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Analysis of Factors Affecting Motorcyclists' Crash Severity in Mandalay City

Nandar Wady Aung[a], Kyaing[b], Nandar Tun[c]

[a,b,c] Department of Civil Engineering, Yangon Technological University, Yangon, 11011, Myanmar
[a]E-mail: nandarwadyaung@gmail.com
[b]E-mail: kyaingkyaing63@gmail.com
[c]E-mail: michiko.ndt@gmail.com

Abstract: As the number of motorcycle users is increasing, the severities of motorcyclists are increasing as well in Mandalay city. Therefore, the aim of the research is to understand the factors affecting the crash severity of motorcyclists in Mandalay City and propose countermeasure against reducing the motorcyclists' casualty rates. To find that, the Ordered Probit Model is fitted with the four year data from 2011 to 2015. The data used in the research is obtained from Myanmar Police Force and Road Transport Administration Department. The results show that the rider, older motorcyclists, riders riding not wearing helmet, Head on collision type, colliding with fell alone and fixed object, accident happening in urban are higher injury severity than their reference cases in Mandalay. Moreover, the preventive measurement of plans for government organizations, non-government organizations, and traffic engineers are proposed to improve the road safety in Mandalay city.

Keywords: Severity, Motorcyclists, Ordered Probit, Mandalay

1. INTRODUCTION

The economic growth in Myanmar caused an expending network of roads and an increasing number of vehicles including motorcycles. Since Myanmar is one of the developing countries in the world, motorcycle use in Myanmar as a primary mode of transport has continually increased. And another reason is that the authorities relaxed its policy in 2011, re-granting licenses to previous illegally-imported vehicles through border points evading taxation after required taxes are levied. Therefore, the number of motorcycle in Myanmar has increased on the road. The combination of a dramatic increase in the number of vehicles and more drivers with minimal experience was bound to lead to increased danger on the roads. Recent road safety statistics are alarming in Myanmar because the numbers of road accidents are more than year by year.

Among the cities in Myanmar, motorcycle is the most popular mode of travel and most of road injuries were motorcyclists in Mandalay city. The number of motorcycle registered in Mandalay city has increased from 309872 in 2011 to 821137 in 2015. As a result, the injuries and fatalities of motorcycle riders and passengers are increasing and this becomes a major problem. Motorcyclists are one of the most vulnerable road users which need immediate attention to improve its safety. It is important to prevent motorcycle fatalities and injuries in Mandalay city because motorcyclist casualty rates are three times higher than other road users.

To reduce the motorcycle crashes and the consequent injuries, there is a need for better understanding motorcycles crashes and identify characteristics of problem areas so that motorcycle safety can be improved. Accordingly, this study proposes to investigate characteristics of motorcycle crashes in Mandalay city as there is no research concerning with motorcycle accidents in Myanmar.

2. LITERATURE REVIEW

2.1 Motorcyclists' Characteristics

From various researches indicated that gender is a closed relationship with crash severity when a crash happens. Sitthiprapha, (2011) found that male motorcycle rider has higher severity in motorcycle accident. It is found that the percentage of male motorcyclists is approximately four times higher than female motorcyclists in all type of injury severity (Ath, 2014).

The other factor that has been associated with motorcycle fatalities is helmet use. Head injuries are the principal of death in motorcycle crashes and using helmets are primary measure for reducing crash-related head injuries (Glassbrenner, 2006). Moreover, analysis of factors affecting the severity of motorcycle casualties in Cambodia indicated that there is the slight decrease of percentage of victim wearing helmet from severe injury to fatal injury about one percent only (Ath, 2014).

Age is another factor that has been associated with high motorcycle fatalities. Drivers who are greater than 60 ages appear to have the highest injury severity levels (Sitthiprapha, 2011). Also, Quddus et al. (2002) point out that the group of motorcycle riders who age >60 years old are higher risk in the severity level of motorcycle crash than others.

According to NHTSH (2008a), several factors have been associated with high motorcycle fatalities and alcohol is one of them. Motorcyclists who use alcohol will certainly increase the chance of a fatality or injury (Zhu, 2014).

Speeding is another factor related to motorcycle safety. Crash that occur on highway or freeways with higher speed limits are more likely to result in injuries and fatalities (Zhu, 2014). Eustace et al. (2011) found that the chance of severe injuries is double that of minor injuries if speeding is involved.

2.2 Environmental Characteristics

A motorcyclist being killed in a crash during the nighttime is significantly higher than during the day (Indupuru, 2010). It is not surprising as it is likely that speed and alcohol use are greater during the nighttime (Quddus et al., 2002). Also, Ath (2014) found that 61.9% of motorcyclists had accidents during at night that is over 1.5 times higher than the occurrence in daytime.

2.3 Collision Type Characteristics

Indupuru (2010) found that 51.4% of motorcycle fatality resulted from single vehicle crashes and 48.6% of the motorcycle fatality involved multi-vehicle crashes. In the same study, more than half, 52.6% of fatalities were due to motorcycles that ran off the road, 13.5% due to overturning, 13.1% due to crossing median, 6.6% due to colliding with animals and other contributed to about 7.7% of the fatalities in single vehicle crashes.

2.4 Roadway Characteristics

According to study of Ath, (2014) about an analysis of factors affecting the severity of motorcycle casualties in Cambodia, the higher grade of severity injury of motorcyclists may not be related to the intersection of geometry of road. Sitthiprapha, (2011) pointed out that the motorcycle accidents occurring on six land road have high rate of death injury.

2.5 Motorcycle Characteristics and Opponent Involved

Quddus et al. (2002) found that the higher the motorcycle's engine, the higher the severity level. Injury severity is greatest when colliding with the heavy truck Ath, (2014). But Quddus et al. (2002) pointed out that colliding with a stationary object has the greatest increase in the probability of fatality.

2.6 Statistical Methodology of Crash Severity Model

It is important to think crash severity model for the ordinal outcomes of injury data; such as, ranging from no injury, to possible injury, to non-incapacitating, to incapacitating injury, to fatal. Some researchers may interest Multinomial logit model (MNL) but if they used it in finding the factors affecting crash severity, it may result in loss of efficiency not for accounting the ordinal data. To solve the problem of ordinal discrete data, the traditional ordered probability models are widely used in modeling of crash injury such as ordered logit model ((Abdelwahab and Abdel-Aty, 2001; Khattak and Rocha, 2003; Jung et al., 2010; Jin et al., 2010) and ordered probit model (Renski et al., 1999; Khattak, 2001; Kockelman and Kweon, 2002; Khattak et al., 2002; Abdel-Aty and Abdelwahab, 2004; Abdel-Aty and Keller, 2005; Garder, 2006; Gray et al., 2008; Wang et al., 2009; Zhu and Srinivasan, 2011).

3. METHODOLOGY

3.1 Study Area

Mandalay City is the main commercial center of upper Myanmar. It is found in the upper part of the country, located on the east bank of the Irrawaddy River. The estimated population of this city was 1,225,553 (2014 census). There are Seven townships in Mandalay City; Aungmyaythazan, Chanmyathazi, Chanayethazan, Maha Aungmyay, Amayapuya, Patheingyi and Pyigyidagon. Mandalay city is the most prevalent regions for motorcycle usage. The streets of this city are usually full of motorcycles especially during peak hours.

The figure 3.1 shows the total number of motorcycle crashes in each township. Overall, it can be seen that motorcycle accident happened in A Ma Ra Pu Ra township was higher than the other six townships. Following by A Ma Ra Pu Ra township, Chan Mya Thar Zi had the number of 315 motorcycle accidents. Aung Myay Thar Zan township is the lowest number of accidents. There is no significant difference between Chan Aye Thar Zan, Ma Har Aung Myay, Pa Thein Gyi and Pyi Gyee Ta Gon.

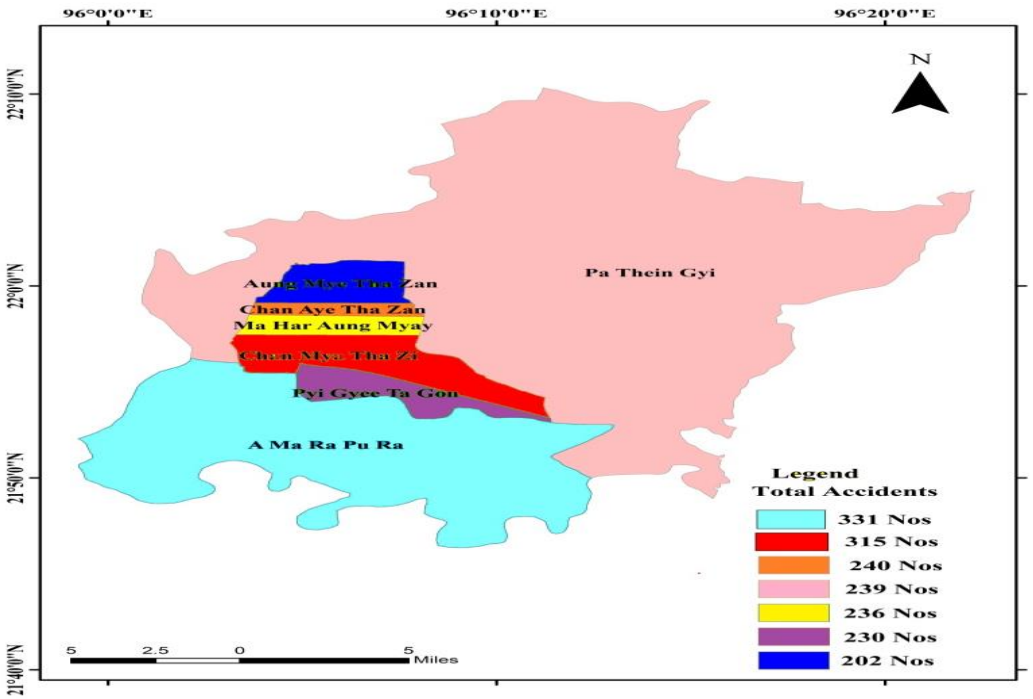

Figure 1 Number of Motorcycle Accident in Seven Townships of Mandalay City (2012-2015)

3.2 Information of the Data

The focus of this research is to investigate the injury severity of motorcyclists. The data included for years (2012-2015) of traffic crash records is provided by Mandalay Police Force. There were 1770 useable records in the database which contained a variety of information including conditions of weather, roadway, driver and vehicle as well as crash severities reported at the time of the accidents. The injury severity is classified into three categories: slight injury, severe injury and fatal. There are 34 independent variables used to explain the injury severity of motorcyclists.

3.3 Coefficients' Estimation Fitted by Ordered Probit Model

The ordered probit model is usually motivated in a latent (i.e., unobserved) variables framework. The general specification is

$$y_i^* = X_i \beta + \epsilon_i \quad (1)$$

Where;

y_i^* = a latent variable measuring the injury severity of i^{th} accident

X_i = independent variables

β = vector of unknown parameters

ϵ_i =random error term following standard normal distribution.

In any given accident it is reasonable to expect that a high risk of injury to the motorcycle, y_i^* will be translated into a high level of observed injury, y_i. Therefore, the observed and coded discrete injury severity variable, y_i is determined from the model as follows

$$y_i = \begin{cases} 1 \text{ if } -\infty \le y_i^* \le \mu_1 & \text{(Slight injury)} \\ 2 \text{ if } \mu_1 < y_i^* \le \mu_2 & \text{(Severe injury)} \\ 3 \text{ if } \mu_2 < y_i^* \le \infty & \text{(Fatal)} \end{cases} \quad (2)$$

Where;

The μ_1 and μ_2 represent threshold to be estimated (along with the parameter vector β). The predicted probability of the type of injury severity, m, for given X_i is

$$\Pr(y = m \mid X_i) = F(\mu_m - X_i\beta) - F(\mu_{m-1} - X_i\beta) \quad (3)$$

Calculation of these probabilities allows a better understanding of the relative effectives of the independent variables. Thanks to the increasing nature of the ordered classes, the interpretation of this model's primary parameter set, β, is as follows; positive signs indicate higher motorcyclist injury severity as the value of the associated variables increase, while negative sighs suggest the converse. These interactions must be compared to the ranges between the various thresholds, μ_i, in order to determine the most likely injury classification for motorcyclists.

3.3.1 Dependent Variables (Predicted Variables)

The motorcyclists' crash severity level plays as the dependent variable to identify the contributing factors in crash severity prediction model. According to dataset, the discrete outcomes of the crash dataset taking into account in the model and used in this study are divided into three levels.

- Slight injury : Law No. 337
- Severe injury : Law No. 338
- Fatality : Law No. 304

3.3.2 Independent Variables (Predictor Variables)

The collected data from annual crash database can be divided into six main groups of independent variables such as driver related, collision type related, roadway related, environmental related, opponent related and location related. These six categories are considered as the significant input variables for the independent variables.

Since the impacts of the human factors to the crash are the fundamental elements, they should be involved more in the analysis. Although driver distraction, changing lane or direction without care and whether one of the vehicles was following too close behind another vehicle were considered as independent variables for human factors, unfortunately those three variables are not available in the dataset. Finally, the final input variables for the human factors are gender, users' age and helmet use, rider, overtaking, against traffic flow, drunk driving, and speeding. In this research, age variable is classified at 15 intervals. The sample of age under 15 is too little but this age interval targets the high school students. The high school students are restricted the driving of motorcycles. Therefore, this age interval may be the interesting group for investigating.

Environmental effects also play the important part for crash severity of motorcyclists. In this research, some factors are considered such as weekend, time trend of accident,day type of accident and weather condition.

Roadway condition and characteristics is the supplementary factors to provoke the crash severity even higher grade. The elements included in the roadway factor are road surface, curve, roundabout, straight, T-junction, and X-junction.

Furthermore, one of the primary factors for influence to crash severity is crash pattern. The independent attributes for crash pattern are head-on, right angle, rear end, and side swipe and other collision types .

The impact of human factor to the crash severity is main interest, but we also want to think the influence of the opponents involved since they also contribute to crash severity. The opponent involved such as bicycle, car, fell alone, motorcycle, pedestrian, fixed object and tractor are included as the independent variables.

Moreover, the accident happening in urban or suburban is included as the factor that affect crash severity of motorcyclists.

The table 2 below shows the defination of each variable included in the models.

Table 2 Definition of variables used in the models

Variable	Definition
Gender male	1 if the motorcyclist is male, 0 otherwise
Use helmet	1 if the motorcyclist wear helmet, 0 otherwise
Rider	1 if the motorcyclist is the driver, 0 otherwise
Age <15	1 if the motorcyclist age is <15 years old, 0 otherwise
Age 15_29	1 if the motorcyclist age is between 15 to 29 years old, 0 otherwise
Age 30_44	1 if the motorcyclist age is between 30 to 44 years old, 0 otherwise
Age 45_59	1 if the motorcyclist age is between 45 to 59 years old, 0 otherwise
Age over 60	1 if the motorcyclist age is over 60years old, 0 otherwise
Speeding	1 if the crash involves speeding, 0 otherwise
Overtaking	1 if the crash involves overtaking, 0 otherwise
Drink driving	1 if the crash involves drink driving, 0 otherwise
Against traffic flow	1 if the crash involves against traffic, 0 otherwise
Paved road	1 if the crash happens at paved road, 0 otherwise
Curve	1 if the crash happens at curve, 0 otherwise
Roundabout	1 if the crash happens at roundabout , 0 otherwise
Straight	1 if the crash happens at straight road, 0 otherwise
T junction	1 if the crash happens at T junction, 0 otherwise
X junction	1 if the crash happens at X junction, 0 otherwise
Weekday	1 if the crash occurs at the weekday, 0 otherwise
Night	1 if the crash occurs during night time (6pm to 6am), 0 otherwise

Weather	1 if the crash occurs during rainy, 0 otherwise
Bicycle	1 if the opponent is bicycle, 0 otherwise
Car	1 if the opponent is car, 0 otherwise
Motorcycle	1 if the opponent is motorcycle, 0 otherwise
Fell alone	1 if the crash is single crash, 0 otherwise
Fixed object	1 if the opponent is fixed object, 0 otherwise
Pedestrian	1 if the opponent is pedestrian, 0 otherwise
Tractor	1 if the opponent is trawlargyi, 0 otherwise
Head on	1 if the collision crash is head on , 0 otherwise
Rear end	1 if the collision crash is rear end, 0 otherwise
Right angle	1 if the collision crash is right angle, 0 otherwise
Side swipe	1 if the collision crash is side swipe, 0 otherwise
Other collision	1 if the collision crash is other collision , 0 otherwise
Suburban	1 if the accident occurs in suburban, 0 otherwise

4. RESULTS AND DISCUSSIONS

It is found out that the percentage of male motorcyclists is nearly 4 times as high as the one of female motorcyclists in any type of injury severity in table 3. The percentage of male motorcyclists apparently increases from the lowest severe injury to the highest injury from which it can be pointed out that the male motorcyclists tend to risk the highest severe injury comparing to the female motorcyclists.

The percentage of victims wearing helmet is lower than the one not wearing helmet in severe and fatal injury. Especially in fatal injury type, the victims wearing helmet is around 20% but the victims no wearing helmet is around 80%. This shows that there is a big gap between the victims who wearing and not wearing the helmet. Noticeably, the percentage of victims wearing helmet is 1.5 times greater than not wearing helmet in PDO.

The significant increase of the casualties for all severity types is age over 60 years old. And then, age between 15 to 29 shares the highest proportion in all three types of injury severity than the others. But, investigating this age interval is also interesting and it is found that the severity ranks are decreasing gradually.

The percentage of human fault factors causes the injury severity of motorcyclists by classified into each injury grade pointed out that speeding factor share the highest percentage in all injury severity types while other factors share below 20%. This means that probably these factors are the main contributors to the crash severity if the motorcycle accident occurs.

According to the table 3, the straight road geometry shares the highest proportion in all types of injury severity around 70%. Following by straight road, the percentage of casualties at the X-junction occupied almost 30% while the proportion of other geometry types has fewer than 10%.

The accidents happening on the paved road gives rise to higher proportion of each of the three types of severity than the ones occurring on the unpaved road. The percentage of paved road accident keeps over 90%. This may infers that the paved road offered the good surface for the motorcycle drivers increase their speed which causing to the higher severity of injury than the low speed when the accident happens.

By thought of week type accident happening, the proportion of victims travelling on weekday shared 2.7 times as high as one travelling at the weekend in term of all injury grade except PDO. In spite of the fact that the percentage of weekend shared lower than percentage of weekday, the weekend is still the critical week type since it comprises of just two days while the weekday consists of five days and also there is the slight increase of percentage of the injury severity grade ranging from slight injury (almost 23%) to the fatal injury (almost 30%).

It is remarkable that there is an increase in percentage of victim riding in night time from PDO nearly 35% to the fatality about 60%. In opposite trend, the percentage of victim riding in day time decreased from about 65% in PDO to 40% in fatality. This implies the night motorcyclists will probably be in the higher severity injury contrasting to the day time motorcyclists.

When an accident happens in rainy, the percentage of severity level is increased from 1.54% (PDO) to 10.3% (Fatal).

There were a variety of transportation modes considering as opponents which provoke three sorts of the crash severity of motorcyclists. As per table 3, the car opponents shares the highest proportion in all injury types over 40%; interestingly, the pedestrian opponents drops from around 26% in PDO to 1.2% in fatal injury. This means that, the injury severity level of motorcyclists will be decreased when they crashed with pedestrian.

In case of PDO and slight injury, right angle collision played the most severe collision type almost 48 % and 35% respectively contrasting with other kinds of collision. However the right angle collision percentage decreases in severe injury and fatality, while the head on collision increased from each categories of injury grade from approximately 13% in PDO to 26% in fatal injury. It is clear that the head on collision is the most severe collision since it shared over 2 times as high as other kinds of collisions in fatality.

With respect to the location accident happening, urban shares the highest proportion in all injury levels. Based on this figure, suburban is still considered the critical location since it increases from around 9% in PDO to 38% in fatal injury.

Table 3 Descriptive statistics

Variable		Slight injury	Severe injury	Fatality	PDO
Gender	Male	61.31%	80.59%	80.48%	87%
	Female	38.69%	19.41%	19.52%	13%
Helmet	Use helmet	53.57%	33.65%	17.47%	60.87%
	Not use helmet	46.43%	66.35%	82.53%	39.13%
Ridership	Rider	55.65%	65.29%	79.62%	100%
	Passenger	44.35%	34.71%	20.38%	0%
Age	Age <15	6.5%	2.62%	1.19%	0%

	Age 15_29	61.31%	58.29%	54.96%	52.17%
	Age 30_44	26.79%	31.79%	31.68%	47.83%
	Age 45_59	4.76%	6.31%	8.73%	0%
	Age over 60	0.59%	1.19%	3.43%	0%
Human errors	Speeding	67.85%	70.6%	56.85%	86.96%
	Overtaking	12.8%	10.47%	11.99%	0%
	Drink driving	7.74%	14.12%	20.03%	8.7%
	Against traffic flow	11.61%	15.18%	11.13%	4.35%
Road Surface	Paved road	97%	94%	91%	100%
	Unpaved road	3%	6%	9%	0%
Road Geometry	Curve	7.14%	10.12%	7.88%	0%
	Roundabout	0%	0.24%	0.35%	0%
	Straight	57.74%	53.18%	63.18%	56.52%
	T junction	5.95%	9.18%	8.05%	13.04%
	X junction	29.17%	27.29%	20.55%	30.43%
Day types	Weekday	77.08%	72.71%	70.03%	56.52%
	Weekend	22.92%	27.29%	29.97%	43.48%
Time	Day time	48.51%	43.41%	39.9%	65.22%
	Night time	51.49%	56.59%	60.1%	34.78%
Weather	Rainy	3.27%	4.71%	10.3%	1.54%
	Dry	96.73%	95.29%	89.7%	98.46%
Opponent	Bicycle	5.06%	2%	0.68%	13.03%
	Car	40.77%	41.76%	44.52%	47.83%
	Motorcycle	30.06%	40.59%	25.68%	4.35%
	Fell alone	2.08%	2.94%	10.45%	0%
	Fixed object	1.49%	5.18%	15.24%	8.7%
	Pedestrian	18.75%	4.94%	1.2%	26.09%
	Tractor	1.79%	2.59%	2.23%	0%
Collision	Head on	27.98%	33.76%	25.51%	13.04%

Types	Rear end	23.51%	23.53%	20.72%	26.09%
	Right angle	35.12%	29.06%	19.69%	47.83%
	Side swipe	11.31%	10.71%	25.34%	4.35%
	Other collision	2.08%	2.94%	8.73%	8.7%
Location	Urban	78.27%	72.35%	62.16%	91.3%
	Suburban	21.73%	27.65%	37.84%	8.7%

Table 4 describes the estimated coefficients fitted by Ordered Probit model in casualties' severity injury. Addition to estimation of coefficients, ancillary parameters are also examined in the model such as cut1, cut2, the number of observation, likelihood ratio, critical chi-square value, log likelihood at zero, log likelihood at convergence, and R2 value. The testing of the likelihood ratio test is also conducted. The null hypothesis of this testing is that all the estimated parameters of the independent variables are zero. As the result, the value of critical $\chi 2$ is much less than the calculated likelihood ratio value from the model. It suggested that the null hypothesis should be rejected at the 0.05 significant level.

Table 4. Final Ordered Probit Model Estimation Results

Independent variable	Coefficient	P-value
Helmet (relative to "not use")		
Helmet use	-0.6077	0.000*
Ridership (relative to "Pillion Passenger")		
Rider	0.4786	0.000*
Location (relative to "Urban")		
Suburban	-0.2134	0.001*
Weather condition (relative to "Dry")		
Rainy	0.6505	0.000*
Collision types (relative to "Side Swipe")		
Head on	0.3717	0.000*
Human Errors (relative to "Overtaking")		
Speeding	0.5098	0.000*
Against Traffic Flow	0.5235	0.000*
Drunk Driving	0.6791	0.000*
Counterpart (relative to "Motorcycle")		
Bicycle	-0.9841	0.000*

Pedestrian	-1.1247	0.000*
Fell alone	0.7159	0.000*
Fixed object	0.5906	0.000*
Age of users (relative to “Age 30_44”)		
Age <15	-0.5123	0.001*
Age15_29	-0.1895	0.000*
Age >60	0.6793	0.010*
Ancillary parameters		
/cut1	-0.3638	
/cut2	1.1973	
Observation	1770	
LR chi2	503.29	
Prob > chi2	0.0000	
Log likelihood	-1590.93	
R^2	0.1366	

Note (*) : significant at 95% level

Table 5. Marginal Effect for Fatal Injury Probability

Independent variable	Fatal
Helmet (relative to “not use”)	
Helmet use	-0.1908
Ridership (relative to “Pillion Passenger”)	
Rider	0.1530
Location (relative to “Urban”)	
Suburban	-0.0736
Weather condition (relative to “Dry”)	
Rainy	0.2451
Collision types (relative to “Side Swipe”)	
Head on	0.1338
Human Errors (relative to “Overtaking”)	
Speeding	0.1663

Against Traffic Flow	0.1925
Drunk Driving	0.2521
Counterpart (relative to “Motorcycle”)	
Bicycle	-0.2287
Pedestrian	-0.3086
Fell alone	0.2714
Fixed object	0.2208
Age of users (relative to “Age 30_44”)	
Age <15	-0.1463
Age15_29	-0.065
Age >60	0.2584

According to the table 4 fifteen variables remain in the final model since they make significant contributions to the crash severity. The negative value of using helmet variable shows that the motorcyclists who wearing the helmet are likely to have less severity comparing to the motorcyclist not wearing the helmet. According to the table 5, the probability of fatal injury decreases by 19% if motorcyclists wear helmet. It is found that the helmet use has strong influences on the reduction of the fatality and incapacitating crashes. The helmet use probably can reduce the head injury of motorcyclists when the accident happens.

When the accident occurs, the motorcycle operators have tendency to get into the higher severity grade comparing to the pillion passengers. The table 4 points out that the probability of fatal injury of motorcycle driver increases 15% than the pillion passenger. The reason that the motorcycle drivers have higher fatal and severe injuries probability comparing to the motorcycle passengers is probably due to the positioning attribute. It is obvious that the motorcycle operator’s seat position is in the front seat; therefore, that one is likely to absorb the full impact of collision rather than the pillion passengers sitting at the back seat when the accident happens.

Accident happened in suburban is likely to cause less severity to motorcyclists than urban motorcyclists. The reality of urban situation consists of complicated destructions; many assess roads along the main road and the high density of traffic volume with bad behaviours of road users.

The type of collision that occurs is estimated relative to side swipe collision type. Head on collision is likely to cause severe severity to motorcyclists referring to side swipe collision. The increase in the probability of having a fatal injury occurs in case of head on collision, around 13% more than side swipe collision. Head on collision is likely to increase the highest probability for both fatalities and severe injuries since the other collision types are not significant at 95% confidence level.

The positive sign of rainy variable indicates that the chance for motorcyclists driving in rainy is leading to an upward trend in injury severity .The predicted probability of fatality of driving in rainy is increased by 25% than in dry condition.

Moreover, human fault is considered as the main contributing factor to the crash severity of motorcyclists. Among all types of human error, overtaking variable is set as the reference for comparison to other types of human error in model. As the results fitted from the models, variables (speeding, against traffic flow and drunk driving) showed the statistically significance at 95% level in model. It is quite interesting that the coefficients of those variables are positive which means that the motorcyclists involving in any of those activities prone to more injury comparing to overtaking fault. Moreover, there is no statistically significance at 95% found between the speeding and against traffic flow. The effect of alcohol use is the strongest factor in elevating the likelihood of being fatally and severely injured comparing to the other type of human faults according to the model result. According to the marginal effect, the increase of fatality probability of speeding, against traffic flow and drunk driving are 17%, 19% and 25% respectively than the overtaking human error.

With regards to the other vehicle involved in accidents, collision with bicycle and pedestrian resulted in less severe accidents rather than motorcycle opponent based on the modeling results. There is no significant difference of fatality probability between colliding with bicycle (23%) and pedestrian (31%). Consequently, accidents involving motorcycles colliding with fixed object led to more crash severity comparing to motorcycle opponent. This finding is obvious that when collision involves with high impact of opponents (fixed object), the probability of fatality of the motorcyclist seems significantly increase. Another interesting point is that motorcyclists tend to have higher severity when they fell alone. The highest significant increase in the probability of having a fatal injury occurs when the motorcyclists fell alone, which is about 27% higher than the motorcyclists having a crash between motorcycles.

Comparing to the age between 30 to 44, the younger driver age under 15, 15 to 29 and the older driver age over 60 are found 95% confidence. The negative sign of age under 15 and age between15 to 29 variable shows that the young motorcyclists are likely to get into the slight injury severity while positive sign of age over 60 shows that the senior motorcyclists have tendency to have more severe injury grade. This result seems to imply that the older motorcyclist is, the higher probability of severe injury or fatality is. The reason is that the old motorcyclists have lower concentration and the driving skills, higher vulnerability due to their age, and lower the reaction time with ages than the younger motorcyclists. The decrease in fatality probability of motorcycle drivers falling into age under 15 and 15 to 29 are 15% and 7% respectively in table 5. But the fatality probability increases 26% when the age is over 60.

5. COUNTERMEASURES TO DECREASE IN CRASH SEVERITY OF MOTORCYCLIST IN MANDALAY CITY

All motorcyclists including passengers must wear the helmet for all age of group especially the older motorcyclists. Traffic police should punish exactly the motorcycle drivers and passengers who do not use helmets while driving.

The authority should enforce and educate related to riding behavior and all motorcycle operators should drive carefully and need to follow the traffic law.

The older motorcycle drivers should be limited for allowing in driving the motorcycle because the increase age of driver has high relationship with the casualties' severity. Therefore, the government should encourage the old people don't not drive the motorcycle.

Positive effects of using helmet and negative effects of alcohol that are improvement on public alertness should be shared out in public and nationwide via TV or radio or any types of

social media. When the traffic polices find the motorcycle drivers who are relating to speeding or against traffic flow, they should punish without any tolerance.

Regarding to the location, urban area needs for effective remedy of the injury severity of motorcyclists.

For the head-on collision, the effective solution is placing the median barriers. This can reduce the crash severity by the splitting traffic direction.

The safety of roadside infrastructure (provide adequate drainage, improve roadway lighting and skid resistance, install guardrail, barrier curb breakaway posts, or remove fixed object, etc.) are needed to be improved for motorcyclists since collisions with fixed objects in the roadside had high severity.

6. CONCLUSION

In the research, the Ordered Probit model was performed by using the four years data set from Mandalay police station to find how variations in various factors, such as gender, age, helmet use, ridership (driver or passenger), human errors (overtaking, against traffic flow, drunk driving and speeding), road surface (paved or unpaved), road geometry (curve, roundabout, straight, T-junction and X-junction), weekend, month, time trend of accident, day type of accident, weather conditions (rainy or dry), opponent involved (bicycle, car, fell alone, motorbike, pedestrian, fixed object and tractor), collision types (head-on, right-angle, rear-end, side swipe and other collision types), and location of accident (urban or suburban), can result a superior understanding of factors contributing to different injury severity levels.. The OP model is able to evaluate the statistical significance of various factors and the changes in the relative probability of the level of crash severity of motorcyclists. The following conclusions have been drawn regarding these objectives based on the analysis conducted in this study.

The results of the current study suggested that several variables did influence the likelihood of a motorcycle vehicle crash being injury or fatal. The influential factors include non-use of helmets, motorcycle rider, rainy weather, speeding, drunk driving, against traffic flow, head on collision, the senior motorcyclists, fell alone, collide with (fixed object, bicycle, pedestrian) and urban location are the factors affecting the motorcyclists crash severity in Mandalay City.

For the factors of non- use helmet, speeding, against traffic law, drunk driving and older motorcyclists, the government organization can introduce and enforce of suitable road safety legislation, presents the current knowledge about motorcycle crash severity and need to be taken in order to tackle the riders who do not follow the law enforcements. In rainy weather, the motorcyclists should drive more carefully than in dry weather. And then, to reduce the accident frequency & crash severity of motorcyclists, new and better road safety planning can be drawn by both government organizations and nongovernmental organizations. Motorcycle crashes involving collisions with fixed objects had a higher risk of severe injury among motorcycle riders. These result point out that needed to improve the roadside infrastructure for motorcyclists. So, the traffic engineers can improve the roadside infrastructures (install the guardrail, median barriers, breakaway signpost and remove fixed objects, etc.) to reduce the damage done when a vehicle leaves the travel lane. Based on findings of this research, government organization, nongovernment organization and traffic engineer can prepare the planning and the motorcyclists should follow the traffic laws for reducing the crash severity of motorcyclists in Mandalay City.

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