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The Congestion Factors of Container Truck Travel from Tanjung Emas Port to the Hinterland Region

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Abstract Semarang Container Terminal or Terminal Petikemas Semarang (TPKS) at Tanjung Emas Port is one of the container terminals in Indonesia with growing container traffic, recorded in 2020 reached 712.062 TEUs. The interaction of the components of the transportation system between ports, road facilities and container trucks needs to be synergized, for the smooth flow of container traffic and avoiding travel obstacles or road congestion. Container movement congestion is the result of an imbalance between traffic volume and road capacity, especially container trucks, resulting in the level of road service which ultimately results in a decrease in vehicle speed. This research aims to find the clarity about the main factors forming congestion based on the dynamics of environmental change, using an analysis of the variables causing congestion based on the results of a survey in 2013 with 30 samplings of container trucks and 60 samplings of container trucks in 2019 on the road from Tanjung Emas Port, Semarang to the hinterland area around Ungaran, Semarang Regency. The analysis was conducted by using descriptive regression method and model testing with Minitab 18 software. It can be explained that the main factors causing congestion that have an impact on decreasing speed affecting the travel time of container trucks are road geometric such as road gradients, vertical alignments, intersection and activity on shoulder.

Keywords Congestion, Container Truck, Road Geometric, Road Service Level

1. Introduction

Semarang Container Terminal Ports plays a very important role in the logistics transportation system and becomes the basis for consideration in regional and city development planning. The existence of the port is related to the transportation network from and/or to the hinterland area. The growth of world containers in 2018 was shown through the flow of container traffic reached 793.260.606 TEUs with a growth of 4.7% yoy and in Indonesia reached 14.060.600 TEUs with a growth rate of 4.54% or 1.77% of the total world containers [1,2]. Container traffic at other ports in Indonesia is still in the range below 1 (one) million TEUs. As one of the included, Semarang Container Terminal reached 608.201 TEUs in 2015 and experienced an increase of 18% in the period from 2015 to 2020.

A form of anticipation with the intention that the container traffic system does not experience obstacles or delays known as congestion, it is necessary to synergize elements of the transportation system between ports, road facilities, and container trucks. The purpose and objective of this research is to find and understand the main factors forming container traffic congestion on certain roads based on changes in environmental dynamics.

The problem of congestion is the result of an imbalance between the growth of motorized vehicles and road capacity of Volume/Capacity or V/C ratio [3]. The high growth of traffic flow and the limited width of the road, especially those traversed by container vehicles affect the level of road transportation services, is the limited capacity of the road for vehicles [4]. The development of roads tends to have not anticipated or adapted to the development of vehicles models and Dimension that develop over time [5]. Another cause of congestion is a decrease in vehicle speed due to high road V/C. One of the causes of the decrease in the speed of container transport vehicles is the road surface with a high level of road gradient, both horizontally and vertically [5,6]. The high vertical gradient forms the contours of the uphill road surface and makes the speed of each vehicle slow.

Another congestion factor is related to road variables and the limited choice of alternative routes of travel resulting in container trucks mixing with other vehicles because there are no other options [7,8,9], also stated that the volume of trucks as heavy vehicles accounted for 30% of the total volume of mixed vehicles on highways in the state of Arizona, United States. This value greatly affects the road capacity in supporting the smooth flow of traffic [6,10]. Other constraints on the travel route are the number of Intersection, whether signaled or not, parking vehicles on the road body that are not in accordance with the designation and the behavior of the driver or the stress level of the driver and so on [12].

A review of literature on congestion problems related to various factors and causal variables, although it has not been stated in the summary of a specific discussion, which means the components are in different transportation topics. Congestion is still the main object or factor in the debate over the impact. However, it is still difficult to determine the root of the trigger so it is necessary to look at the root of the problem to solve the problem on target. Ideally, the discussion of the problem is based on identifying the root causes of interaction problems between the components of the transportation system so that it can strengthen solutions, including planning directions, references to ministerial regulations and the government of the Republic of Indonesia that prevent congestion or at least minimize congestion events.

Congestion triggering factors and variables should be measured, especially for container truck traffic. For this reason, research is needed that focuses on congestion problems in order to form a comprehensive transportation infrastructure network system [9] especially those that are directly related to container or trailer transporation.

2. Methods

The research was conducted quantitatively and qualitatively, collection primary and secondary field operational data and/or survey documents on selected variables. Survey in 2013 was conducted on 30 trucks and in 2019 there were 60 sampling trucks, the research location was on the road from Tanjung Emas Port, Semarang to an industrial factory located in Ungaran (Figure 1), Semarang Regency in Central Java. Data collection used the *Weigh in Motion* method [11], placing surveyors on vehicles to follow container trucks as the object of research and equipped with a Global Positioning System (GPS) tool to measure travel time, road slope, and location of truck vehicle movements. Data analysis used a descriptive method using Minitab 18 software for regression analysis, testing the regression model with assumption tests, to get the sensivity value of the influence of the variables causing congestion.

The grouping of variables causing congestion is based on the results of the literature study as shown in Table 1. Factors that cause congestion systematically consist of three congestion factors. The independent variables used include Activity, Dimension, Intersection, Toll Gate, Gradient, and Steep hill downwards.

Table 1. Congestion Causes Factors

	FACTORS		
	% Volume of Container Vehicles on the Road	**Number of Intersection**	**Road Characteristics and geometry**
VARIABLES	Container vehicle volume	Road capacity	Vertical alignment
	Traffic flow volume	Queue time	Horizontal alignment
	Axle load of container transport vehicles	Number of Intersection points	Number of points of road damage or extent of damage
	Vehicle age		

Source: [8, 9, 10]

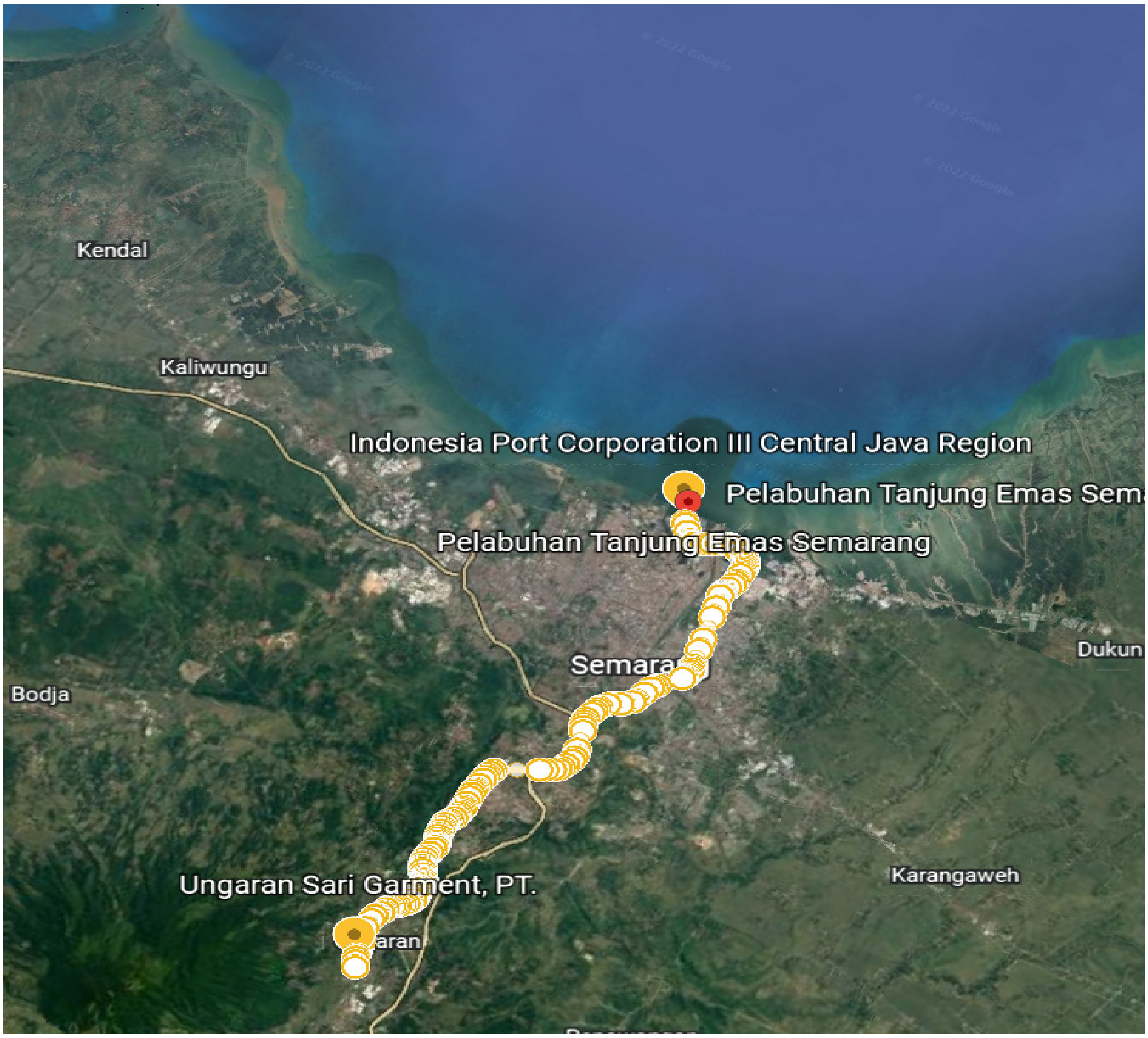

Figure 1. Yellow Line is a container truck route from locations from the port of Tanjung Emas to locations around Ungaran (30 Km) [18]

3. Result and Discussion

Congestion in this research is permanent which if axlenot addressed immediately can cause bigger problems and affect logistics transportation costs. Congestion events occur on roads repeatedly, for instance roads that have geometric contours or geographical conditions uphill, road capacity is limited while vehicle volume is very dense.

The impact of congestion on the analysis results is reflected to the level of road service as a derivative variable from the speed factor determined by the independent variables, traffic volume, and road capacity. In general, the impact of congestion occurs due to a high increase in vehicle volume, including the percentage of container and non-container trucks, vehicle speed which is influenced by age and axle load that exceeds its capacity, resulting in traffic volume ratio with road capacity being exceeded, long queues or delays as well as due to the large number of Intersection traversed.

3.1. Congestion in 2013

The total average travel time from the survey results in 2013 was 68.4 minutes for container trucks with a distance of approximately 30 km, the average speed under conditions of congestion was 26.3 km/hour with variations in load and driving style of truck drivers. The results of descriptive analysis based on sampling of 30 data are presented in Table 2.

Table 2. Travel Time and Congestion Factors (seconds)

Variable		N	Mean	StDev	Min	Max
Travel Time	(Y)	30	4102	788	2880	6324
Activity	(X1)	30	121.2	70.1	12.5	212.2
Dimension	(X2)	30	85.19	40.21	34.00	191.80
Intersection	(X3)	30	491.5	124.6	315.4	754.0
Toll Gate	(X4)	30	347.87	47.63	260.00	500.47
Gradient Up	(X5)	30	887.8	259.1	506.4	1646.4
Gradient Down	(X6)	30	128.06	52.62	59.63	198.00

Table 3. MSA-on Congestion variable

		Dimensions	Intersection	Toll Gate	Gradient
Anti-image Covariance	Dimension	0.229	-0.103	0.003	-0.025
	Intersection	-0.103	0.222	0.019	-0.037
	Toll Gate	0.003	0.019	0.072	-0.054
	Gradient	-0.025	0.037	-0.054	0.051
Anti-image correlation	Dimension	0.886[a]	-0.457	0.024	-0.233
	Intersection	-0.457	0.853[a]	0.015	-0.345
	Toll Gate	0.024	0.150	0.730[a]	-0.882
	Gradient	-0.233	-0.345	-0.882	0.711[a]

Measure of Sampling Adequacy (MSA)

The data from the survey in Table 2 shows that the six main variables of congestion that affect the travel time of the truck to the destination, the Gradient variable is the highest rank variable that becomes the obstacle with the average value of truck while on Gradient reached 887.8 seconds. While the lowest order inhibiting variable is the Dimension variable with an average value of 85.19 seconds. The results of the analysis using the Minitab 18 software, the initial equation for Travel Time (Y) is obtained as follows:

$$Y = 1944 + 1.13(X1) + 3.78(X2) - 0.29(X3) - 2.36(X4) + 2.791(X5) + 1.46\,(X6) \quad (1)$$

This equation is not in accordance with the residual value of the regression model, it is not on regression line that is formed. Furthermore, using the Principal Component Analysis method by removing a sampling of distraction. Then, the variable feasibility test was carried out with the analysis of Measurement Sampling Adequacy (MSA). It can be seen that the MSA values in the four variables, are Dimension, Intersection, Toll Gate, and Gradient, show numbers greater than 0.5, as shown in Table 3.

The results of the manual calculation of factor values were re-analyzed by using regression analysis with the new variable (F1). The results of the data analysis component score coefficient matrix, obtained Equation (2).

$$F_1 = 0.261X2 + 0.261X3 + 0.267X4 + 0.275X5 \quad (2)$$

The analysis is carried out by changing the factor values into the original model through the principal component values, the final equation model is obtained as in Equation (3) by substituting the F_1 value in equation (2) is obtained.

$$\text{Travel Time (Y)} = 804.301 + 1.73\,X2 + 1.73\,X3 + 1.77\,X4 + 1.823\,X5 \quad (3)$$

The value of the Y variable error is 80.183 and the F_1 variable is 0.158. The correlation value of R2 from the regression model is 0.985, means that the travel time can be explained by the Dimension, Intersection, Toll Gate, and Gradient Up variable of 0.985 or 98.5% while the remaining 1.5% is explained by other variables.

3.2. Congestion in 2019

The survey results in 2019 are a continuation of 2013 survey period with the addition of the number of vehicle sampling as many as 60 container trucks. This is done considering that there have been many changes to the road field, such as repairing asphalt to concrete and widening the road as well as the activation of the *one gate toll system* in the addition of Trans Java toll road. In addition, there are changes in the number of residents that have an impact on vehicle ownership and economic growth on the movement of goods which also affects the logistics system. The total travel time for the survey was 67.4 minutes with an average congestion speed of 26.7 km/hour.

Descriptive statistical analysis provides an overview of the inhibiting variables on the study of the journey of 60 trucks from the start to the final destination, which is shown in Table 4.

Table 4 shows that the level of diversity of data from one truck trip to another tends to be high. The fastest travel data is 2878 seconds and the longest is 5441 seconds. According to the average value of the six congestion inhibiting variables that affect the trip, it can be explained that the Gradient Positive variable is the highest inhibiting variable with the average time of the truck being on the Gradient Positive was 214.48 seconds. The results of the coefficients of the three variables, are Activity on Shoulder (X1), Intersection (X3), and Gradient Positive (X5) which meet the significance. The magnitude of the constant obtained as in Equation (4) with a correlation value of R^2= 0.7561.

$$\text{Time Travel (Y)} = \\ = 1518 + 6.90X1 + 8.24X3 + 10.093X5 \quad (4)$$

The results of the test of the congestion variable in 2013 and 2019 as shown in Table 5 indicate that the effect of Activity on Shoulder (crowded activities caused by the presence of markets/street food, schools, factories etc.), Intersection, and Gradient Positive variable on Travel Time results in a t-count are greater than the t-table. It would be concluded that these variables have a significant effect on Travel Time. The regression coefficients on the three variables have a positive direction, which means that the higher the Activity on Shoulder, the more the number of Intersection, or more the number of Gradient and/or the longer the distance of the Gradient, the longer time taken.

The equation for congestion of container trucks passing through the road from Tanjung Emas Port to industrial locations around the Ungaran area is formed into two equation models, which are shown by Equations (3) and (4). Table 6 describes a series of formulations of the main sub-variables forming congestion consisting of Truck Speed, Length of Segment for each change. The positive and negative constants in the congestion equation have the same behavior as the main equation in the travel time contribution. There are two variables, Dimension (X2) and Toll Gates (X4) in the equation that is not formed from the results of the calculation process, the equation is zero and directly contributes to the main variable. More details are presented in Table 7.

3.3. Variable Sensitivity

The formed equation is continued with sensitivity analysis as in Equation (5). The results of the sensitivity analysis in Table 8 describe that the truck travel time is the most sensitive to the congestion variable is the Gradient Positive factor compared to other factors.

To find out the extent of the response rate of the dependent variable with changes that may occur in the independent variable in the regression analysis, the sensitivity equation is used

$$\varepsilon_i = \beta_i \frac{\overline{X_i}}{\overline{Y}} \quad (5)$$

Where β_i is the coefficient of regression, $\overline{X_i}$ is the average value of an independent variable, and $\overline{Y}$ is the average value of all dependent variables. Table 8 shows that the Gradient Positive variable ranks first as a sensitive variable that affects truck travel time and has an impact on congestion levels compared to other variables.

Table 4. Time Travel and Congestion Factor (seconds)

Variables		N	Mean	StDev	Min	Max
Travel time	(Y)	60	4024.5	680.1	2878	5441.0
Activity on Shoulder	(X1)	60	25.82	16.48	3.0	75.00
Dimensions	(X2)	60	210.15	51.65	115.00	340.00
Intersection	(X3)	60	16.42	11.69	2.11	51.00
Toll Gate	(X4)	60	34.18	32.05	7.00	187.00
Gradient Positive	(X5)	60	214.48	55.71	91.60	391.20
Gradient Negative	(X6)	60	123.17	31.59	61.00	237.00

Table 5. Results of regression analysis using Minitab 18 based on 2019 data

Term		Coefficient	SE Coeff.	T-Value	P-Value	VIF
Constant		1518	207	7.34	0.000	
Activity on Shoulder	(X1)	6.90	2.73	2.52	0.015	1.01
Intersection	(X3)	8.24	3.91	2.11	0.040	1.01
Gradient Positive	(X5)	10.093	0.827	12.21	0.000	1.02

Table 6. t-test results significant variable

Independent Variables	t count		t table	
	2013	2019	2013	2019
Activity on Shoulder (X1)	-	2.52	-	2.006
Dimension (X2)	155.72	-	2.048	-
Intersection (X3)	161.68	2.11	2.048	2.006
Toll Gate (X4)	192.39	-	2.048	-
Gradient Positive (X5)	204.83	12.21	2.048	2.006

Table 7. The main sub variable equation for congestion

Variables			Equations
Activity	(X1)		$63.36 - 4.840$ Velocity $+ 15.18$ Length of Segment
Intersection	(X3)	0 day	$-31.00 + 1.9050$ Velocity $+ 0.25459$ Length of Segment
		1 day	$-32.12 + 1.9050$ Velocity $+ 0.25459$ Length of Segment
Gradient Positive	(X5)		$69.9 - 27.81$ Velocity $+ 0.2840$ Length of Segment

Note Ordinal Code: 0 is Busy Day and 1 is Non-Busy Day

Table 8. Variable Sensitivity Test Results In 2013 and 2019

Variable		Coefficient of Regression		Average of $\frac{\overline{X_1}}{\overline{Y}}$		Sensitivity		Rank	
		2013	2019	2013	2019	2013	2019	2013	2019
Activity on Shoulder	(X1)	-	6.90	-	0.007	-	0.045		2
Dimension	(X2)	1.73	-	0.021	-	0.04	-	4	
Intersection	(X3)	1.73	8.24	0.123	0.004	0.21	0.034	2	3
Toll Gate	(X4)	1.77	-	0.087	-	0.15	-	3	
Gradient Positive	(X5)	1.823	10.093	0.219	0.054	0.40	0.542	1	1

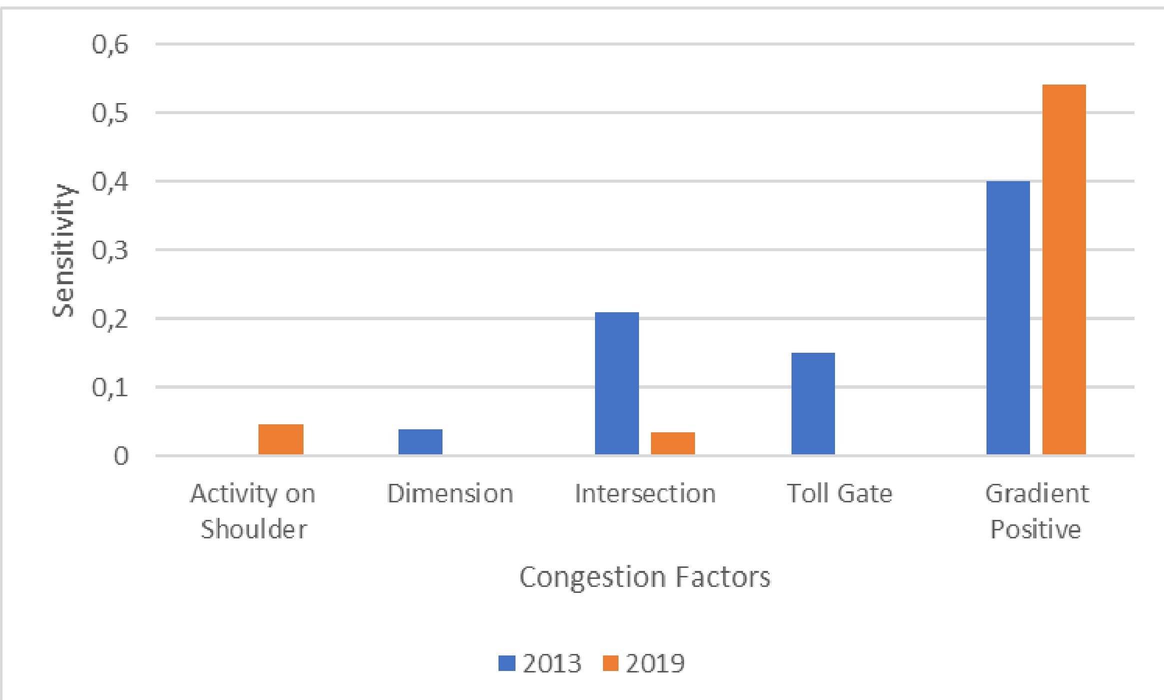

Figure 2. Comparion of Congestion Factors based on Sensitivity Values

The first rank of congestion variable in 2013 was Gradient Positive, Intersection, Toll Gate, and Dimension. While in 2019 the congestion variable remained on Gradient Positive, Activity on Shoulder, and Intersection factors as a contributor to congestion time. The condition of these variables geographically does not change but is influenced by the growth factor in the flow of vehicle and goods traffic due to population growth and economic activity as well as changes in space users to the outside of Semarang city. More detailed results are shown in Figure 2.

4. Conclusions

The main factor causing congestion on the road from the Semarang Container Terminal to the Hinterland Region in the industrial factory area in Ungaran, Semarang Regency has changed. The main factors that affect congestion in 2013 are Gradient Positive, then Intersection, Toll Gate, and Dimensions, while in 2019 Congestion Factors are Gradient Positive, Activity on Shoulder, and Intersection. The most influential congestion factor is the geometric condition of the road, especially the Gradient Positive and Intersection factors. According to the analysis conducted in 2019, the government's policy about the implementation of e toll and canal toll gates, has no effect to the Toll Gate and Dimention variable. The congestion factor formed produces an average congestion time value of 25.3 minutes or 37.6% of the total travel time of container trucks. Gradient Positive factor is the biggest contributor to congestion with a factor coefficient of 10.093. This case is unavoidable in a series of supply chain transportation routes in the logistics system network, especially for companies located at an elevation of +300 Mlws above sea level.

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