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Research Paper

Assessing Risk Factors Associated with Motorcycle Crash Severity in Mashhad, Iran

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Abstract

Accurate assessment of motorcycle safety requires examining the complex relationships between vehicles, roads, and human factors involved in a crash. This study deals with the case study of Mashhad as one of the metropolises of the country. It investigates the role of different characteristics in the severity of motorcycle crashes by examining 9663 cases of motorcycle crashes in the three-year period from 2014 to 2016. For this purpose, the study uses the descriptive analysis of the data and a logistic regression model. The variables studied in this paper are divided into three categories: crash variables, environmental variables, and motorcyclist variables. Investigation of crash variables shows that the probability of fatal crashes increases from 22 to 10 in the morning. Further, the probability of a motorcyclist's death in crashes with heavy vehicles and crashes without another involved party is 3.27 and 4.41 times higher than that of a motorcyclist in a crash with light vehicles. Environmental variables indicate that the probability of more severe motorcycle crashes increases in roundabouts, roads with recreational use, and expressways. Further, the severity of crashes increases on highways and roads with shoulders, divided medians, higher speed limits, and roads without adequate lighting. In addition, the variables related to motorcyclists show that the probability of more severe crashes rises with the increasing age of motorcyclists. Finally, this study analysis the role of various factors, examines the problems in crash information, and offers solutions related to improving the safety of motorcyclists.

Keywords: Crash, Motorcycle, Vulnerable User, Logistic Regression, Crash Severity

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1. Introduction

Every year, traffic crashes lead to the death of many people or cause injuries or disabilities. In addition, it causes billions of dollars in financial losses to various countries around the world. According to data provided by the World Health Organization (WHO), in 2021, an average of 1.3 million people will die annually due to road crashes. These data show that the death rate from road crashes in low- and middle-income countries is 29.4 per 100,000 populations (WHO 2021). The same study shows that 93% of fatal crashes occur in low- and middle-income countries, although they have only about 60 percent of the world's vehicles. If the increasing trend of crashes continues at the current rate, the number of fatalities due to road crashes in 2025 will increase by 66% compared to 2005 (Goh 2014). Further, according to the World Health Organization (WHO), road crashes are the leading cause of death in the age range of 5 to 29 years. This indicates the need for further studies in this area.

Statistical Research and Training Centre (2020) reported that 17183 people were killed, and more than 30 thousand people were injured in Iran in 2018 due to road crashes. This means that the average death rate due to road crashes in Iran was 20.5 people per 100,000 population. In the discussion of crashes, the safety of vulnerable users (motorcyclists, cyclists, and pedestrians) is essential because they are more at risk than others. According to a report by the World Health Organization (WHO), more than half of all road deaths worldwide belong to these users, and they are also more prone to concussions and direct collisions with other vehicles (Toroyan 2016). Moreover, motorcycles are one of the most popular vehicles around the world. From 2010 to 2015, the number of motorcycles worldwide grew by 27% (Toroyan 2016). The reason can be summarized in the special advantages of this vehicle, such as the possibility of passing traffic on the streets, ease of parking even on narrow streets, as well as a better price and lower fuel consumption than four-wheeled vehicles. Although motorcycles account for a small share of total road traffic, the number of casualties from motorcycle crashes is significant. World Health Organization reports show that about a quarter of all motorcycle crashes worldwide are related to motorcycles (WHO 2021). Motorcyclists' refusal to wear a helmet, speeding, passing a red light, white lining, and performing unusual movements have made this vehicle one of the most vulnerable vehicles. Motorcyclists or their pillion riders are 37 times more likely to be killed in injuries than users of four-wheeled vehicles (Toroyan 2016). The provided information shows the urgent need for a comprehensive and complete study about motorcyclists' safety in the country.

2. Literature Review

Many studies have been done in various fields related to the safety of motorcycles due to the increasing use of this vehicle in urban transportation. Further, due to the unprotected cabin, motorcycle riders are at considerable risk of injury and death. Therefore, one of the critical concerns of the authorities is to reduce the number and severity of motorcycle crashes by developing and implementing a comprehensive strategic plan (Rizzi et al., 2015). According to studies, some of the critical factors affecting the severity of motorcycle crashes are: not wearing a helmet (Savolainen and Mannering 2007), speeding (Shaheed and Gkritza 2014), high-power motorcycles (De Lapparent 2006), driver age (Schneider and Savolainen 2011), driving without a valid certificate (Dandona et al. 2006), road lighting conditions (Chung et al. 2014), driving under the influence of alcohol (Shaheed and Gkritza 2014), and type of road classification (Eustace et al. 2011).

In general, the factors affecting all road crashes are divided into three categories: road and environmental characteristics, vehicle characteristics, and human factors. Among these, the human factor is considered the most important factor affecting crashes (Shinar 2017). Road and environmental characteristics include street land use, street width, shoulder width, pavement surface conditions, weather conditions, lighting conditions, the impact of vertical and horizontal curves, and more. The vehicle's specifications include the type and power of the motorcycle, the braking system, the vehicle's age and health, and other items. Human factors include a wide range of parameters, including age, gender, marital status, driving history, social and economic status, or personality factors (Reason 1990).

A sample of 6,530 motorcycle crashes in California found that most motorcycle crashes that resulted in severe head injuries occurred in people over the age of 55. In addition, the probability of injury severity in crashes increases significantly with age (Talving et al., 2010).

Various studies have been conducted to evaluate the characteristics of the road and environmental factors and the vehicle's characteristics. The study conducted in Australia showed that the number of fatal crashes increased from 175 in 1997 to 238 in 2006. The concluded reason was the significant increase in motorcyclists' number and the increase in the age of these road users (Haworth and Nielson 2008). Another study in this country revealed the vulnerability of this particular group. In 2015, motorcycles accounted for 4.5% of Australia's registered fleet; although, their crash rate was 18% (Stephens et al., 2017). Pérez et al. (2009) showed that in Europe, 21.1% of crashes were related to motorcyclists. The study indicated that the number of motorcycle deaths in 2005 was 22% higher than in 1996. A study of 9,176 fatal motorcycle crashes in Malaysia showed that the areas with curves, without road markings, and poorly paved roads significantly increase the likelihood of fatal motorcycle crashes (Lankarani et al., 2014). Abrari Vajari et al. (2020) examined the factors affecing motorcycle crashes at Australian intersections and showed that the severity of motorcycle crashes depends on the intersection layout.

In addition, regarding the vehicle's characteristics, Teoh (2011) showed that the death rate on motorcycles with an anti-lock braking system (ABS) is 37% less than on motorcycles without this system. Another study also found that the anti-lock braking system reduced motorcycle crashes by 29 percent in Spain and 34 percent in Sweden. The reduction in fatal crashes in Spain and Sweden was 34% and 42%, respectively (Rizzi et al., 2015).

As an example of studies conducted in the Middle East and neighboring Iran, studies in Pakistan showed that there had been a disproportionate growth in the number of vehicles in the past decade. Due to the lack of proper public transportation, motorcycles accounted for 61% of vehicles in 2015 and have grown by 371% in 10 years (Waseem et al., 2019). Moreover, this study indicated that this country's annual production of motorcycles has increased from 89,000 in 1998 to 1.36 million in 2016. This dramatic increase in the number of motorcycles combined with poor road safety has led to a 137% increase in motorcycle crashes in the past eight years in Rawalpindi, Pakistan (Waseem et al., 2019). These experiences in the neighboring country, taking into account the current situation in Iran, warn researchers and experts that they should pay special attention to motorcycles and their safety.

In Iran, traffic crashes are the third leading cause of death (Saadat et al., 2015). Among them, motorcyclists are the most victims of urban and rural crashes, so that the probability of death of a motorcyclist per mile of driving is 34 times higher than other road users (Bazargani et al., 2017). Bhalla et al. (2009) and Naghavi et al. (2009) showed that the number of fatal crashes in Iran is much higher than in developed countries. Traffic and Transportation Organization of Mashhad (2019) reported that motorcycles accounted for only 8% of city traffic, but 24.2% of fatal crashes and 39.4% of injuries were related to motorcycles.

Although extensive studies have been conducted on motorcycle crashes around the world, most of the studies in Iran were conducted by medical approach or were using simple statistical analyzes, and few studies may be found that have dealt with statistical modeling and more comprehensive analyzes. Moreover, it should be noted that the factors considered for the analysis of motorcycle crashes are highly related to the completeness of the associated data. In recent years, the Traffic and Transportation Organization of Mashhad has recorded more accurate crash data. Therefore, using these complete information and up-to-date modeling methods can effectively predict and prevent crashes.

Therefore, the aims of this study are two-folded: first, descriptive analysis of motorcyclists' crash information to observe the pattern of occurrence of these crashes and describe the role of various factors in motorcyclists' crashes. Second, using statistical modeling tools to identify influential factors in increasing the severity of motorcycle crashes and analyzing the results from the transportation aspect to determine how these factors affect.

3. Data and Methodology

3.1. Data Description

This study uses the data provided about motorcycle crashes in Mashhad in cooperation with the Traffic and Transport Organization. This information was collected by related organizations such as Mashhad's Police, Emergency Medical Services, and Forensic Medicine Organization in the three-year period from 2014 to 2016.

The data recorded by the police was used as a basis for descriptive analysis of the data and estimation of the statistical model; because it had the most comprehensive specifications and the most information recorded from the crash. Then, the other organs' data was merged with the original data according to the date and time of the crash, the motorcyclists' age, and the approximate location of the crash. The data that could not be repaired was removed from the database. As a result, this study used 9662 motorcycle crashes to analyze data and construct a statistical model. The following subsection describes the variables used in this study. Table 1 shows the number of crashes and their severity for each variable.

3.2. Variables

Motorcyclist variables: Age and gender are used as variables related to motorcyclists in studies of the severity of motorcyclist crashes. Although there is no gender discrimination in obtaining a motorcycle license in Iran, there are very few female motorcyclists in this city due to cultural issues and special conditions in Mashhad. For this reason, the study of gender variables in this study has been omitted. Details of age ranges are given in Table 1.

Environmental variables: This study considers six environmental variables. They include: road shoulder (having or not), light (day, at sunrise or sunset, night with sufficient light, and night without sufficient light), median (having or not), speed limit (50 km/h or less, more than 50 km/h), land use (residential, office/commercial, educational, recreational, and non-residential), and the place where the crash occurred (road segment, intersection, and roundabout).

Crash variables: The crash variables in this study are the time of the crash (hour, year) and the other party involved in the crash. The second one is divided into six categories: light vehicle, heavy vehicle, motorcycle/bicycle, pedestrian, no involved party, and other items

3.3. Model

This study uses a binary logistic regression model. Accordingly, the severity of crashes is divided into two categories: fatal and injury crashes. A death up to 30 days after a crash is considered a fatal crash. The property damage only (PDO) crashes are not considered; because their recording has been accompanied by many errors and cannot be cited.

The binary logistic regression estimates the relationship between several independent variables and a binary dependent variable. It predicts the probability of a phenomenon occurring by fitting data on a logistic curve. In order to estimate the coefficients, the maximum likelihood method has been used. To evaluate the goodness of fit, the Chi-square test and the Hosmer–Lemeshow test were used. Also, to evaluate the statistical significance of regression coefficients, the Wald test and the P-value test were used. The level of confidence was 95%. The same method has been used to model urban transit bus crash severity in Mashhad (Nasri and Aghabayk 2021). IBM SPSS Statistics 25 has been used software for modeling.

4. Results and Discussions

4.1. Motorcyclist Variable

The age of the motorcyclist is one of the variables investigated in the severity of motorcyclist crashes. Due to the high number of unregistered ages by databases, the category of unregistered ages was used as the indicator variable in modeling. The p-value statistic for ages 25 to 29 is equal to 0.003 and for two age groups of 50 to 60 years and more than 60 years is less than 0.001, which indicates the significance of these three groups. In addition, the Wald test for these three age groups shows their importance on the dependent variable. Model coefficients and odds ratios for these three age groups show that increasing age significantly increases the severity of motorcycle crashes; the probability of an crash resulting in death in the age range of 25 to 29 years is 2.051 times the base age, in the age range of 50 to 60 years is 4.008 times, and for the age range of more than 60 years is 7.012 times the base age. In line with the above findings, previous studies have shown that increasing the age of motorcycle riders increases the death rate due to motorcycle crashes (Savolainen & Mannering 2007, Talving et al. 2010, Schneider & Savolainen 2011).

Another noteworthy point is to pay attention to the age range of less than 18 years (people without a license). The P-value statistic for this variable is 0.179, which shows that 17.9% of the dependent variable changes are affected by this independent variable; although at a level of 80% confidence. However, the model coefficient of this variable is estimated to be 0.493 and the odds ratio of this variable is 1.638, indicating an increase in the probability of the severity of motorcycle crashes in this age range

4.2. Environmental Variables

4.2.1. Speed Limit

In general, the structure of motorcycles is such that it has much lower safety compared to cars. On the other hand, high-speed crashes can be much more dangerous. Therefore, according to previous studies, it is expected that roads with higher speed limits (such as highways and arterial roads) are more likely to have severe crashes (Shaheed & Gkritza 2014, Waseem et al. 2019, and Truong et al. 2019). In this study, in order to investigate the effect of the speed limit, streets are divided into two categories: streets with a speed limit of 50 km/h or less and streets with a speed limit of more than 50 km/h. For modeling, streets with a speed limit of 50 km / h and less are considered the indicator variable. The P-value of less than 0.001 and also the Wald test value of 13,895 indicate the significance and importance of this variable on the changes of the dependent variable. The coefficient of this variable is estimated to be 0.530, and the fact that this coefficient is positive indicates that increasing the speed limit raises the probability of fatal crashes. The odds ratio for this variable is also estimated at 1,699, which indicates that the higher speed limit category increases the 69.9% chance of crashes resulting in the death of motorcyclists.

4.2.2. Shoulders

On city streets, expressways and freeways often have shoulders. On the other hand, the speed limit in this category is more than others, and it is expected that the probability of more severe crashes on these roads is higher than the other road types. To investigate the effect of shoulders on the severity of motorcycle crashes, streets with shoulders were defined as the indicator variable in modeling. The model coefficient for the roads without shoulders is estimated to be -0.564, which indicates lower severe crashes than the shoulder roads. Also, the odds ratio of this variable is 0.569, which shows that the probability of motorcycle crashes with higher severity on shoulderless roads is 43.1% lower than the occurrence of crashes on shoulder roads. The P-value for this variable is 0.003 and its Wald test result is 8,909, indicating the significance of this variable with 95% confidence level. It should be noted that most of the information obtained from the forensic organization did not have the street shoulder information or the accurate address of the crash from which shoulder information could be obtained. Therefore, the percentage of fatal crashes in the unrecorded category was high.

4.2.3. Median

The presence of medians can reduce head-on crashes by separating the opposite paths (Waseem et al., 2019). On the other hand, medians increase the average speed of passing traffic, channelize the traffic and create space for more maneuvering of motorcycles, thus increasing the severity of motorcycle crashes (Haque et al. 2010). In order to investigate the median effect, roads without medians were considered as the indicator variable. The modeling results show that the roads with medians have a P-value of less than 0.001, which indicates the significance of this variable with a 95% confidence level. The coefficient of this variable is estimated to be 0.492, and its odds ratio is 1.635. This means that the risk of fatal crashes is 63.5% higher on median roads than on non-median roads**.**

4.2.4. Land Use

In this study, land uses are divided into residential, office/commercial, educational, recreational, non-residential (urban expressways and freeways), and others (agricultural, industrial, etc.). The residential use was considered as the indicator variable. The modeling results show that the prediction coefficients of the model for office/commercial, educational, and other uses are -0.63, -0.183, and -0.161, respectively. Therefore, fatal crashes are less likely to occur in these uses than in residential uses, although the P-values are not significant for these variables. A review of recreational and non-residential uses shows that the P-value is statistically at the 95% confidence level. The prediction coefficients of these variables are 0.867 and 0.641, respectively. The odds ratios of these variables are 2.381 and 1.899, respectively. The results show that the probability of fatal crashes in recreational and non-residential uses is about 2.4 and 1.9 times higher than residential use. This can be due to the sudden presence of people in the recreational area and also the high speed of motorcyclists on expressways and freeways, leading to more severe crashes (Shankar & Mannering 1996, Albertsson & Falkmer 2005, Shaheed & Gkritza 2014).

4.2.5. Facility Type

The type of facility where the crashes occurred was divided into three categories: road segments, intersections, and roundabouts. Road segments were considered as the indicator variable for modeling. The P-value and Wald test value for intersections are 0.001 and 10,729, respectively. So, it is a significant independent variable for the dependent variable. The coefficient of this variable is -0.617, which indicates that the severity of motorcycle crashes at intersections is lower than on the road segments. In addition, the odds ratio for this variable is 0.540, which indicates that the probability of a fatal crash at intersections is 46% lower than on the road segments. The P-value statistic for the roundabouts is 0.247, which indicates that this variable has no significant relationship with the dependent variable at the 95% confidence level. The reason for the insignificance of this variable might be the less number of these crashes compared to other facility types.

4.2.6. Lighting

The lighting condition of the crash site was divided into five variables: day, at sunrise or sunset, night with sufficient light, night without sufficient light, and unrecorded. The day variable was the basis variable in modeling. The night without sufficient light has a P-value of 0.002 and a Wald test value of 9,982, indicating the importance of this variable to changes in the dependent variable. The model coefficient of this variable is estimated to be 1.161, and the odds ratio of this variable is 3.194. This odds ratio indicates that the probability of crashes resulting in the death of motorcyclists at night without adequate lighting is more than 3 times that of the day. Also, the odds ratio for the sunrise or sunset time and the night with sufficient light are 1.483 and 1.214, respectively, indicating the increases in the probability of fatal crashes in these conditions compared to the day. Although the P-values for these variables do not show the significance of these two variables with a 95% confidence level, previous studies are consistent with these findings. Lankarani et al. (2014) showed that the proportion of fatal crashes at sunrise and sunset is higher than the daylight. Also, Chung et al. (2014) showed that the probability of crashes leading to death at night is higher than during the day.

4.3. Crash Variables

4.3.1. Day Hour

The hours of a day were divided into five categories according to the different traffic conditions information provided by the Traffic and Transport Organization of Mashhad. Due to the occurrence of many crashes during the evening peak hours (18 to 22), this interval was considered as the indicator variable for the modeling. The results show that the model coefficients are positive for all time period variables. This means that although the number of crashes is higher during the peak traffic period, their severity is lower. However, only 6-10 in the morning, 22-6 at midnight, and the unrecorded periods are statistically significant. These three groups will be further discussed. The odds ratio for the period from 6 to 10 in the morning indicates that the probability of a fatal crash occurring during this period is about 2.5 times greater than the base period. Also, this ratio in the period of 22 to 6 shows that the probability of a fatal crash is more than two times compared to the base period. This could be due to the rush or speed of vehicles during these hours and the possibility of further maneuvering of motorcycles; compared to the peak traffic hours. It should be noted that many crashes did not have this information in the data set. The existence of the high number of fatal crashes in the unreported group led to its statistical significance in the model.

4.3.2. Year

The study used the three-year period data from 2014 to 2016. The indicator variable was 2016. The modeling results show that the coefficients for 2014 and 2015 are estimated at 1.191 and 0.165, respectively. The positive values mean that the probability of a more severe crash in these years was higher than the base year. In addition, the odds ratio for 2014 and 2015 are equal to 3.291 and 1.180, respectively. That means, in 2014 and 2015, the probability of an crash resulting in death was 3.291 and 1.180 times higher than in 2016, respectively. This reflects the impact of the measures taken to reduce the severity of crashes in these years. However, the P-value for 2014 indicates the statistical significance of the variable at the level of 95%, but not for 2015.

4.3.3. Another Involved Party

Another party involved in the crash is one of the most critical factors in assessing the severity of motorcycle crashes. This indicates the severity of the vulnerability of motorcyclists from different types of road users. For this purpose, five variables have been considered, including light vehicles, heavy vehicles, motorcycles or bicycles, pedestrians, no involved party, and others. The light vehicle variable was considered as the indicator variable. For heavy vehicles, the P-value is less than 0.001 and the Wald test value is 23,633, indicating the significance of this variable at the 95% confidence level. The coefficient of this variable is estimated to be 1.186, which indicates the higher probability of a severe crash with this vehicle compared to a light vehicle. The odds ratio of 3.274 in the model shows that the probability of fatal crashes when the parties involved in motorcycle crashes are heavy vehicles is about 3.3 times higher than when the parties are light vehicles. The P-value statistic for the variable of motorcycles/bicycles in modeling indicates the insignificance of this variable. Also, the odds ratio of this variable is approximately equal to one. So, statistically, there is no difference between the variables. The P-value for checking motorcycle and pedestrian crashes is less than 0.001 and the Wald test value is 40,638. The coefficient of this variable is 1.030 and its odds ratio is 2.800. This means that the probability of death in a motorcycle-pedestrian crash is 2.8 times higher than a motorcycle-light vehicle crash. The next category shows the crashes in which the motorcycle collided with an obstacle or overturned without colliding with another road user. The P-value for this variable is less than 0.001. The Wald test value is also 44,183. These values indicate the significance of this variable with a 95% confidence level. The predicted coefficient for this variable is 1.484, which indicates the possibility of more severe crashes than motorcycle crashes with light vehicles. In addition, the odds ratio for this variable is 4.412. This means that the probability of death in a single-vehicle crash is nearly 4.5 times higher than when a motorcycle collides with a light vehicle. It should be noted that most of these crashes are due to motorcyclists' unusual maneuvers on the roads at high speeds and without the use of safety equipment. Moreover, due to the lower safety of this vehicle, the presence of obstacles on roads can cause irreparable damage to this group of road users.

5. Limitations

Lack of interaction between the institutions responsible for collecting and recording crash information has led to inconsistencies and reduced the efficiency of the existing data. The most crucial problem is the lack of unique identifiers, which can facilitate merging data obtained from different sources. A more complete data set can help researchers to conduct better analyses.

Another essential characteristic not available in the recorded data was the site traffic information, such as average daily traffic. This information can be of great help to researchers in the field of crash investigation.

There was no information about the pillion riders in the data set, although the presence or absence of the pillion riders and their characteristics can help researchers in more accurate and better modeling. It is also advantageous to have any information about the presence or absence of boxes on the motorcycles.

The recorded data did not provide essential details about the motorcyclists' characteristics, especially demographic characteristics such as age, education, marital status, and history of crashes. Such information can improve data analysis and model development.

6. Summary and Conclusion

This study investigated motorcycle crashes in Mashhad during the three-year period from 2014 to 2016 and examined the variables associated with the severity of this type of crash. The distribution of motorcycle crashes at different times of the day shows that about 75% of motorcycle crashes occur between 10 am and 10 pm; the afternoon peak (18-22) has the highest number of crashes. However, the probability of a more severe motorcycle crash is much higher from 10 pm to10 am. Lighting-based distribution of crashes shows that most crashes occur in daylight. However, the statistical modeling shows that the probability of a crash occurring at night without adequate lighting is more than three times higher than that in the daytime. Therefore, it is highly recommended to identify the areas without sufficient lighting and install the necessary equipment.

Analysis of speed limits shows that the probability of a more severe crash on the road with a speed limit of more than 50 km/h is 1.7 times higher than where the speed limit is 50 km/h or less. Further, any road enhancement that leads to a speed increase (such as having medians and having shoulders) exacerbates the severity of motorcycle crashes. This problem shows that any upgrade without considering all the issues is not necessarily good. There is a need for stricter law enforcement, such as using traffic control cameras to reduce the severity of crashes, especially at night when the roads are quieter.

A study of the age distribution of motorcycle riders shows that people under 30 have the highest number of motorcycle crashes. In addition, statistical modeling shows that the probability of crashes increases with age. This is especially true for people over the age of 60. It is recommended that to consider particular criteria in renewing motorcycle driver's licenses for people over 60 years, which can ensure the ability of these riders. Proper and comprehensive training courses can also be practical for young people when they receive a certificate.

In a crash between motorcycles and heavy vehicles, the probability of death is 3.2 times higher than when motorcycles collide with light vehicles. Also, in the event of a motorcycle crash with a pedestrian, the probability of a fatal crash is high. Therefore, it is recommended to consider a special lane for motorcycles on the roads where more heavy vehicles pass. Also, providing suitable pedestrian facilities can be effective, but it is necessary to control these facilities not to be used by motorcycles. In addition, with attention to the land use analysis, it is recommended to encircle parks and recreational areas, and warn motorcyclists about the sudden presence of people on the streets.

Importantly, motorcycles are most likely to be vulnerable to single-vehicle crashes. It should be noted that most of these crashes are due to motorcyclists' unusual maneuvers on the roads at high speeds and without the use of safety equipment. In this case, more control and law enforcement could be helpful. Moreover, due to the lower safety of this vehicle, the presence of obstacles or damages on roads can cause irreparable problems to this group of road users. Therefore, thorough audits should be conducted to investigate the infrastructures' safety with consideration of motorcycles.

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9. Appendix

Table 1. Descriptive statistics of independent variables

Variables	Fatality	Injury	Total
Motorcyclist characteristics			
Age			
>18	15	464	479
24-18	85	2353	2438
29-25	87	2212	2299
39-30	48	1716	1764
49-40	20	569	589
59-50	34	378	412
>60	33	196	229
Not recorded	42	1410	1452
Environmental characteristics			
Shoulder presence			
Yes	39	1260	1299
No	183	7963	8146
Not recorded	142	75	217
Median presence			
Yes	240	4656	4896
No	124	4642	4766
Speed limit			
Up to 50 Km/h	203	6673	6876
Over 50 Km/h	161	2625	2786
Light			
Day	168	4784	4952
Sunrise/Sunset	57	1376	1433
Night with light	105	2898	3003
Night without light	29	232	261
Not recorded	5	8	13
Accident location			
Road Segment	292	6673	6965
Intersection	43	2153	2196
Roundabout	29	472	501
Land use			
Residential	174	5370	5544
Commercial/Official	70	2138	2200
Educational	2	36	38
Recreational	11	111	122
Non-residential	82	779	861
Others	25	872	897
Crash characteristics			
Hour			

6_10	51	1016	1067
10_14	72	2105	2177
14_18	77	2309	2386
18_22	80	2455	2535
22_6	73	1396	1469
Not recorded	11	17	28
Year			
2014	165	1888	2053
2015	108	3271	3379
2016	91	4139	4230
Other side			
Light vehicles	130	6368	6498
Heavy vehicles	41	305	346
Motorcycle/Bicycle	14	489	503
Pedestrian	128	1744	1872
Without other parties	48	357	405
Others	3	35	38

Table 2. Coefficients and characteristics of independent variables of logistic regression model

Variables		**β**	**S.E**	**Wald**	**P-value**	**Exp(β)**	**95% C.I for Exp(β)**	
							Lower	**Upper**
Speed limit	(>50)	0.53	0.142	13.895	0.001>	1.699	1.286	2.245
Hour	18_22			20.873	0.001			
	6_10	0.855	0.308	8.237	0.004	2.424	1.324	4.436
	10_14	0.453	0.308	2.168	0.141	1.573	0.861	2.877
	14_18	0.35	0.252	1.926	0.165	1.419	0.866	2.326
	22_6	0.712	0.212	11.289	0.001	2.037	1.345	3.086
	Not recorded	1.872	0.878	4.545	0.033	6.502	1.163	36.351
Year	2016			60.881	0.001>			
	2014	1.191	0.166	51.701	0	3.291	2.378	4.553
	2015	0.165	0.18	0.845	0.358	1.18	0.829	1.678
Light	Day			13.904	0.008			
	Sunrise/Sunset	0.394	0.249	2.503	0.114	1.483	0.91	2.415
	Night with light	0.194	0.279	0.484	0.487	1.214	0.703	2.098
	Night without light	1.161	0.368	9.982	0.002	3.194	1.554	6.563
	Not recorded	1.14	1.261	0.817	0.366	3.125	0.264	36.976
Age	Not recorded			63.039	0.001>			
	>18	0.493	0.367	1.805	0.179	1.638	0.797	3.364
	24-18	0.326	0.234	1.943	0.163	1.386	0.876	2.192

	29-25	0.718	0.231	9.69	0.002	2.051	1.305	3.224
	39-30	0.142	0.257	0.305	0.581	1.153	0.696	1.19
	49-40	0.391	0.355	1.359	0.244	1.478	0.766	2.852
	59-50	1.388	0.291	22.728	0	4.008	2.265	7.092
	>60	1.948	0.315	38.216	0	7.012	3.782	13.003
Shoulder presence	Have shoulder			527.575	0.001>			
	Not have shoulder	-0.564	0.189	8.909	0.003	0.569	0.393	0.824
	Not recorded	3.881	0.242	256.474	0	48.492	30.156	77.978
Median presence	No	0.492	0.142	11.989	0.001>	1.635	1.238	2.61
Accident location	Road Segment			13.271	0.001			
	Intersection	-0.617	0.188	10.729	0.001	0.54	0.373	0.781
	Roundabout	0.283	0.244	1.339	0.247	1.327	0.822	2.143
Other side	Light vehicle			76.394	0.001>			
	Heavy vehicles	1.186	0.244	23.633	0	3.274	2.03	5.282
	Motorcycle/Bicycle	0.038	0.345	0.012	0.913	1.038	0.528	2.043
	Pedestrian	1.03	0.162	40.638	0	2.8	2.04	3.843
	Without other parties	1.484	0.223	44.183	0	4.412	2.848	6.835
	Others	1.428	0.762	3.515	0.061	4.171	0.937	18.562
Land use	Residential			18.722	0.002			
	Commercial/Official	-0.063	0.173	0.135	0.714	0.939	0.669	1.316
	Educational	-0.183	0.998	0.034	0.854	0.833	0.118	5.884
	Recreational	0.867	0.394	4.848	0.028	2.381	1.1	5.154
	Non-residential	0.641	0.19	11.392	0.001	1.899	1.309	2.756
	Others	-0.161	0.258	0.389	0.533	0.852	0.514	1.411
Constant		-6.262	0.448	195.2	0.002			

Table 3. Characteristics related to the model's good fit

Number of observation	Nagelkerke R Square	P value	df	chi-square	-2 log likelihood
9662	0.393	<0.001	34	1103.656	1997.423

Table 4. The Hosmer-Lemeshow test results

Chi-square	df	P-value
5.105	8	0.746