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Preliminary Study of Traffic Characteristics Based on Data Flow And Speed of Vehicles (Case Study of Nginden Road, Surabaya)

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A B S T R A C T

An arterial road is a high capacity urban road used by various categories of vehicles. The arterial road characteristics composed of traffic flow, traffic density and speed of vehicles. Therefore, every arterial road has different characteristics depends on its type and actual data. In order to identify the characteristics of arterial road based on traffic density and speed of vehicles, this research implements a least square method into a case study in Surabaya assumed that the relationship of traffic density and vehicles speed is linear and the traffic characteristic model based on Greenshield. At the end, this research concludes that Nginden Road as case study has maximum vehicle speed at 26 km/h and traffic density at 166 pcu/km with the Greenshield model $S = 35{,}75 - 0{,}7942.\ D$, where S is the speed of vehicles and D is the traffic density.

Keywords: Traffic Flow, Traffic Density, Speed Of Vehicles, Traffic Analysis

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1. Introduction

Arterial road is an important road segment that connects various existing collector roads with different traffic density depends on various parameters such as road width, traffic volume, side obstacle factor, road conditions, rush hour and others (Li, Li, Zhu, Lan, & Chang, 2017; Mohan Rao & Ramachandra Rao, 2012; Taylor, Olstam, Bernhardsson, & Nitsche, 2017). As the main road, the arterial road has a very high traffic density affected by the speed of vehicles which depends on the type of vehicle, the emotions of the rider or the weather at that time (Corpuz, 2016; Hjälmdahl, Krupenia, & Thorslund, 2017; Thorslund, Strand, & Willstrand, 2017).

Nginden road is one of the arterial road in Surabaya with high traffic dynamics, especially during the rush hour in the morning or afternoon or the times during which the most people commute.

Previous research stated there is a tight relationship between traffic flow, traffic density and the speed of vehicles (Wibisana H., Utomo N., 2017). It said that the speed of vehicles depends on the traffic density to avoid a traffic jam and a high traffic flow will reduce the speed of vehicles to avoid the friction among vehicles that can cause a traffic accident (Cao, Yang, & Zuo, 2017; Dickerson, Peirson, & Vickerman, 1998; Renuraj, Varathan, & Satkunananthan, 2015)

This study aims to identify the characteristics of the Nginden road as a case study that presents the traffic flow, traffic density and speed vehicles in mathematical relationship. In this study, the Greenshield approach is used whose quite simple model to implement and assumes that the relationship of traffic density and vehicles speed is linear as shown in equation 2.

1.1. Traffic Characteristic

The relationship between variables that build traffic characteristics is given by the equation model as follows (Tamin, 2003):

$$V = D.S \qquad (1)$$

Where: V is the traffic flow variable (pcu/hour), D is the traffic density (pcu/km), and S is the vehicle speed (km/h).

The Greenshield model states the mathematical relationship between vehicle speed and traffic density is expressed by the model form of the equation:

$$S = S_{ff} - \frac{S_{ff}}{Dj}.D \qquad (2)$$

Where the Sff is a free flow speed and Dj is a density at saturated flow.

If the mathematical equation 2 is modified based on the equation 1, so that, a mathematical model presents the relationship between traffic flow with the speed of the vehicle by replacing the variable D with the form V / S which later, produced a model equation 3 below.

$$V = Dj.S - \frac{Dj}{S_{ff}}.S^2 \qquad (3)$$

Similarly, if the mathematical equation (2) is modified by substituting the S variable to form V / D, a new equation will be generated which

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states the relationship between traffic flows with the traffic density shown in equation 4.

$$V = S_{ff}.D - \frac{S_{ff}}{Dj}.D^2 \qquad (4)$$

From equations above, a traffic characteristic model will be formed based on Greenshield approach. Beside that, the maximum value both of vehicle speed and traffic density at study case will be achieved.

2. Methods

To collect the actual data in this study, a field observation is necessary. In order to calculate the traffic volume of Nginden Road in vehicles per hour, a digital stopwatch and flag meter are used. A flag meter will be placed as a start and finish line of observation point for every 50 m to measure the speed of vehicles. This observation witnesses the time of the front wheels of the passed vehicle at flag meter 1 until its back wheel reach the flag meter 2. So that, by measuring the time with digital stopwatch in second unit, a meter/second will be converted into km/h. The various types of vehicles in this observation consists of light vehicle (LV), heavy vehicle (HV), and motorcycle (MC). This study held on January 14, 2018 with the selection of rush hour in the morning from 06.00 am until 09.00 pm for 3 hours running with lapse record every 15 minutes, therefore, 12 data traffic volume is obtained.

2.1. Linier Regression

Linear regression analysis can be done by converting the recorded field data into pcu/hour, an then those data will be processed to obtain the mathematical equation model: y = a + bx, where y is the independent variable and x is the independent variable, a and b are the coefficients of each variable.

The purpose of linear regression analysis is to achieve the value of coefficients a and b, where the value of b is obtained by these formulas:

$$b = \frac{S_{xy}}{S_{xx}} \qquad (5)$$

$$b = \frac{N.\sum xy - \sum x.\sum y}{N.\sum x^2 - \sum x.\sum x} \qquad (6)$$

$$a = \frac{\sum y}{n} - b.\frac{\sum x}{n} \qquad (7)$$

After obtaining the value of coefficients a and b, modifying and converting the Greenshield equation model for the relationship of traffic characteristics which consists of traffic flow, traffic density and vehicle speed are conducted.

The correlation coefficient R2 will be calculated to determine the strength of the relationship of each variable on the linear regression using the following equation:

$$R = \frac{S_{xy}.S_{xy}}{S_{xx}.S_{yy}} \qquad (8)$$

2.2. Linier Regression On Greeshield Models

The form of the accepted linear regression equation is:

$$y = a + bx \qquad (9)$$

Where : y is a dependent variable, x is a independent variable while a and b is a coefficient of variable.

The Greenshield equation model states that the linear relationship between the speed of the vehicle and the traffic density which is expressed in equation (2). In equation (2), the variable S can be written as variable y, at the same time, variable D can be inserted as x. From this calculation, the coefficient a and b as shown in equation (9) can be associated with the value of Sff and Dj on the Greenshield model, where a = Sff dan nilai

$$b = \frac{Sff}{Dj} \text{ atau } Dj = \frac{Sff}{b}.$$

By obtaining the value of the free current velocity of Sff and the density of the current saturated Dj then the whole Greenshield model can be fully modeled. After the Greenshield model finished, the next step is to obtain maximum speed and maximum traffic density, the model will be differentiated in level 1 of mathematical differentiation and assume the result would be $\frac{dV}{dS} = 0$ dan $\frac{dV}{dD} = 0$.

3. Result and Discussion

Based on the results of field observation, the traffic volume data can be presented as it shown in Table 1. This collected data consists of several types of vehicles, therefore the total volume of traffic per hour is the total volume of those passed vehicles on Nginden road.

Table 1. Calculation of Traffic Volume at Nginden Road on January 14 2018

Q tot (pcu/h)	MC (pcu/hr)	LV (pcu/hr)	HV (pcu/hr)
1437	870	538	29
1672	989	649	34
1684	1032	631	21
1825	1321	479	25
1357	905	436	16
1429	1033	382	14
1461	947	495	19
1528	1079	437	12
1365	1027	315	23
1176	759	388	29
944	409	512	23
1039	526	483	30

MC= motor cycle; LV= light vehicles ;HV= heavy vehicles (kendaraan berat); Qtot= Volume lalu lintas (MC+LV+HV)

From Table 1., the total volume of motor vehicle traffic passing through the Nginden road segment for 12 data retrieval periods was

obtained from the observation of the V speed of vehicle S in the final unit as km / h and the results of this record are shown in Table 2 , where the existing traffic density D is a calculation of the traffic flow divided by the speed of the vehicle.

Table 2. Result from calculation density (D), Volume of traffic (V) and speed of vehicles (S) at Nginden mainroad

	Nginden Mainroad		
No	V (pcu/hr)	S (km/hr)	D (pcu/hr)
1	1437	29,4	48,878
2	1672	28,5	58,667
3	1684	26,7	63,071
4	1825	26,3	69,392
5	1357	28,4	47,782
6	1429	27,9	51,219
7	1461	31,2	46,827
8	1528	28,5	53,614
9	1365	30,6	44,608
10	1176	31,9	36,865
11	944	34,2	27,602
12	1039	33,7	30,831

Source : field calculation

With the used of least square for calculating data which presented in Table 2., the result shown liniar regression equation with the value of R = 0,91 as a : $y = 39{,}3075 - 0{,}1974.\ x$

Where :

A= 39,3075

B= -0,1974

The value of the coefficient then modified in the Greenshield model and the value of Dj became $A = S_{ff} = 39{,}3075$

$$b = -\frac{S_{ff}}{Dj}$$

$$Dj = \frac{-39{,}3075}{-0{,}1974}$$

Dj = 199,082 pcu/km

Rounded to :

$$Dj = 199\ smp/km$$

The Greenshield model equations for the relation of vehicle speed to the traffic density become

$$S = S_{ff} - \frac{S_{ff}}{Dj}.D$$

$$S = 39{,}3075 - 0{,}1974.D$$

This means that every increase in traffic density of 1 unit will decrease vehicle speed by 0.1974 km / h, the graphical display is shown in Figure 1.

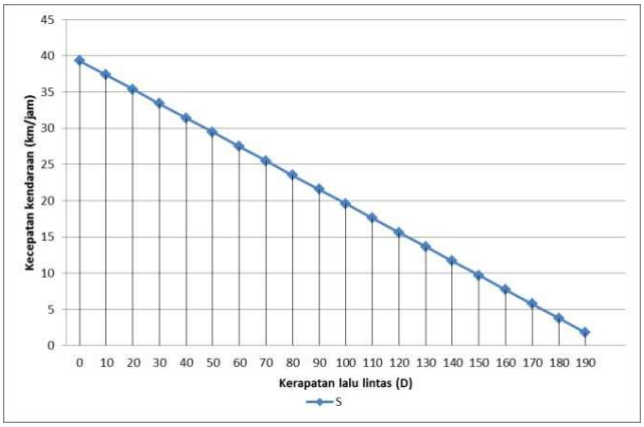

Figure 1. The Greenshield model equations for the relation of vehicle speed to the traffic density

To see the relationship between traffic flow variable and vehicle speed, the Greenshield model equation for equation (3)

$$V = Dj.S - \frac{Dj}{S_{ff}}.S^2$$

By entering the known values of Sff and Dj then the equation model becomes:

$$V = 199{,}082.S - 5{,}065.S^2$$

The mathematical meaning of the equation model is that each increase of 1 unit from the speed of the vehicle on the Nginden highway will cause the value of the traffic flow will increase until it reaches the maximum value at speed of 20 km / hour traffic flow will decrease the number of vehicles passing in the road Nginden highway as seen in Figure 2.

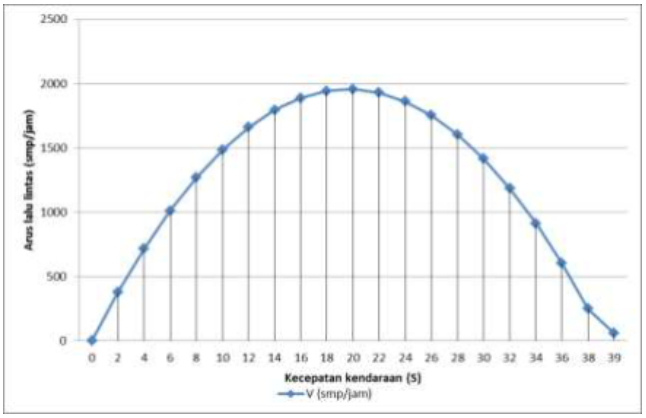

Figure 2. The Greenshield model equations for the relation of vehicle speed to the traffic volume

Otherwise for the relationship between the traffic variable with the traffic density in the Greenshield models are corresponded with the equation (4) like :

$$V = S_{ff}.D - \frac{S_{ff}}{Dj}.D^2$$

By entering a value like Sff and Dj the result for the models :

$$V = 39{,}3075.D - 0{,}1974.D^2$$

The mathematical equation model means that for every increase of one unit of traffic density (D) then the traffic flow will increase to limit when the D value reaches 100 vehicles per kilometer and then it will decrease until it reaches the lowest limit of 200 for a gasoline cracker, for a density greater than that value the Greenshield model will provide a negative value for the traffic flow, whereas this phenomenon is unlikely to occur, so it can be said that the interval for traffic density that can represent real traffic flows is 0 to 200 vehicles per kilometer, where the graph's peripheral hose will form a parabola that has a maximum value for the existing traffic density as shown in Figure 3.

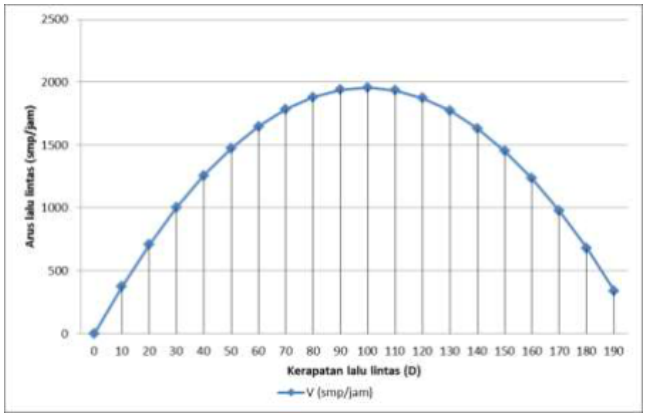

Figure 3. The Greenshield model equations for the relation of traffic density to the traffic volume

4. Conclusion

The main road of Nginden has the traffic characteristic models with the expression of mathematical equation : S = 39,3075 − 0,1974. D for the relationship between traffic density and vehicle speed, V = 199,082. S − 5,065. S^2 for the relationship between traffic flow with the vehicle speed, and V = 39,3075. D − 0,1974. D^2 for the relationship between traffic flow with the traffic density.

The maximum velocity value is derived from a first-rate derivative for the equation

V = 199,082. S − 5,065. S^2 where to meet S maximum value ½ S_{ff} = 19,65 km/jam

The maximum density value is derived from a level 1 derivative for a mathematical equation $V = S_{ff}.\ D - S_{ff}/D_j.\ D^2$ where the value of D maximum could be obtained by ½ D_j = 99,54 pcu/km or round up with Dmax = 100 pcu/km

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