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Evaluating the Risk Factors in Fatal Accidents involving Motorcycle – Case Study on Motorcycle Accidents in Sri Lanka

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Abstract: Motorcycles comprise nearly 30% of the traffic flow in most Sri Lankan highways. The rapid increase in motorcycle usage has led to a significant increase in the number of motorcycle related accidents and fatalities. Motorcycle related accidents account for nearly 40% of total road accidents in recent years. However, the current studies related to motorcycle accidents are only based on the basic statistical data analysis which does not comprehensively evaluate the risk factors related to such accidents, especially for fatal accidents. This study aims to evaluate the level of risk for factors involved in motorcycle related fatal accidents. In this study, accident data were analyzed under four categories. The stepwise binary logistic regression approach was adopted to identify the risk ratio of each evaluated parameter. The findings show that the motorcycle fatal accident risk is higher for accidents involving heavy vehicles, head-on collisions, and collision with hard objects. There were significant levels of accidents involving motorcyclists and pedestrians as well, where the highest fatality risk was at mid-block segments of the roadway. Findings would be useful to identify effective measures to improve the motorcycle riders' safety in Sri Lanka.

Keywords: Accident analysis, Motorcycle, Road safety, Risk analysis, Casual factors

1. Introduction

As in most developing countries in the Asian region, motorcycles are the most common mode of transportation in Sri Lanka. Nearly 55% of total registered vehicle fleet comprise motorcycles [1]. Inadequate improvements in the country's public transport sector and growth in the population in the lower to middle-income categories have resulted in an influx of motorcycles into the road network. Motorcycles have filled the void as the transport mode of urban and rural commuters. It is a popular mode of transport of the lower to middle-income families as well as youth due to lower transportation costs. 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.

The number of registered motorcycles in Sri Lanka in year 2016 was 3,699,630. It is 55% of the total registered vehicle population. Sri Lanka has seen a significant increase in its motorcycle population in the vehicle stream, from 2012 to 2016. The number of registered motorcycles increased by 45% with the growth rate of 11% per year. This scenario shows the significant growth of motorcycle population in thecountry.

Motorcycle related accidents account for nearly 40% of total accidents reported every year. Rapid increase of motorcycle population, rider behavior, and increasing motorcycle related mortality and morbidity emphasize the need for paying immediate attention to motor cycle accidents. 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 in the year 2015. One of the SDG targets is to halve the number of global deaths and injuries from road traffic accidents by the year 2020.

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Therefore, finding the causes of motorcycle related accidents and implementing counter measures are important when considering the safety of motorcyclists and other vulnerable road users.

The objective of this study is to evaluate the causal factors attributed to fatal accidents involving motorcycles and evaluate the risk of the factors related to fatal accidents involving motorcycles in Sri Lanka. The risk factors have been identified with respect to the road users involved in an accident, collision type, location and roadway condition, weather, and time of day.

2. Casual Factors of Motorcycle Related Accidents

2.1 Human Factors

The majority of motorcycle collisions continue to occur at speeds less than 60 km/h. The mean impact speed of motorcycles is generally between 30-45 km/h. The risk and seriousness of a collision injury, generally increases with the impact speed [2]. Results of a naturalistic study on motorcycle accidents indicate that excessive speed is the factor for 45% of accidents observed in curves [3]. Aggressivity or negligence of young riders in age group 21-25 is more likely causes of road crashes and the chance of being a fatal crash is relatively higher. [4].

The most common age group involved in accidents is 21 to 30 years (44.67%) followed by 31 to 40 years (27.66%) [5]. Majority of victims in motorcycle accidents are younger male riders, the productive force of the country. Speed violations and alcohol consumption are the key pre-crash factors in motorcycle accidents [6].

The only significant protective equipment for a motorcyclist is the appropriate safety helmet. It is capable of a significant reduction of head injury severity and frequency. The majority of motorcycle users, cannot afford to buy helmet for their children because of rapid physical growth of children. Managing to travel without helmets lead the way for increased child casualties [4]. About 99% of the riders and 87% of the pillion riders wear helmets in Sri Lanka. Thus the helmet wearing rate is so close to that of United States of America which is 99% [7]. But, still helmet usage in rural areas is recorded to be low due to lack of law enforcement [8]. In 2013, 37% of children who died in road crashes did not wear a helmet [4].

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. Hurt, et al. (1981) indicated that motorcycle riders involved in accidents, are essentially without training, 92% self-taught or learned from family or friends [9].

2.2 Environmental Factors

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

Environmental factor is the cause for 13.5% of motorcycle accidents [10]. The reported environmental factors were poor road design, slippery road and lack of road signs (8.1%), vegetation (3.4%) and animals (2%). Unexpected movement of animals such as cows and dogs crossing the road also do cause motorcycle accidents. Riders manoeuvre to avoid pedestrians, cyclists, animal, or other objects which increases the near-crash risk by nearly 12 times [3].

Steep slopes, potholes and road bumps also affect the speed and stability of the motorcycles. Roadway defects (pavement ridges, potholes, etc.) were the causes in 2% of the accidents [9]. 11% of the recorded accidents were due to surface defects [11].

2.3 Regulatory Factors

More effective enforcement of licensing and registration for motorcycles could serve as potential measures to reduce crashes. In Sri Lanka, the minimum age limit for getting a licence is 18 years. A study indicated that 29% of motorcycle riders in Sri Lanka have not been able to provide a valid driving license at the time of accident, with 9% of them below 18 years of age [4]. Countries like UK, USA, Canada, New Zealand and some others countries have been practicing graduated licensing system. In UK, compulsory Basic Training (CBT) is a must for all learner drivers [12]. After successful completion of the CBT training only, riders are allowed to ride with L-Plates for a period of maximum two years.

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

2.4 Vehicle Factors

In many vehicles, incorrect or inappropriate breaking is critical in most circumstances. An in-depth study of fatal motorcycle accidents revealed that the cause is incorrect breaking in many accidents [13]. One of the recently introduced improved breaking system in motorcycle is Anti-lock Brake System (ABS). Recent studies demonstrate that ABS fitment reduces motorcycle injury crashes in Europe up to 39 %, 37% in US and 33% in India [14].

There is no scientific evidence that engine size is a major factor in motorcycle accidents and does not emerge as a serious risk factor [15]. The same study revealed that there is an effect of bike size on accident severity.

2.5 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 a national structure in place to promote and enforce quality road safety laws and regulations.

In 2011, there were 100 million motorized two-wheelers in India, representing 70% of the motor vehicle fleet in the country [16]. In year 2016, motorcycles contributed to 34% (162,280) of total accidents and 31% (41,608) of fatal accidents.

Based on the vehicle types involved in accidents during 2016 in India, 29% road users were died and 31% of the road users sustained injuries in motorcycle involved accidents [17].

In 2015, there were approximately 1.5 million registered motorcycles in Bangladesh, which accounted for 57% of registered motor vehicle fleet [18]. In Bangladesh, motorcycles share 12% in total accidents followed by buses (38%), trucks (30%), cars (11%) and baby taxis (9%) in year 2013 [19].

In 2013, there were 10 million [20] powered two wheelers, representing half of the total registered vehicle population in Indonesia. Powered two wheelers accounted for 61% of the total road deaths in Malaysia [20]. According to the World Health Organization's (WHO's) Global status report on road safety 2015 [21], almost half of the estimated deaths on roads worldwide per year are among those with least protection, i.e., vulnerable road users which include motorcyclists (23%), pedestrians (22%) and cyclists (4%).

There are specific challenges in general, including PTW safety in low-middle-income countries. Lack of institutions responsible for road safety, lack of laws, lack of knowledge of traffic rules, lack of enforcement, lack of proper infrastructure, improper maintenance, sale of low-cost PTWs and lack of data to properly assess safety issues are among them [16].

3. Methodology and Data Collection

Accident data was retrieved from the Police accident data base in Sri Lanka (2012-2014). Accidents involving motorcycle - motor vehicle, motorcycle – pedestrian, motorcycle – cycle and motorcycle self-accidents were considered in the study. Damage only accidents were not considered in this analysis because they are under reported.

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

Other than the accident data, vehicle registration, operating vehicle population, census data and technical specifications of motorcycles from manufacturers were also used and incorporated in the analysis.

3.1 Introduction to Logistic Regression

Logistic regression is generally used to study relationship between a binary response variable and a group of predictors. These variables can be either categorical or continuous. This method has been widely used by scholars for accident severity analysis. In Sri Lanka, the logistic regression modelling has been used to find out the factors affecting the severity of heavy vehicle related crashes [6].

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

$P(Y=1 \mid x)=(\exp(\beta 0+\beta 1\, x))/(1+\exp(\beta 0+\beta 1\, x))$
where, β0 and β1 are regression coefficients.
In this study, relative risk of the relevant variable considered in the analysis is evaluated using odds ratio method. The odds ratio (Exp(B)) is the relative risk of an occurrence of fatal accident when compared to grievous and non-grievous accident, when a given variable was present. For example, when considering vehicle type involved in accidents with motorcycles, three wheelers represented the highest percentage. Therefore, relative risk to motorcyclists from other vehicles was estimated based on three wheelers. In case where the category with the highest percentage is 'unknown' or 'not applicable', the next highest category was chosen to find out the relative risk. Likewise, relative risk factors in between the other variables were calculated.

Significance of each factor that contributed to accident severity is tested by using likelihood ratio test. Likelihood ratio test is a test of significance of the difference between the likelihood ratios for the researcher's model and 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.

The Hosmer-Lemeshow's goodness of fit test divides subject into categories based on predicted probability (p), and then computes a chi-square from observed and expected frequencies. Then, a p value is computed from the chi-square distribution to test the fit of the logistic model. If the p value is greater than 0.05, the model is said to have a good model fit.

4. Results and Discussion

4.1 Descriptive Analysis

As is shown in Figure 1, it can be seen that the operating motorcycle population has been increasing over years. But, grievous injuries per 100 million motorcycle kilometres travelled show the decreasing trend. The fatal risk is averaged to 5.22 fatalities per 100 million motorcycle kilometres travelled. However, the significant increase in motorcycle usage is directly proportional to the increase in the number of motorcycle accidents [22] [23] [24] [25].

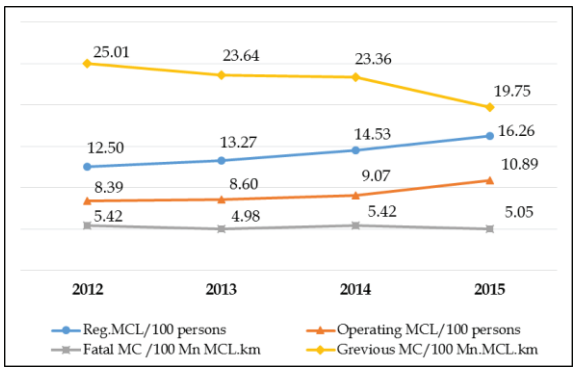

Figure 1 - Comparison of Registered Motorcycles (MCL) per 100 Persons, Operating MCL per 100 Persons, and Fatalities to Motorcyclists per 100 Million MCL kilometres and Grievous Injuries to Motorcyclists per 100 Million MCL kilometres

Motorcycle related accidents account for nearly 40% of total accidents. It is approximately half of the total fatal, grievous, non-grievous injuries recorded since 2012 to 2014. The involvement of different road users in fatal accidents in the year 2015 is 36% of motorcyclists, 29% of pedestrians and 9% of cyclists [22]. When compared with WHO's Global Status Report on Road Safety 2015, vulnerable road users died in worldwide roads include motorcyclists (23%), pedestrians (22%), and cyclists (4%).

Overall fatalities per 10,000 operating motorcycles in Sri Lanka is 4.76 and grievous injuries is 21.63 [22].

Table 1 - Fatalities to Motorcyclists per 10,000 Operating Vehicles

Motorcycle Collision with	Fatalities to Motorcyclists / 10,000 operating vehicles
Buses	21.38
Lorries	8.39
Dual purpose vehicles	3.2
Land vehicles	2.57
Motor cars	0.56
Motor vehicles	0.46
Three-wheelers	0.32

Table 1 indicates fatalities to motorcyclists per 10,000 operating vehicles. It was estimated by using average vehicle fleet in operation from 2012 to 2014 and the average number of motorcyclists dying in the same period in accidents. Fatalities to motorcyclists per 10,000 operating buses is the highest although buses share only 1.25% of the total operating vehicle

fleet in this country. Yet, it has created the most fatalities and grievous injuries to motorcycle users. Lorries contribute to 6% of the total operating vehicle fleet. Fatalities to motorcycle users per 10,000 operating lorries is 8.39 which is 2.5 times lesser than the fatalities caused by buses. These results are useful to create specific awareness programs and training to educate the motorcycle users about the specific risks relevant to them. The least contributor to the fatalities to motorcyclists/10,000 operating vehicles is three-wheeler, which is 0.32.

Motor Cycle – Motor Vehicle Accidents

A total of 17,670 two vehicle accidents, where one motorcycle was involved with one or more other vehicles were analysed. Out of that, 7% (n=1,252) are fatal, 34% (n=6,072) grievous, and 59% (n=10,346) are non-grievous accidents.

The most number of accidents had occurred between 3.00 pm and 6.00 pm, which accounts for 23% of total accidents. This is followed by 19% of accidents recorded between 6.00 pm and 9.00 pm. Likewise, 17% of accidents occurred between 12.00 pm and 3.00 pm. When it is considered in 12 hour intervals, 69% of accidents have occurred from 6.00 am to 6.00 pm, 27% of accidents recorded from 6.00 pm to midnight and 4% of accidents occurring late night. But, accidents occurring at late night are more likely to become fatal than those in normal hours.

Head-on collision is more dominant and very risky in motorcycle – motor vehicle accidents which contributed to 26% of total accidents followed by rear end collisions 17%.

Motorcycle – Pedestrian Accidents

Fatal risk to pedestrians in Sri Lanka roads are 1.32 times higher compared to fatalities on roads worldwide. Nearly 30% of motorcycle-pedestrian accidents are fatal while 45% of motorcycle-pedestrian accidents are grievous.

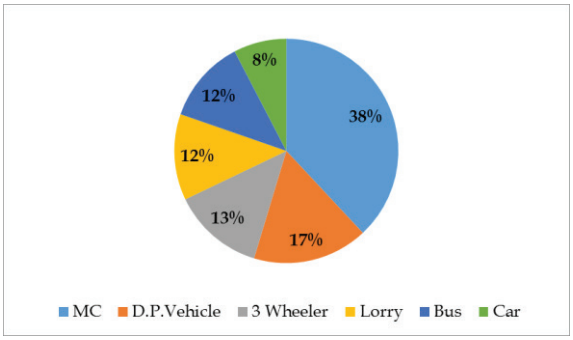

Figure 2 - Pedestrian Fatal Accidents with Different Vehicle Types

Figure 3 shows the distribution of pedestrian fatal accidents with different vehicle types. Pedestrian fatal accidents with motorcycles account for 38% of total pedestrian accidents followed by dual purpose vehicle 17% and three wheelers 13%. The least contributor for the pedestrian fatal accidents is cars which contribute only 8%.

When risk to pedestrians from 10,000 operating vehicles is concerned, the highest risk is due to buses. It accounts for nearly 16 pedestrians killed per 10,000 operating buses. But for motorcycles, it accounts for only 1.20. This lesser value is due to the higher population of motorcycles compared to buses.

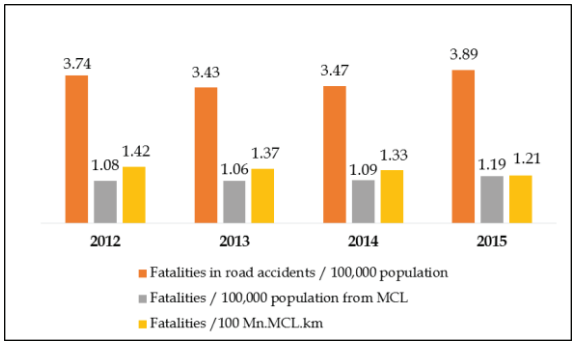

Figure 3 - Comparison of Fatalities of Pedestrians in Road Accidents per 100,000 Population, Fatalities due to Motorcycles per 100,000 Population and Fatalities to Pedestrians per 100 Million Motorcycle kilometres.

Figure 3 shows that the number of fatalities of pedestrians in road accidents per 100,000 population is 3.89, which is the highest in year 2015. The number of fatalities per 100,000 population from MCL in year 2015 is 1.19. The number of fatalities to pedestrians per 100 million motorcycle kilometres travelled is around 1.21 in the same year.

The data set considered for the analysis comprises a total of 7,637 single vehicle accidents. where one pedestrian struck by a single motorcycle. From Figure 3, 8% (n=626) contributed to fatal cases, 33% (n=2,524) was grievous injury cases and non-grievous injury cases comprised 59% (n=4,487).

Type of location where a pedestrian is involved in an accident can also be considered as one of the significant factors in Motorcycle-Pedestrian accidents. At 'pedestrian crossings beyond 50 m', 41% of accidents were recorded while 17% of accidents occurred on pedestrian crossing (PCs) and 13% within 50 m of a pedestrian

crossing. In Motorcycle Pedestrian accidents in total, 19% occurred on roads without sidewalks. It indicates the lack of pedestrian walkways on many roads in Sri Lanka and, where available, they are not in a position to be used by pedestrians due to lack of maintenance or occupied by street vendors. Accidents on sidewalks account for 6% of total accidents. What could be observed is that, motorcyclists and pedestrians share the same road space in urban or sub-urban roads without adequate pedestrian infrastructure.

Age of the pedestrians who got affected by motorcycle accidents is also a considerable factor in the analysis process. Pedestrians whose age is greater than 60 years involved in 27% of total motorcycle accidents while pedestrian accidents for age groups 54 to 59, 48 to 53 and 6 to 11 were exposed to accidents 10%, 11% and 11%, respectively. It shows that involvement of older pedestrians in accidents is high compare to younger pedestrians while fatal risk to pedestrians increases with age.

Motor Cycle – Cycle

Cyclists are vulnerable road users all over the world. In total fatalities occurred in road accidents every year, cyclists account for nearly 9% of the accidents. According to the WHO Global Status report on road safety 2015, death of cyclists worldwide per year is 4% of total accidents. In Sri Lanka, this figure was 9% in the year 2015. Fatal risk to cyclists in Sri Lanka roads is nearly 2.25 times higher compared to fatal risk associated with world roads.

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

Involvement of older cyclists and younger motorcycle riders in accidents is high. But, probability of dying in accidents is high and increases with age for older riders. Head-on and rear-end collisions are more prominent collision patterns which account for 24% and 35% of the total motorcycle and cycle accidents respectively. The most number of motorcycle and cycle accidents have been recorded between 6.00 pm and 9.00 pm in rural areas.

Motor Cycle – Self Accidents

The data used for this study consist of a total of 3,110 motorcycle - self accidents. That is motorcycles running off roads without being hit by another vehicle or pedestrian. Out of 3110 accidents, 24% (n=738) contributed to fatal cases, 76% (n=2,372) were grievous and non-grievous injury cases.

'Rolling over' of rider is one of the major factors that has contributed to accident severity. As a percentage, it is 40 % of accidents, followed by 'Hitting a pole or post' which is 10%. But, fatal accident risk due to hitting a pole, stone, barrier and other fixed objects on a road is considerably high when compared to rolling over in accidents.

Of 3,110 self-accidents analysed in total, 43% (1,340) of accidents are recorded as to have occurred in 'daylight 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 on roads without street lighting. 17% (301) occurred at night on roads with improper street lighting, 10% (173) at night with good street lighting and 5% (97) at dusk or dawn. In total, 85% accidents occurred on roads at night time without street lighting or roads with improper street lighting. Accidents occurring at night time in rural roads without street lighting and improper street lighting are high and more likely to become fatal accidents.

Table 2 - Accident Severity by the Type of Accident

	Accident Severity		
	Fatal		Fatal
MC-MV Accidents	7%	MC-MV Accidents	7%
MC-P	30%	MC-P	30%
MC-C	31%	MC-C	31%
MC-S	24%	MC-S	

Note: -

MC-MV : Motor Cycle-Motor Vehicle Accidents
MC-P : Motor Cycle–Pedestrian Accidents
MC-C : Motor Cycle-Cycle Accidents
MC-S : Motor Cycle-Self Accidents

Table 2 is a summary related to the severity by the nature of the accident.

According to the values of Tables 1 and 2, the highest value for the ratio of fatal accidents per 10,000 operating vehicles/grievous accidents per 10,000 operating vehicles was obtained for the buses, which is 0.33 (21.38/64.81). For the three wheelers, the ratio is the lowest i.e., 0.04 (0.32/6.81).

4.2 Regression Analysis

Motor Cycle–Motor Vehicle Accidents

Table 3 shows the statistically significant results of the crash details model of motorcycle – motor vehicle accidents. Fatal accident risk of motorcycles with lorries is 7.313, greater when compared to accidents with three wheelers. In the same way, a motorcycle accident with a dual purpose vehicle is 3.678 times more probable to become fatal than an accident with a three wheeler. The number of motorcycles associated in accidents with articulated vehicles is the highest according to the crash detail model.

Table 3 - Motorcycle – Motor Vehicle Accidents

Variable Description	Sig	Exp(B)
Motor Vehicle Type		
Three wheeler	**0**	**1.000**
Dual Purpose Vehicle	**0**	**3.678**
Lorry	**0**	**7.313**
Articulated Vehicle	**0**	**11.247**
Bus (SLTB, Private, Intercity)	**0**	**7.077**
Land Vehicle / Tractor	**0**	**6.340**
Rider's Age		
24-29	**0**	**1.000**
48-53	**0**	**1.712**
54-59	**0**	**2.029**
>= 60	**0**	**2.611**
Human pre-crash factors		
Aggressive or Negligent driving	**0**	**1.000**
Influenced by Alcohol	**0.009**	**1.523**
Fatigue / Fall asleep	**0.002**	**6.140**
Speeding	**0.004**	**1.382**
Other / Not Known	**0.015**	**0.847**
Crash Factor Contributed to Accident Severity		
Rolled Over	**0**	**1.000**
Hitting Pole / Post	**0.001**	**6.294**
Not Known	**0.008**	**0.802**

Motorcycle riders who are more than 60 years old have been exposed to the most accidents which is 2.611 times more probable than for the riders having an age between 24-29 years. Fatal accident risk of a motorcycle due to rider pre-crash factors such as 'influenced by alcohol', 'fatigue or falling asleep', 'speeding' is high when compared with accidents due to human pre-crash factor 'Aggressive or negligent driving'. Pre-crash factor "fatigue or falling asleep" is the highest amongst all. When considering the crash factors that contributed to accident safety, "Hitting Pole/Post" can be identified as the crash factor that has contributed the most, 6.294 times more probable compared to the factor "Rolling Over".

Table 4 - Crash Environment Details Model (Motorcycle–Motor Vehicle Accidents)

Description	Sig	Exp(B)
Road Surface		
Dry	0.005	1.000
Wet	0.005	1.432
Flooded with water	0.037	1.973
Time Range accidents occurred		
3.00 pm – 6.00 pm	0	1.000
9.00 pm – 12.00 am	0.001	1.449
12.00 am - 3.00 am	0	2.538
3.00 am – 6.00 am	0	2.806
Collision Type		
0 120	0	1.000
0 130	0	0.483
0 210	0.010	0.635
0 310	0	0.597
Others	0	0.728

Where,

0120 – Head-on collisions
0130 – In conjunction with U-turn ahead of vehicles in the opposite lane
0210 – Intersecting without turning off
0310 – Rear-end collisions

Table 4 shows the statistically significant results of the crash environment details model of motorcycle–motor vehicle accidents. The number of accidents occurring on a wet road surface is 1.432 times likely to become crucial compared with accidents occurring on dry road surfaces.

The period of time that has contributed the most for the occurrence of motorcycle-motor vehicle accidents is the time period between 3.00 am and 6.00 am. This is 2.806 times greater than the contribution of accidents occurring over the time period, 3.00 pm – 6.00 pm.

Fatal accident risk due to rear-end collisions is 1.675 times less compared with head on collisions.

Motor Cycle – Pedestrian Analysis

Table 5 - Crash Environment Details Model (Motorcycle–Pedestrian Accidents)

Description	Sig	Exp(B)
Time Range accidents recorded		
6.00 pm to 9.00 pm	**0**	**1.000**
12.00 noon to 3.00 pm	**0**	**0.510**
3.00 pm to 6.00 pm	**0.004**	**0.685**
3.00 am to 6.00 am	**0.031**	**1.782**
Pedestrian Location		
50 m beyond Pedestrian Crossing	**0**	**1.000**
On Pedestrian Crossing	**0**	**0.591**
Hit outside sidewalk	**0.046**	**0.477**
Hit on side walk	**0.024**	**0.608**

Table 5 shows the statistically significant results of the crash environment details model of motorcycle–pedestrian accidents.

Accidents occurring during evening peak from 3.00 pm to 6.00 pm are 1.343 times (0.685/0.510) crucial when compared to afternoon peak from 12.00 noon to 3.00 pm. The most number of motorcycle–pedestrian accidents were recorded in the time period of 3.00 am to 6.00 am.

Table 6 - Pedestrian Related Factors Model (Motorcycle–Pedestrian Accidents)

Description	Sig	Exp(B)
Pedestrian Gender		
Male	0	1.000
Female	0	0.645
Pedestrian Age		
Greater than or equal to 60	0	1.000
0 to 5	0	0.078
6 to 11	0	0.030
12 to 17	0	0.029
18 to 23	0	0.088
24 to 29	0	0.112
30 to 35	0	0.161
36 to 41	0	0.168
42 to 47	0	0.182
48 to 53	0	0.385
54 to 59	0	0.477

Table 6 shows the statistically significant results of the pedestrian related factors model of motorcycle–pedestrian accidents. Unlike other kinds of accidents, involvement of females is significant in motorcycle-pedestrian accidents and accounts for 44%. Male pedestrians are 1.55 times more likely to get involved in an accident when compared to female pedestrians.

Pedestrians who are 60 years of age or more, are the most exposed age group for the motorcycle-pedestrian accidents. It is 34.48 times greater than for the age group of 12 – 17 years, which is the least exposed age group. Risk in accidents is 8.93 times less for people who are in the age group of 24 – 29 years, when compared to the highly exposed age group.

Motor Cycle – Cycle/Single Vehicle

Table 7 - Crash Details Model (Motorcycle – Self Accidents)

Description	Sig	Exp(B)
Rider's Age		
24 - 29	0.002	1.000
54 - 59	0.003	2.034
>=60	0	2.891
Human Pre - Crash Factor		
Aggressive or negligent driving	0	1.000
Blinded by another vehicle or sun	0	1.547
Crash factor for accident severity		
Rolling over	0	1.000
Hitting pole or post	0	3.231
Hitting stone or boulder	0.019	3.175
Hitting barrier	0	2.690
Hitting other fixed objects	0	2.141
Hitting tree	0	4.260

Table 7 shows the statistically significant results of the crash details model of motorcycle – self accidents.

Riders who are 60 years of age or above, face highest risk in motorcycle-self accidents, 2.891 probable than for the age group of 24-29.

The human pre-crash factor which has contributed the most for motorcycle-self accidents is, "blinded by another vehicle or sun". It is 1.547 times more likely than the pre-crash factor "Aggressive or Negligent driving". The most probable crash factor accident severity is hitting a tree.

In motorcycle-self accidents, collision types "travelling straight and leaving the road to left", "travelling straight and leaving the road to right", and "turning over and remains on the road" accounts for 32%, 11% and 12% of the accidents, respectively. Fatal risk ratio for accidents occurring in collision pattern 0821 (motorcycle entering in a curve, run off

straight) is 1.885 compared with accidents occurring in collision pattern 0811 (motorcycle coming straight, veer-off the road to the left side).

The risk for an accident to occur on a wet surface is 1.7 times more than on a dry surface. The risk for a motorcycle-self accident to occur at night time with no street lighting is 1.225 times more when compared to the risk at day time.

5. Conclusions and Recommendations

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, motorcyclists can be considered to be in the vulnerable road user category in Sri Lanka. The study evaluated the primary risk factors related to motorcycle accidents in Sri Lanka.

Motorcycle fatal accident risk ratio increases significantly for lorries and buses when compared to other vehicle types (risk ratio is more than 7 when compared to three-wheeler accidents). Similarly, fatal accident risk ratio increases by 40% and 70% for collision with other vehicles and single vehicle accidents during wet weather. With respect to the time of day, accident volumes are highest during the period 3 am to 6 pm (23% of the total accidents). But, fatal accident risk ratio increases 44% during the period 9 pm to midnight and by more than 2.5 times during midnight to 6 am. For single vehicle accidents, more than 57% fatal accidents occur in the night. The risk ratio increased by more than 20% in the night on road segments without street lighting. Similar findings were observed for time periods where motorcycle-pedestrian accidents occur.

Furthermore, pedestrian-motorcycle fatal accidents were at greatest risk within mid-block sections of the road. Pedestrians aged 60 and above were at the highest risk of suffering a fatality during a motorcycle accident compared to pedestrians from other age groups. The fatal accident risk ratio is significantly high when the motorcycle collision involves hitting a pole/tree or fixed object compared to other collision types (risk ratio over 3.0). Head on collision appears to be the one with the highest risk for motorcycle accidents with other vehicles.

The study provides useful insights into identification of the main casual factors with respect to motorcycle fatal accidents. The identification of these risk factors can be used to formulate effective countermeasures to improve road safety related to motorcyclists in the country. This can be incorporated into the highway design process and to identify training requirements in obtaining motorcycle driving licenses plus specifying standards for motor cycles and awareness programs targeting specific user groups.

5.1 Limitations of the Study

Pre-crash factors of cyclists, pedestrians, riders, roads and vehicles that contributed to accidents are not known most of the times. That was the major limitation of this study. Details regarding 'number of years license issued since the time of accident' are not known in more than 30% of accidents. Measures have to be taken to properly record these factors in accident sheets.

References

1. http://www.motortraffic.gov.lk/, Visited, 2017/11/17.

2. Elliott, M. A., Baughan, C. J., Broughton, J., Chinn, B., Grayson, G. B., Knowles, J. & Simpson, H., "Motorcycle Safety: A Scoping Study.TRL Report No. 581," TRL Limited, 2003.

3. Williams,V., McLaughlin, S. & Atwood, J., "Factors that Increase and Decrease Motorcyclist Crash Risk," Motorcycle Safety Foundation, Virginia, 2016.

4. Behera, C., Rautji, R., Lalwani, S. & Dogra, T. D., "A Comprehensive Study of Motorcycle Fatalities in South Delhi". Journal of Indian Academy of Forensic Medicine, vol. 31(1), 2009, pp. 6-10,.

5. Albalate, D. & Villadangos, L. F., "Exploring Determinants of Urban Motorcycle Accident Severity: The Case of Barcelona," University of Barcelona, Barcelona, 2009.

6. Devasurendra, K., "Accident Analysis Beyond Descriptive Statistics", University of Moratuwa, 2016.

7. Dharmaratne, S. D., Jayatilleke, A. U., Abeyrathna, A. N., Mabharana, I. D. M. & Kumbukgolle, K. G. B., "Prevalence of Motorcycle Helmet Use in Sri Lanka: An Observational Study," Global Journal of Public Health and Epidemiology, 2013, pp. 54-56.

8. Amarasinghe. N., "Characteristics of Motorcycle Crashes," in 8th International Research Conference, Colombo, 2015.

9. Hurt, H. H., Ouellet, J. V. & Thom, D. R., "Motorcycle Accident Cause Factors and Identification of Countermeasures, Volume 1," Traffic Safety Center,University of Southern California, Los Angeles, California, 1981.

10. Ndunguru, M., "Assessment of the Factors for Motorcycle Accidents and their Impact in Kinondoni Municipality, Dar es Salaam-Tanzania," Imperial Journal of Interdiscipilinery Research, vol. 2, no. 5, 2016, pp. 1362-1367.

11. McCarthy, M. G., Walter, L. K., Hutchins, R., Tong, R. & Keigan, M., "Comparative Analysis of Motorcycle Accident Data from OTS and MAIDS," Department of Transport,Road User Safety Division, 2007.

12. Huang, B. & Preston, J., "A Literature Review on Motorcycle Collisions Final Report," Transport Studies Unit - Oxford University, 2004.

13. Sporner, A. & Kramlich, T., "Motorcycle Braking and Its Influence on Severity of Injury," Institute for Vehicle Safety, Munich, 2003.

14. Fildes, B., Newstead, S., Rizzi, M., Fitzharris, M. & Budd, L., "Adoption of Anti-lock Braking Systems (ABS) for Motorcycles in Australia", Monash University, Australia, 2015.

15. Honk, J. V., Klootwijk, C. W. & Ruijs, P. A. J., "Literature Survey of Motorcycle Accidents with Respect to the Influence of Engine Size," TNO Road - Vehicle Research Institute, Netherland, 1997.

16. OECD, "Improving Safety for Motorcycle, Scooter, Moped Riders," OECD, Paris, 2015.

17. Ministry of Road Transport & Highways Transport, "Road Acccidents in India – 2016," Ministry of Road Transport & Highways Transport Research Wing, New Delhi, 2017.

18. Ahamed, I., "Road Safety Situation in Bangladesh," DC Traffic West Division, DMP, Bangaladesh Police, Dhaka, 2016.

19. Power and Participation Research Center [PPRC], "Road Safety in Bangladesh Ground Realities and Action Imperatives," Power and Participation Research Center, Dhaka, 2014.

20. Soehodho, S., "Road Accidents in Indonesia," Transport Research Group, University of Indonesia, Jakarta, 2009.

21. World Health Organization, "Global status Report on Road Safety," World Health Organization, 2015.

22. Shajith, S. L. A., "Motorcycle Accident Analysis in Sri Lanka", University of Moratuwa, 2018.

23. Central Bank of Sri Lanka, Sri Lanka Socio-Economic Data, Colombo: Central Bank of Sri Lanka - Statistics Department, 2015.

24. Central Bank of Sri Lanka, Economic and Social Statistics of Sri Lanka- 2014, Colombo: Central Bank of Sri Lanka - Statistics Department, 2014.

25. Department of Census and Statistics, Census of Population and Housing, Colombo: Department of Census and Statistics & Ministry of Finance and Planning, 2012.