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Identifying Accident Severity Factor on Surabaya Secondary Arterial Roads

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Abstract

One of the CBD (Central Business District) areas of Surabaya is located at the center of the city, which is also known as the CBD Tunjungan area. CBD Tunjungan area is a hub for trade and services and has important accessibility which is surrounded by secondary arterial roads. Some secondary arterial roads which have access and high mobility to the CBD Tunjungan Area are Darmo Raya Road, Urip Sumoharjo Road and Basuki Rahmat Road. The high activity and mobility in the CBD area cause several transportation problems, one example is traffic accidents. The traffic accident data by the Directorate of Traffic and City Resort Police of Surabaya show that there are quite a several traffic accidents on these two roads. Traffic accidents are divided into three levels of severity i.e. slight, serious, and fatal injuries. To obtain the probability model of traffic accidents within every accident severity, it is necessary to do an analysis using the multinomial logistic regression method. The independent variables such as vehicle speed, lane width, accident time, and accident type, are considered to affect the equation model. Thus, it can be discovered the variables that affect the probability at the three levels of traffic accident severity.

Keywords:
Accident Severity, Multinomial Logistic, Surabaya, Traffic accident

1. Introduction

Surabaya is one of the metropolitan cities in Indonesia with fairly advanced development and has many CBD (Central Business District) areas spread throughout the city (Safitri, Budisusanto, Deviantari, & Dediyono, 2016; Walikota Surabaya, 2014). One of the CBD centers located in the middle of Surabaya is the Tunjungan CBD area, and this area is the center of trade and services in Surabaya (I, Kurniawan, & Usman, 2010; Sistyaningsih & Kisnarini, 2017; Walikota Surabaya, 2014). Tunjungan CBD area has very crucial accessibility and is surrounded by secondary arterial roads such as Darmo Raya Road, Urip Sumoharjo Road, and Basuki Rahmat Road (Sistyaningsih & Kisnarini, 2017; Sulistiono, Mawardi, & Arifin, 2016; Syafi'i, Pambagus, & Kartika, 2020). The three roads become access to connect the CBD area with the southern part of Surabaya. The high activity and mobility in the CBD area cause several problems, one of which is a traffic accident (Bagloee & Asadi, 2016; Hermawan, 2016). Traffic accidents should be considered specifically as a safety aspect to facilitate a transportation system (H. Widyastuti & Budhi, 2020). In addition, road safety is also included in one aspect of environmentally friendly transportation (Machsus, Prayogo, Chomaedhi, Hayati, & Utanaka, 2017). Based on data obtained from the Directorate of Traffic and City Resort Police of Surabaya, on Darmo Raya Road, Urip Sumoharjo Road, and Basuki Rahmat Road, there is a reasonably high volume of traffic accidents. This is certainly drawing attention as traffic accidents are one of the highest causes of death in the world (Mathers & Loncar, 2006; Murray & Lopez, 2013; World Health Organization, 2016, 2019). In general, traffic accident severity is divided into three types, i.e. fatal injury, serious injury, and slight injury (Pemerintah Republik Indonesia, 1993).

In analyzing the severity of traffic accidents, various methods have been applied (Savolainen, Mannering, Lord, & Quddus, 2011). One method that can be used is the statistical method by considering the variables and data which will be used (Savolainen et al., 2011). Several statistical methods that can be used are binary logit and multinomial logit, wherein these two methods there are many derivative models (Mannering & Bhat, 2014; Savolainen et al., 2011). Binary logit and multinomial logit methods can be used in statistical analysis related to traffic accident severity analysis (Mannering & Bhat, 2014).

Some previous studies have been conducted by using logistic regression models related to accident severity factors and prediction of accident severity (Ratanavaraha & Suangka, 2014; Shankar, Mannering, & Barfield, 1996). Halim et al. (2018) used a logistic multinomial regression approach to obtain a model of the correlation between the severity of accidents with the independent variables such as gender, day of the accident, age, time of the accident, position of the victim, type of accident, type of vehicle, education, as well as type of collision and location of the accident (Halim, Ramli, Adisasmita, Aly, & Prasetijo, 2018). Ratanavaraha and Suangka (2014) used speed, Annual Average Daily Traffic (AADT), number of lanes, time of the accident,

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weather conditions, accident location, and cause of the accident as independent variables to obtain a multinomial logistic regression equation model of the severity of accident (Ratanavaraha & Suangka, 2014). Meanwhile, Crocco et al. (2010) conducted a logistic regression model analysis using different variable variations such as weather conditions, road surface conditions, pavement maintenance, geometric characteristics, and types of accidents (Crocco, De Marco, & Mongelli, 2010). Several aspects can affect the probability of a traffic accident in Surabaya, i.e. income, age, and the number of children. (Utanaka & Widyastuti, 2019; Hera Widyastuti, Dissanayake, & Bell, 2011; Hera Widyastuti & Utanaka, 2020).

Therefore, in this study, the multinomial logistic regression method is used to obtain an equation model and the probability of a traffic accident for each level of severity. The equation model is formed based on the significant variables. The variables that are considered affecting the equation model are accident time, type of the accident, vehicle speed, and lane width which are categorized as independent variables. These variables were selected based on previous studies and by the availability of data. Thus, this study is expected to figure out the significant variables that affect the probability at each of the three-level of traffic accidents severity.

2. Material and method

2.1. Traffic Accident

A traffic accident is an event that occurs on a road that is accessible to public traffic resulting in one or more people being injured or killed, which involves at least one moving vehicle (Dahiya, 2016; Masuri, Isa, & Tahir, 2017). In addition, the classification of traffic accident victims in Indonesia is divided into 3, and those are (Pemerintah Republik Indonesia, 1993):

1. Fatal injury is a victim who is confirmed dead as a result of a traffic accident within a period of no longer than 30 (thirty) days after the accident.
2. Serious injury is a victim who due to their injuries suffered from permanent disability or must be treated for more than 30 (thirty) days since the accident occurred.
3. Slight injury is a victim who due to their injuries suffered from no permanent disability and should not be treated in less than 30 (thirty) days since the accident occurred.

2.2. Study location

This study was conducted in Surabaya, specifically on 3 secondary arterial roads located around one of the CBD in Surabaya. These roads include Darmo Raya Road, Urip Sumoharjo Road and Basuki Rahmat Road. These three locations are quite crowded and have different infrastructure characteristics. Details of each of these roads can be seen in Table 1 (Vyolita & Mahardi, 2020; Wijaya, 2015). The table contains road descriptions in the form of road status, road type, road length, and average lane width. The detailed image of The Darmo Road, Urip Sumoharjo Road, and Basuki Rahmat Road can be seen in Figures 1.

Table 8. Condition of Raya Darmo Road, Urip Sumoharjo Road, and Basuki Rahmat Road (Vyolita & Mahardi, 2020; Wijaya, 2015)

Parameter	Raya Darmo Road	Urip Sumoharjo Road	Basuki Rahmat Road
Road Status	Urban road	Urban road	Urban road
Road Type	6/2D (six lanes, two ways divided)	6/2D (six lanes, two ways divided)	4/1 (four lanes, one way)
Road Length	2.7 km	0.5 km	1.2 km
Average Lane Width	4.4 m	3 m	3.95 m

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Figure 8. Road sections of the study location

2.3. Data and Tool

The data used in this study were primary data and secondary data. Primary data were obtained from observations of travel time and road length, so that speed can be obtained in each road condition in real-time. The assistive program used to obtain the data is Google Maps. In addition to primary data, this study also used secondary data in the form of accident data from 2015-2017, as well as geometric data of each road obtained from related agencies.

2.4. Multicollinierity test

Multicollinearity is a condition where two or more predictor variables in regression models are highly correlated. (Daoud, 2018). Multicollinearity occurs when two or more independent variables in the regression model are correlated (Daoud, 2018). Multicollinearity can cause information overload, which means it causes overlap between the independent variable and the dependent variable (Wonsuk et al., 2013). In the multicollinearity test, values that need to be seen are Tolerance and Variance Inflation Factor (VIF). If the Tolerance value is more than 0.1 and the VIF value is less than 10, it indicates no multicollinearity in the independent variables. (Ghozali, 2005). The multicollinearity test has the objective to find a correlation between independent variables in a regression model (Denziana, Indrayenti, & Fatah, 2014). The correlation between independent variables should not be in the regression model (Denziana et al., 2014).

2.5. Heteroscedasticity test

Heteroscedasticity is a condition where the variance in a regression model is not constant (Mokosolang, Prang, & Mananohas, 2015). Therefore, it is necessary to do a heteroscedasticity test to detect the variance dissimilarity in a regression model (Imam, 2011). Where in a regression model there should be no heteroscedasticity (Pamungkas, Junaidi, & Hardono, 2016). One method that can be used in the heteroscedasticity test is the Glejser Method (Widarjono, 2007). The regression model can be considered that there is no heteroscedasticity if the significance value is above 5% or 0.05 (Imam, 2011).

2.6. Multinomial logistic regression

The analysis conducted in this study is to look for independent variables that have an effect or correlation to dependent variables by using the multinomial logistic regression method. This method was chosen because the dependent variable consists of several categories (Ratanavaraha & Suangka, 2014). The average value of dependent variables that are affected by independent variables becomes the key quantity in each regression analysis (Al-Ghamdi, 2002). The multinomial logistic regression equation is as follows (Ratanavaraha & Suangka, 2014).

$$T_{ki} = \propto_k + \beta_k X_{ki} \qquad (1)$$

In which:

αk = constant parameters for accident severity category k

βk = vector parameters that can be estimated for accident severity category k

Xki = represents the explanatory variable vector variables that affect the severity of the accident for i in the accident severity category k

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k = represents the three accident severity levels: slight injury, serious injury, fatal injury

Hence, there are three categories of dependent variables, to calculate the probability of each accident severity level can be seen in Equation 2 – Equation 4 (Ari & Aydin, 2015). Where Pi(k) is the probability of an accident for each severity level (Ratanavaraha & Suangka, 2014).

$$P_{i1}(k) = \frac{exp(T_{ki1})}{1+exp(T_{ki1})+exp(T_{ki2})} \quad (2)$$

$$P_{i2}(k) = \frac{exp(T_{ki2})}{1+exp(T_{ki1})+exp(T_{ki2})} \quad (3)$$

$$P_{i3}(k) = \frac{1}{1+exp(T_{ki1})+exp(T_{ki2})} \quad (4)$$

Multinomial logistic regression can estimate the probability of the accident severity that is affected by several factors. The considered factors as independent variables that affect the probability of the accident severity consist of accident time, type of accident, vehicle speed, and road lane width. Therefore, the effect of independent variables on the probability of the traffic accident severity using the multinomial logistic regression method can be identified (Ratanavaraha & Suangka, 2014). Analysis to obtain the multinomial logistic regression model was carried out using SPSS (Statistical Package for the Social Sciences) program because it can be used for various statistical analysis purposes and can process it quickly and accurately (Hasyim & Listiawan, 2015; Zein et al., 2019).

In this study before conducting the multinomial logistic analysis, the independent and dependent variables were categorized. The independent variable categorization is carried out on the accident time variable and the type of accident variable. The accident time variable is divided into 3-time categories, category 1 is 00.00-07.59, category 2 is 08.00-15.59, and category 3 is 16.00-23.59. The types of accidents variable are divided into 5 categories, category 1 is a front collision, category 2 is a rear collision, category 3 is a side collision, category 4 is a vehicle-hit human collision, and category 5 is a single accident. The speed and lane width variables are not categorized because they use the original values.

Table 9. Variables used in the analysis

Variable	Code	Variable	Code
Severity level		Accident type	
Slight injury	0	Front collision	1
Serious injury	1	Rear collision	2
Fatal injury	2	Side collision	3
Accident time		Vehicle-hit human collision	4
00.00 – 07.59	1	Single accident	5
08.00 – 15.59	2	Speed	-
16.00 – 23.59	3	Lane Width	-

3. Result

3.1. Multicollinearity and heteroscedasticity test

Before being analyzed by multinomial logistic regression, independent variables were tested statistically to prove the independent variables could be used in multinomial logistic regression analysis. There are 2 types of statistical tests performed, i.e. multicollinearity test and heteroscedasticity test. The results of the multicollinearity test can be seen in Table 3 and the results of the heteroscedasticity test can be seen in Table 4.

Table 10. Multicollinearity test results

Variable	VIF	Interpretation
Accident Time	1.025	No multicollinearity
Accident type	1.076	No multicollinearity
Speed	2.509	No multicollinearity
Lane Width	2.424	No multicollinearity

Table 11. Heteroscedasticity test results

Variable	Sig	Interpretation
Accident Time	0.467	No heteroscedasticity
Accident type	0.229	No heteroscedasticity
Speed	0.586	No heteroscedasticity
Lane Width	0.457	No heteroscedasticity

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Based on Table 3, shows that the VIF value of the independent variables is above 0.1 and below 10. Thus, this interprets that the independent variables do not experience multicollinearity. Based on Table 4, shows that the significance value of the independent variables is above 0.05 or 5%. Thus, it can be interpreted that there is no heteroscedasticity on the independent variables. With no indication of multicollinearity and heteroscedasticity, the independent variables can be used in multinomial logistic regression analysis.

3.2. Multinomial logistic regression

The multinomial logistic regression analysis in this study was carried out using the SPSS program by including related variables. The dependent variables in this analysis are the traffic accident severity (Y), while the independent variables are accident time (X1), the type of accident (X2), vehicle speed (X3), and lane width (X4). The output results of the SPSS analysis can be seen in Table 5.

Table 12. SPSS output results of multinomial logistic regression analysis

Severity		B	Sig.
Slight injury	Intercept	85.122	.000
	Speed	-1.018	.000
	Lane width	-14.034	.000
	[Accident time=1.00]	12.596	.991
	[Accident time=2.00]	-1.342	.277
	[Accident time=3.00]	0	.
	[Types of accident=1.00]	14.205	.993
	[Types of accident=2.00]	-.510	.689
	[Types of accident=3.00]	.495	.705
	[Types of accident=4.00]	-2.697	.066
	[Types of accident=5.00]	0	.
Serious injury	Intercept	85.343	.000
	Speed	-1.023	.000
	Lane width	-14.309	.
	[Accident time=1.00]	11.307	.992
	[Accident time=2.00]	-1.610	.216
	[Accident time=3.00]	0	.
	[Types of accident=1.00]	14.387	.993
	[Types of accident=2.00]	-1.918	.266
	[Types of accident=3.00]	.573	.698
	[Types of accident=4.00]	-1.620	.317
	[Types of accident=5.00]	0	.

The results of the analysis showed the prediction of accident severity for slight injuries compared to fatal injuries and predictions of accident severity for serious injuries compared to fatal injuries. From the table above, it can be known that there were only two variables that have a significant effect on accidents with the severity of slight injuries and serious injury.

Two variables that are significant to each model of the equation are the variable of speed (X3) and lane width (X4) because it has a sig value of <0.05. While other variables such as time and type of accident that have a sig value of >0.05 indicate no significant effect on the model. Thus, the equation model is as follows:

$$g_1(x) = \ln\frac{p(slight\ injuries)}{p(fatal\ injuries)} = 85.122 - 1.018(X3) - 14.034(X4)$$

$$g_2(x) = \ln\frac{p(slight\ injuries)}{p(fatal\ injuries)} = 85.343 - 1.023(X3) - 14.309(X4)$$

From those two functions, the obtained probability function for each type of traffic accident severity is as follows:

$$\pi_1 = \frac{\exp g_1(x)}{1+\exp g_1(x)+\exp g_2(x)}$$

$$\pi_2 = \frac{\exp g_2(x)}{1+\exp g_1(x)+\exp g_2(x)}$$

$$\pi_3 = \frac{1}{1+\exp g_1(x)+\exp g_2(x)}$$

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Where π_1 is the probability function for the accident severity of the slight injury category, π_2 is the probability function for the accident severity of the serious injury category, and π_3 is the probability function for the fatal injury accident category. If it is assumed that a motorist drives at 40 km/h on a road that has an average width per lane of 3 meters. This speed of 40km/h is the maximum allowed urban speed (Machsus et al., 2017). Then the probability is as follows:

$$g_1(x) = \ln\frac{p(slight\ injuries)}{p(fatal\ injuries)} = 85.122 - 1.018(40) - 14.034(3) = 2.300$$

$$g_2(x) = \ln\frac{p(slight\ injuries)}{p(fatal\ injuries)} = 85.343 - 1.023(40) - 14.309(3) = 1.496$$

$$\pi_1 = \frac{\exp(2.300)}{1+\exp(2.300)+\exp g_2(1.496)} = 0.646 = 64.6\%$$

$$\pi_2 = \frac{\exp g_2(1.496)}{1+\exp(2.300)+\exp g_2(1.496)} = 0.289 = 28.9\%$$

$$\pi_3 = \frac{1}{1+\exp(2.300)+\exp g_2(1.496)} = 0.065 = 6.5\%$$

The calculation result above shows the probability if a motorist drives at a speed of 40 km/h on a road that has a lane width of 3 meters. The probability of a traffic accident for the severity of slight injuries is 64.6%, serious injuries is 28.9%, and fatal injuries is 6.5%.

4. Conclusion and Discussion

The results of this study indicate that there are only two significant variables out of the 4 applied independent variables, consisting of accident time, the type of accident, vehicle speed, and lane width. The two variables are vehicle speed and lane width. This can be seen from the significance values on both variables which are less than 0.05. With the model obtained, it can be interpreted that the higher the vehicle speed, the higher the probability of the accident severity. In addition, the wider the lane, the higher the probability of the accident severity.

Therefore, this study implies that it is important to enforce speed limits on urban roads, by providing related warning signs or the need for socialization to the public. Moreover, stakeholders can consider the aspects of road safety when going to widen the road. Furthermore, to get a better result, further research can be carried out on other variables which are supported by the availability of more adequate data. So that, it is expected that better results can be obtained from further research.

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