Research Paper/Technical Note/Review Article

Motorcycle accident model for highlands regions by applying Generaliazed Linear Model (GLM)

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ABSTRACT

Motorcyclists are the major victims in highway accidents due to instability of motorcycle vehicle and driver behavior. Currently, insufficient studies related to motorcycles accident model considering road geometry and traffic characteristics in highland regions were conducted. This study carried out the investigation on crashes involving motorcycle, development of motorcycle accident model for highland regions of Malang City, East Java Province as a case study. The research analysis employed the Generalized Linear Model (GLM). The model was developed by using accidents data from Police Department and investigation of traffic and road geometry as black spots. On ten road sections investigated and distributed questionnaires to 100 respondents, the respondents experience 1-2 times accidents with light injuries (26%) and serious injuries (11%), and no injury (3%). Accidents occur at noon (11%) and afternoon (13%) and due to their own fault and crashing with other motorcycle (27%). The results are found out that motorcycle accident model influenced by traffic factors, i.e. flow and speed and also road geometric factors, i.e. lane width (LW), shoulder width (SW), number of lanes (NL), number of access roads (NA) and walkway width (WW).

Index Terms— Generalized Linear Model (GLM), Highland regions, Motorcycle accident model, Road geometry, Traffic characteristic

1. Introduction

Transportation safety is a global concern which is as focus of WHO with setting a theme on World Health Day 2004 Event “No Accident in Road Safety” (WHO,2004). According Department of Indonesian Police data in 2012, the report informs that 109,038 accidents with die 27,441 persons and economic losses approximately 203-217 trillion per year (2.9- 3.1 % of GDP of Indonesia). While in 2011, the total of accidents is 109,776 incidents with 31,185 deaths. The victims of accidents are dominated by young people using motorcycle and paratransit/ public transport. This information corresponds to WHO data, accidents occur in developing countries approximately 85% with victims of traffic accidents died, on the other hand, the number of vehicles in these countries, only 32% of the total vehicle population in the world (WHO,2004).

To decrease the number of motorcyclist victims, Indonesian government has targeted a decreased-fifty percent of traffic accident in 2019 from the accident rate in 2014. Economic development has an effect in growing

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the number of motor vehicles approximately 3% per year, particularly for motorcycle growth 5%. The growth of motorcycle also increases the number of accidents up to 7% (Statistic Bureau of Malang City, 2018).

Increasing the number of motorcycle accidents occurs in most cities in Indonesia. Malang District ("Kabupaten Malang") also has this trend which is indicated by increasing from 217 to 308 accidents with motorcyclist as victim. The highest motor vehicles accident happens in 2016 ±774 incidents which are rising from 542 incidents in 2015. This condition occurs because of increasing the number of motorcycle from 2012 to 2016 approximately 4 times (171,000 motorcycles increasing 680,000 motorcycles) (Department of Malang City Police, 2016).

Investigation of the relationship between accidents and various geometric and road feature was carried out. The geometric road consists of the number of lanes, number of lanes, gradient, and surface condition (Tjahjono, 2007).

Seventy percent of all fatalities occur on undivided urban roadways, on the other place, rural undivided roadway have approximately 42 percent of all fatalities (NHTSA, 2010). Road section with dedicated lane for motorcycle impacts on motorcyclist behavior in increasing speed (Ambarwati et al, 2014). Here with, space and minimum pore size is set in road section in order to minimize the number of motorcycle accidents.

The accident occurrence rate is in line with increase of traffic volume. Accident occurrence rate increases 7-8% by rising 10% of traffic volume. Speed also has an effect on accident occurrence rate. Minimum number of accident occurs in speed 40 kph in highland region (Wicaksono et al, 2010). Forty percent of all motorcyclist fatalities are associated with speed as a contributing factor. Speed is as a factor in the crash under the age of 30 (60 percent of all fatally injured motorcyclists) (NHTSA, 2010).

Insufficient research concerns on motorcyclist behavior and factors caused accident on highlands region due to geometric road and traffic condition with motorcyclist as victims.

Briefly, the research focuses on description of motorcyclist characteristics and developing model with influence of geometry and traffic on the number of accidents in the city of Malang, ±556 m above mean sea level.

The remaining paper is organized as follows. Motorcyclist behavior and characteristics, and accidents model is explained in Section 2, methods, clarifying significance of variables influencing motorcycle accidents is described in the following sections. Results and Discussions section explains how to describe the variables influencing accidents model in detail. Finally, the study concludes information and recommends some effort to minimize motorcycle accidents.

2. Motorcycle accident

2.1 Motorcycle behavior

Motorcyclist has high risk in accident with the age of 16-30 due to lowest discipline in obeying law (Warpani, 2002). Education also influences on motorcyclist discipline when driving.

Experience in driving is also important factor in controlling motorcyclist behavior. Education concerning on interaction of human-vehicle-environment and driving skill has an effect on driver behavior (Khisty and Kent, 2005). The usage of motorcycle depends on the number of motorcycle licenses and members using public transportation in household (Hsu, 2007). According to Hsu (2007), in Taichung, the motorcycle usage has effects directly its ownership and indirectly in usage of car and public. In Kaohsiung, due to the inconvenience of public transportation, car ownership and motorcycle ownership increase.

2.2 Motorcycle accident model

Motorcycle accident model is developed applying Generalized Linear Model (GLM), the format of the model is as follows:

$$A = kQ^{\alpha} \quad (1)$$

$$A = kQ^{\alpha} e^{b_1 x_1 + \ldots + b_n x_n} \quad (2)$$

which *A* is the average number of automobile accidents in a year, *Q* is traffic flow, x_1, x_2 ... is variable and $\alpha, k, b_1, b_2,$ ...is parameters to be estimated.

Motorcycle accident occurs in either times whenever and location wherever and many factors involving. Estimation of the total of motorcycle accidents in the future is applied by Generalized Linear Model representing the probability distribution(Aitkin et al, 1989; Swan et al, 1994).

Applying GLM is set up to understand motorcycle accident with distribution parameter of traffic variables (volume and speed) and highway geometric variables, i.e. the number of lanes, lane width, road shoulder width, the number of access road, and pedestrian walkway width.

3. Methods

Steps for developing model aims to identify relationship between the number of motorcycle accident (response variable) and traffic variables also geometric road variables (explanatory variables). This study will determine model between response variable and explanatory variables on ten road section in the city of Malang identified as black spot (high number of motorcycle accident). Algorithmic model applies multiple regressions with response variable (the number of motorcycle accident) and explanatory variables (traffic flow, speed, number of lanes, lane width, road shoulder width, the number of access road, walkway width).

The number of motorcycle accident can be predicted for the future years with those explanatory variables determined. Here with, checking the suitability of the distribution of each variable is required. The analysis is done by using the number of motorcycle accidents (*MCA)* as the dependence variable or response variable. Five percent significance level as requirement in estimation of model parameter is set up in algorithmic analysis. The model fit should have high correlation between response and explanatory variables by finding correlation value (*r*) approximately ±1. Other statistical tests are conducted by measuring coefficient of determination, value of *F* and *t*.

The statistical tests are explained as follow:

a. Determining the hypothesis.
Ho means that there is no significant relationship, whereas H_1 explains there is a significant relationship between the number of motorcycle accidents (*MCA)* and explanatory variables, i.e. the number of lanes, lane width, road shoulder width, the number of access road, and pedestrian walkway width.

b. Determining the significant levels.
Two-tailed test is used with a significant level $\alpha = 5\%$ on both sides in order to determine a significant correlation.

c. F test
With F test, significant value (*sig*.) < α means H_o rejected, inversely significant value (*sig*.) is concluded H_o accepted

d. t-test
by using t-test, H_o is rejected if $Sig. \langle \alpha$, whereas H_o is accepted

e. Formulating the model.
After the F test and t-test, the correlation result of the relationship between the response and explanatory variables can be known from the level of significance, and then the next analysis formulates the model from all explanatory variables (independent variables) and a response variable (dependent variable) (Tamin, 2000).

The proposed model is as follows:

$$MCA = k \quad Q^{\beta_0} e^{(\beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n)} \quad (3)$$

Where *MCA* is the number of motorcycle accident, *Q* is the traffic volume, *k* and β are parameters to be estimated, and *x* is an explanatory variable (independent variable). Equation (4) is an approach of nonlinear equations to simplify a linear calculation. With Logarithmic transformation, the Log-linear form of the model is:

$$\ln(MCA) = \ln(k) + \beta_0 \ln(Q) + \beta_1 (x_1) + \beta_2 (x_2) + \ldots + \beta_n (x_n) \quad (4)$$

Prediction of the factors that cause accidents is an effort to improve the safety of motorcycle drivers. The model of motorcycle accident is based on road geometric characteristics and traffic. This model is to predict proposed several action programs in order to improve the safety of motorcycle drivers in the city of Malang.

4. Results and discussions

4.1 Motorcycle characteristic

Motorcyclist characteristics are important factors in planning and design for motorcycle infrastructure such as exclusive motorcycle lane in order to minimize the number of motorcycle accident. Their characteristics include age, sex, education, income, career, the number of motorcycles and ownership.

The characteristics of motorcyclist in the city of Malang are as follows:

a. Most of motorcyclist is male (± 70%) in age of 17-35 years (60%) with education background 79% passed from junior high school-senior high school.

b. Most of motorcyclist has income 1-2 million IDR as private employees. They have motorcycle ±1-3 units.

c. Sixty percent of respondents had had an accident 1-2 times (32%) with light injuries (26%), serious injuries (11%), and no injury (3%). Accidents occurred at noon (11%) and evening (13%) caused by accidents with other motorcycles (13%) and self-fault (joking, sleepy, etc.)± (11%).

4.2 Road and traffic condition

According to technically and its function, road is ideal which has high strength, safe, and comfort. Road geometry is needed to develop motorcycle accident model. Road geometry is as explanatory variables in model, i.e. number of lanes, lane width, road shoulder width, the number of access roads, walkway width. Road geometry is investigated concurrently with a survey of traffic conditions for ten roads.

Traffic variables are applied in the accident model, i.e. traffic volume and speed. From traffic volume data indicates that highest traffic volume happened on Raya Areng-areng/ Raya Dadaprejo Street on 07.50-09.50 a.m. approximately 3,710 vehicles/hour. This road is a gateway to Batu City from the municipality of Malang, as consequence a lot of vehicles and many workers go to the central city of Malang. The lowest traffic volume occurs on 07.00-08.00 a.m. at Brigjen Abdul Manan Street ± 1,012 vehicles/hour. The traffic condition indicates many workers going to the government office of municipality of Batu, as shown in Table 1.

Table 1. Geometric condition for each road**.**

Street	Road length (m)	The number of accidents	Traffic Volume (vehicles/h)	Motorcycle Volume (vehicles/h)	Speed (km/h)	Lane width (m)	Shoulder width (m)	The number of lanes	The number of access roads	Walkway width (m)
Hayam Wuruk Gondanglegi	2,400	25	1,526	1,302	40.97	6	2.7	2	38	0
Raya Bululawang (Raya Wandanpuro)	1,500	38	1,236	954	42.34	6.5	1.25	2	40	1.6
Sultan Agung Kepanjen	600	37	1,110	889	41.218	5	3	2	9	2.1
Panglima Sudirman/ Mojosari Kepanjen	2,200	23	1,226	866	36.27	5	2	2	33	1.5
Raya Genengan	1,000	29	1,170	743	36.24	5	1.5	2	31	0
Brigjen Abdul Manan Pujon	17,500	29	1,012	1391	46.68	6	1.75	2	65	1.37
Raya Mojorejo Batu	2,000	32	1,987	1406	35.51	6	1.5	2	22	1
Panglima Sudirman Batu	1,600	27	2,009	601	43.32	9	1	4	28	2
Pattimura Batu	1,700	23	3,055	2139	32.64	6	1.5	2	35	1.5
Raya Areng-areng (Raya Dadaprejo/ Soekarno)	1,600	52	3,710	2,597	48.22	10	1	4	20	0

Table 1 informs traffic condition and road geometric characteristics which are needed to develop motorcycle accident model. The number of accident depends on road geometry and traffic condition, in detail as follows:

a) The highest accidents occur on Raya Areng-areng/ Dadaprejo Street because traffic volume is the highest ±3,710 vehicles/ hour and 85% of speed is about 43.32 km/hour. This road has specific characteristics such as 1,600 m of road length, 20 access roads, 10 m (lane width), 1 m (shoulder width), 0 m (walkway width) and 4 lanes. As consequences, this road causes 52 accidents.

b) On the other hand, the lowest accident, 5 incidents occur on Mojosari and Pattimura Street with 2,200 m and 1,700m for the length, 5 m and 6m (lane width), 2 m and 1.5 m (shoulder width), 1.5 m and 1.5 m (walkway width) and only 2 lanes respectively. These roads are passed through 1,226 and 3,055 vehicles/hour with 36.27 and 32.64 km/hour (85% of speed) respectively.

4.3 Accident characteristic of motorcyclist

Data from Police Department of the city of Malang municipality during four years (2016-2019), it is pointed out that the characteristics of accident include the number of accident, the types of vehicle involved, time of accident, the location, total value of vehicle losses. The accident characteristic which involve motorcyclist as victim has feature as follows:

1) The total of accident in 2019 for the city of Malang which motorcyclist is as victim is 316 incidents. Based on the severity of accident victims, there were 26 fatalities (8%), 107 heavy-injured victims (34%), and 183 light-injured victims (58%). Eight percent of victims are fatal accidents which indicate that motorcycle accident causes serious problem for motorcyclist. Special infrastructure for motorcyclist is poor facilitation which is shown by all cross section of roads without lane for two-wheel vehicles
2) Eighty two percent of respondents hope local government providing the motorcycle lane with markings on the surface of road (64%) or exclusive lane separated by median (32%). Most of motorcyclists wish that local government facilitate one or two special lane for motorcycle movement with more than 1.75 m of lane width.
3) Most respondents (95%) always use motorcycle even though they already have other type of vehicles.
4) The types of vehicle involved in accidents within pedestrian as victim are dominated by crashing with motorcycle (more than 75%), followed by car.

4.4 Analysis of Accidents

Analysis of motorcycle accidents on ten roads in the city of Malang is carried out to develop accident model based on traffic condition and road geometry on ten roads, as shown the following Table 2.

The data of 10 roads are processing by performing several iterations. From the analysis, it is shown that the best and most significant parameters can be identified from 10 roads in the city of Malang, as explained in Table II. Table II shows that the highest number of accidents involving cars in in the city of Malang is on Raya Areng-areng/ Dadaprejo Street, which is 54 incidents in 2016-2019

Table 2. Accident data in the city of Malang**.**

Street	Acc	ln(Acc)	F (vehicles/h)	Ln(F)	Speed (km/h)	Lane width (m)	Shoulder width (m)	Number of lane	Number of access	Walkway width (m)
Hayam Wuruk Glegi	25	3.219	1526	7.330	40.97	6	2.7	2	38	0
Raya Bululawang	38	3.638	**1236**	7.120	42.34	6.5	1.25	2	40	1.6
Sultan Agung Kepanjen	37	3.611	1110	7.012	40.22	5	3	2	9	2.1
Mojosari Kepanjen	23	3.135	1226	7.112	36.27	5	2	2	33	1.5
Raya Genengan	29	3.367	1170	7.065	36.24	5	1.5	2	31	0
Brigjen A.Manan Pujon	29	3.367	1012	6.920	46.68	6	1.75	2	65	1.37
Raya Mojorejo Batu	32	3.466	1987	7.594	35.51	6	1.5	2	22	1
P. Sudirman batu	27	3.296	2009	7.605	43.32	9	1	4	28	2
Pattimura Batu	23	3.135	3055	8.025	32.64	6	1.5	2	35	1.5
Raya Areng-areng	54	3.989	3710	8.219	48.22	10	1	4	20	0

Note: MC_A= total of motorcycle accidents; *Flow* = traffic volume, *S*= speed, *LW* = lane width, S*W* = shoulder width, NL = number of lane, *NA* = number of access, *WW*= walkway width.

4.5 Development model for motorcycle accident

The following table will describe the steps to estimate the initial parameters in the case of the car accident on the road sections.

Table 3. Model summary**.**

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	1.000[a]	1.000	0.999	0.009951

a. Dependent Variable: $LnMC_A$
b. Predictors: (Constant), walkway width, the number of access roads, shoulder width, speed, Lnflow, The number of lanes, lane width.

Table 4. Anova**.**

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	0.601	7	0.086	867.081	0.001[b]
	Residual	0.000	2	0.000		
	Total	0.601	9			

a. Dependent Variable: $LnMC_A$
b. Predictors: (Constant), walkway width, the number of access roads, shoulder width, speed, Lnflow, The number of lanes, lane width.

The results of the analysis explain that the value of coefficient value of determination (R square or adjusted R square) is 1.000. From the model set up, the variables involved significantly in developing motorcycle accident model are traffic volume and speed (traffic comdition); total of access road, lane width, shoulder width, the number of lanes and walkway width (road geometry).

Table III explained that the value of R is equal to 1.000, meaning variability of motorcycle accidents as a response variable explained by the traffic volume and speed (traffic condition) and road geometry variables (total of access road, lane width, shoulder width, the number of lanes and walkway width) as independent variables of about 100%.

Analysis of simultaneous influence (F test) in Table IV is used to find out whether independent variables have simultaneously effect on response variables or dependent variables. It can be seen at the value of F = 867.081 with significant level of 0.001. The value of significance level (α) has to less than 0.05 (Sig.< α), 0,001< 0,05 means independent variables of traffic volume, speed, lane width, shoulder width, number of lane, number of access, walkway width have simultaneously effect to the level of motorcycle accidents on highways in the city of Malang.

In Table V, the coefficient describes the influence of each independent variable to the dependent variable. There are seven independent variables included in the model because the asymptotic significant values are smaller than 0.05. It is concluded that traffic volume and speed (traffic condition) and road geometry variables (lane width, shoulder width, number of lane, number of access, walkway width) influence motorcycle accident on the city of Malang. From the analysis of t-test for each independent variable, speed and traffic volume (traffic condition) and road geometry variables (lane width, shoulder width, number of lane, number of access, walkway width) have *t* values less than 0.05, i.e. *Sig.t* = 5.705 and 38.692 (traffic condition), -4.619, -33.295, -19.741, -58.058, -7.547 (geometry variables) respectively.

4.6 Motorcycle accident model for the city of Malang

Motorcycle accident model on the highway in the city of Malang is developed by Generalized Linear Model (GLM), From equation (3) with respect to Table-II, the model is developed with a coefficient value of the parameter using the following equation:

$$MCA = kQ^{\alpha} e^{(b_1 g_1 + b_2 g_2 + b_3 g_3 + b_4 g_4 + b_5 g_5 + b_6 g_6)} \quad (5)$$

where:
MCA = the number of car accidents
Q = traffic volume
g_1 = speed
g_2 = lane width

Table 5. Coefficient of the model**.**

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	1.422	0.178		7.985	0.01
	Flow	0.127	0.022	0.220	5.705	0.02
	Speed	0.086	0.002	1.695	38.692	0.00
	LW	-0.067	0.015	-0.445	-4.619	0.04
	SW	-0.316	0.009	-0.867	-33.295	0.00
	NL	-0.319	0.016	-1.039	-19.741	0.00
	NA	-0.020	0.000	-1.174	-58.058	0.00
	WW	-0.033	0.004	-0.105	-7.547	0.01

a. Dependent Variable: $LnMC_A$
b. MC_A= total of motorcycle accidents; *Flow* =traffi volume, *S*= speed, *LW* = lane width, S*W* = should

g_3 = shoulder width (SW).
g_4 = the number of lanes (NL)
g_5 = total of access road (NA)
g_6 = walkway width (WW)

$k, \alpha, b_1, b_2, b_3, b_4 =$ parameter.

Motorcycle accident model is set as follows:

$$MCA = kQ^{\alpha} e^{(b_1 Speed + b_2 LN + b_3 SW + b_4 NL + b_5 NA + b_6 .WW)} \quad (6)$$

To develop accident model, nonlinear regression equation is set. The result is explained in Table V. The model is:

$$MCA = 0.1422.Flow^{0,127} e^{0.086S - 0..067.LW - 0.316SW - 0.319NL - 0.020NA - 0.033WW} \quad (7)$$

where:

MCA = Motorcycle accidents (accident / year).
Flow = traffic volume (vehicles/hour)
S = speed (km/hour)
LW = lane width (m)
SW = shoulder width (m)
NL = number of lane (unit)
NA = number of access (unit)
WW = walkway width (m)

4.7 Assumption of motorcycle accident model

Assumption id required to develop model, which has a limitation regarding to the existing location characteristics. The model is set up regarding to traffic characteristics and elements of the road segment as follows:

Location : urban area.
Traffic volume : 1,012 - 3,710 vehicles/hour
Speed of vehicle : 32.64- 48.22 km/hour (85 percentile speed)
Lane width : 5 - 10 m
Shoulder width : 1 - 3 m
Number of lane : 2 - 4
Number of access : 9 - 65
Walkway width : 0 - 2.1m

4.8 Contribution of accident model

Analysis of the contribution of each explanatory variable (flow, speed, lane width, shoulder width, number of lane, number of access, walkway width) to the number of car accident is conducted.

1. *Influence of traffic volume on the number of accidents*

From the analysis, volume of motorcycles has significant effect on the number of motorcycle accidents.

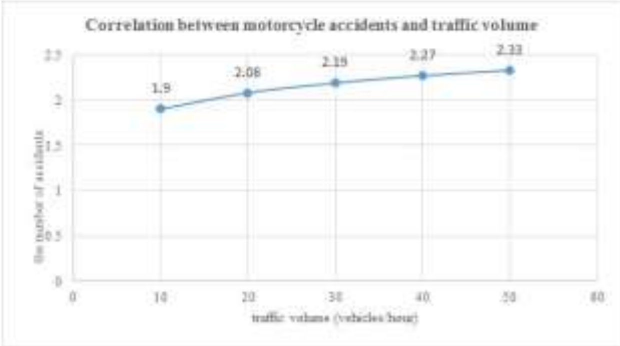

Fig. 1. Correlation of motorcycle accidents (response variable) and traffic volume (explanatory variable)

The coefficient of traffic volume + 0.127 means that under stable speed and geometry road conditions, an increase of 1 value of car speed will increase car accident as much as multiplication of $e^{0.127}$ or multiplication of 1.422. The number of motorcycle accidents will increase in line with the increase of motorcycle volume on the roads in the city of Malang. The growth of car volume approximately 5% will increase the number of car accidents of 63.28%, as explained in Fig.1.

The result of the analysis reveals that the number of accidents increases according to the increase of traffic volume and in line with previous studies. A double of traffic volumes on major approaches at intersection is estimated to increase a potential accident of 46%, and a double of traffic volume on minor approaches can increase potential accident up to 13% (Mountain, 1998).

2. *Effect of speed on the number of accidents*

The coefficient of speed + 0.086 means that under steady traffic volume and geometry road conditions, an increase of 1 value of car speed will increase car accident as much as multiplication of $e^{0.086}$ or multiplication of 1.091. An increase of motorcycle speed ±10% will increase the number of motorcycle accidents by 0.9%, as illustrated in Fig.2. Fig.2 illustrates that the higher speed will increase the number of motorcycle accidents.

The results of this study support research of Andrew (1999) which stated that an increase of 10 mph of vehicle speed increases accidents up to 33% at 3-legs of the un-signal intersection, 21% at 4-legs of un-signal intersections in the urban areas and 40% of crashes at 4-legs un-signal intersections in the periphery of town areas. An increase of speed 10 mph is predicted to increase car accidents with serious injury and death ± 14% (Frank and Nuyts, 2006).

3. Effect of lane width on the number of accidents

The coefficient of lane width -0.067 means that under stable traffic conditions and other geometry road

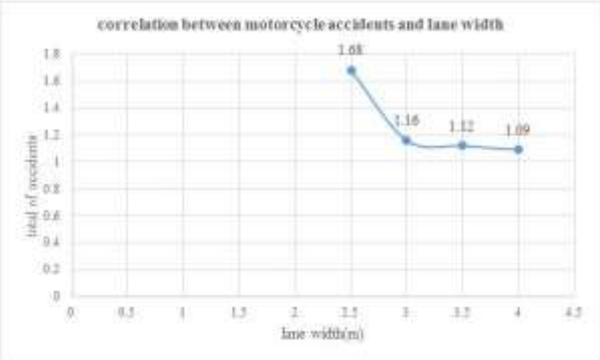

Fig.3. Correlation between motorcycle accidents and lane width

variables, an increase of 1 value of lane width will reduce motorcycle accident as much as multiplication of $e^{-0.067}$ or multiplication of 0.935. An addition of lane width 50% will reduce the number of motorcycle accidents by 3.31%, as illustrated in Fig.3. The wider lane width will lessen the number of motorcycle accidents.

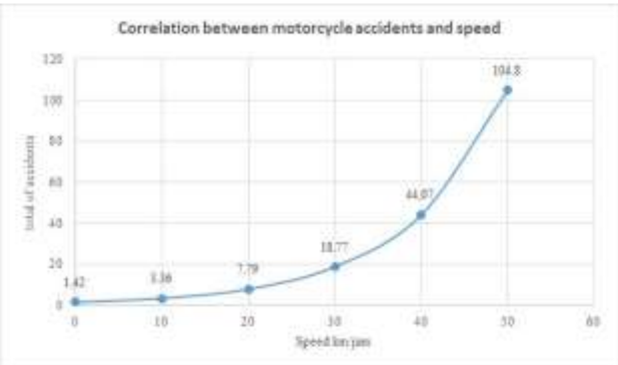

Fig.2. Correlation between motorcycle accidents and speed

4. Effect of shoulder width on the number of accidents

The coefficient of lane width -0.316 means that an increase of 1 value of shoulder width will increase motorcycle accident as much as multiplication of $e^{-0.316}$ or multiplication of 0.729. With stable traffic conditions and other geometry road variables, an addition of shoulder width 25% will reduce the number of motorcycle accidents by 7.72%, as illustrated in Fig.4. The wider shoulder width will decrease the number of motorcycle accidents.

5. Effect of the number of lane on the number of accidents

The coefficient of speed -0.319 means that an increase of 1 value of number of lane will decrease accident as much as multiplication of $e^{-0.319}$ or multiplication of 0.727. With stable traffic conditions and other geometry road variables, an increase of number of

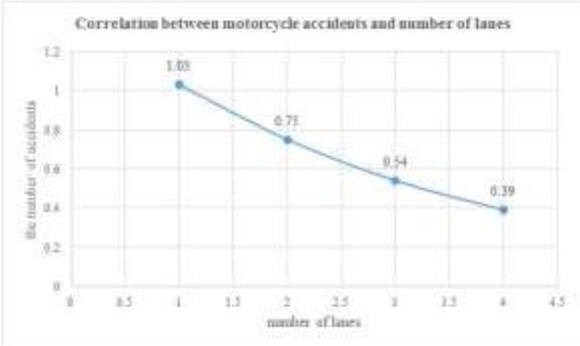

Fig 5. Correlation between motorcycle accident and number of lanes

lane 100% will reduce the number of motorcycle accidents by 27.37% per year, as illustrated in Fig.5. Fig.5 illustrates that the higher number of lane lessens the number of motorcycle accidents.

6. Effect of the number of access on the number of accidents

The coefficient of speed - 0.02 means that that under stable traffic conditions and other geometry road variables, an increase of 1 value of the number of access will diminish motorcycle accident as much as multiplication of $e^{-0.02}$ or multiplication of 0.98. An addition

Fig.4. Correlation between motorcycle accident and shoulder width

of the number of access 10 units decreases the number of motorcycle accidents by 18.13%, as illustrated in Fig.6. Fig.6 illustrates that the higher access road will decline the number of motorcycle accidents because motorcyclist will be carefully and reduce speed when driving.

7. Effect of walkway width on the number of accidents

The coefficient of walkway width -0.033 means that an increase of 1 value of shoulder width will reduce motorcycle accident as much as multiplication of $e^{-0.033}$ or multiplication of 0.97. With stable traffic conditions and other geometry road variables, an addition of walkway width 25% will reduce the number of motorcycle accidents by 0.77%, as illustrated in Fig.7. The wider

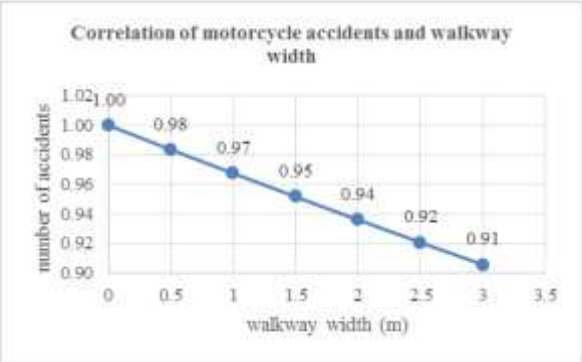

Fig 7. Correlation between motorcycle accident and walkway width

walkway width influences comfortable pedestrian when walking and minimizes the number of motorcycle accidents.

5. Conclusions

1. Motorcyclist is as victim who is identified as follows male (± 70%) in age of 17-35 years (60%) with education background 79% passed from junior high school-senior high school. They have income 1-2 million IDR as private employees and motorcycle ±1-3 units. They (60% of respondents) had had an

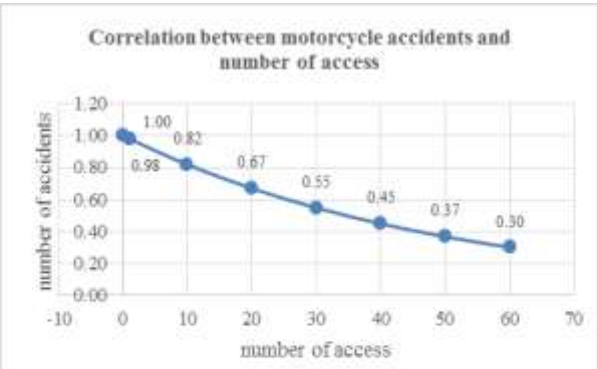

Fig 6. Correlation between speed and motorcycle accident

accident 1-2 times (32%) with light injuries (26%) occurring at noon (11%) and evening (13%) caused by accidents with other motorcycles (13%) and self-fault (joking, sleepy, etc.) (11%).

2. Traffic characteristics and road geometry are as explanatory variables in developing motorcycle accident model with case study area, the city of Malang. The model can be explained:

a. Significant variables of traffic condition influencing motorcycle accident on several road sections as black spot in the city of Malang are speed and traffic volume.

b. Geometric characteristics such as lane width, shoulder width, number of lanes, number of access and walkway width have also significant effects on motorcycle accident.

3. The analysis of significant variables influencing on motorcycle accident proves traffic condition and road geometry as major factors, as shown in this model:

$$MCA = 0.1422.Flow^{0,127} e^{0.086S - 0..067.LW - 0.316.SW - 0.319.NL - 0.020.NA - 0.033WW)}$$

which:

MCA = Motorcycle accidents (accident / year).
Flow = traffic volume (pcu/hr)
S = speed (km/hr)
LW = lane width(m)
SW = shoulder width (m)
NL = number of lane (unit)
NA = number of access (unit)
WW = walkway width(m)

4. The contribution of this research revealed that speed and traffic volume (traffic condition) and road geometry variables (lane width, shoulder width, number of lane, number of access, walkway width) significantly have the effect on the number of motorcycle accidents. The number of motorcycle accidents will rise with the increase in vehicle volume and speed, on the other hand, will reduce with the addition of lane width, shoulder width, number of lane, number of access, walkway width

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