Exploring the Determinants of Fatal Motorcycle Accidents in Sri Lanka

Abstract— **Motorcycle Accidents have emerged as a prominent subset of Road Traffic Accidents in Sri Lankan context. Motorcycle Accidents account for approximately 40% of reported Road Traffic Accidents annually. Therefore, this study aims to identify the risk factors associated with fatal Motorcycle Accidents in Sri Lanka during the period of 2013 to 2019, providing valuable insights for policymakers and decision makers. The research objectives were achieved by analysing secondary data on personal factors of motorcyclists, characteristics of Motorcycle Accidents, and motorcycle attributes (motorcycle ownership and motorcycle age). The association between the severity of Motorcycle Accidents and the aforementioned factors was investigated. Based on a fitted binary logistic regression model, several influential factors were identified. The facts revealed through the calculated odds were that fatal motorcycle accidents are approximately 60 times more likely to happen on dry road surfaces compared to other types of road surfaces, nearly 3 times more likely in rural areas compared to urban and estate areas, nearly 3 times more likely on weekdays, nearly 2 times more likely on roads with no junctions, nearly 2 times more likely when the motorcyclist is in age group of 40 to 59, and equally likely among male and female motorcyclists.**

Keywords—Binary Logistic Regression, Fatal Accidents, Non-fatal Accidents

I. INTRODUCTION

Road traffic accidents (RTAs) pose a significant risk that can be prevented with appropriate precautions, but they continue to be a common occurrence with far-reaching consequences. Developing countries face the escalating challenge of RTAs, which adversely impact public health and hinder national development. These accidents result in injuries, fatalities, and substantial financial burdens.

Sri Lanka, an upper-middle-income country in South Asia, grapples with a high number of RTA fatalities and associated damage. According to World Health Organization (WHO) data from 2015, RTAs in Sri Lanka caused 3,554 deaths, accounting for 2.80% of total fatalities, with an age-adjusted death rate of 16.33 per 100,000 individuals. The Census and Statistics Report Sri Lanka in 2020 highlights RTAs as a leading cause of death, with the country ranking 96th globally in terms of age-adjusted death rate as per the report of WHO in 2019. In comparison to neighboring countries, Sri Lanka exhibits the highest road fatality rate. The increased usage of motorcycles, particularly among the lower middle class, has contributed to the rise in motorcycle-related RTAs. Motorcycles are favored due to their affordability, convenience in navigating urban traffic, and popularity among various social classes. However, the lack of helmet usage, especially in developing countries, contributes significantly to the prevalence of injuries in motorcycle-related RTAs.

Given the fuel crisis in Sri Lanka, motorcycles have become the preferred mode of transportation not only for lower and middle-income groups but also for the upper class. As motorcycle usage continues to increase, the frequency of motorcycle accidents (MAs) is expected to rise accordingly. It is imperative to identify the risk factors contributing to MAs to address this pressing public health issue effectively.

Considering the facts, it is evident that MAs represent a significant global and Sri Lankan public health concern. While MAs can be controlled compared to other leading causes of death, immediate and effective actions are required to mitigate this risk. Identifying the risk factors influencing MAs is crucial to curbing the impact of this consequential public health problem. A major part of the responsibility of ensuring the safety of transportation system users rests with the Sri Lanka Police, who are entrusted with enforcing rules and regulations. Given the widespread popularity of motorcycles as a mode of transportation, it is crucial to give special attention to Motorcycle Accidents (MAs). Therefore, it is necessary to regularly update information on the factors that influence MAs. However, due to a lack of timely, comprehensive, accurate studies, there is a need for professionals to conduct research to identify and enhance our understanding of the contributory factors. Furthermore, the incidence of fatal MAs remains alarmingly high, underscoring the need to continuously emphasize the factors that contribute to these accidents. Thus, this paper tries to identify the factors causing MAs and aims to assess the impact of these identified factors using data from 2013 to 2019.

The data gathered from previous research highlights the urgent need to address the risk of MAs within RTAs and implement effective preventive measures. MAs constitute a significant proportion of RTAs according to the WHO, necessitating a comprehensive understanding of the associated risk factors. By classifying these risk factors, stakeholders at various levels, including government, industry, international agencies, non-governmental organizations, motorcycle users, and manufacturers, can make informed decisions and take proactive measures to reduce MAs. The increasing popularity of motorcycles in Sri Lanka, driven by the fuel crisis, requires particular attention to identifying the factors contributing to MAs in order to mitigate their occurrence.

II. LITERATURE REVIEW

Asia is home to the majority of the world's motorcycles, accounting for 79% of all registered motorcycles [1]. WHO reports in 2013 that China has the highest number of motorcycles with 110 million, followed by India with 82 million, Indonesia with 60 million, and Vietnam with 31 million. Past research has emphasized that motorcycles are highly vulnerable to accidents, particularly due to the lack of protective structures [2]. This vulnerability leads to a high risk of injury and fatality, as observed in some other research in developing countries in Asia, including Afghanistan, Bangladesh, Bhutan, Myanmar, and Nepal, witness more than 50% of road crash fatalities among vulnerable road users such as motorcyclists, pedestrians, and bicyclists [3].

Providing insights into specific regulations for motorcyclists in different countries for example Brunei and Indonesia, motorcyclists are required to drive on the left side of the road, Cambodia mandates the use of helmets while riding, and in Malaysia, motorcyclists must possess a valid national license and wear a helmet, Singapore and Vietnam enforce left-side driving and mandatory helmet usage for both drivers and passengers, while Thailand mandates helmet usage and left-side driving for motorcyclists [4].

In Sri Lanka it is stated that motorcyclists are exposed to a higher degree of risk and are 16 times more likely to face the risk of death compared to car occupants due to the absence of safety precautions like airbags, seat belts, and limb protection [5]. As per records in Sri Lanka, in 2018 there have been 1,227 accidents involving motorcycles, with motorcyclists' fatalities accounting for 39.61% of total accident-related fatalities. Further the situation in Sri Lanka is described as there is a lack of information and insufficient attention from public policy authorities at the provincial and national levels on accident prevention [6].

According to department of motor traffic Sri Lanka, motorcycles frequently share the roads with fast-moving vehicles such as cars, buses, and lorries, making motorcyclists more vulnerable to heavy traffic due to their smaller size and limited protective measures [7]. Despite the documented higher crash risks faced by motorcyclists, there remains a lack of knowledge of effective measures to reduce these risks. Sri Lanka has a significant proportion of motorcycles (55% of all motorized vehicles) compared to the United States, indicating the popularity of motorcycles as an affordable mode of transportation in the country [2].

A. Factors Identified in Previous Studies

According to the European Association of Motorcycle Manufacturers, a significant number of motorcycle accidents involve males under the age of 25 [8]. A study conducted in Delhi further supports this finding, showing that 93.6% of motorcycle accident victims were males, primarily in the age groups of 21-30 and 31-40 [9].

Training-based interventions have proven effectiveness in reducing motorcycle accidents. However, improving the necessary skills and knowledge to ensure better vehicle control is a challenge. Riders require a more complex skill set compared to other vehicle operators, particularly in emergency situations. Scoping studies suggest that enhancing higher-order cognitive skills, educating riders on risk levels and safe riding practices, and acknowledging the lack of skill among riders can improve motorcycle safety [10].

Environmental factors, including road conditions and surroundings, significantly contribute to motorcycle accidents. Road surface defects, furniture, vegetation, and sudden animal movements all play a role in accident occurrences. It has been scientifically revealed that grooved road surfaces and raised road markings can lead to instability and accidents [10]. Accident locations also tend to concentrate at intersections, with other vehicles violating motorcycle right of way and traffic controls. Junctions, especially T-junctions, are common accident sites [11]. Furthermore, road alignment influences accident occurrences, with a majority of accidents happening on straight-road sections. Smooth road surfaces can contribute to increased speeding and the severity of accidents. In Tanzania, it was found that motorcycle accidents were more likely to occur on paved roads [12].

Proper enforcement of licensing and registration requirements for motorcycles is crucial in minimizing accidents. In Sri Lanka, it is discovered that a significant portion of riders failed to produce a valid driver's license, and some were below the minimum age requirement of 18 [13]. Accident data from 2008 to 2012 in Sri Lanka revealed that the majority of motorcycles involved in accidents were less than five years old, primarily ridden by young riders [14].

All the above evident the disclosure of numerous factors associated with MAs in Sri Lanka for further attention.

III. RESEARCH METHODS

A. Secondary Data

This study utilizes panel data on MAs in Sri Lanka, obtained from the Sri Lanka Police department, covering the period from 2013 to 2019. The Sri Lanka Police department has identified multiple causes of motorcycle accidents.

B. Statistical Model

This study employs binary logistic regression analysis to assess the risk factors associated with RTAs in Sri Lanka and predict the relative likelihood of fatal motorcycle accidents compared to non-fatal ones. The primary objective of using binary logistic regression in this study is to examine the relationship between the severity of motorcycle accidents (fatal or non-fatal) and various explanatory variables, encompassing road, human, vehicle, accident, time, and environmental characteristics. By identifying the best fitted binary logistic regression model, the estimation of odds ratios is done based on the parameters obtained for each explanatory variable. The dependent variable (Y) is a binary variable, denoting its levels, "fatal accidents" by 1 and "non-fatal accidents" by 0.

The general form of the logistic regression model is:

$$\pi\,(x) = p = \frac{e^{\beta_0 + \sum_{i=1}^{n} \beta_i x_i}}{1 + e^{\sum_{i=1}^{n} \beta_i x_i}} \tag{1}$$

The logit transformation of the model is:

$$logit\,(p) = \ln\left(\frac{p}{1-p}\right) = \beta_0 + \sum_{i=1}^{n} \beta_i x_i \tag{2}$$

where,

β_0 - Model constant

β_i - Parameter estimates for independent variables

x_i - Independent variables $(i = 1,2, \dots \dots, n)$

p - Probability ranges from 0 to 1

C. Model Interpretation and Diagnostics

The odds ratios are used to analyze the binary logistic regression model. If the odds ratio is greater than 1, it means that as the predictor gets stronger, the event is more likely to happen. If the odds ratio is less than 1, it means that as the predictor gets stronger, the likelihood of the event happening decreases. The odds ratio for categorical predictors compares the likelihood that an event will occur at two different levels of the predictor.

The Hosmer and Lemeshow (H-L) goodness of fit test classifies participants into groups based on expected probabilities, then uses the expected and observed frequencies to calculate a Chi-square. The logistic model's fit is then evaluated using a probability value that was obtained from the Chi-square distribution. The null hypothesis, which states that there is no difference between observed and model-predicted values, is not rejected if the Hosmer and Lemeshow goodness-of-fit test results are larger than 0.05, which is needed for well-fitting models. This indicates that the model fits the data with an acceptable level of accuracy.

IV. Statistical Analysis

Descriptive statistics followed by the application of comprehensive statistical tools to achieve the objectives of the analysis are performed.

A. Personal Factors of Motorcyclists

TABLE I. DESCRIPTIVE STATISTICS OF PERSONAL FACTORS OF MOTORCYCLISTS

Factor and the levels	Percentage (%)
Gender of the motorcyclist	
Male	77.70
Female	22.20
Age of the motorcyclist	
Below 18 years	2.20
18 - 40 years	16
40 - 60 years	27.60
Above 60 years	3.9
Validity of License	
Valid license for the motorcycle	73
Without a valid license for the motorcycle	2.2
Another license	0.02
Results of alcohol test	
Not tested	79.70
No alcohol or below the legal limit	18
Over the legal limit	2.30

The data indicates that a majority of 77.7% of male motorcyclists and a minority of 22.2% of female motorcyclists experienced MAs. Additionally, the gender of 52 individuals involved in MAs was not specified. Among the recorded accidents, 61% occurred within the 18-40 age group, which is significantly higher than the 27.6% observed in the 40-60 years age group and the 7.5% in the under 18 years age group. A smaller proportion of accidents, specifically 3.9%, involved individuals over the age of 60. The age of 5.3% of motorcyclists was not provided in the data.

Regarding licenses, 73% of motorcyclists possessed a valid motorcycle license, while 2.2% did not possess one. A minimal percentage of 0.02% held licenses such as probation licenses, learner permits, or international licenses that allowed them to ride. Furthermore, the availability of licenses was not mentioned for 25.3% of motorcyclists involved in MAs.

It is worth noting that for a substantial 79.7% of the total accidents that occurred between 2013 and 2019, there was no information regarding whether the riders had consumed alcohol. Among the accidents with reported information, 18% indicated that the riders had not consumed alcohol or were below the legal limit. Only a small percentage, specifically 2.3%, exceeded the legal alcohol limit.

B. Determine the Risk Factors Associated with MAs

Based on the chi-square analyses carried out separately for each variable, it was found that all other categorical variables have a significant influence on the severity of MAs separately. Thus, to find the combined impact from the best set of the independent variables out of all the significant variables, binary logistics regression was carried out under the forward stepwise ward method. The results of the final model are shown in Table II. The significance of the Hosmer and Lemeshow test statistic concludes that the fitted model is significant at 5% level.

The results in Table II indicate that the variable, weekday of the week (DW), road surface (RS), weather (W), light condition (LC), location type (LT), vehicle age (VA), vehicle ownership (VO), age of the driver (AD), validity license (VL), gender of the driver (GD), type of day (TD) and sector (S) to predict the outcome variable are significantly associated with severity of accidents when all the variables are taken into consideration simultaneously.

TABLE II. VARIABLES IN THE EQUATION

Variable	B	S.E.	Wald	df	Sig.	Exp(B)
Weekday (DW)	1.046	.046	520.079	1	.000	2.845
Dry (RS)	4.098	.351	135.990	1	.000	60.232
Other (W)			101.193	2	.000	
Clear (W)	1.525	.152	101.193	1	.000	4.594
Humid (W)	-20.166	1332.421	.000	1	.988	.000
Night – Good (LC)			515.245	2	.000	
Daylight (LC)	.357	.057	39.129	1	.000	1.429
Night – Improper (LC)	-.308	.059	26.939	1	.000	.735
Other (LT)			77.368	3	.000	
Roundabout (LT)	-.179	.051	12.179	1	.000	.836
Junction (LT)	.043	.057	.572	1	.449	1.044
Road-No Junction (LT)	.731	.161	20.585	1	.000	2.077
>30 years (VA)			35.356	2	.000	
10 – 30 years (VA)	.118	.221	.284	1	.594	1.125
< 10 years (VA)	.335	.223	2.257	1	.133	1.398
Service (VO)			8.172	2	.017	
Government (VO)	-.205	.206	.993	1	.319	.815
Private (VO)	.510	.336	2.306	1	.129	1.666
>60 years (AD)			566.363	3	.000	
40 – 59 years (AD)	.609	.124	24.204	1	.000	1.838
18 – 39 years (AD)	-.813	.098	68.354	1	.000	.443
<18 years (AD)	-.244	.103	5.628	1	.018	.783
No Valid License (VL)	-2.272	.227	99.928	1	.000	.103
Male (GD)	.107	.032	11.099	1	.001	1.112
Holiday (TD)			312.410	2	.000	
Normal Working Day (TD)	.573	.092	39.099	1	.000	1.774
Normal Weekend (TD)	-.210	.099	4.437	1	.035	.811
Rural (S)	1.155	.031	1358.41	1	.000	3.173
Constant	-2.415	.555	18.955	1	.000	.089

Hosmer and Lemeshow Test Statistic: $\chi^2_8 = 115.636$ (p = .000) concludes that the fitted model is significant at a 5% level.

TABLE III. CLASSIFICATION BASED ON THE FITTED MODEL

Observed		Predicted		
		Type of Accident		Percentage Correct
		Non-Fatal	Fatal	
Type of Accident	Non-Fatal	1134	6174	15.5%
	Fatal	82	61287	99.9%
Overall Percentage				90.9%

According to Table III, the model employed in this study demonstrates a high overall productivity power of 90.9%. The probability of accurately classifying a fatal motorcycle accident as fatal is estimated at 0.999, indicating a strong predictive ability. Similarly, the probability of correctly identifying a non-fatal motorcycle accident as non-fatal is recorded at 0.155.

The results in Table IV of the Cox & Snell R^2 and Nagelkerke R^2 indicate that the explained variation in the dependent variable based on the model varies from 1.19% to 2.41%. Both statistics indicate the percentage of the variance of the dependent variable is explained by the model. However, various authors have citizen these two indicators.

TABLE IV. MODEL SUMMARY

-2 Log likelihood	Cox & Snell R^2	Nagelkerke R^2
37870.49	0.119	0.241

Using the model estimates the following results can be obtained.

- The odds of fatal motorcycle accidents happening on a weekday is 2.845 times higher than what occurs on a weekend when all other variables in the model are fixed.
- The odds of fatal motorcycle accidents happening on a dry road surface is 60.232 times higher than that it occurs in wet road surface when all the other variables are fixed.
- The odds of happening motorcycle fatal accidents in clear weather is 4.594 times higher than what occurs in humid weather when all other variables are fixed.
- The odds of fatal motorcycle accidents happening during daylight is 1.429 times higher than what occurs during the night with good street lighting when all the other variables are fixed.
- The odds of fatal motorcycle accidents happening in roads with no junction is 2.077 times higher what occurs in other location types when all the other variables are fixed.
- The odds of fatal motorcycle accidents happening when the age of the driver is between 40 to 59 is 1.838 times higher than when the age of the driver is more than 60 years old when all the other variables are fixed.
- The odds of fatal motorcycle accidents happening among male are 1.112 times higher than that of among females when all the other variables are fixed.
- The odds of motorcycle fatal accidents occurring during a normal working day is 1.774 times higher than during the holidays when all other variables are fixed.
- The odds of motorcycle fatal accidents occurring in rural area is 3.173 times higher than in urban areas when all other variables are fixed.

V. CONCLUSION, RECOMMENDATIONS AND SUGGESTIONS

A. *Conclusion*

A significant portion of fatal motorcycle accidents, accounting for 68%, occurred in rural areas. The majority of these accidents, around 73.2%, took place on weekdays, specifically normal working days. Surprisingly, nearly 90% of the motorcyclists involved in these accidents were not subjected to alcohol testing. Moreover, a similar proportion of the accidents, approximately 92.6%, occurred on dry road surfaces. Approximately 53.8% of the accidents happened during daytime. In terms of road characteristics, a considerable 71.4% of the accidents occurred on roads without junctions. Additionally, 83.4% of the vehicles involved in the crashes were less than 10 years old. It is worth noting that 99.3% of these newer vehicles were privately owned. Analyzing the driver demographics, it was observed that 76% of the drivers involved in the accidents were males within the age range of 18-40, all of whom possessed valid licenses. Regarding the factors contributing to fatal motorcycle accidents, the binary logistic regression model identified several variables with a significant positive influence on the odds ratio. These variables included weekdays, dry road surfaces, clear weather conditions, daytime, nights with inadequate street lighting, roundabouts, roads without junctions, drivers aged 40-59, drivers aged 18-39, drivers under the age of 18, drivers without valid licenses, male drivers, normal working days, normal weekdays, and rural areas.

B. *Recommendations*

To prevent pedestrian fatalities and injuries, various measures can be implemented. These include the use of signalization systems, the construction of pedestrian bridges, and the establishment of pavement tunnels to minimize pedestrian exposure to moving vehicles. Another effective approach is the installation of active signage systems that can automatically detect pedestrian movement and alert pedestrians to potential dangers through lighting and other visual signals. To enhance motorcycle safety, it is advisable to create dedicated lanes for motorcycles and raise awareness about their presence by encouraging motorcyclists to wear conspicuous upper-torso garments and keep their headlamps on during daytime. Furthermore, the implementation of interconnected brake systems can greatly improve cyclist safety by enabling coordinated braking actions. Additionally, the development of advanced training programs for cyclists can help enhance their skills and awareness on the road. To address the issue of road safety overall, it is crucial to focus on the maintenance of high collision concentration zones and hazardous roads. Regular inspections and maintenance activities in these areas can help identify potential risks and ensure appropriate measures are taken to mitigate them, thereby reducing the occurrence of accidents, and improving overall road safety.

The choice to use binary logistic regression instead of model fitting for imbalance sampling in MAs research is justified by its specific relevance and effectiveness in addressing the research objective. Binary logistic regression is a statistical technique commonly used MAs and a set of independent variables (such as road conditions, driver demographics, and other relevant factors). Imbalance sampling refers to situations where the distribution of the target variable (i.e., the occurrence of fatal MAs) is significantly imbalanced, with one outcome being more prevalent than the other. In this research, the occurrence of fatal accidents is relatively rare compared to non-fatal accidents. This imbalance can pose challenges when fitting traditional models and may lead to biased results.

By utilizing binary logistic regression in motorcycle accident research, effectively explore the influence of various factors on the occurrence of fatal accidents. This statistical approach allows identifying variables that have a significant positive influence on the odds ratio of fatal MAs, helping policymakers and researchers gain valuable insights into the key factors contributing to these accidents. The use of binary logistic regression in motorcycle accident research is supported by relevant references in the field. For example, studies conducted by researchers such as Patel and Zhang have successfully employed binary logistic regression to investigate the determinants of MAs and fatalities. These studies have demonstrated the utility and applicability of binary logistic regression in understanding and addressing the unique challenges associated with MAs. Overall, the justification for using binary logistic regression instead of model fitting for imbalance sampling in MA research lies in its ability to handle imbalanced data, provide meaningful insights into the factors associated with fatal accidents, and draw upon the established success of this approach in related studies.

C. Suggestions

To promote road safety, it is vital to emphasize certain practices for drivers. Strict adherence to lane driving and the proper use of signals can greatly reduce the risk of accidents. Additionally, conducting programs that highlight the importance of seatbelt usage and the need to remain attentive while driving can contribute to safer roads. Furthermore, ensuring that motorbikes are in proper working condition is crucial. Regular maintenance should be carried out not only on the engine and brakes but also on tires, headlights, gears, and signals. It is important to develop the habit of inspecting the bike for any potential defects before each use. To maintain a safe driving distance, it is advised to avoid tailgating and keep a distance of at least 4 seconds from the vehicle in front. Having an escape route in mind can provide an added layer of safety in unexpected situations on the road. By promoting these practices, we can create a safer driving environment and reduce the likelihood of accidents, benefiting both drivers and other road users.

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