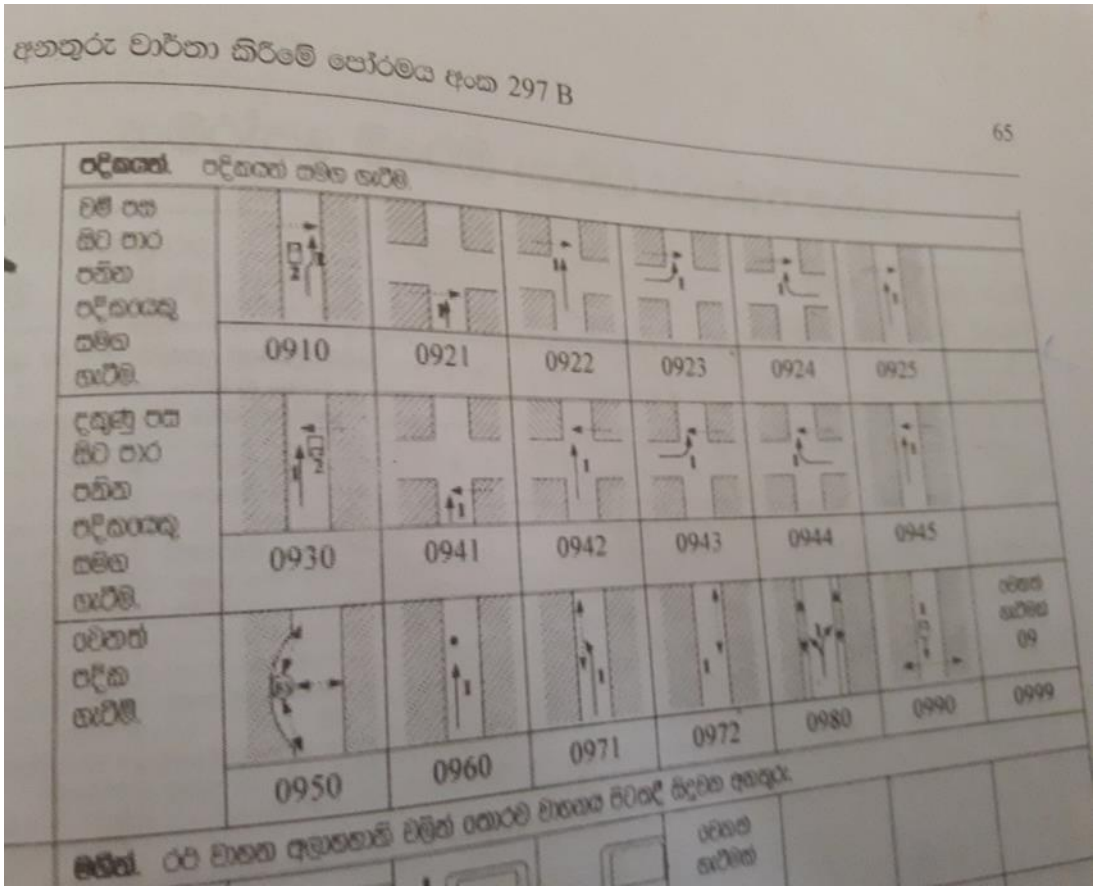
ආචාර අනතුරු වාර්තා කිරීමේ පෝරමය අංක 297 B

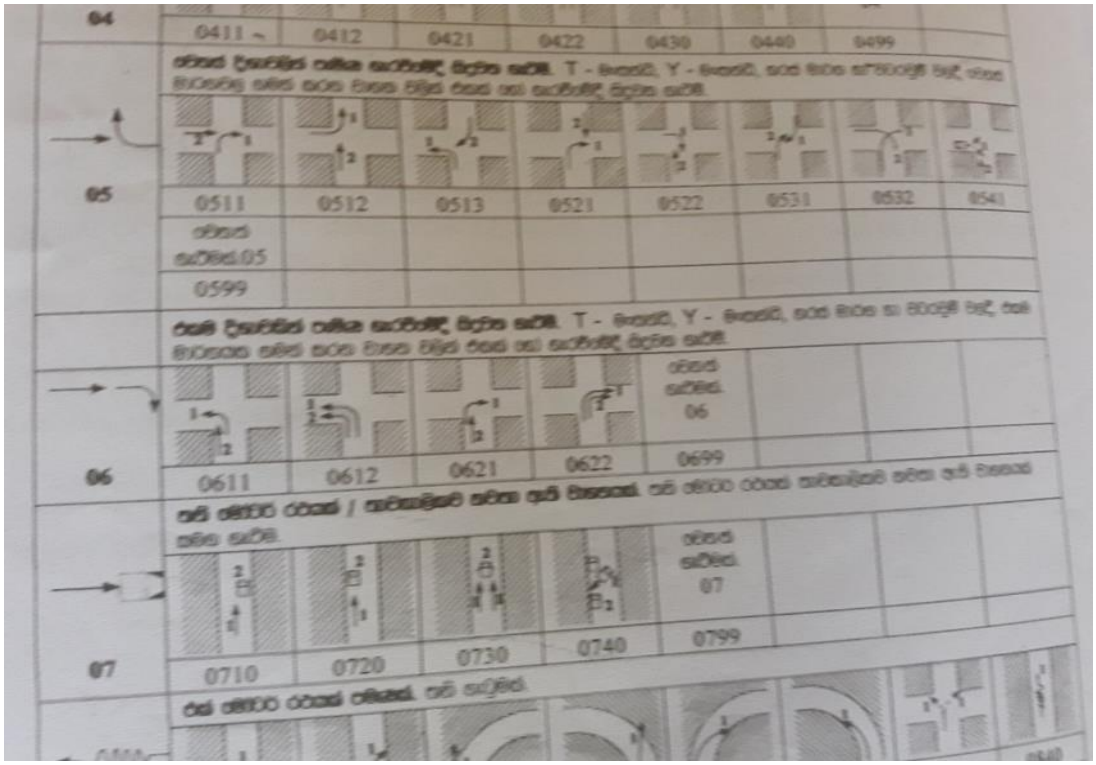
01	0110	0120	0130	0140	0199	
02	0210	0299				
03	0310	0321	0322	0399		
					0499	



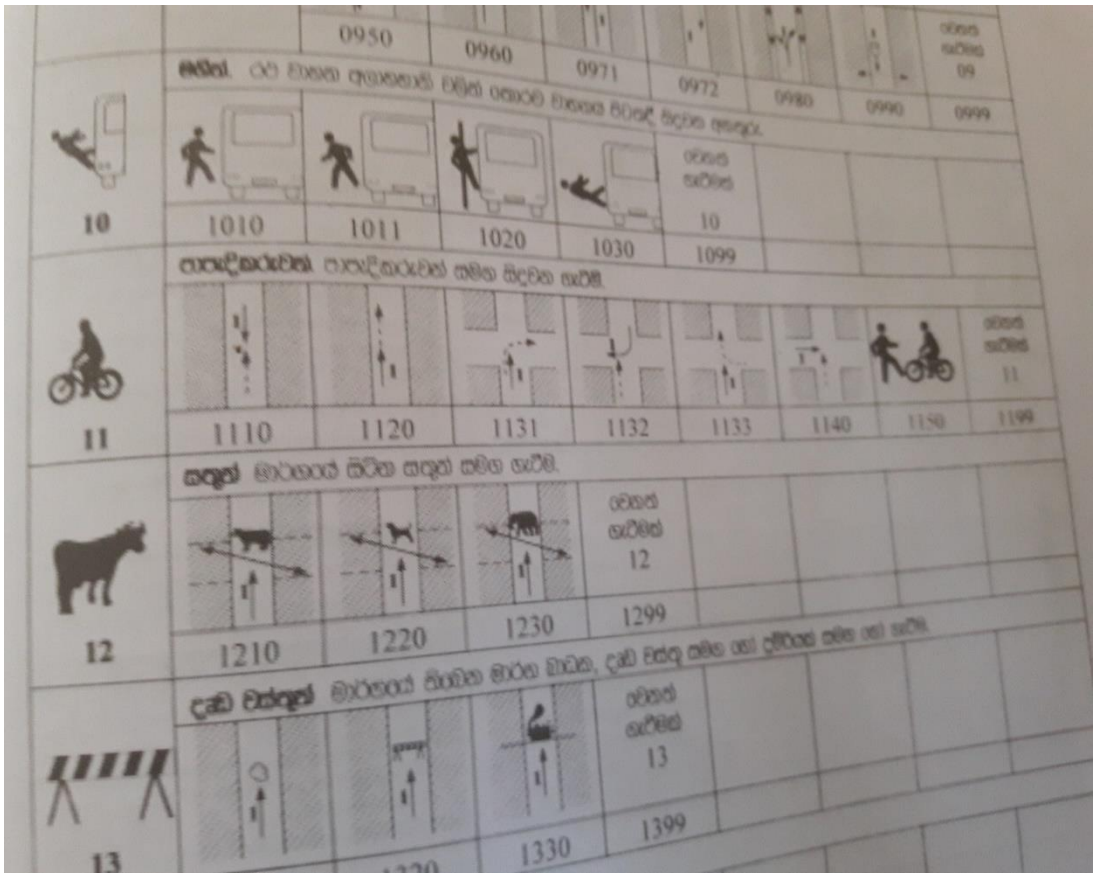
අනතුරු වාර්තා කිරීමේ පෝරමය අංක 297 B

65

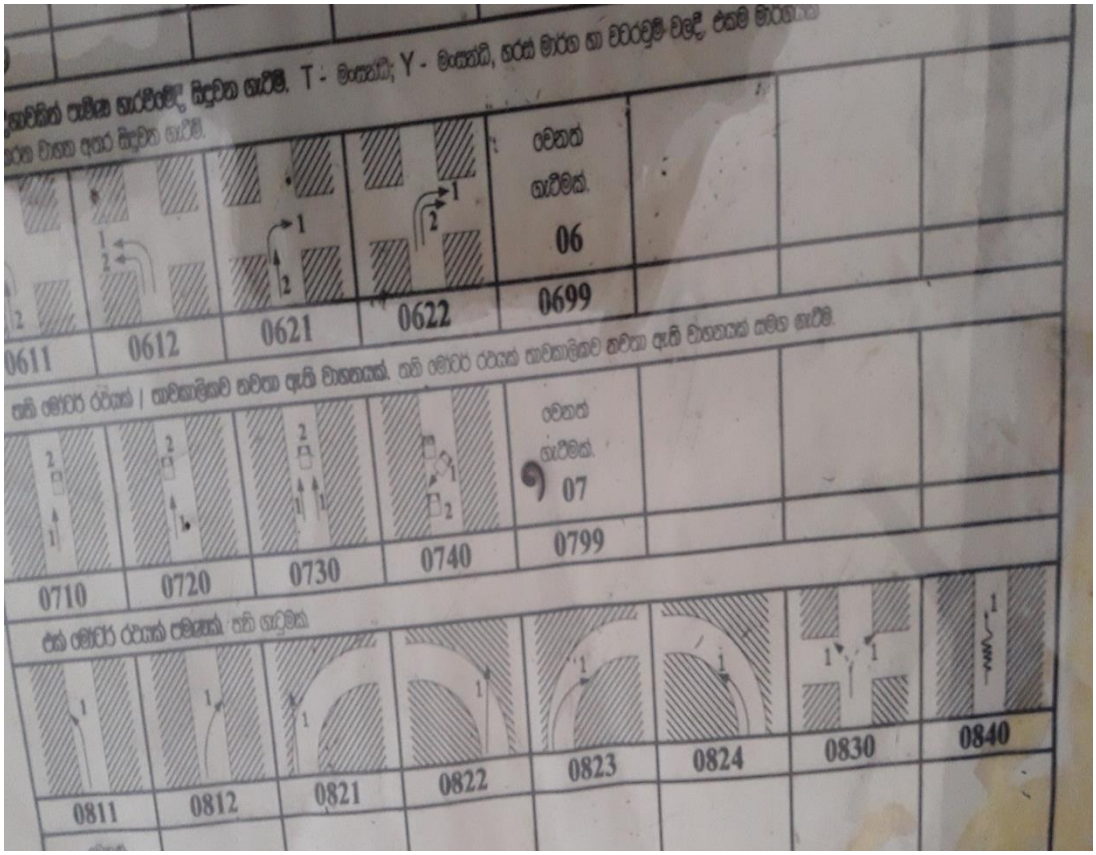
	0910	0921	0922	0923	0924	0925
	0930	0941	0942	0943	0944	0945
	0950	0960	0971	0972	0980	0990
						0999



04	0411 -	0412	0421	0422	0430	0440	0499	
05	0511	0512	0513	0521	0522	0531	0532	0541
	වෙනත් සැලසුම්.05							
	0599							
06	0611	0612	0621	0622	වෙනත් සැලසුම් 06	0699		
07	0710	0720	0730	0740	වෙනත් සැලසුම් 07	0799		



	0950	0960	0971	0972	0980	0990	වෙනත් සැලසුම් 09	0999
10	1010	1011	1020	1030	වෙනත් සැලසුම් 10	1099		
11	1110	1120	1131	1132	1133	1140	1150	වෙනත් සැලසුම් 11	1199
12	1210	1220	1230	වෙනත් සැලසුම් 12	1299			
13			1330	වෙනත් සැලසුම් 13	1399			


T - මීතෙත්; Y - මිනෙත්, ගරස් මාර්ග හා වටරවුම් වලදී එකම මාර්ගය
වෙනත් ගැටීමක්
06
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වෙනත් ගැටීමක්
07
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0840

Appendix D - SPSS Analyzing Procedure

After finalizing the accident data base for each type of accident based on the requirement, data base were directly imported to the SPPSS software

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

	Name	Type	Width	Decimals	Label	Values	Missing	Columns	Align	Measure	Role
1	HighestSeverity	Numeric	1	0	Highest Severity	None	None	1	Right	Nominal	Input
2	ElementType	Numeric	2	0	Element Type	None	None	2	Right	Nominal	Input
3	OTHERElementType	Numeric	2	0	OTHER Eleme...	None	None	2	Right	Nominal	Input
4	AGEOFVEHICLENEW	Numeric	12	1	AGE OF VEHI...	None	None	12	Right	Nominal	Input
5	RIDERGender	Numeric	1	0	RIDER Gender	None	None	1	Right	Nominal	Input
6	RIDERAgeNEW	Numeric	12	1	RIDER Age NEW	None	None	12	Right	Nominal	Input
7	ValidityofLicence	Numeric	1	0	Validity of Lice...	None	None	1	Right	Nominal	Input
8	NumberofYearsSincel...	Numeric	12	1	Number of Year...	None	None	12	Right	Nominal	Input
9	HumanPreCrashFact...	Numeric	2	0	Human Pre Cra...	None	None	2	Right	Nominal	Input
10	RoadPreCrashFactor	Numeric	1	0	Road Pre Cras...	None	None	1	Right	Nominal	Input
11	VehiclePreCrashFactor	Numeric	1	0	Vehicle PreCra...	None	None	1	Right	Nominal	Input
12	CrashFactorforSeverity	Numeric	1	0	Crash Factor fo...	None	None	1	Right	Nominal	Input
13	OtherCrashFactor	Numeric	1	0	Other Crash Fa...	None	None	1	Right	Nominal	Input
14	AlcoholTest	Numeric	1	0	Alcohol Test	None	None	1	Right	Nominal	Input

File Edit View Data Transform Analyze Direct Marketing Graphs Utilities Add-ons Window Help

4 : OTH_CRA_FAC 9

	AGE_VEH	RID_GEN	RID_AGE_NEW	VAL_LIC	NUM_YE_LIC_ISS	HU_PRE_FAC	RD_PRE_FAC	VE_PRE_FAC	CRA_FAC_SEV	OTH_CRA_FAC	AL_TEST
1	1	1	2	1	1	19	9	9	9	9	3
2	3	1	3	2	5	4	9	9	9	9	2
3	1	1	2	2	5	19	9	9	9	9	3
4	1	1	4	1	2	19	9	9	9	9	3
5	3	2	3	2	5	19	9	9	9	9	3
6	1	1	2	2	5	19	9	9	9	9	3
7	1	1	1	2	5	1	9	9	9	9	3
8	1	1	2	1	2	19	9	9	9	9	3
9	1	1	6	9	5	19	9	9	7	9	3
10	4	1	3	2	5	1	9	1	9	9	2
11	1	1	2	1	1	4	9	9	9	9	2
12	1	1	9	2	5	1	9	9	9	9	2
13	1	1	3	2	5	1	9	9	9	9	1
14	1	1	3	1	1	19	9	9	9	9	3
15	1	1	3	1	2	19	9	9	9	9	3
16	1	1	5	1	3	19	9	9	9	9	3
17	1	1	2	1	1	1	9	9	9	9	1
18	4	1	5	2	5	2	9	9	9	9	1
19	1	1	6	2	5	2	9	9	9	9	2
20	1	1	2	1	2	19	9	9	9	9	3
21	4	1	6	1	2	19	9	9	9	9	3
22	2	1	2	2	5	19	9	9	9	9	3
23	2	1	3	1	1	19	9	9	9	9	3

Name, Type, Decimals and Label in the variable interface were edited. When label given to name, it should be easily identifiable and meaningful for the easy interpretation of SPSS outputs.

After completing the above task, some variables were recorded to get meaningful results in the analysis. Fatal accidents in database, denoted by "1" and grievous and non-grievous accidents denoted by "2" and "3" respectively. Both were recoded to "0". It's also possible to convert fatal and grievous accident to "1" means crucial and Non-grievous accident to "0". But, when model is developed for that category, it was found that model fit was poor.

Fatal Accidents – "Fatal" – "1"

Grievous and Non-Grievous Accidents – "Non-Fatal" – "0"

Here, accident severity is the dependent variable. It has two categories "1" and "0". Therefore, Binary Logistic regression method was used for the analysis.

Likewise, some other independent variables also recorded to get meaning full results in the analysis. Because, the output of the logistic regression analysis compare the odds ratio of each category with respect to the numerically first category of the variable.

For example, the bellow table explains the Road Surface Condition at the time of MC-MV accident. Here, more accidents occurred in "Dry" road surface condition and it is already numerically first category (1). Therefore, recoding of variable is not necessary here.

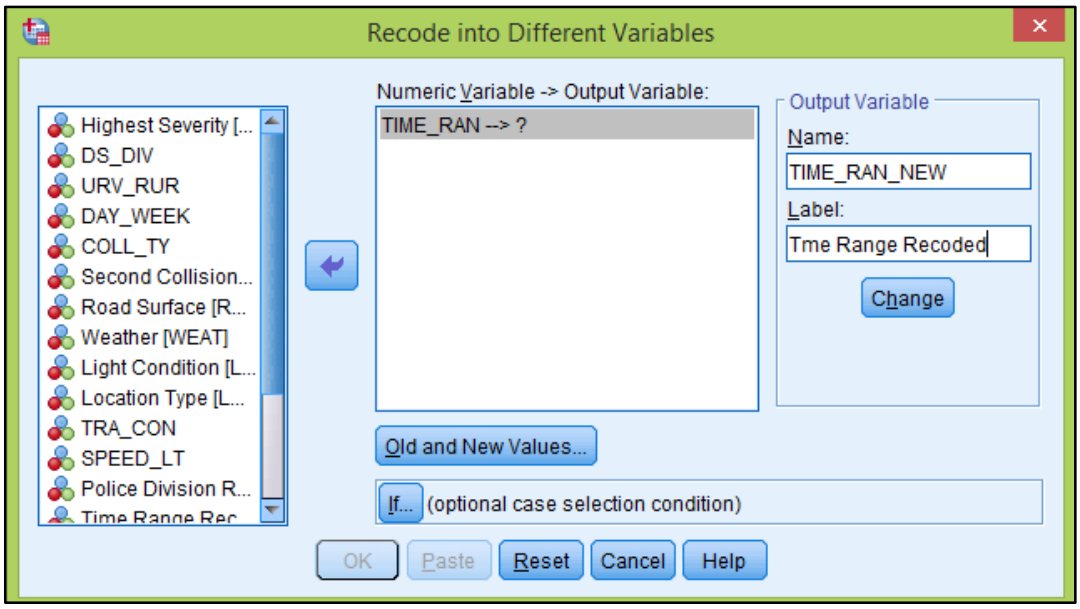
ID	Road surface condition	Frequency	Percentage
1	**Dry**	**16831**	**95.00**
2	Wet	719	4.00
3	Flooded with water	85	0.48
4	Slippery Surface	35	0.20
Total		**17670**	**100.00**

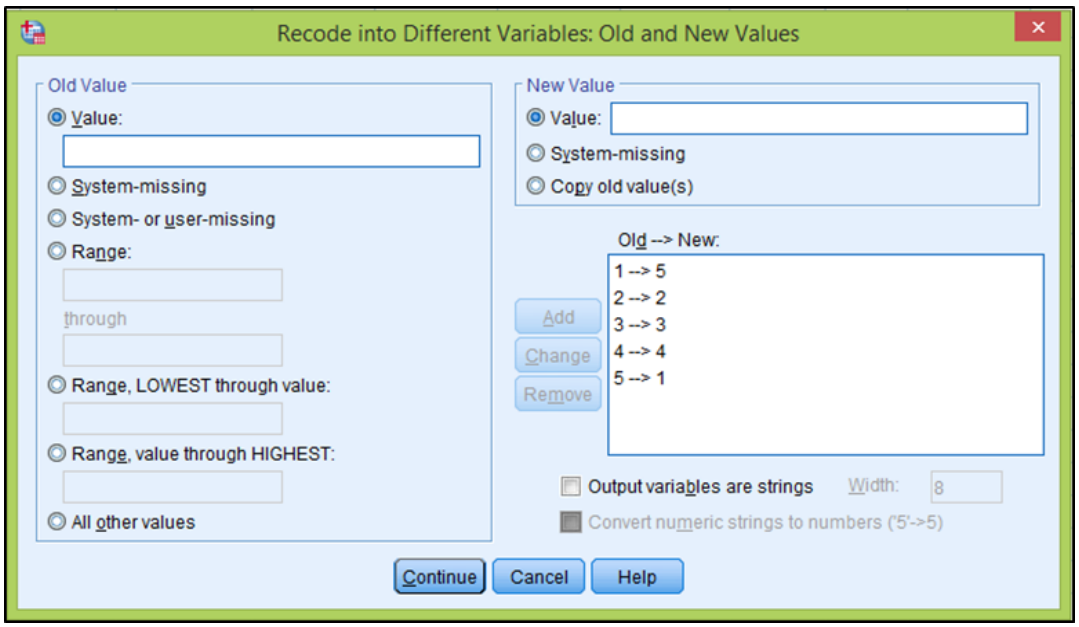
But, if riders' pre-crash factors contributed to accident is concerned "other/Not Known" category contributed to 55% of accidents. Making this category as first category will not give meaningful results. Therefore, the category with the next highest frequency was considered. It was "Aggressive/negligent driving" which contributed to 35% of accidents. But, it is numerically second category. Therefore, numerically first category "Speeding" was recoded into "10". Now, Aggressive or

negligent driving becomes the first category and odd ratio is calculated with respect to the first numerical category of the variable. Likewise, Recoding of variables was carried out.

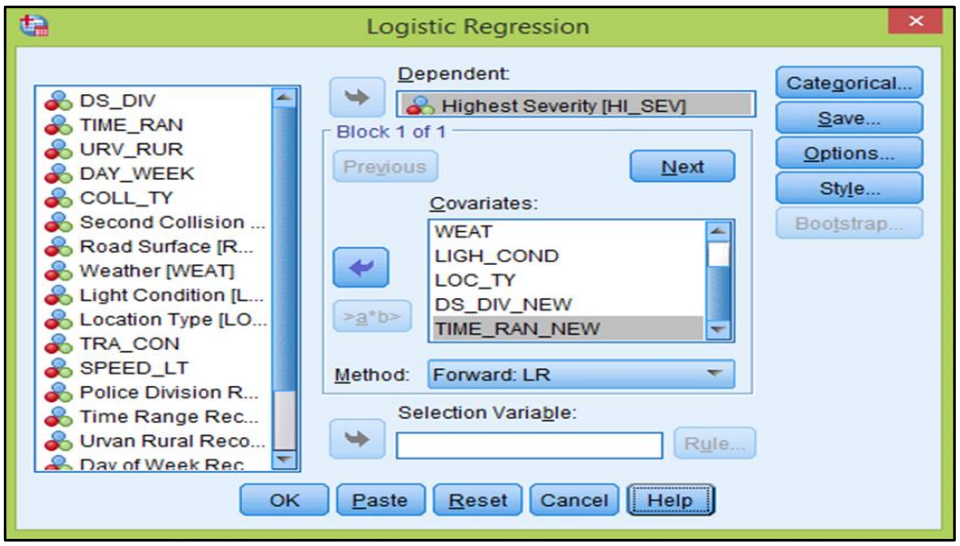
ID	Human Pre crash factor -01	Frequency	Percentage	Re-Code
1	**Speeding**	**1146**	**6.00**	**10**
2	**Aggressive/negligent driving**	**6130**	**35.00**	**2**
3	Error of Judgment	183	1.00	3
4	Influenced by alcohol	409	2.00	4
5	Fatigue / Fall asleep	16	0.09	5
6	Distracted/In attentiveness	20	0.11	6
7	Poor eye sight	1	0.01	7
8	Sudden illness	1	0.01	8
9	Blinded by another vehicle	9	0.05	9
19	**Other/Not known**	**9755**	**55.00**	**19**
Total		**17,670**	**100.00**	

The bellow figure shows the recoding of variable in SPSS. It is always advisable to use “Recode into Different Variable” option in SPSS rather than “Recode into same Variable” option. Because, “Recode into Different Variable” option keep the parent data and create the duplicate with another name.



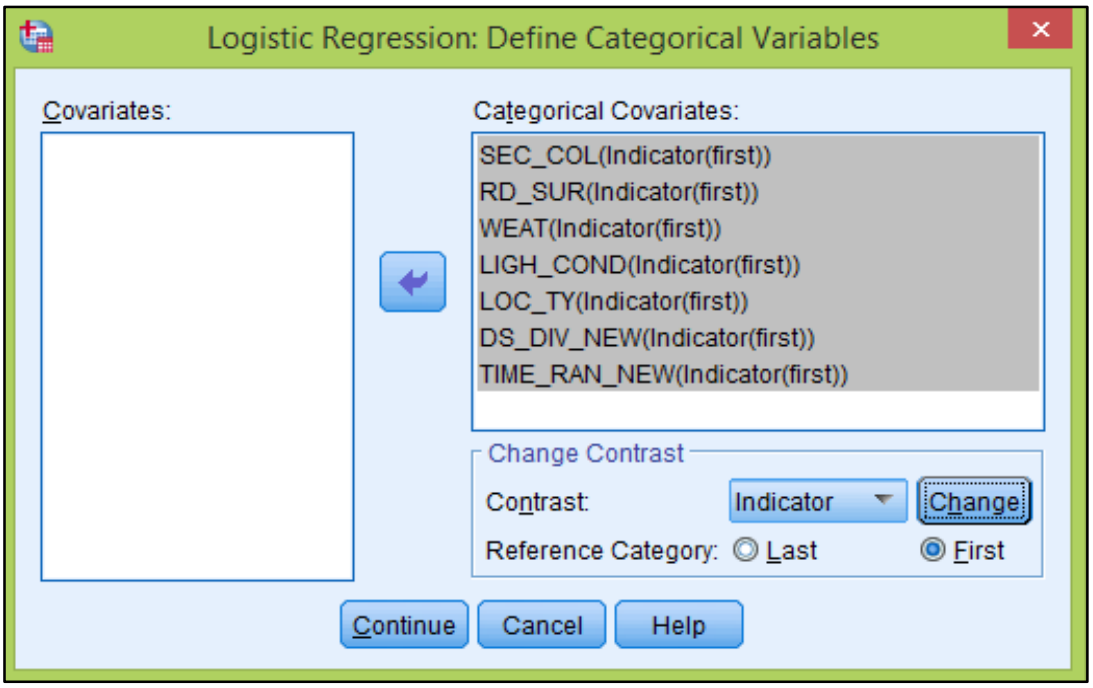


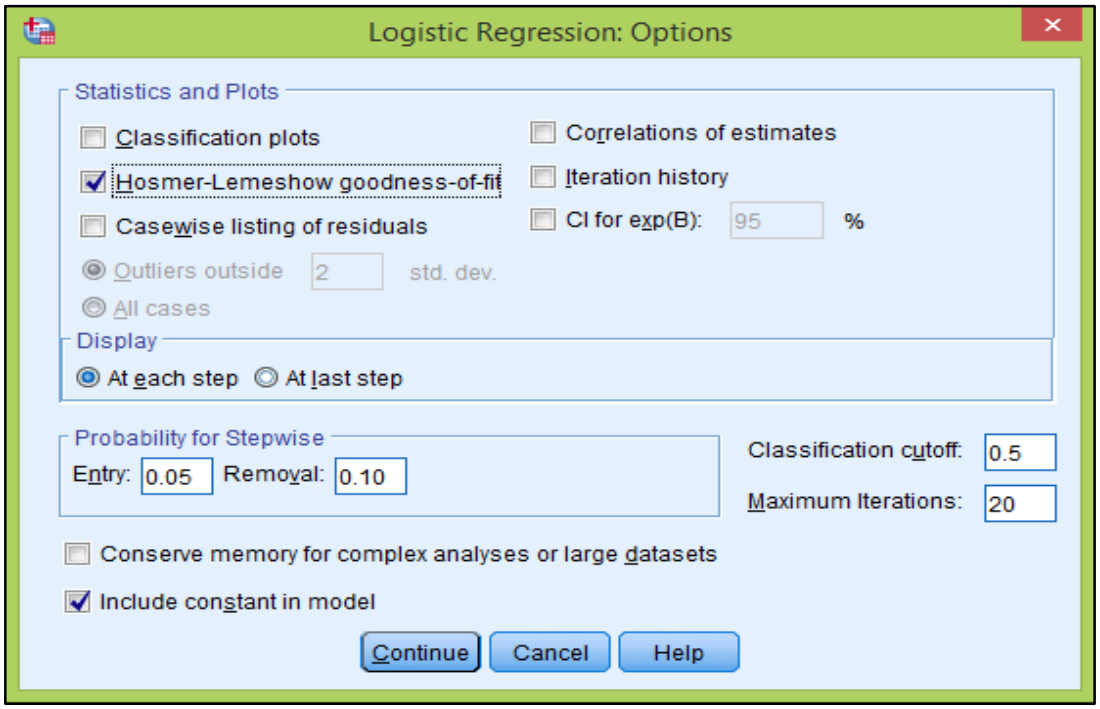
After the recoding of variables, frequencies test was done to make sure whether any missing value or wrong entry in the data. Then, multi-co-linearity of independent variables were checked before incorporating them directly into the model. This was confirmed by doing a chi-square test among independent variables. Because, multi-co-linearity between independent variables can produce errors in the model. After doing all these checks, binary logistics regression was performed.



Here, the dependent variable is "Highest Severity" of accident and Covariates are other independent variables. Here, "Forward: LR" method was selected which means Forward Likelihood Ratio method. It is a stepwise selection method. In this method, variables that can make the biggest positive change in log-likelihood ratio with statistically significant are keep adding to the model until the biggest change, but not statistically significance occur. It is done in several iterations and stopped when significance of change in model log likelihood greater than 0.05.

After that, all the covariates were moved to the Categorical Covariates box and the contrast was changed to "Indicator First". It means SPSS compare the other categories of a certain independent variable with respect to the first category. For example, in variable "weather", "Clear" weather is the first category. In this method, accident severity in "Wet" weather is compared with respect to the accident severity in "Clear" weather which is the first category in variable "weather".





After defining categorical variables, in "Option' select "Hosmer-Lemeshow goodness-of-fit and click continue. The SPSS will give results in another interface.