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Influencing Factors on Severity of Motorcycle Rear End Collisions in Thailand

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Abstract: Motorcycle rear end crashes can be identified as one of the most common crash patterns that have higher severity. Therefore, it is necessary to find out the contributing factors and the factors affecting severity of rear end crashes in order to take safety actions. The descriptive statistical analysis was carried out to find out contributing factors while ordered logistic regression model was used to obtain the factors affecting for the severity level of the crashes. The data was taken from the motorcycle accident investigation which covers Central, North, South and Northeast regions of Thailand from August 2016 to August 2017. The relationships between characteristics and rear-end MC crashes were graphically represented in the results. Moreover, it is found that impact speed, time of crash, gender, type of other vehicle, pre-crash motion of OV and traveled lane are significant factors affecting the severity level of motorcycle rear-end crashes in Thailand.

Keywords: Rear-end crash, Severity level, MC hit rear end of OV, OV hit rear end of MC

1. INTRODUCTION

Thailand is one of the countries that has the high amount of deaths due to road crashes, with the eight highest ranking in the world as reported by WHO in 2018 (WHO, 2018). From this number of total deaths, motorcycle has involved in the highest amount of road crash deaths, with the average of 5500 fatalities per year. Based on the WHO Global Status Report, Thailand is the highest ranking in terms of motorcycle crash deaths in the world (WHO, 2018). Motorcycles play dominant role as one of the most common transportation modes in Thailand because of many reasons. The main reasons are affordability, quickness, lower fuel consumption, and less maintenance. Because of the common use of motorcycle in the country, the number of motorcycle crashes have increased rapidly.

The contributing factors of motorcycle crashes can be divided into three main categories, human, vehicle, and road and environment. There are several crash patterns in common such as rear-end, side-impact, sideswipe, head-on and single vehicle collisions. This paper mainly focuses on one of the most common crash types observed in Thailand which is rear-end crash. This rear-end crash type defines as either motorcycle (MC) hitting the parked vehicle or moving vehicle from its front, or other vehicle (OV) hitting the MC from rear-end. The causes of rear-end crash crashes can be due to unexpected braking of the vehicle in front or due to the fact that the acceleration of the back vehicle is higher than the acceleration of the front vehicle. When rear-end collision occurs, the fault normally goes to the driver/rider at the back vehicle. Unable to maintain the stopping distance with other vehicle, loss of the concentration or following too closely are the reasons always be considered why the rider/driver in back vehicle is at fault.

Previous research stated that 75% of motorcycle crashes in Thailand involved with one passenger car. Among those crashes, the most frequent crash pattern was the rear-end type. (Vira Kasantikul, 2001). In 2018, a research conducted by Kanitpong et al. (2018) found that the rear-end collisions are also the most common type of crashes as observed from the motorcycle crash investigation in Thailand during 2016-2018. The fatality rate from rear-end collisions was also considerably high. Therefore, it is necessary for Thailand to find the contributing factors affecting the severity of the rear-end motorcycle crashes in order to find the countermeasures to reduce or prevent the deaths from motorcycle rear-end crashes. The objective of this paper is to investigate the characteristics of rear-end motorcycle crashes in order to find out the contributing factors affecting the severity of rear-end motorcycle crashes.

2. LITERATURE REVIEW

2.1 Rear End Motorcycle Crashes

Many developing countries have faced the problems of rear-end motorcycle crashes and resulting in high number of deaths each year. A study conducted by Kasantikul (2001) in Bangkok, Thailand found that the occurrence of rear-end crashes have the highest percentage of 14.4. Likewise, Kasantikul (2001) found that the most common crash type in upcountry of Thailand was also rear-end crashes with MC impacting rear-end of OV with proportion of 9.2%. Among those crashes, two thirds of accidents occurred due to MC following too closed to the OV. Another study by Anvari *et al.* (2017) found that the most significant contibuting factors of MC rear-end crashes in Iran were passenger characteristics and rider age. In addition, it was found that there is a higher chance that the rider is at fault in rear-end crashes comparing to head on crashes. Schneider *et al*. (2012) also showed that when accidents occur, in most cases, the MC rider is more likely to be at fault than OV driver. As a countermeasure, Anvari *et al.* (2017) suggested to train MC riders under age of 29 because it was found that this age range has a higher chance of being at fault comparing to MC riders who were older than 29 years of age.

A study by Davoodi *et al.* (2011) was carried out to evaluate the response time of motorcyclists in rear-end collision conditions in Malaysia. According to that research, the rider age and gender were not found to be significant variable for perception reaction time. The average perception reaction time of MC riders was smaller than OV drivers. Therefore, the design of facilities and equipment to allow for better perception time of MC riders is needed.

2.2 Severity of Rear End Motorcycle Crashes

According to study conducted by Naqvi et al. (2017), it was observed that the number of lane results in rear-end motorcycle crashes differently in India. The rear-end motorcycle crashes with the highest number of fatalities were found mostly in more number of lanes such as four-lane and six-lane highways. In addition, the study stated that the number of vehicles and time of crash were observed to have significant effect on motorcycle fatal crashes.

Kasantikul (2001) stated that the most "MC impacting rear-end of OV" fatal crashes happened at night on the curb lane. Among those crashes, the OV was a large abandoned truck without any warning lights, reflectors or flashers to warn other road users.

According to Zulkipli *et al.* (2012), among all crash types, the rear-end crashes had the highest risk percentage for the spinal injury. Although using helmet can minimize head injuries, it does not protect the spinal injury. Zulkipli *et al.* (2012) also mentioned that the risk of having a spinal injury is higher for motorcycle rear end crashes because the entire spinal column was unprotected, unlike that of a car occupant who has seatbelt and seat to protect the spinal code. The study by Hsieh *et al.* (2007) showed that upon rear impact, the spinal column suffered a compression backward bending and torsion pattern, but there were no bone fractures.

3. METHODOLOGY

3.1 Data Collection

In this study, the data were collected from the in-depth motorcycle crash investigation conducted during 2016-2017. When the motorcycle crash occurs, motorcycle and vehicle data, rider and occupant data, injury data and crash scene and environment data were recorded by using a standard crash investigation form. In addition, the data were also collected through the photos of motorcycle, other vehicle, and crash scene, the videos of the traffic behavior in the crash area, the CCTV footages of the crash scene, and the interviews of victims, police and witnesses. The data such as visual obstructions, traffic condition, direction of traffic, characteristics of roadway, pre and post-crash motion etc. were gathered by inspecting the crash scene. Additionally, the interviews of rider, passengers, driver of other vehicle were carried out in order to find out trip information, safety precautions, use of alcohol, riding experience, and etc. The motorcycles were also inspected by the investigators to find the conditions of the components of motorcycle before and after the crash. Besides that, the data such as model of motorcycle, engine capacity, suspension and brake characteristics were collected. All gathered data were combined into motorcycle crash investigation database. In this study, the data were obtained from Central, North, South and Northeast regions covering the whole Thailand. In this study, only rear-end crashes were used in the analysis, and a total of 67 rear- end motorcycle crashes were collected from all over the country during 2016-2017.

3.2 Data Analysis

In this study, the descriptive statistical analysis was carried out to determine the contributing factors for rear-end motorcycle crashes, while the ordered logistic regression model was used to analyze the factors affecting severity level of rear-end collisions.

Descriptive statistics analysis is a summary of the collected data. By using descriptive analysis, it is possible to find the characteristics of rear-end MC crashes such as the most common travelled lane of MC before the rear-end crashes, types of other vehicles involved in the crashes, injuries or fatalities by body region for MC rider, and the percentage of severity levels of the crashes. By using the results from descriptive analysis, the contributing factors of rear-end

MC crashes can be obtained and used in the regression analysis to determine factors affecting severity of rear-end MC crashes.

To find out the factors affecting severity of rear-end MC collisions, the coefficients values and the p values were calculated using the ordered logistic regression model. The reason to choose this model was due to the behavior of outcome variables (dependent variable). Four-level variable called severity level (1,2,3,4) was used as dependent variable of this analysis. In this study, the outcome variable or the severity level is ordered as minor, moderate, serious, fatal and was put in the selected model. The age of motorcyclist, sex, helmet use, crash speed, and others were considered as independent variables. The model represents how the independent variables influence to the dependent variable.

$$\text{Logit}\ (Y \geq i) = \alpha_i + \beta_{i1} X_1 + \ldots\ldots + \beta_{i\,m} X_m, \quad i = 1,2,3,\ldots..,k$$

In the model, "Y" has taken as dependent variable which is severity level and X_n was taken as independent variables which are time of crash, impact speed, injury specification, helmet use, alcohol use, age, gender, crash type, other vehicle type, pre-crash motion of OV, road condition (dry, wet), road surface (asphalt, concrete), separation of traffic flow, intersection, distance of rider from POI to POR and MC travelled lane before the crash. Table 1 shows the definitions of independent variables used in the model.

Table 1. Definitions of Variables

Variable			Definition
Dependent	Severity		1 = minor injury
			2 = moderate injury
			3 = serious injury
			4 = fatal injury
Independent	Time of crash	TOC	1 = accident occurred at night 0, otherwise
	Impact Speed	SP40	1 = speed was below 40 km/h 0, otherwise
		SP40to80	1 = speed was between 40 and 80 km/h 0, otherwise
		SP80	1 = speed was above 80 km/h 0, otherwise
	Injury Specification	ISHeadFace	1 = Injured area was head 0, otherwise
		ISUpper	1 = Injured area was Upper extremities 0, otherwise
		ISLower	1 = Injured area was Lower extremities 0, otherwise
	Helmet Use	Helmet	1 = helmet used 0, otherwise
	Alcohol Use	Alcohol	1 = alcohol used 0, otherwise

	Age	Teen	1 = Rider’s age is between 15 to 19 0, otherwise
		Young	1 = Rider’s age is between 20 to 25 0, otherwise
		Adult	1 = Rider’s age is above 25 0, otherwise
	Gender	Gender	1 = male drivers 0, otherwise
	Crash type	MChitrearendofOV	1 = MC hit the rear end of OV 0, otherwise
	Other vehicle type	OVPC	1 = other vehicle was a passenger car 0, otherwise
		OVPickup	1 = Other vehicle was a pickup 0, otherwise
		OVTruck	1 = Other vehicle was a truck 0, otherwise
		OVMC	1 = Other vehicle was a motorcycle 0, otherwise
	Pre-crash motion of OV	ParkedOV	1 = MC was crashed into a parked vehicle 0, otherwise
	Road condition	Roadconditiondry	1 = Road condition is dry 0, otherwise
Independent	Road surface	RoadsurfaceAsphalt	1 = Road surface is Asphalt 0, otherwise
	Separation of traffic flow	Separationoftrafficflows	1 = The road was divided using frontage road or median 0, otherwise
	Intersection	Intersectionyes	1 = Accident occurred in an intersection 0, otherwise
	Distance of rider from POI to POR	DR0to2	1 = Rider’s POR was less than 2m from POI 0, otherwise
		DR2.1to5	1 = Rider’s POR was between 2.1m to 5m from POI 0, otherwise
		DRmorethan 5	1 = Rider’s POR was higher than 5m from POI 0, otherwise
	Lane travelled	Shoulder	1 = MC was travelling in the left shoulder 0, otherwise

The data analysis using ordered logit model was divided into two data sets to find out which variables affecting the severity level in each situation. The first data set included the crash cases that were occurred due to MC hitting to rear-end of OV and OV hitting to rear-end of MC

(67 cases). The second data set only included crashes that were occurred due to MC hitting to rear-end of OV (52 cases).

The correlations between each independent variable were checked. For this analysis, the moderate co-linearity probability was taken into account. If the coefficients value between two variables were more than 0.70, then those two variables was taken as the correlated independent variables. In that case, one variable was taken out from the model due to co-linearity. After removing correlated independent variables, the other independent variables were used to proceed with the model. Afterward, the model was run, the coefficients values and p values were taken as the results. The factors affecting the severity level of rear-end MC crashes can be explained by p-values and coefficient values of each variable in the model.

4. RESULTS AND ANALYSIS

4.1 Descriptive Statistical Analysis of Motorcycle Rear-End Crashes

From the collected data, the MC hit to rear-end of OV is about 77.61% of all rear-end MC crashes, and the rest of 22.39% is the OV hit to rear-end of MC. When considering all rear-end crashes, 52% of crashes were only minor crashes, while fatal crashes show about 28% in total of crashes. Moderate and serious injured crashes were 14% and 6%, respectively (Figure 1).

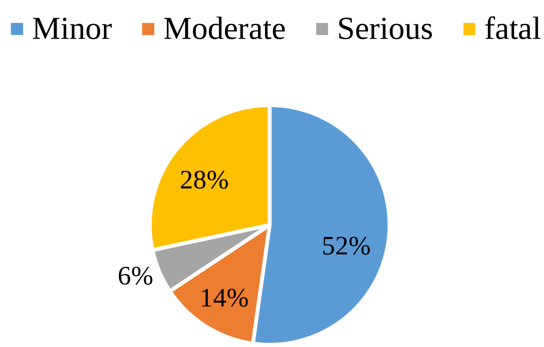

Figure 1. Severity Level for All Crashes

According to Figure 2, the crashes that were occurred because of OV hitting to rear-end of MC is more likely to have minor severity level comparing to other. If crashes occurred due to MC hitting to rear-end of OV, fatal crashes were higher than those occurred due to OV hitting to rear-end of MC. Therefore, from the data, it is more likely that the severity is higher especially in the cases of MC hitting to rear-end of OV. Moderate and serious injured severities do not have significant difference when comparing between two crash patterns.

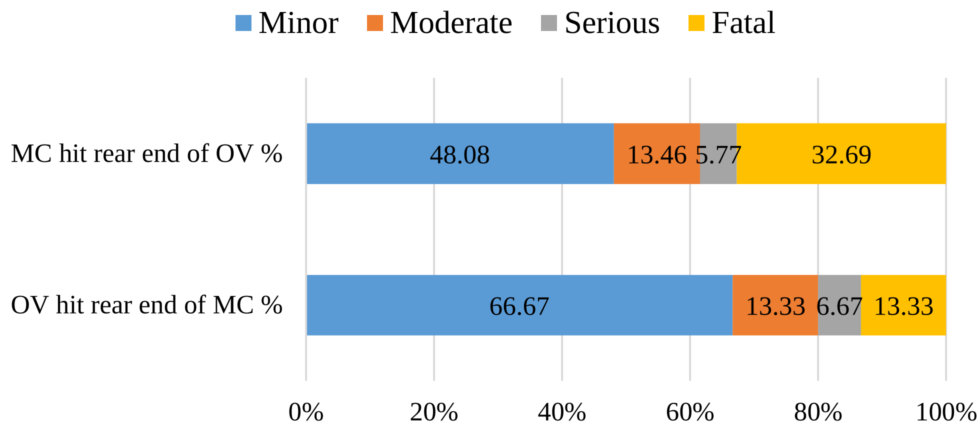

Figure 2. Crash Severity Classified by Crash Patterns

When considering the types of OV involved in the rear-end crashes, Figure 3 shows the comparison of OV types involved in two patterns of crashes. Passenger cars show the highest proportion in both crash patterns. However, it shows higher proportion for the crashes occurred due to OV hitting to rear-end of MC (60%). The involvement of the pickup was higher in cases of MC hitting to rear-end of OV (30.77%) comparing to those of OV hitting to rear-end of MC (20%). It is interesting to see that the truck involvement was much higher (28.85%) when MC hit to the rear-end of OV comparing to when OV hit to the rear-end of MC.

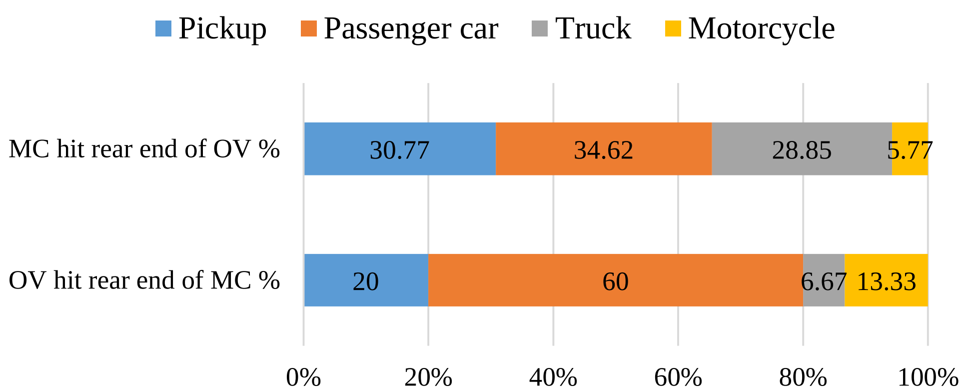

Figure 3. Types of OV involved in Rear-End Crashes

Figure 4 shows the impact speed variations for all crashes and fatal crashes. The impact speeds were divided into six ranges. Among all crashes, most of the crashes were occurred between 20 km/h to 40 km/h impact speed range. When considering the fatal crashes, most percentage of deaths were occurred between the impact speed range of 60 km/h to 80 km/h. No fatal crash was observed at the impact speed lower than 20 km/h. When the impact speed was above 60 km/h, fatal crashes were likely to be occurred.

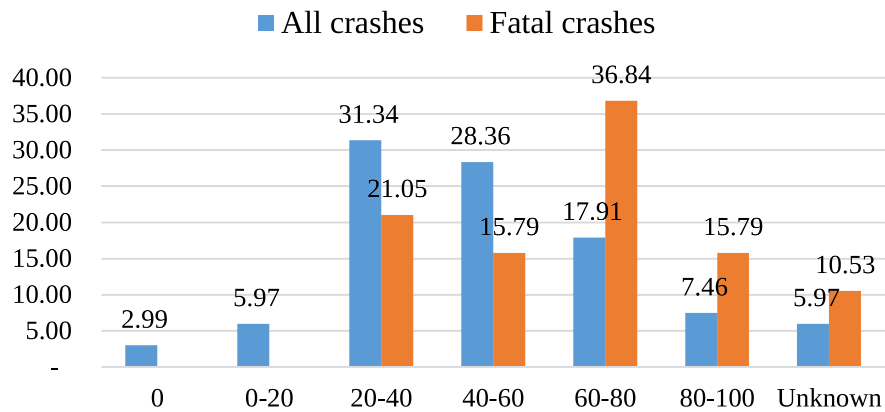

Figure 4. Impact Speed (km/h) of MC crashes

Figure 5 shows the impact speed ranges of the motorcycles of all crashes according to the travelled lanes. According to this figure, the zero impact speed can be recognized only in lane 1, which is the most right lane next to the median. Those crashes were occurred while MC was trying to take a right turn. In that situation, MC was stopped on the right side of the lane while waiting for the clearance of the opposite side direction of traffic, then OV was collided into the rear end of the stopped MC in the right lane.

The speed range of 0-20 km/h can be recognized only in lane 1 and 2 due to the same reason which was explained previously. The crashes which were between 20-40 km/h were occurred in almost every lane. Among them, most of rear-end crashes were in lane 2. The collisions which had impact speed limit of 40-60 km/h, were happened in all kind of lanes including left shoulder lane. Among the impact speed of 40 km/h to 60 km/h, most percentage of crashes were occurred in lane 3 or over lane 3. The crashes which had impact speed more than 60 km/h were occurred in lane 1, lane 2 and left shoulder. Among the impact speed of above 60 km/h, the highest percentage of collisions were took part in the left shoulder.

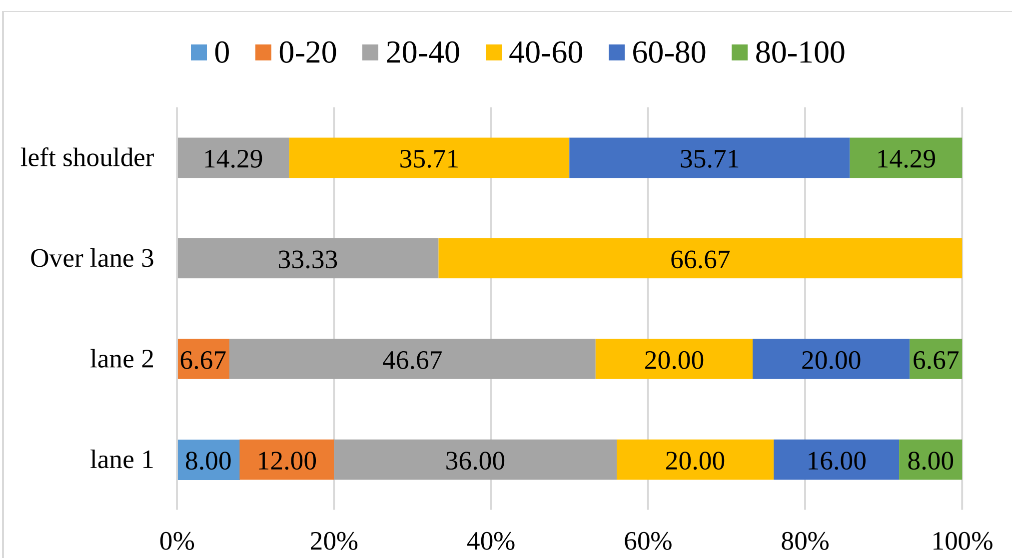

Figure 5. Impact Speeds (km/h) According to the Travelled Lanes

Figure 6 shows the travelled lanes of MC classified by two crash patterns. Most of the crashes occurred in lane 1 and lane 2 were due to OV hitting to rear-end of MC. The crashes that were occurred in lane 3, lane 4, lane 5, and left shoulder are mostly the crashes of MC hitting to rear-end of OV. It can be concluded from this figure that for the high-speed moving lane, it is more likely that OV will hit to the rear-end of MC, while for the slow-speed moving lane, MC is more likely to hit the rear-end of OV.

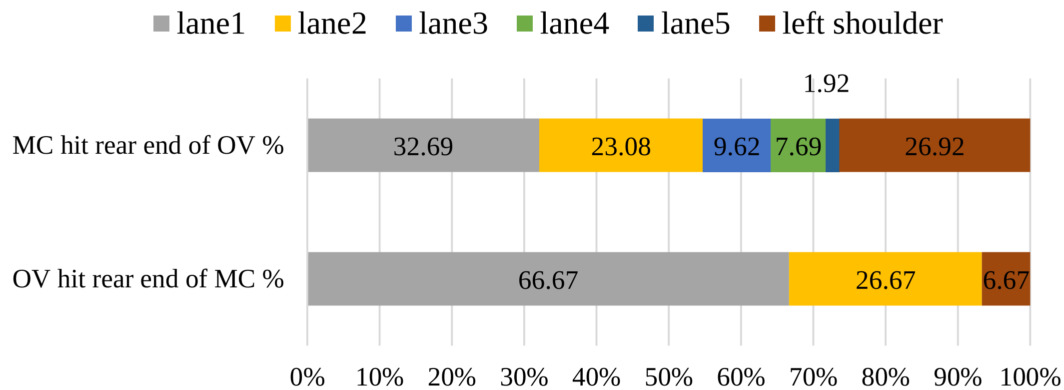

Figure 6. Travelled Lane Classified by Crash Patterns

When considering nonfatal crashes, most of them were occurred in day time, while fatal crashes were occurred at night time at a higher proportion as shown in Figure 7.

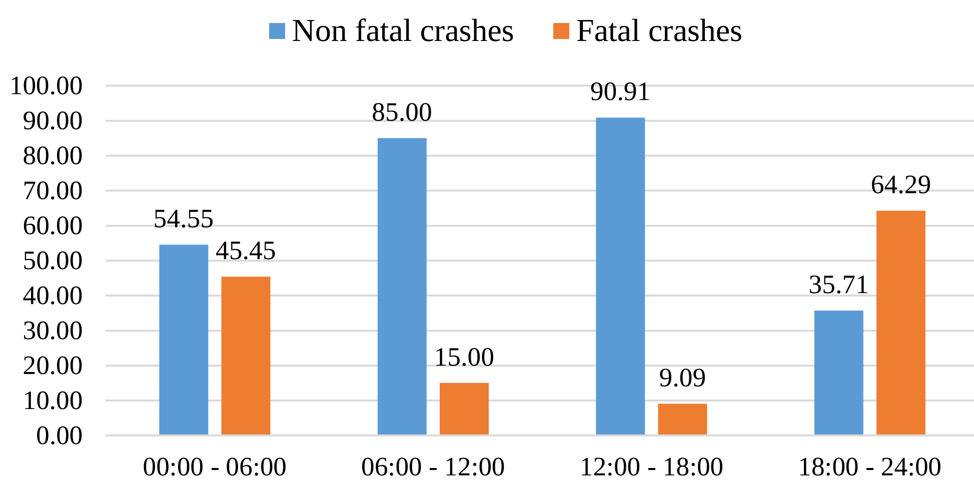

Figure 7. Times for All Patterns of Rear End Crashes

According to Figure 8, the rear-end crashes which occurred under dark-no street light were mostly fatal crashes. The moderate and serious collisions have proportion of 21.43% and 7.14% respectively under dark-street lights. Most of the crashes occurred in day light caused minor injuries having percentage of 66.67. The lowest percentage of fatal crashes can be recognized under the day light condition.

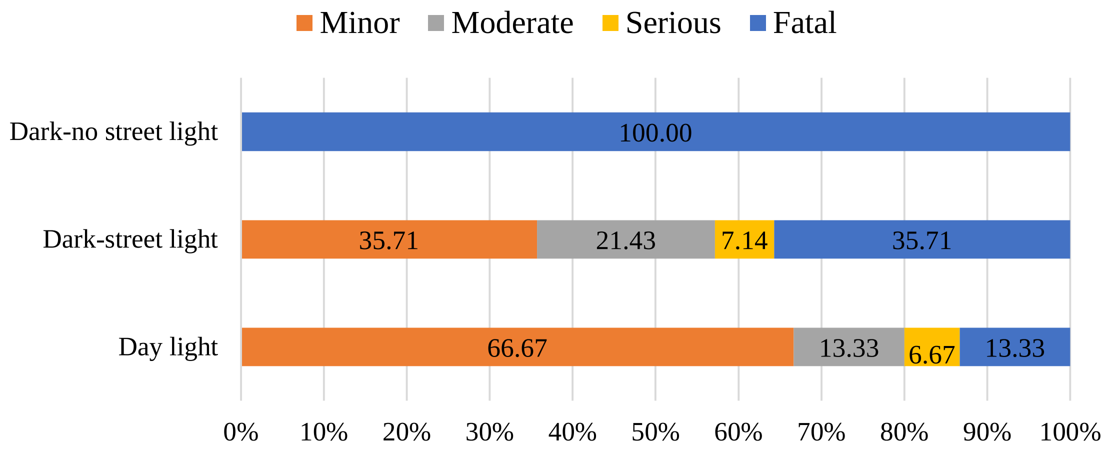

Figure 8. Different Severity Levels According to Light Condition

The chance of causing a fatal crash, when the impact speed is increasing can be considered as risk of death. The risk of death can be calculated from the total number of deaths in each case divided by the total number of occupants, and reported in percentage as shown in the following equation.

$$\text{Risk of death} = \frac{\text{Number of deaths}}{\text{Total occupants}} \times 100\%$$

Table 2 shows the calculation of the risk of death.

Table 2. Calculation of Risk of Death

Impact speed range	**Total cases**	**Total occupants**	**Number of deaths**	**Risk of death %**
0	2	2	0	0.0
0-20	4	5	0	0.0
20-40	21	29	4	13.8
40-60	19	26	3	11.5
60-80	12	17	8	47.1
80-100	5	5	3	60.0

Figure 9 represents the variation of risk of death vs impact speed. According to the graph as the impact speed increases, the risk of death also increases. Above 60 km/h, the risk of death is increasing rapidly. When the impact speed is between 60 km/h to 80 km/h, the risk of death is about 47.1%. If the impact speed is higher than 80 km/h, there is a higher chance of death with a risk of death of 60%.

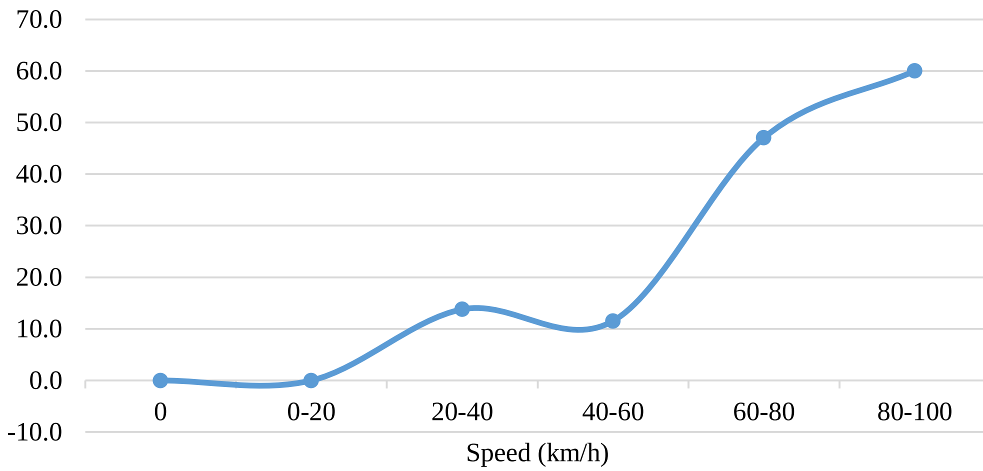

Figure 9. Risk of Death

Figure 10 shows the percentage values of injuries to each body region. Lower extremities is the most damaged body region with proportion of 40.58%, followed by the upper extremities with the percentage of 27.54.

However, in fatal crashes, (Figure 11), the highest percentage of damages were head injuries with a proportion of 72.73%, followed by thorax with a proportion of 18.18%. As a conclusion, there is a high chance of death when rider's head or thorax got injured.

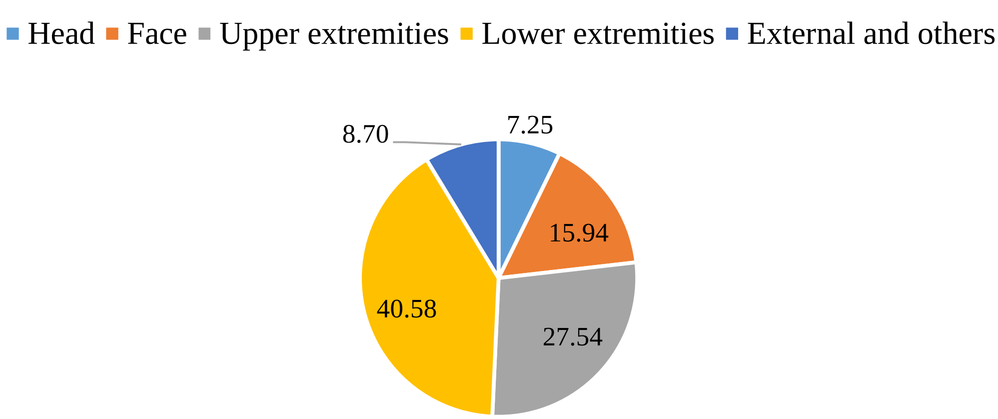

Figure 10. Injuries by Body Region

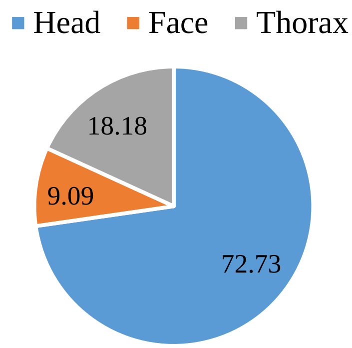

Figure 11. Fatalities by Body Region

4.2 Factors Influencing Rear-End Motorcycle Crash Severity Level

As mentioned in the methodology section, two data sets were analyzed in this study. The first data set included the crash cases that were occurred due to MC hitting to rear-end of OV and OV hitting to rear-end of MC, and the second data set only included crashes that were occurred due to MC hitting to rear-end of OV. With these two data sets, four scenarios were analyzed by using the ordered logistic regression models. Scenario 1 and 2 used the first data set, and scenario 3 and 4 used the second data set. In scenario 1 and 3, some independent variables were considered as discrete variables, while in scenario 2 and 4, the same independent variables were considered as continuous variables. These variables include age, impact speed, and distance from POI to POR. Table 3 to 6 show the results of the analysis from the ordered logit regression model

Table 3. Analysis Results of Scenario 1

Independent variables		**Model 1**		**Model 2**	
		Coef.	**P-value**	**Coef.**	**P-value**
Time	TOC	1.788	*	1.910	***
Impact Speed	SP40				
	SP40to80	1.417		0.146	
	SP80	4.905	***	3.267	***
Injury Specification	ISHeadFace	1.481			
	Upper	-0.669			
	Lower				
Helmet Use	Helmet	0.069			
Alcohol Use	Alcohol	-1.434			
Age	Teen	1.062			
	Young	0.083			
	Adult				
Gender	Gender	2.023	**	0.844	
Crash type	MChitrearendofOV	-			

		0.414			
Other vehicle type	OVPC	1.376		-0.147	
	OVPickup	4.047	**	1.279	
	OVTruck	3.448	*	0.838	
	OVMC				
Pre-crash motion of OV	ParkedOV	2.999	***	1.612	**
Road condition	Roadconditiondry	-0.877			
Road surface	RoadsurfaceAsphalt	1.970			
Separation of traffic flow	Separationoftrafficflows	0.568			
Intersection	Intersectionyes	2.106			
Distance of rider from POI to POR	DR0to2				
	DR2.1to5				
	DRmorethan5	1.525			
Lane travelled	Shoulder	1.566	*	1.297	
Summary of Statistics:					
Number of Observations		67		67	
LR chi2		68.24		52.16	
Prob > chi2		0		0	
Pseudo R2		0.4489		0.3431	
Log likelihood		-41.893		-49.933	

***significant at 99% Significant Level, ** significant at 95% Significant Level, * significant at 90% Significant Level

Table 4. Analysis Results of Scenario 2

Independent variables		**Model 1**		**Model 2**	
		Coef.	**P-value**	**Coef.**	**P-value**
Time	TOC	1.271			
Impact Speed	Speed	0.053	*	0.057	***
Injury Specification	ISHeadFace	1.143		0.751	
	Upper	-2.770	**	-2.745	***
	Lower				
Helmet Use	Helmet	-0.204			
Alcohol Use	Alcohol	-1.829			
Age of rider	Age	-0.058			
Gender	Gender	2.701	**	1.630	**
Crash type	MChitrearendofOV	-0.273			
Other vehicle type	OVPC	2.527		1.475	
	OVPickup	4.282	**	3.145	*
	OVTruck	5.550	**	4.462	**
	OVMC				

Pre-crash motion of OV	ParkedOV	3.877	***	3.347	***
Road condition	Roadconditiondry	-0.460			
Road surface	RoadsurfaceAsphalt	2.917	**	2.976	***
Separation of traffic flow	Separationoftrafficflows	-0.305			
Intersection	Intersectionyes	2.242			
Distance of rider from POI to POR	POItoPOR	0.167	***	0.156	***
Lane travelled	Shoulder	1.286			
Summary of Statistics: Number of Observations LR chi2 Prob > chi2 Pseudo R2 Log likelihood		 63 61.13 0 0.4236 -41.5849		 63 51.95 0 0.3600 -46.1742	

***significant at 99% Significant Level, ** significant at 95% Significant Level, * significant at 90% Significant Level

Table 5. Analysis Results of Scenario 3

Independent variables		Model 1		Model 2	
		Coef.	P-value	Coef.	P-value
Time	TOC	2.476	*	1.215	
Impact Speed	SP40 SP40to80 SP80	 3.092 9.333	 * ***	 1.446 4.535	 **
Injury Specification	ISHeadFace Upper Lower	4.227 -0.635	***	2.072 -0.957	**
Helmet Use	Helmet	0.931			
Alcohol Use	Alcohol	-1.909			
Age	Teen Young Adult	1.441 -1.923			
Gender	Gender	3.152	*	1.423	
Other vehicle type	OVPC OVPickup OVTruck OVMC	2.585 8.030 7.780	 ** **	0.908 3.278 3.798	 *
Pre-crash motion of OV	ParkedOV	3.798	**	2.058	**
Road condition	Roadconditiondry	1.189			
Road surface	RoadsurfaceAsphalt	5.829	***	3.212	**

Separation of traffic flow	Separationoftrafficflows	2.888			
Intersection	Intersectionyes	-2.848			
Distance of rider from POI to POR	DR0to2				
	DR2.1to5				
	DRmorethan5	1.502			
Lane travelled	Shoulder	3.269	**	1.997	**
Summary of Statistics:					
Number of Observations		52		52	
LR chi2		64.87		52.95	
Prob > chi2		0		0	
Pseudo R2		0.5414		0.4419	
Log likelihood		-27.4757		-33.4348	

***significant at 99% Significant Level, ** significant at 95% Significant Level, * significant at 90% Significant Level

Table 6. Analysis Results of Scenario 4

Independent variables		**Model 1**		**Model 2**	
		Coef.	**P-value**	**Coef.**	**P-value**
Time	TOC	1.272			
Impact Speed	Speed	0.061			
Injury Specification	ISHeadFace	1.734			
	Upper	-2.136			
	Lower				
Helmet Use	Helmet	-0.150			
Alcohol Use	Alcohol	-1.530			
Age of rider	Age	-0.036			
Gender	Gender	1.646			
Other vehicle type	OVPC	2.255		0.631	
	OVPickup	4.812	*	1.262	
	OVTruck	5.970	**	2.208	
	OVMC				
Pre-crash motion of OV	ParkedOV	2.849	**	1.424	**
Road condition	Roadconditiondry	-0.301			
Road surface	RoadsurfaceAsphalt	3.414	**	1.287	
Separation of traffic flow	Separationoftrafficflows	0.769			
Intersection	Intersectionyes	0.920			

Distance of rider from POI to POR	POItoPOR	0.153			
Lane travelled	Shoulder	2.075	*	1.675	**
Summary of Statistics:					
Number of Observations		49		49	
LR chi2		47.62		18.04	
Prob > chi2		0.0002		0.0061	
Pseudo R2		0.4155		0.1574	
Log likelihood		-33.4923		-48.2821	

***significant at 99% Significant Level, ** significant at 95% Significant Level, * significant at 90% Significant Level

The analysis was carried out for two models as shown in above tables (

Table 3 to 6). All independent variables were included in model 1. Then variables which were significant in model 1 were re-analyzed in model 2. According to the scenario 1 (

Table 3), the impact speed of MC which is the speed above 80 km/h is statistically significant at 95% significance level. When comparing to the impact speed below 40 km/h, the impact speed higher than 80 km/h tends to result in higher severity level for MC rear-end crashes. The impact speed is also significant in scenario 2 as well (

Table 4). When impact speed increases, severity level of rear end crashes also increases. Gender is another factor that significantly influences the severity level of rear-end crashes for both scenario 1and 2 (

Table 3 and

Table 4). Male is more likely to have higher severity than female. Types of OV involved in the crashes and pre-crash motion of other vehicle show significant effect to the severity level for scenario 1 and 2.

According to scenario 3 and 4, types of OV was significant to the severity level of MC hitting to rear-end of OV. When other vehicle was truck, the severity level of that case is more likely to be at higher level comparing to other types of vehicle. Pickups also have some sort of significance to severity level (

Table 5 and ***significant at 99% Significant Level, ** significant at 95% Significant Level, * significant at 90% Significant Level

Table 6). When MC hitting to rear-end of parked vehicle, severity is more likely to be rather than when other vehicle is in motion. In addition, the chance of being at higher severity level is higher when MC travelled in shoulder lane.

5. CONCLUSION AND RECOMMENDATIONS

The objective of this study is to investigate the characteristics of rear-end motorcycle crashes in order to find out the contributing factors affecting the severity of rear-end motorcycle crashes. The descriptive statistical analysis was carried out to determine the contributing factors for rear-end motorcycle crashes, and the ordered logistic regression model was used to analyze the factors affecting severity level of rear-end collisions.

In the descriptive statistic analysis of this study, it was found that “MC hitting to rear-end of OV” has higher percentage than the crash pattern of “OV hitting rear-end of MC”. In most crashes, the riders were observed to be at fault. Moreover, more fatality rate was observed in the crash pattern of “MC hitting to rear-end of OV”. This could be due to the direct impact of rider with other vehicles. In the cases of MC hitting to rear-end of OV, trucks and pickups seem to have higher percentage of involvement. Most of the crashes were occurred in range of 20 km/h to 40 km/h impact speed. Most of the fatal crashes were occurred at the impact speed between 60 km/h to 80 km/h, and most of them were occurred on the left shoulder.

Based on the results from ordered logistic regression models, from all crashes observed, impact speed, gender, types of OV involved, and pre-crash motion of OV can be identified as influencing factors to severity level of rear-end crashes. As the impact speed increases, the impact force on rider will be higher, and thus, resulting to higher severity level to the riders and occupants. Sometimes riders were observed to be separated from MC due to high impact speed, and this might contribute to the higher severity level of crash.

Male riders were observed to have higher severity than female riders. When trucks and pickups were involved in rear-end crashes, the severity is more likely to be higher. Trucks can be even more dangerous especially at night time due to poor light condition in rear of the vehicle. Poor visibility of the trucks can cause rear-end crashes. The results show that when OV was parked in the shoulder lane, there was a high chance of rear-end crashes, and the severity of crashes was much higher. When considering only the crash pattern of MC hitting to rear-end of OV, travelled lane seems to be significant effect on the severity level of the crashes. Most fatal crashes were observed in the left shoulder. As in Thailand, left shoulder is always used for parking purposes; therefore, MC which is a slow-moving vehicle on highways always travel on the left shoulder and has greater chance to crash into the rear-end of parked vehicles resulting higher severity to the motorcyclist.

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