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Accident Frequency Model Based on Microscopic Characteristics of Heterogeneous Traffic in Makassar City

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Abstract: Heterogeneous traffic in urban arterial roads are many developing cities in Makassar city, leads to the high potential of traffic accident occurs in the cities. Regarding the issue, the present study aims to model the traffic accident frequency which occurred in urban arterial roads which case study in Makassar city, Indonesia. This study constructed the model based on microscopic characteristics of the heterogeneous traffic, namely longitudinal distance and lateral distance between two nearby vehicles. The data collection involved two stages. Firstly, the data collection for traffic accident characteristics which occurred in the city and secondly, the traffic characteristics, namely traffic flow in arterial roads of the city. There were three steps in constructing the traffic accident frequency model. The first step applied a micro-traffic simulation in calibrating the microscopic characteristic values. The second developed a relationship model between traffic flow and both microscopic traffic characteristics. The third step constructed the traffic accident frequency model using the longitudinal and lateral distance between two nearby vehicles. The model was acceptable regarding root mean square error test. The model is useful in estimating the traffic accident number in urban arterial roads in developing cities where its traffic characteristic are heterogeneous.

Key words: Traffic accident frequency, microscopic traffic characteristic, heterogenous traffic, urban arterial roads estimating, characteristics

INTRODUCTION

One of the most common phenomena in developing countries is the high number of accidents. Makassar city is one of the big cities in Indonesia with accident rate reaching 3.2 people per day who become accident victim (Halim *et al*., 2017a, b). The high number of accidents in a region requires developing prediction models of accident level. Several previous studies that examine accident model prediction such as Ki Joon Kim and Jaehoon Sul who do accidental prediction research in Sungnam city with micro simulation. Another study explored mathematical models that could be used to predict accidents number, on an inter-city toll road section (Haryadi, 2011). Periodic series modelling is conducted to predict accident number, deaths, serious injuries, minor injuries and material loss due to accidents in Indonesia (Suprayoga, 2014). In addition to predicting accident rates, some researchers predict accidents in aspects of traffic accidents severity (Zong *et al*., 2013).

In making an accident prediction the form of a mathematical model must be logically acceptable to that model does not predict a negative value of accident number and it must be ensured that zero value of the free variable in use will result in a zero-valued of accident rate (Sawalha and Sayed, 2006). Various models approach used to predict accident frequency included using Poisson regression model, binomial negative regression model, zero-inflated poisson regression model and zero-inflated negative binomial regression model (Rakhmat *et al*., 2012). Model Generalized Linear Modelling (GLM) is one of the most commonly used methods to predict accident frequency. This model is used in accident formation model predictions with data not assumed normal distributed (Machsus *et al*., 2013).

An accident is an unexpected and unplanned event due to an accident influenced by several factors: human, vehicle, road and environment or the interaction of several factors. In addition to these factors, macro traffic factor is very supportive of accidents. Research conducted by Haryadi *et al*. (2009) revealed that the frequency of accidents is influenced by traffic volume factors. The model of the relationship between the frequency of accidents and the volume of traffic is expressed in the exponential function (Haryadi *et al*., 2009). Road geometric factors play an important role in the occurrence of accidents. Research related to this as done by Sumarsono *et al*. (2010) in his research make the prediction model of accident rate is the relationship between traffic accidents in the corner with horizontal alignment in the geometric design of the road.

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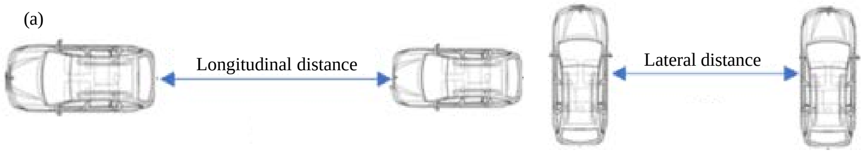

Fig. 1: a) Illustration of longitudinal distance and b) Lateral distance

Generally, in the research the factors used in analysing are geometric road characteristics and traffic flow characteristics. The accidents risk is not only affected by external of a driver but internal factors of a driver. Internal factors are microscopic conditions one of which is the longitudinal distance (headway) and lateral distance. This distance describes driver behaviour in placing his vehicle either in a longitudinal or lateral direction, so as not to cause accidents with other vehicles. Therefore, this study aims to model accident frequency of the microscopic characteristic in heterogeneous traffic conditions.

Definition of accidents: The definition of traffic accidents is widely contained in various studies, journals and the legislation of a country. One of the traffic accidents definition as mentioned in the government regulation. The legislation states that a traffic accident is an unexpected and unintended road accident involving a moving vehicle with or without other road users, resulting in human casualties and property loss.

Microscopic characteristics of traffic flow: Traffic flow is formed from the movement of individual riders and vehicles that interact with each other on the road and the environment. One such linked form is in the form of microscopic conditions. Microscopic is the behaviour of individual vehicles in parts of traffic flow related to each other's interaction. The microscopic approach examines several important parameters that greatly affect the response to the vehicle itself in road traffic as well as parameters such as spacing, headway, lane occupancy and gap (clearance) (Budiarto and Mahmudah, 2007).

The microscopic concept of traffic flows that is intended in this study is driver ability to maintain a safe distance between vehicles both from a direct movement or opposite movement. Thus, there are two distances to be noticed by a driver that is longitudinal and lateral distance. The longitudinal distance is a safe distance between two vehicles for longitudinal direction while the lateral distance is a safe distance between vehicles for lateral direction (Fig. 1).

Microscopic traffic simulation-based safety assessment: The microscopic traffic approach can use support software to facilitate traffic simulation, one of which is VISSIM device. In recent years some researchers have used VISSIM as a support software in traffic-based simulation-related traffic decisions. Some of the studies related to the use of VISSIM include safety analysis of roundabouts, traffic safety analysis of toll road traffic flows, security implications of mandatory speed limiters for trucks. Other studies are about assessing aggressive driving safety on the highway, the safety benefits of vehicle-driven signal control, security comparison and priority ranking of the geometric layout of the intersection. The advantages of simulation-based security analysis are fast, low cost and can be used to assess the broad network security implications including un-built infrastructure and unexplored traffic management strategies (Habtemichael and Santos, 2012).

Driver behaviour parameters: Driver's behaviour is an individual matter that is likely to occur in the field due to interaction with other factors such as vehicle distance, acceleration, deceleration and existing traffic rules. In VISSIM can set behaviour, the behaviour of the driver by determining its parameters based on the car-following model, following behaviour, lane change behaviour, lateral behaviour and behaviour at signal controllers. In VISSIM there are three following car models in managing driver behaviour in modelling there is no interaction, Wiedemann 74 and Wiedemann 99. No. interactions are used for vehicles that do not recognize other vehicles. The Wiedemann 74 Model is suitable for both urban and joint traffic. While the Wiedemann 99 Model is suitable for roads without regional merging. In the Wiedemann 74 Model for urban areas there are three available parameters: average standstill distance additive part of safety distance and multiplicative part of safety distance.

The concept of accident modelling: The concept of an approach to making an accident prediction is to use a conventional linear regression when data is included normally distributed. Another concept that can be used is

Generalized Linear Modelling (GLM). This method is used if observation data (response variable) is not normally distributed. Regression analysis is a statistical method that is widely used in research. Simple regression analysis is an approach method of relationship modelling between one dependent variable and one independent variable. In a regression model, the independent variable describes the dependent variable. In a simple regression analysis, the relationship between variables is linear where the change in variable x will be followed by changes in variable y constantly. While in the non-linear relationship, the change of variable x is not followed by the change of y variable proportionally. In this research, the dependent variable is accident frequency and independent variables are longitudinal distance and lateral distance.

The model of the curve equation used is model of linear equation, polynomial, exponential and logarithmic. These four models are compared and the model has the largest R^2 value as the model selected for further analysis (Syilfi *et al.*, 2012).

MATRIALS AND METHODS

Research sites: The research location which is an object of research is road segment that fell into a category of AC for the ident-prone area. The crash-prone areas in Makassar are Perintis Kemerdekaan Street, Urip Sumiharjo Street and Pettarani Street (Halim *et al.*, 2017a, b). As for the formation of models and validation of several road models that exist in Makassar city. Data collection was obtained from traffic unit of Makassar city traffic police. The accident data used is accident data onto 2012-2015.

Data collection: In data collection there are two types of data collected, i.e., data related to macroscopic and microscopic characteristics. For macroscopic data, retrieval is done by recording traffic conditions. This recording aimsto obtain data ontraffic volume and speed of a road segment. Traffic volume data is calculated using traffic counting method of 06:00-21:00 O'clock by classifying vehicle type to 11 kinds. While next primary data is inventory data/road geometric that is done manually. Speed velocity measurements and free current speeds are used for speed gun velocity. This tool serves to measure a speed of moving objects. To obtain data ontomicroscopic characteristics of traffic flows associated with longitudinal distances and lateral distances used VISSIM Software. The use of this software requires secondary data onto a form of aerial photographs taken from Google Earth to facilitate the depiction/creation of VISSIM road network.

Table 1: Characteristics of traffic accidents in Makassar city in 2012-2015 period

	Years			
Indicators	2012	2013	2014	2015
Numbers of accidents	1,051	961	781	810
Numbers of victims	1,581	1,494	1,192	1,222
Died	139	133	114	115
Heavy injuries	293	257	228	56
Minor injuries	977	927	716	918
Material loss× 10^3 (IDR)	163.924	2.212,215	2.062,065	1.887,930
Number of the acciden location	200	207	180	170

Statistical test: A statistical test is necessary for a study as a tool for sample determination, validity testing and instrument reliability, data presentation and data analysis. In this research some statistical model is tested normality and variance test. Normality tested aims to prove whether a variable has distributed data normally or not. This is closely related to analytical methods to be used. If a data is not normally distributed then analysis uses model Generalized Linear Modelling (GLM). Normality tested can be done by testing Shapiro Wilk or Lilliefors and Kolmogorov Smirnov. The provisions of these two tests are if respondent ≥50 then Kolmogorov-Smirnov method used while if respondent ≥50 then using the Shapiro-Wilk method (Razali and Wah, 2011). Data can be said to have a normal distribution if significance level ≥0.05 ($p\geq 0.05$). The next statistical test is variance analysis. Tests are commonly known by the name of known F-test or simultaneous test which is a test to see how the effect of all independent variables together to dependent variables. While to regression models we make is significant or not significant. If the model is significant then used for prediction, otherwise if it is not significant then regression model cannot be used. Test F can be done by comparing F calculate with if F counts> from F table then the model is significant. Moreover, vice versa if F counts<F table then the model is not significant.

Curve equation model: The use of the approach to a curve equation models is one method that will be used to determine the relationship between two or more variables in the mathematical form. Some models of curve equation function are described in Table 1. From the equation, curve needs to be validated to determine the accuracy of a test or scale in performing its measurement function. Measurements can be said to have high validity when generating data that accurately provides an idea of a variable being measured as the purpose of measurement. There are several methods can be used to evaluate available data have produced the model. One method is coefficient of determination (R^2), correlation (r) and Root Mean Squared Error (RMSE).

The value of determination coefficient (R^2) can be used to predict an effect of a free variable (X) to the dependent variable (Y) with the result of F tests forsignificant regression analysis. Conversely, if F tested results are not significant then the value of determination coefficient (R^2) cannot be used to predict contribution effect of variable X to variable Y. The value of determination coefficient between 0-1. The smaller value then effects of independent variables to the dependent variable, otherwise if the value of R^2 is closer to 1 then the effect will be stronger. Whereas correlation coefficient symbolised by "r" is a measure of linear correlation (a relationship, both regarding magnitude and direction) between two variables. The correlation coefficient has a value of -1 to +1 with plus and minus signs indicating positive and negative correlations. If the correlation coefficient is exactly -1, the relationship between two variables is a perfect negative. Meanwhile, if the correlation coefficient is exactly +1, the relationship between two variables is perfectly positive.

Root Mean Squared Error is an alternative method of evaluating prediction techniques used to measure the accuracy of predictive model results. RMSE is an average value of sum squares error, it can also state error size generated by a predicted model. Mathematically, the formula is written as follows (Hermawati *et al*., 2017):

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\hat{y}_i - y_i)^2} \quad (1)$$

RESULTS AND DISCUSSION

Characteristic of traffic accident in Makassar city: As one of the cities in Indonesia which has a high growth vehicles rate, it gives impact on increasing number of accidents in Makassar city. In general, the data collected from traffic accident unit of police as an accident management authority on Makassar city provides an overview of an accident within last 4 years time frame of a period of 2011-2015 as in Table 1.

From the results of previous research it is known that there are 3 road segments identified as accident-prone locations with the weight of accident equivalent are greater than upper control limit (Halim *et al*., 2017a, b). The three streets are Perintis Kemerdekaan, Urip Sumiharjo and A.P Pettarani, based on traffic flow characteristics and geometric road characteristics simulated using VISSIM Software. For calibration process is done by forming appropriate parameter values, so that, model can replicate traffic to the closest possible conditions. The calibration process can be done based on the behaviour of observed area drivers. The method used is trial and error concerning previous studies on calibration and validation using VISSIM. Validation on VISSIM is the process of testing truth in calibration by comparing results of observation and simulation. The validation process is done based on volume amount of traffic flow. While the method used is statistical formula Geoffrey E. Havers (GEH). GEH is a modified statistical formula for Chi-squared by combining difference between relative and absolute values.

From the results of this simulation is known that traffic volume has a close relationship between longitudinal and lateral distance. This can be seen in Fig. 2a, b. From these two images we can find the relationship between traffic volume of longitudinal and lateral distance. It is also known that two equations have a high enough coefficient of determination >0.90 this shows that both variables have a strong relationship. These two equations are used to determine the longitudinal and lateral distance based on each road segment volume used as a study object. The road segment as a study object objected to as many as 13 road segment of different geometric conditions. The 13 segments are categorized as accident-prone areas. The accident-prone location is a site where accident number is high with the incidence of recurrent accidents in space and relatively same time span caused by a particular cause (Anonymous, 2004).

Using the equations in Fig. 2a, b based on traffic volume of each road segment we will know the microscopic characteristics of the road segment. Microscopic characteristics include Longitudinal distance (L_o) and Lateral distance (L_a). An overview of these thirteen road segments as related to traffic volume, microscopic characteristics and frequency of accidents as in Table 2.

Normality test: As have been previously described that normality testsare used to determine normal of distribution, distributed data or not. The formulation of hypothesis used is:

- H_0: distribution of normallydistributed observation data
- H_a: distribution of not normally distributed observation data

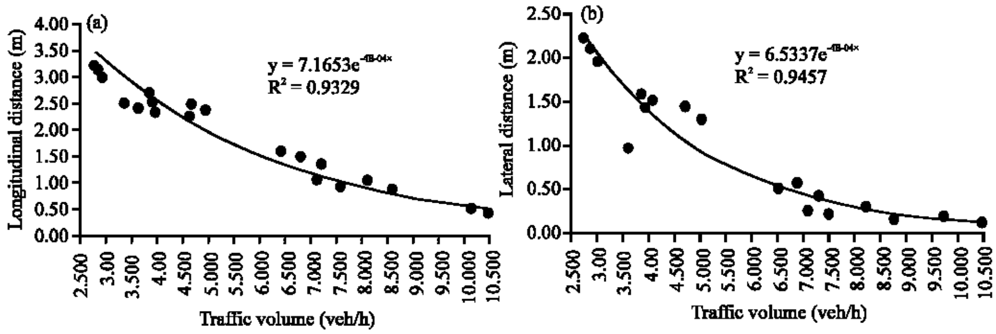

Fig. 2: a, b) The relationship between traffic volume and microscopic characteristics

Table 2: Traffic volume, microscopic characteristics and frequency of accident

Name of street	Traffic volume (vehicles/jam)	Microscopic characteristics L_o	Microscopic characteristics L_a	Accident frequency (Years) 2012	2013	2014	2015
Rajawali	2.498	3.42	2.20	4	5	5	3
Gagak	1.708	4.20	2.80	1	2	1	2
Abdullah Dg. Sirua	2.780	3.20	2.03	19	13	8	11
Antang Raya	2.928	3.09	1.94	0	11	5	5
Daeng Tata	3.273	3.22	2.21	9	12	4	6
Jend. Sudirman	5.067	1.96	1.07	19	17	13	15
Arif Rate	4.791	3.51	2.26	2	6	4	2
Haji Bau	1.604	4.33	2.90	2	2	2	1
Sam Ratulangi	4.460	1.78	1.12	16	10	15	14
Veteran Selatan	9.541	2.08	1.17	22	23	11	13
Veteran Utara	7.581	2.56	1.53	18	18	8	11
Hertasning	6.422	2.90	1.80	20	9	8	10
Boulevard	6.015	3.04	1.90	9	10	7	8

Table 3: Normality test for accident frequency

Parameters	Method: Kolmogorov-Smirnov	Shapiro-Wilk
Statistic	0.174	0.955
Sig.	0.200	0.668

Normality tests resultusing the statistical software as shown in Table 3. Table 3 describes results of normality test with the amount of data <50 then analysis used is Shapiro Wilk method. The result shows that p-value of the calculation resulted obtained the value equal to 0.668.This value is higher than 0.05 (>0.05), so that, it can be concluded H_0 accepted or distribution of normally distributed data. So that, modelling can be formed by line arregression mode land nonlinear.

Microscopic variable relation model and accident frequency: Furthermore, the accident frequency data onto Table 3 as a dependent variable and microscopic characteristic data are longitudinal and lateral distance as an independent variable. To analyse microscopic characteristics can be done by looking for patterns relationships of accident frequency. To determine the pattern is used curve matching to approach the test. The fit of curve model with observation data by calculating the

Table 4: Match value model curve to longitudinal distance

Equation	Model summary R^2	F-values	Sig.	Parameter estimates Constant	β1	β2
Linear	0.907	107.552	0.000	22.233	-5.040	
Logarithmic	0.932	149.875	0.000	22.654	-14.590	
Quadratic	0.930	66.217	0.000	30.295	-10.726	0.940
Exponential	0.853	63.859	0.000	83.642	-0.891	

Table 5: Match value model curve to lateral distance

Equation	Model summary R^2	F-values	Sig.	Parameter estimates Constant	β1	β2
Linear	0.896	94.965	0.000	19.841	-6.696	
Logarithmic	0.916	120.260	0.000	14.334	-12.126	
Quadratic	0.915	53.764	0.000	25.303	-12.869	1.596
Exponential	0.862	68.536	0.000	56.220	-1.197	

coefficient of determination (R^2). The curve with the highest R^2 values to indicate that curve has the best match rate of observed data compared to other curves. The results complete calculation of curve matching to test described in Table 4 and 5.

From Table 6 and 7 show that calculation results from Longitudinal distance parameter curves (L_o) and Lateral (L_a) shows relationship model with Logarithmic function can be used to predict the effect of a free variable (X) to the dependent variable (Y). This is based on logarithmic functions having the highest R^2 value compared to other

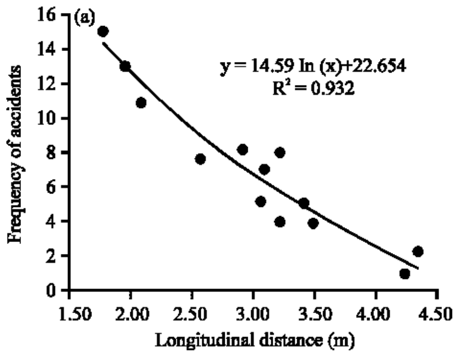

Fig. 3: a, b) The relationship model between accident frequence with microscopic characteristics

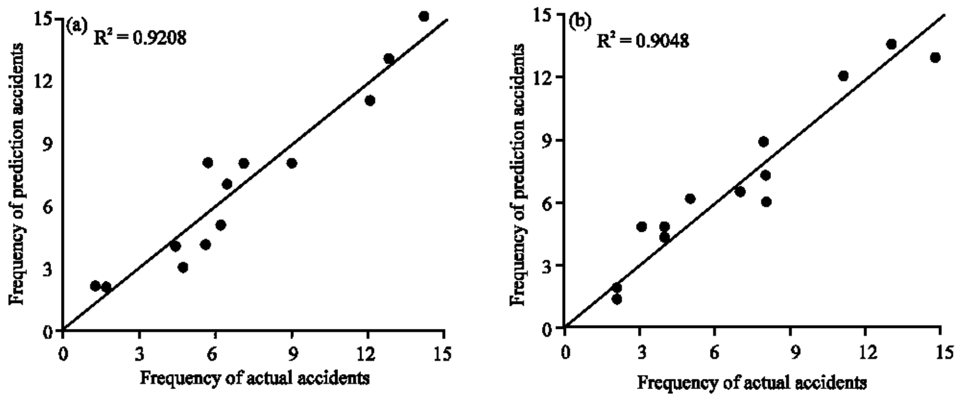

Fig. 4: a, b) Validation model of the relationship between the frequency of accidents with microscopic characteristics

Table 6: The value of t-test against regression coefficient for longitudinal distance

	Unstandardized coefficients		Standardized coefficients		
Parameters	β	SE	Beta	t-values	Sig.
$\ln(L_o)$	-14.590	1.189	-0.965	-12.242	0.0000
(Constant)	22.654	1.314		17.216	0.0000

Table 7: t-test value against regression coefficient for lateral distance

	Unstandardized coefficients		Standardized cofficients		
Parameters	β	SE	Beta	t-values	Sig.
$\ln(L_a)$	-12.124	1.106	-0.957	-10.966	0.000
(Constant)	14.326	0.753		19.026	0.000

functions. The model function of longitudinal distance parameters is Y = -14.59 ln (x)+22.654 with coefficient of determination R^2 = 0.932. As for lateral distance parameters show the same result that is forming a logarithmic relationship model with function model Y = -12.13 ln(x)+14 334 with coefficient of determination R^2 = 0.916

From ANOVA or F-test result it is known that F_{count} is 149, 875 for longitudinal parameter and lateral parameter equal to 120.260 with significance level 0.000 for both parameters. Therefore probability values <0.05 it can be concluded that regression model with logarithmic function can be used to predict accident frequency. To regression coefficient test for Longitudinal distance (L_o) and Lateral distance (L_a) parameters were used t-test. The hypothesis formed is:

- H_0: regression coefficient is not significant
- H_a: regression coefficient is significant

The t-test results are described in Table 6 for longitudinal distance parameters and Table 7 for lateral distance parameters. Table 6 and 7 not that probability value of both parameters are 0.000. If the probability value <0.05 then H_0 is rejected. So, it can be concluded that significant regression coefficient or longitudinal distance parameter and lateral distance significantly affected accident frequency. The curve relation of both parameters to accident frequency by using Logarithmic functions model as in Fig. 3 and 4.

Model checking: The model examination should be done to know whether the model can be used to predict accident frequency of Makassar or not. From equations in Fig. 3a, b, we can calculate prediction accident frequency as described in Table 8 and Fig. 4 illustrate results of validation model. From the table actual accident frequency and prediction accident frequency result based on longitudinal distance and lateral distance. Another result

Table 8: Comparison of actual accident frequency with RMSE prediction and value

	Accident frequency			Distance	
		Prediction		Longitudinal	Lateral
Road segment	Actual	L_o	L_a	$(\hat{y}-y)^2$	$(\hat{y}-y)^2$
Rajawali	3	4.7	4.8	2.900	3.200
Gagak	2	1.7	1.8	0.100	0.000
Abdullah Dg. Sirua	8	5.7	5.8	5.300	5.000
Antang Raya	5	6.2	6.3	1.400	1.600
Daeng Tata	4	5.6	4.7	2.500	0.500
Jend. Sudirman	13	12.8	13.5	0.000	0.300
Arif Rate	4	4.4	4.4	0.100	0.200
Haji Bau	2	1.3	1.4	0.500	0.400
Sam Ratulangi	15	14.2	12.9	0.600	4.400
Veteran Selatan	11	11.9	12.5	0.900	2.100
Veteran Utara	8	8.9	9.1	0.900	1.300
Hertasning	8	7.1	7.2	0.800	0.600
Boulevard	7	6.4	6.5	0.300	0.200
RMSE				1.125	1.233

is RMSE value for longitudinal distance RMSE value is 1.125 and for lateral distance value of 1.233. While in Fig. 4 shows determination coefficient (R^2) of microscopic characteristic. For longitudinal distance obtained of 0.9208 and for lateral distance obtained of 0.948.

These validation results show the level significance of the relationship between prediction result and actual observation is very good for RMSE value <10. Like wise with a result of a determinant coefficient to identify that longitudinal distance variable can explain 92.08% variation in accident frequency variable and lateral distance variables can explain 90.48% variations of accident frequency variables.

CONCLUSION

This study that examines traffic accidents in Makassar city concludes that microscopic characteristics affect accident frequency. The intended microscopic characteristic is driver's behaviour in maintaining a safe distance between vehicle's longitudinal direction and lateral direction. The model of the relationship between the frequency of accidents with microscopic characteristics has a model fit with a logarithmic function. From the logarithmic function and based on the Root Mean Squared Error (RMSE) test and the model validation using the coefficient of determination test shows that both models can significantly identify that the frequency of accidents can be explained by longitudinal distance variations and lateral distances. Thus, this model is useful in estimating the number of traffic accidents on urban arterial roads in developing cities where the traffic characteristics are heterogeneous.

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