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Analysing Motorcycle Injuries using A Latent Class Binomial Logit Model

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Abstract: The unobserved heterogeneity in accident data has widely been discussed as one of a major issue in road safety studies. Biased predictions and incorrect interpretations occurred due to this unobserved data heterogeneity when improper approaches were used. This study aims to identify the influencing factors for motorcycle accident injuries. The dataset used consists of 1061 motorcycle accident injuries from 2010 to 2015 in Tabanan Regency, Bali. A latent class binomial logit model was estimated with specific attention to unobserved heterogeneity issues by classifying homogeneous attributes of two different accident data classes. This study found that male and older motorists, head on collisions and motorcycle at fault significantly influencing fatal motorcycle injuries. In addition, motor vehicle accidents, day time, right angle collisions and traffic violations significantly associated with serious motorcycle accident injuries. Based on the contributing factors identified in this study, some countermeasures for reducing the motorcycle accident injuries were proposed.

Keywords: Latent Class Analysis, Motorcycle Accident Injuries, National Road Network

1. INTRODUCTION

Road traffic accidents result from an array of factors related to the elements of the transport system comprising of human, vehicles, roads, and the environmental (World Health Organization, 2018). Therefore, it is not always possible to gain access to all relevant data that could potentially take into account when identifying the causes for traffic accidents. In addition, significant accident data may not be reported to and collected from the police or the law enforcement agencies. These data are classified to as unobserved factors or unobserved heterogeneity (de Ona et.al., 2013; Mannering and Bhat., 2014; Mannering, et.al., 2016).

If both of these unobserved and observed factors are statistically correlated, then model parameters may be predicted inaccurately. For instance, age is a significant factor to influence a traffic accident injury, while in fact age is associated with physical health and reaction times, which may reduce the accident severity. Considering only age in the model estimation, it consequently represents many primary factors which considerably diverge across a traffic accident injury observation. The reason is because road users with the same age may have dissimilarities within these unobserved factors (Mannering and Bhat., 2014). On the assumption that age has similar influence on a traffic accident injury for all road users, consequently the developed model is considerably limited. This may influence conclusions taken from the parameter estimate of the age-variable as well as other parameter in the model. Many statistical methods can be used to cope with this problem, however many scientists previously disregarded this problem (Mannering and Bhat., 2014).

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Heterogeneity probably come from these unobserved factors when constructing motorcycle accident injury models as a function of observed factors, causing biased parameters and inaccurate interpretations (de Ona et.al., 2013; Mannering and Bhat., 2014; Mannering, et.al., 2016). In addition, numerous factors are discovered to influence motorist injury severity. In addition, the random parameters illustrate that these effects diverging among accidents and road users (Russo, et.al., 2016).

Several studies conducted both in developed and developing countries have utilised the latent class regression methods to analyse road traffic accident injuries. A past study carried out in the US by Shaheed and Gkritza (2014) employed a latent class multinomial logit model to address unobserved heterogeneity by identifying two distinct accident data classes with homogeneous attributes. Another study performed in the US by Shaheed, et.al (2013) used a mixed logit model to investigate the factors that affect accident severity outcomes in a collision between a motorcycle and another vehicle. Meanwhile, a study in Belgium segmented a heterogeneous motorcycle accident data into various classes and injury analysis was carried out for each class. The results of these class-based analyses are compared with the results of a full-data analysis (Depaire, et.al., 2008). A past study conducted in China estimated a new model to estimate real time traffic accident risk in accordance to some highly chosen on traffic flow' characteristics. The results of the study demonstrated that the general accuracy of the latent class logit model is higher than the traditional logistic regression model (Huang et.al., 2017). Overall, these past studies recommended that the latent class approach is favorable method to model traffic accident severity outcomes.

Meanwhile, traffic accidents in Bali frequently occurred on roads that are part of the national road network such as Denpasar-Gilimanuk and Denpasar-Singaraja road networks in Tabanan Regency. With regard to traffic accident data, motorcycle accidents dominated more than 70% of total traffic accidents in Bali (Bali Regional Police, 2016). Tabanan Regency is one of the districts with a high number of accidents, namely 1364 accidents during 2011-2015 with 67.59% occurring on Denpasar-Gilimanuk national road network (Bali Regional Police, 2016). This figure was a reported accident however in fact it may be more than that because the community often does not report traffic accident occurrences to the authorities. The national road network of Denpasar-Gilimanuk is important as it is connecting freight and passenger transport between Bali and Java islands. In addition, the road network Denpasar-Singaraja is important as it is linking between the southern and northern parts of Bali island. The length of distance travelled along the road with various geometric conditions passing through the plains low and highlands makes the high number of accidents and accident-prone areas scattered along the Denpasar-Gilimanuk and Denpasar-Singaraja road networks within Tabanan Regency.

The analysis of road traffic accidents will be more complicated with the existence of heterogeneity in the raw data of traffic accident. This study, therefore, uses a latent class approach to investigate the contributing factors and their influences of motorcycle accident injury outcomes using Denpasar-Gilimanuk and Denpasar-Singaraja national road networks in Tabanan Regency as the case study. This study describes a detailed discussion of unobserved heterogeneity in the context of motorcycle accident data and analysis. This is in line with one of the main goals of traffic accident analyses is to distinguish key factors that influence traffic accident casualty. In addition, these findings are expected to provide an important source to conduct traffic policy measures in order to reduce motorcycle accident severity particularly on national roadways in Bali.

2. METHODS

2.1 Latent Class Modelling Framework

In a latent class binary logit model, the dependent variable is *Y* and considers the value *y = 0* and *y = 1*. The formula of the latent regression logit model with *J* latent classes is as follows:

$$P(Y=1\mid \mathbf{x}) = \sum_{j=1}^{j=J} P(Y=1\mid \mathbf{x}, \Xi=\varepsilon_j)P(\Xi=\varepsilon_j) = \sum_{j=1}^{j=J} \frac{\exp(\alpha+\boldsymbol{\beta}\mathbf{x}+\varepsilon_j)P(\Xi=\varepsilon_j)}{1+\exp(\alpha+\boldsymbol{\beta}\mathbf{x}+\varepsilon_j)} \quad (1)$$

where,

$P(\Xi=\varepsilon_j)$	:	the frequency of the *j*'th latent class in the population
$\boldsymbol{\beta}$	:	a corresponding row vector of regression coefficients
$\mathbf{x}$	:	a vector of explanatory variables
ε_j	:	the effect of the *j*'th latent class on the probability of observing *Y = 1*
α	:	a constant term

The estimated model parameters are $\boldsymbol{\beta}$, α, $P(\Xi=\varepsilon_j)$, ε_j, *j = 1,..,J*, where *J* is the number of latent classes. This model considers unobserved heterogeneity resulting from excluding predictor variables. The unobserved heterogeneity may either be considered as the description of a true discrete distribution of unobserved heterogeneity or as a proxy to any unknown distribution of unobserved heterogeneity, discrete or continuous. The latent class frequencies, $P(\Xi=\varepsilon_j)$ must require the limitation : $P(\Xi=\varepsilon_j)>0$ and $\sum_{j=1}^{j=j} P(\Xi=\varepsilon_j)=1$. The subsequent re-parameterisation therefore is suitable when predicting the frequencies:

$$P(\Xi=\varepsilon_j) = \frac{\exp\left(\tilde{\delta}_j\right)}{\sum_{j=1}^{j=J}\exp\left(\tilde{\delta}_j\right)} \quad (2)$$

where,

$\tilde{\delta}_j$, *j = 1,…J* are parameters to be estimated.

Furthermore, equation (2) is divided with $\tilde{\delta}_1$ to get:

$$P(\Xi=\varepsilon_j) = \frac{\exp\left(\tilde{\delta}_j-\tilde{\delta}_1\right)}{1+\sum_{j=2}^{j=J}\exp\left(\tilde{\delta}_j-\tilde{\delta}_1\right)} = \frac{\exp\left(\delta_j\right)}{1+\sum_{j=2}^{j=J}\exp\left(\delta_j\right)} \quad (3)$$

Equation (3) keeps to the number of special parameters for the latent class frequencies that is *J–1*. Furthermore, re-defining an equation of $\tilde{\varepsilon}_j=\alpha+\varepsilon_j$ will leave $P(Y=1\mid \mathbf{x},\Xi=\tilde{\varepsilon}_j) = P(Y=1\mid \mathbf{x},\Xi=\varepsilon_j)$, *j = 1.. J*. Hence a normalisation of the effect of the latent classes is warranted as the so called dummy-coding and normalise $\varepsilon_1=0$ are followed. This paper is intended as a discussion of the intuition behind identification and not a full rigorous proof of identification of the latent class model, so a simplified two-class model with one independent variable is constructed. The model is then written as:

$$P(Y=1\,|\,x)=\sum_{j=1}^{j=2}\frac{\exp(\alpha+\beta x+\varepsilon_j)P(\Xi=\varepsilon_j)}{1+\exp(\alpha+\beta x+\varepsilon_j)} \tag{4}$$

where,

x is currently a single continuous variable and β is a regression coefficient ($\varepsilon_1=0$ and $\varepsilon_2=\varepsilon$).

Equation (4) shows the log-likelihood function for a sample of n independent observations is constructed as follows

$$\ln L=\sum_{i=1}^{i=n} y_i \ln P(Y=1\,|\,x_i)+\left(1-y_i\right)\ln\left(1-P(Y=1\,|\,x_i)\right) \tag{5}$$

where,

$P(Y=1\,|\,x_i)=pP_{0i}+\left(1-p\right)P_{i\varepsilon}$ and

$P_{0i}=\dfrac{\exp\left(\alpha+\beta x_i\right)}{1+\exp\left(\alpha+\beta x_i\right)}, P_{i\varepsilon}=\dfrac{\exp\left(\alpha+\beta x_i+\varepsilon\right)}{1+\exp\left(\alpha+\beta x_i+\varepsilon\right)}$ and lastly

where,

$P(\Xi=0)=p$ and $P(\Xi=\varepsilon)=1-p$.

In addition, these equations below are indirectly employed:

$$P(\Xi=\varepsilon_1=0)=\frac{1}{1+\exp\left(\delta_2\right)};P(\Xi=\varepsilon_2)=\frac{\exp\left(\delta_2\right)}{1+\exp\left(\delta_2\right)} \tag{6}$$

For detailed discussions on Latent Class Analysis Binomial Logistic Regression the reader is referred to Jin, et.al, (2018).

2.2. Data Description

Table 1 shows motorcycle accident injuries taking into account of three severity groups such as killed, serious and slight injuries,during period between 2010 and 2015 on the road networks of Denpasar-Gilimanuk and Denpasar-Singaraja within Tabanan regency, Bali. Of those all motor vehicle injuries, nearly 63% comprise of motorcycle KSI (Killed or Serious Injuries).

Table 1. Motorcycle accident Injuries data at the case study road networks

Fatal Injuries	Serious Injuries	Slight Injuries	Total
330	340	391	1061

Meanwhile, Table 2 shows that some independent variables are overlooked due to their small proportion (p_i) on the assumption that its lower value of 95% confidence level is less than 0.2. Based on the test, there were six variables excluded from the model development stages, for instance accident type (with pedestrians), collision types (out of control and rear end collisions), accident cause (failed to yield), vehicle types (heavy and light vehicles). As the result, there were ten variables included in the model construction consisting of accident type (with vehicles), day time, age of 17-25 years at fault, age of 26-60 years at fault, male motorists at fault, collision types (right angle and head on), accident cause (others and wrong way) and motorcycles at fault.

Table 2. Selecting variables for model construction

Variable Description	X	N	p_i	95% Confidence level	
				Lower	
Accident type - With pedestrians	167	1061	0.157	0.135	*Accident type - With pedestrians*
Accident type - With vehicles	813	1061	0.766	0.741	Accident type - With vehicles
Time of accident (day time code = 1)	687	1061	0.648	0.619	Time of accident (day time code = 1)
Age of 17-25 years at fault	365	1061	0.344	0.315	Age of 17-25 years at fault
Age of 26-60 years at fault	648	1061	0.611	0.581	Age of 26-60 years at fault
Male motorists at fault	926	1061	0.873	0.853	Male motorists at fault
Collision Type - Out of Control	171	1061	0.161	0.139	*Collision Type - Out of Control*
Collision Type - Right Angle	337	1061	0.318	0.290	Collision Type - Right Angle
Collision Type - Rear End	192	1061	0.181	0.158	*Collision Type - Rear End*
Collision Type - Head On	271	1061	0.255	0.229	Collision Type - Head On
Accidents Cause - Others	482	1061	0.454	0.424	Accidents Cause - Others
Accidents Cause -Wrong way	273	1061	0.257	0.231	Accidents Cause -Wrong way
Accidents Cause -Failed to yield	163	1061	0.154	0.132	*Accidents Cause -Failed to yield*
Vehicle type (at fault) - Motorcycle	767	1061	0.723	0.696	Vehicle type (at fault) - Motorcycle
Vehicle type (at fault) - Light vehicle	177	1061	0.167	0.144	*Vehicle type (at fault) - Light vehicle*
Vehicle type (at fault) - Heavy vehicle	117	1061	0.110	0.091	*Vehicle type (at fault) - Heavy vehicle*

Notes:
N = sample size; X = number of occurrence (yes =1)
Italic : statistically insignificant at the 5% level (the 95% confidence limits)

There are relevant explanations for these variable inclusions in the model construction. Age and gender were apparently considered as the most important motorcyclist-specific factors that influence both severity and frequency of motorcycle accidents (Shaheed and Gkritza, 2014). This previous study discovered that older motorcyclists have higher probability than younger motorcyclists to be severely injured as they are considered to have slower reaction time, reduced sensory, less perceptual ability and less physical strength to motorcycle accidents. On the other hand, older motorcyclists were more likely to have more riding experience that was a significant risk factor related with motorcycle accidents.

Age of the casualty is associated with physical characteristics, reaction times and risk-taking behavior of the road users in which may influence their accident injury severity. Age, however, may be used only as a substitute for these unobserved and unmeasured factors. The influence of age on accident injury severities, therefore, may diverge across road users at the same age. Further, age is frequently included in a model' variable, for instance if age is between 17 and 24 years old, it is given code =1 and so forth. This causes the heterogeneous effects of age can be even more declared (Mannering et.al., 2016). In terms of gender, there are obviously physical and physiological distinctions between men (code =1) and women (code = 0). In addition, there is considerable differences among road users at the same gender including height, weight, physical health and other factors that are definitely unobserved to the researcher (Mannering et.al., 2016).

In terms of collision types, right angle was significantly included in the model variable as many of the accidents happened at the road network junctions (Chin and Haque., 2012) and typically in Bali that many motorcyclists pulled into main road at any time without waiting. Meanwhile head-on collision was more likely to occur because these road networks were two-lane two-direction of single carriageways.

3. MODEL DEVELOPMENT

Subsequently, these ten predictor variables are used to determine the number of appropriate latent classes using the software of M-Plus version 7.4. Statistically, there have been multiple criteria to retain number of latent classes include:

a. Bayesian Information Criterion (BIC) and Adjusted BIC (ABIC)
b. Lo-Mendell-Rubin likelihood ratio test (LMR LRT)
c. The bootstrap likelihood ratio test (Bootstrap LRT)
d. The p-value for both Pearson χ^2 and Likelihood Ratio χ^2

Based on these criteria, two (2) latent classes shown in Table 3 are considered as the best model. This illustrates that initial analysis of latent class clustering may uncover concealed relationships among motorcycle accident injuries (Depaire, et.al., 2008).

Table 3 Criteria to retain number of latent classes

LCA Models	BIC	ABIC	*p*-value for LMR	*p-value* for Bootstrap	*p-value for Pearson* χ^2	*p-value for likelihood Ratio* χ^2
2-Class (2-Class vs. 1-Class)	11237.848	11342.155	< 0.001	< 0.001	< 0.001	< 0.001
3-Class (3-Class vs. 2-Class)	10357.680	10516.623	< 0.001	< 0.001	< 0.001	0.486
4-Class (4-Class vs. 3-Class)	10022.645	10236.225	< 0.001	< 0.001	0.150	1.000

More specifically, the inclusion of each variable for the two classes is shown in Table 4. The magnitude of variables is used as the reference to determine the group classification. These variables can be grouped into crash-specific characteristics including time of accident, accident characteristics as well as motorcyclist attributes. For example, in Latent Class 1 the predictors included were time of accidents (day time), adult motorists (age of 26-60 years at fault), right angle collision, other factors as the cause of accident and motorcyclists at fault. Meanwhile, Latent Class 2 comprised of accident type – with vehicles, young motorists (age of 17-25 years at fault), male motorists at fault, head on collision and traffic violations as the cause of accident. Using this classification, the influencing factors on motorcycle fatal, serious and slight injuries are examined.

As shown in Table 5, there have been the evidence of heterogeneity between the two classes of the models such as some of the parameters have the same sign across the two classes, opposite signs or the parameters are not significant. These suggest that heterogeneity exists between the two classes. In other words, Table 5 shows that the latent class model clearly identified significant variables which have rather different effects on motorcycle accident injuries. Due to the heterogeneity, the model results cannot be interpreted using the magnitude and sign of the variables, however, it is instead based on marginal effects on probabilities of motorcycle accident injuries shown in Table 6.

Table 4 The latent classes

Variable Description	Latent class 1		Latent class 2	
	Parameter	t-statistic	Parameter	t-statistic
Accident type – with vehicles	0.68	40.51	**0.99**	284.64
Time (day time)	**0.66**	38.31	0.62	21.44
Age at fault in between 16-25 years old	0.34	19.49	**0.37**	12.27
Age at fault in between 26-60 years old	**0.61**	34.53	0.60	20.01
Gender (Male at fault)	0.86	69.56	**0.89**	49.67
Collision type – Right Angle	**0.42**	23.59	0.04	3.21
Collision type – Head On	0.04	5.26	**0.83**	37.30
Cause of accident – Others	**0.62**	35.76	---	---
Cause of accident – Traffic violations	---	---	**0.95**	56.84
Vehicle types at fault – Motorcycle	**0.75**	47.73	0.66	22.85

Table 5 The estimation of latent class logit model

Variable Description	Latent class 1		Latent class 2	
	Parameter	t-statistic	Parameter	t-statistic
Defined for Fatal Injury				
Accident type – with vehicles			-0.99**	-4.39
Time (day time)	-0.49*	-2.78		
Age at fault in between 16-25 years old			-0.52	-1.26
Age at fault in between 26-60 years old	0.11	0.27		
Gender (Male at fault)			0.33	1.33
Collision type – Right Angle	-1.14**	-4.94		
Collision type – Head On			0.02	0.08
Cause of accident – Others	-0.01	-0.06		
Cause of accident – Traffic violations			-0.51	-1.56
Vehicle types at fault – Motorcycle	0.05	0.22		
Defined for Serious Injury				
Accident type – with vehicles			0.99**	4.39
Time (day time)	0.49*	2.78		
Age at fault in between 16-25 years old			0.52	1.26
Age at fault in between 26-60 years old	-0.11	-0.27		
Gender (Male at fault)			-0.33	-1.33
Collision type – Right Angle	1.14**	4.94		
Collision type – Head On			-0.02	-0.08
Cause of accident – Others	0.01	0.06		
Cause of accident – Traffic violations			0.51	1.56
Vehicle types at fault – Motorcycle	-0.05	-0.22		
Defined for Slight Injury				
Accident type – with vehicles			---	---
Time (day time)	---	---		
Age at fault in between 16-25 years old			3.53*	3.44
Age at fault in between 26-60 years old	---	---		
Gender (Male at fault)			-3.65*	-2.63
Collision type – Right Angle	---	---		
Collision type – Head On			-3.09**	-4.94
Cause of accident – Others	2.74*	2.57		
Cause of accident – Traffic violations			---	---
Vehicle types at fault – Motorcycle	---	---		

Lo-Mendell-Rubin likelihood ratio test = 718.768 ; (p-value : 0.000)

** significantly different from zero at the 0.001 level; * significantly different from zero at the 0.05 level

The direct and marginal effects of each predictor variables on motorcycle accident injuries are illustrated in Table 6. In The probability of a fatal motorcycle injury is significantly associated and increased by approximately 40%, 11%, 2.5% and 4.6% when the motorcycle accidents involving male and older motorists, head on collisions and motorcycle at fault respectively. In relation to the motorcyclist characteristics, male and older motorcyclists involved in a motorcycle accident along the road network of Denpasar-Gilimanuk and Denpasar-Singaraja were more likely to be more fatal injured compared to female and younger motorcyclists respectively. This result might be a reflection of the difference in riding style, experiences, risk perceptions, physical strength and behaviour between male and female motorcyclists (Shaheed et.al., 2013).

Table 6 Marginal effect on probabilities of motorcycle accident injuries

Variable	Fatal injury	Serious Injury	Slight Injury
Accident type – with vehicles	0.37	2.68	---
Time (day time)	0.61	1.63	---
Age at fault in between 16-25 years old	0.59	1.69	34.18
Age at fault in between 26-60 years old	1.11	0.90	---
Gender (Male at fault)	1.39	0.72	0.03
Collision type – Right Angle	0.32	3.14	---
Collision type – Head On	1.03	0.98	0.05
Cause of accident – Others	0.99	1.01	15.43
Cause of accident – Traffic violations	0.60	1.66	---
Vehicle types at fault – Motorcycle	1.05	0.96	---

4. DISCUSSIONS

Motorcyclists younger than 25 years old were less likely to be fatally injured in motorcycle accident compared to older motorcyclists, which is in line with past studies (Shaheed and Gkritza., 2014; Waseem et.al., 2019). The data availability on number of younger motorcyclists passed on the road network of Denpasar-Gilimanuk and Denpasar-Singaraja however, limited further investigation on the influence of age on motorcycle accident injuries. This results need to be further investigated and compared to other national road networks in Bali as demographic information on motorcyclists shows a considerable increase in younger motorcyclists in recent years (Bali Regional Police, 2016).

A similar effect was found for fatal motorcycle accidents with head on collisions and motorcycle at fault as their major cause. The results also show that the probability of a fatal motorcycle injury outcome will be increased by 2.5% and 4.6% in the case of a head on collision and motorcycle at fault respectively. Previous studies also showed that head on collision and motorcycle at fault result in fatal motorcycle accident injuries (Ding et.al., 2019; Waseem et.al., 2019). Those studies demonstrated that head on collisions between light vehicles and motorcycles with both vehicles traveling at 60 km/h (a relative speed at 120 km/h), resulting 55% risk of at least serious injury to the motorcyclists (Ding et.al., 2019).

Meanwhile, as shown in Table 6, the probability of a serious motorcycle injury is significantly associated and increased by approximately 2.68 times (63%), 3.14 times (66.2%) when the accidents involving motor vehicles, time of accident (day time), right angle collisions and traffic violations as the cause of accidents respectively along the road network of Denpasar-Gilimanuk and Denpasar-Singaraja. Accident between or among motor vehicles were significantly discovered showing its influence on serious motorcycle accident injuries. This might be of mixed traffic conditions in which motorcycle, heavy and light vehicles share the roadways together. Segregating motorcycle from other modes on this national road network such as providing special lane on the left side of the road may reduce this kind of accidents.

Previous studies have also outlined that segregating motorcycles from other traffic reduces the accident exposure and improves the safety of motorcyclists (Umar, et.al., 1995: Mama and Taneerananon., 2016; Lea and Nurhidayati., 2016). In one hand, motorcycle lanes are imperative in urban cities to bring down the effect of motorisation and mixed traffic. As the results, the lessened number of road traffic accident will cause road traffic safety achievement and is according to sustainable urban concept. On the other hand, such motorcycle lanes are inappropriate to achieve the objective of sustainable urban mobility that requires less number of motor vehicles in particular motorcycles. Therefore, the role of national government is the key and to intervene with transportation planning policies such as mandatory for local government in every province in Indonesia on providing, operating and maintaining of public transport.

In addition, accident between or among motor vehicles may be indicated with various significant unobserved variables such as speeding, driving/riding with dangerous over-taking, riding without helmets and disrespecting the right of way (Kitamura et.al., 2018). In relation to these unobserved variables, there have been lack of education of road traffic safety and of adequate and appropriate law enforcement on traffic law in South East Asian countries (Kitamura et.al., 2018; Oxley et.al., 2018) including Indonesia. Education and law enforcement have to take a part in rising people's awareness on road safety as they are lacked of care in comparison with engineering dimension in Indonesia.

Table 6 also demonstrates that right angle collisions were significant contributing factors to serious motorcycle accident injuries along the road network of Denpasar-Gilimanuk and Denpasar-Singaraja which having considerable numbers of both signalised and unsignalised junctions. This is in line with a past study conducted in Cambodia (Kitamura et.al., 2018) which also found right angle collisions were contributing factor on motorcycle dominated-traffic accidents. Right angle collision occurred when vehicles arrive on perpendicular roads and collide. There are two main types of right angle collisions – one where entering traffic has stopped, and one where entering traffic disregards a stop or signal for instance, motor vehicles pulled into main road traffic without looking.

Right angle collisions however, can be used as a proxy for these unobserved variables of geometric, traffic, and situational variables in which analysts do not observe and often cannot be measured. Right angle might indicate various significant variables on motorcycle accident injuries such as lane position, junction type, entry/exit points at the roadways, wet surface, presence of passenger, and maneuver of vehicles (Haque and Chin, 2010). Therefore, the effect of right angle collisions on injury severities may vary among individual motorists.

In order to reduce right-angle collisions, putting a Right Light Camera (RLS) at signalised junction the relative accident vulnerability (RCV) or accident-involved exposure of motorcycles at collisions is reduced (Chin and Haque., 2012). In addition, reducing right-angle collisions at signalised junction may be conducted by utilising speed cameras at junctions (similar to RLC but captures speed violations during the green phase), installing dynamic signal warning flashers, removing unwarranted signal and increasing all red clearance' interval. Further, potential countermeasures for reducing right angle collisions at unsignalised junction may be conducted by constructing roundabout and acceleration lanes, clearing sight triangles, posting appropriate speed limit, eliminating skew and targeted enforcement.

Traffic violations are also significantly considered to influence a serious motorcycle accident injury along the national road network of Denpasar-Gilimanuk and

Denpasar-Singaraja. This may be signed with the risky behaviour of many motorcyclists in Bali, for instance making a short cut to reach the destinations quicker by travelling in the opposite traffic direction via the road shoulder. Meanwhile, younger motorcyclists aged in between 16-25 years old significantly contributed by more than 34 times to slight motorcycle accident injuries. This indicated that younger motorists/motorcyclists are less likely to be fatal or seriously injured due to the faster reaction time and higher sensory and perceptual ability, as well as to the higher physical resiliency to motorcycle accidents compared to older motorists/motorcyclists (Shaheed and Gkritza., 2014). In addition, motorcycle accidents caused by other factors significantly influenced slight motorcycle injuries by more than 15 times. These other factors may include variables of human behaviours, motor vehicle conditions, road and environment situations which specifically were not included in this study.

5. CONCLUSIONS

This study found that the probability of a fatal motorcycle injury along the road network of Denpasar-Gilimanuk and Denpasar-Singaraja is significantly associated and increased when the motorcycle accidents involving male and older motorists, head on collisions and motorcycle at fault. This result might be a reflection of the difference in riding style, experiences, risk perceptions, physical strength and behaviour between male and female motorcyclists. Meanwhile, younger motorcyclists aged in between 16-25 years old significantly contributed to slight motorcycle accident injuries along the road network of Denpasar-Gilimanuk and Denpasar-Singaraja.

This indicated that younger motorists/motorcyclists are less likely to be fatal or seriously injured due to the faster reaction time and higher sensory and perceptual ability, as well as to the higher physical resiliency to motorcycle accidents compared to older motorists/motorcyclists. The data availability on number of motorcyclists passed on the road network of Denpasar-Gilimanuk and Denpasar-Singaraja, however, were limited. Meanwhile, further investigation is required to analyse the influence of age on fatal motorcycle accident injuries. This results need to be further investigated and compared to other national road networks in Bali as demographic information on motorcyclists shows a dramatic increase in younger motorcyclists in recent years.

Meanwhile, the probability of a serious motorcycle injury along the road network of Denpasar-Gilimanuk and Denpasar-Singaraja is significantly associated and increased when the motorcycle accidents involving accident between or among motor vehicles, time of accident (day time), right angle collisions and traffic violations as the cause of accidents. Accident between/among motor vehicles might resulted from mixed traffic conditions in which motorcycle, heavy and light vehicles share the roadways together. Segregating motorcycle from other modes on this national road network such as providing special lane on the left side of the road may reduce this accident types. Such motorcycle lanes however are inappropriate to achieve the objective of sustainable urban mobility that requires less number of motor vehicles in particular motorcycles. The role of national government, therefore, is the key and to intervene with transportation planning policies such as mandatory for local government in every province in Indonesia on providing, operating and maintaining of public transport.

In addition, accident between/among motor vehicles may be indicated with various significant unobserved variables such as speeding, driving/riding with dangerous over-taking, riding without helmets and disrespecting the right of way. In relation to these unobserved variables, there have been general lacks of education of road traffic safety and of adequate and appropriate law enforcement on traffic law in South East Asian countries including Indonesia. Education and law enforcement have to take a part in rising people's awareness on road safety as they are lacked of care in comparison with engineering dimension in Indonesia.

Right angle collisions however, can be used as a proxy for these unobserved variables of geometric, traffic, and situational variables in which analysts do not observe and often cannot be measured. Right angle might indicate various significant variables on motorcycle accident injuries such as lane position, junction type, entry/exit points at the roadways, wet surface, presence of passenger, and maneuver of vehicles. Therefore, the effect of right angle collisions on injury severities may vary among individual motorists.

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