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VISSIM MODELING AT BITUNG TOLL GATE TANGERANG INDONESIA FOR IMPROVING TRAFFIC PERFORMANCE

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ABSTRACT

The objective of this research is to know the traffic performance before the existing additional toll booths and whether the number of toll booths at Bitung Toll Gate 1 needs to be increased. This research uses quantitative method with VISSIM model. Previously at Bitung Toll Gate 1, there were five Automatic Toll Booths with the number of cars reaching 1,522 in rush hours from 7 am to 8 am. Thus, PT Jasa Marga (Persero) Tbk as the administrator added two GTOs. From the result of GEH Test calibration and model validation using statistical test of Chi Square which compares the traffic volume using VISSIM model with the data taken from field survey, it is known that the value of GEH Test calibration taken from the highest average value before the GTO addition per hour is 3.352 whereas after the GTO addition the highest average value per hour is 1.902 and this result is below the standard value of <5, thus it is acceptable. Now, the traffic condition at the toll gate after the addition of two new booths shows significant changes from the previous condition.

KEYWORDS: Calibration Parameter, Traffic Performance, Toll Booth, Toll Gate & Traffic Performance

1. INTRODUCTION

Traffic jam now frequently happens on toll highways or paid roads in Jakarta like it happens on ordinary roads. The high growth of motor vehicles volume that can not be balanced by the growing road length becomes one of the triggers for traffic jam on paid roads. Although the tax policy on progressive vehicle ownership, policy on 3 in 1 car, as well as policy on odd-and-even numbered car have been made, they still can not reduce the traffic jam in the Capital City. Even, the Provincial Government of DKI Jakarta will also make a policy on paid road system on the Capital City's protocol streets, namely *Electronic Road Pricing* (ERP). In order to reduce the traffic jam and to smooth the traffic, for both inner city and outer city directions, the government and private parties have developed several toll roads as alternatives to avoid traffic jam. In addition, the existence of toll roads can shorten the distance and save the travel time as well. In general, reducing the use of private vehicles is a priority program that must be implemented through the application of public policies which enforces or limits their use (Castillo, 2018).

As a case example, Bitung Toll Gate 1 Tangerang provides traffic access from the exit toll gate to Bitung and Curug. The toll gate has five GTOs, four of them are special toll booths for multi-class and one for single class. The five toll booths always operate 24 hours every day. Many industrial areas and arterial cross roads make long and crowded queue of vehicles; long delay of travel and traffic jam cause travel time extension. The peak queuing toward Bitung happens every working day from 7 to 8 am, reaching 1,536 vehicles. The efforts that PT Jasa Marga Persero (Tbk) has made to overcome the long queue and to enhance the transaction capacity in Bitung Toll Gate 1 are converting Booth 1 which was previously Special Booth for Class 1 to be booth for multi-class (first phase), extending the transaction line (second phase), and operating mobile reader (third phase).

The traffic volume at Bitung Toll Gate 1 from January to December 2019 significantly decreases in June with 495,910 vehicles and increases in July with 641,359 vehicles, becoming the month with the most number of vehicles passing through Bitung Toll Gate 1. The problems in this research are: (1) The traffic performance before toll booth addition using the modeling application of VISSIM, (2) The implementation of toll booth addition using the modeling application of VISSIM to see the effectiveness of traffic condition. While the objective of this research is to know the traffic performance before the toll booth addition and after that whether using the modeling application of VISSIM can effectively overcome the traffic jam.

Based on the fact, the booth addition at Bitung Toll Gate 1 becomes very necessary to improve the traffic performance, thus analysis needs to be made using the modeling of Verkehr in Staedten Simulation (VISSIM). To reduce the traffic density in rush hours, Jasa Marga, as the administrator, proposes additional booths at Bitung Toll Gate 1 using the modeling application of VISSIM which is expected to give illustration and ease in analyzing the field condition. VISSIM is a microscopic-based simulation model developed for analyzing highway chain which is classified functionally and public transport operation (Bloomberg & Dale, 2000). Calibration and validation using VISSIM are carried out locally and globally (Dutta & Ahmed, 2019). Azam, et al., (2019) has evaluated alternative designs and helped the decision makers select the best design for traffic condition. Such models as Aimsun, Corsim, and VISSIM according to Fransson, (2018), Liu, (2017), dan Ratrout & Rahman, (2009), are appropriate for crowded roads and integrated roads. VISSIM model which is developed by Wang, et al., (2012) is used to simulate various traffic operation with a complicated scheme of toll; then, procedure of standard calibration is proposed to simulate the traffic of freeway in order to enhance the model credibility; and finally, statistical method is developed to analyze the simulation results against the problem of data autocorrelation. Development and implementation of VISSIM are also done by Wei & Sun, (2018), as the main control program proposed for validating the toll model.

Using VISSIM in their research of the condition of toll gates in Indonesia, Yulianto & Munawar (2017) research shows that there is an increase of capacity value in the Toll Highway of Cawang-Tomang-Cengkareng. In the research done by Ningrum, (2017), the long queue of vehicles as well as vehicle delay time can be reduced from the condition before the optimization at Banyumanik Toll Gate Semarang. Another research by Negoro, Munawar, & Irawan, (2018), shows that speed management has influence on the vehicle queue at the exit toll gate during vacation period. In Malaysia, Mahdi, Leong, & Sadullah, (2019), research shows that the percentage of heavy vehicles significantly influences the length of queue in the traffic flow at toll gates. Research by Hamid, (2011) shows that the traffic volume in Malaysia, toll gate orientation, storage capacity, and types of toll services have influences on traffic operation and toll gate efficiency.

Whereas in India, the research by Bains, et.al., (2017) using VISSIM model includes traffic volume, service time for various payment categories, percentage of line usage, and travel time while passing through the toll gate. In other Asian cities like Khobar-Dammam, Saudi Arabia there is also research on the use of Microscopic Simulation-Based Analysis (Al-Ahmadi, et al., 2019). Whereas in Bangkok, the significant parameter for modeling can also be implemented to driver's behavior (Fransson, 2018). The study by Knodler, Hajiseyedjavadi, & Fisher, (2016) (on such VISSIM simulation in the USA) is expected to to give better understanding on driver's behavior at the toll gate, that may lead to a more secure design of toll gate. A similar research in Florida, USA is carried out by Russo, (2008). Implementing VISSIM in Europe, especially in Turkey, Aksoy, Berk, & Gedizlioglu, (2013) research try to minimize the delay and maximize the bottleneck capacity. VISSIM Modeling is carried out in Istanbul, Turkey, by Kesten & Ergün, (2015).

2. METHODS

This research uses quantitative method with VISSIM model, using basic formula of *Chi-squared* i.e. statistic formula developed by Geoffrey E. Havers (GEH) (Gustavsson, 2007). GEH is a statistic formula modified from *Chi-squared* by combining the difference between relative and absolute values. Based on the record of Transportation Agency of Tangerang City, the number of personal cars in 2017 reached 15,304 units, making high traffic volume in Tangerang area. Bitung Toll Gate 1 Tangerang previously has five Automatic Toll Booths with the number of vehicles reaching 1,522. The population of this research is the five toll booths at Bitung Toll Gate 1, consisting of four Semi-automatic Toll Booths or *Gardu Tol Semi Otomatis* (GSO) for multi-class and one Automatic Toll Booth or *Gardu Tol Otomatis* (GTO) for single class.

The steps to implement the simulation model at Toll Gate need to be developed as follows; (1) Make a *link* first and connect using a *connector*. The link geometrically models the roads in the field; (2) Determine the type of vehicle in 2D/3D Models, add and adjust the type of vehicle in *Vehicle Types* and also in *Vehicle Classes*, set the speed of each vehicle in *Desired Speed Distribution*, then set *Vehicle Compositions* to display the type of vehicle as wanted, (3) Input the traffic volume in *Vehicle Inputs* first so that the vehicle can appear when *running*, (4) Determine the travel route in *Static Vehicle Routing Decisions*, (5) Place *Reduce Speed Area* for decreased speed when entering the Toll Gate, (6) Install *Stop Signs* to stop the vehicle as transaction modeling at the Toll Booth, (7) Do calibration using GEH method and do trial and error until the result obtained is close to the observation data, (8) Select the type of evaluation and run the simulation, (9) Repeat step number 7 until obtaining the result that is close to the result of field observation, and (10) Do validation using GEH and Chi square formulas to know whether the simulation model can be stated as valid.

3. RESULTS AND DISCUSSIONS

3.1 Calibration of Simulation Modeling

The calibration process is aimed at obtaining a model that represents the real condition. In the simulation with microscopic scope, the calibration process is carried out using microscopic parameters like driver's behavior. To obtain the output in accordance with the fact in the field, the researcher analyzes the calibration by seeing the number of vehicles and the available access. Furthermore, it is followed by the analysis using GEH (*Geoffrey E. Havers*) Test. (Table 1).

Table 1: Calibration Results of Five Booths at Bitung Toll Gates 1 (Before Booth Addition using GEH Test)

Result	Toll Booth	Period					
		07.00 - 08.00	08.00 -09.00	11.00 - 12.00	12.00 - 13.00	17.00 - 18.00	18.00 - 19.00
Condition	1	1240	1210	1205	1204	996	965
	2	1293	1034	1170	1157	1012	875
	3	1132	1180	1229	1236	1004	924
	4	1227	1175	1135	1242	975	934
	5	1247	1205	1286	1081	983	969
VISSIM Simulation	1	1288	1253	1242	1444	1032	930
	2	1340	1073	1208	1193	1047	909
	3	1175	1220	1193	1199	1040	886
	4	1272	1216	1097	1280	1010	969
	5	1291	1244	1325	1117	1075	940
GEH Test	1	3,319	2,250	1,250	1,437	1,633	1,669
	2	3,352	2,082	1,473	1,102	1,413	1,296
	3	2,566	1,776	1,144	1,124	1,607	1,595
	4	2,624	1,974	1,671	1,311	1,520	1,286
	5	2,316	1,540	1,161	1,179	1,336	1,207

Conclusion	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted	Accepted

Table 1 shows the data resulted from field survey and VISSIM calibration, and the result of calibration based on GEH Test are as follows:

From 7 to 8 am: As many as 1,240 vehicles pass through Toll Booth 1. Based on VISSIM simulation, there are 1,288 vehicles passing through Toll Booth 1. It seems that the traffic density at Toll Booth 1 is very high. The difference between the data from VISSIM and the field data is 48 vehicles. If this result of calibration is tested using GEH method, then the acceptable result will be 3.319. This value is still below five (<5), and hence it is acceptable.

From 8 to 9 am: There are 39 vehicles as the difference between the data from VISSIM and the field data at Toll Booth 2. The result of calibration using GEH Test is 2.082, thus it is acceptable. The difference of volume for each toll booth is still relatively small. At Toll Gate 4, from 8 to 9 am, there is a reletively low increase of volume, that is just two vehicles. The value of calibration using GEH Test is only 1.974, still acceptable as it is below five (<5).

From 11 to 12 am: The difference of volume for each toll booth is still relatively small; three vehicles at Toll Booth 3 and Toll Booth 5. The value of calibration using GEH Test for Toll Booth 1 is 1.144 and the value of calibration using GEH Test for Toll Gate 4 is 1.161. The results of calibration using GEH Test for Toll Booth 3 and 5 are acceptable as it is still below five (<5).

From 12 am to 1 pm: The arrival level of vehicle from each toll booth is decreasing from the previous hours. The result from VISSIM at Toll Booth 1 from 8 to 9 am is 2.250, whereas from 12 am to 1 pm, it is 1.437. It shows that there is a significant decrease but it is acceptable as this is still below five (<5.).

From 5 to 6 pm: the traffic volume at Toll Booth 2 increases as many as 37 vehicles compared with Toll Booth 4 because the density of arriving vehicles in the rush hours after work unravels. The result of VISSIM also shows increase as many as 15 vehicles and the filed data after the calibration using GEH Test does not show a significant difference, that is 1.633, which is acceptable. The results of each calibration using GEH Test are as follows: Toll Booth 2: 1.413; Toll Booth 3: 1.607; Toll Booth Tol 4: 1.520; Toll Booth 5: 1.336 and all the results of all classes are acceptable because it is still under five (<5).

From 6 to 7 pm: The volume of vehicles at all toll booths decreases as well as the VISSIM results, except at Toll Booth 2 shows a significant decrease in arriving vehicles. Each toll booth shows that the value of calibration using GEH Test is less than 2. It is acceptable, because it is still under 5 (<5).

Table 2: Results of Calibration at Seven Booths of Bitung Toll Gate 1 (After the addition of Two Booths at Bitung Toll Gate 1 Using GEH Test)

Result	Class of Vehicle	Period					
		07.00 - 08.00	**08.00 - 09.00**	**11.00 - 12.00**	**12.00 - 13.00**	**17.00 - 18.00**	**18.00 - 19.00**
Condition	I	1140	1025	881	681	750	726
	II	123	154	285	229	178	130
	III	35	27	58	62	40	35
	IV	39	38	32	24	13	10
	V	12	13	14	16	11	7
VISSIM	I	1180	1100	870	700	713	729
	II	127	159	291	234	181	132

Simulation	III	31	30	57	60	42	39
	IV	42	37	31	27	15	8
	V	15	14	16	15	10	6
GEH Test	I	1.902	0466	0.371	0.723	1.367	0.109
	II	0.163	0.398	0.353	0.328	0.223	0.173
	III	0.696	0561	0.130	0.254	0.219	0.657
	IV	0.474	0161	0.176	0.594	0.533	0.666
	V	0.817	0.272	0.364	0.252	0.308	0.391

Table 2 shows the data resulted from field survey, the data of VISSIM calibration and the result of calibration based on GEH Test.

From 7 to 8 am: It shows the highest density of traffic volume at Toll Booth 1. Based on the data from PT Jasa Marga, there are 1,140 vehicles calculated from the average of Class I vehicles passing through Toll Booth 1. From the VISSIM simulation, there are 1,180 vehicles passing through Toll Booth 1 for six consecutive days. The difference of results between VISSIM and field data is 40 vehicles, and if the result of that calibration is tested using GEH Method, acceptable result will be obtained 1.902. This value is still less than 5 (<5). This is because of no significant difference between the field data and the result of VISSIM calibration. For the vehicles of Class II, III, IV and V from 7 to 8 am, the difference between the finding data and result of VISSIM calibration based on GEH Test parameter is under 1, meaning there is no significant difference, thus the result is acceptable.

From 8 to 9 am, the traffic volume of vehicles passing through Toll Booth 1 starts to decrease, but it is still categorized as relatively crowded. However, the result of VISSIM indicates the increase of traffic volume for Class I, II and III. The difference is also still in a relatively small parameter. From the calibration based on GEH Test, there is no significant difference between the field data and the result of VISSIM. The result of calibration using GEH Test is only 0.466, thus it is acceptable. For the vehicles of Class V, namely truck having 5 axles, from 8 to 9 am, there is a relatively small increase of traffic volume, that is just one vehicle. The value of calibration using GEH Test is 0.272, thus it is acceptable.

From 11 to 12 am, the traffic volume of Class I vehicles decreases significantly enough compared with those from 7 to 8 am, that is as many as 259 vehicles. Whereas, the traffic volume of Class II, III, IV, V vehicles increases, but relatively small. The value of calibration using GEH Test is below 5, and the highest value of Class I calibration is 0.371, and hence this is acceptable.

From 12 am to 1 pm, the traffic volume of Class I vehicles passing through Toll Booth 1 continues to decrease from the volume in the previous hours. In this period, the VISSIM result shows an increase of traffic volume of Class I vehicles as many as 19 vehicles compared with the field data. For Class II, the increase of traffic volume is as many as 5 vehicles, and for Class IV as many as 3 vehicles. The results of each calibration using GEH Test are as follows: Class I: 0.723, Class II: 0.328, Class III: 0.254, Class IV: 0.594, Class V: 0.252, and for all classes, there is no significant difference, thus the result is acceptable.

From 5 to 6 pm: In this peiod, the traffic volume of Class I vehicles increases again, sisnce it is the rush hours where people go home from work, but the number of vehicles passing through is more dispersed. The result of VISSIM also shows an increase of traffic volume. The difference between the VISSIM result and the field data after being calibrated using GEH Test is not significant, i.e 1.367. In the other hand, the traffic volume of Class II, III, IV, and V

vehicles during this time decreases. The field data and VISSIM result indicates the same movement. And the result from the calibration using GEH Test for each class is still zero point (under 1), and there is no significant difference, thus it is accepted.

From 6 to 7 pm: Compared to the period of 5 to 6 pm, the traffic volume of all classes decreases. The result of VISSIM, except for Class I vehicles, shows a not so high increase. And the result of calibration using GEH Test indicates the parameter still under 1. The result is accepted.

The result of GEH Test calibration for each period has met the requirements, where the value obtained is <5, meaning that the simulation model has been accepted or calibrated. Based on the result of GEH Test calibration above, there is no significant difference between the simulation model and the real traffic condition in the field.

3.2 Validation of Simulation Modeling

Validation is the most important process before the model is used. To validate the traffic volume, the researcher uses traffic volume thatis compared between the result of the model and the result of field survey on the toll roads through which people frequently pass every day. The adjustment process of the model result to the result of field survey uses Chi Square method (Table 3 and 4).

Table 3: The Result of Statistical Test using Vehicle Speed

No	Model	Chi Square	GEH
1	Default value of average vehicle speed	0.112	0.1143
2	Default value of average vehicle speed, random seed	0.110	0.1115
3	Research at Bitung Toll Gate 1	0.089	0.0912
4	Research at Bitung Toll Gate 1, random seed	0.095	0.1090

Table 4: Result of Chi Square Statistical Test based on Traffic Volume Per Hour

Result	Vehicle Class	Period of Time					
		07.00 - 08.00	08.00 - 09.00	11.00 - 12.00	12.00 - 13.00	17.00 - 18.00	18.00 - 19.00
Condition	I	1140	1025	881	681	750	726
	II	123	154	285	229	178	130
	III	35	27	58	62	40	35
	IV	39	38	32	24	13	10
	V	12	13	14	16	11	7
CHI Test	I	1.899	0.405	0.351	0.679	1.275	0.092
	II	0.157	0.322	0.314	0.286	0.179	0.988
	III	0.594	0.467	0.082	0.213	0.015	0.613
	IV	0.397	0.126	0.093	0.511	0.434	0.620
	V	0.761	0.248	0.337	0.199	0.247	0.310
GEH Test	I	1.902	0.466	0.371	0.723	1.367	0.109
	II	0.163	0.398	0.353	0.328	0.223	0.173
	III	0.696	0.561	0.130	0.254	0.219	0.657
	IV	0.474	0.161	0.176	0.594	0.533	0.666
	V	0.817	0.272	0.364	0.252	0.308	0.391

From the result of statistical test with the parameter of traffic volume, it can be concluded that the value of Chi Square is lower than the value of GEH Test, so it is statistically stated that there is no significant difference between the result of model calculation and the result of survey carried out by the researcher. Every hour from 8 am to 7 pm, the value of Chi is lower than the value of GEH Test, and statistically there is no significant difference every hour. The increase and

decrease of Chi value are directly propotional and under the value of GEH Test, and the result of hourly traffic volume of vehicles passing through Bitung Toll Gate 1 is stated as valid. The model is stated as statistically valid, and it can be continued for further analysis.

3.3 Traffic Performance before the Addition Gate at Bitung Toll Gate 1

On toll highways, the traffic crowd generally happens at the toll gate. At Bitung Toll Gate 1, the existing five toll booths are classified into: one booth is special for Class I (Non-Bus) and four booths for multi-class. From the number of vehicles passing through, especially in the rush hours, that is from 7 to 8 am, when people go to work and from 5 to 6 pm, when people go home from work, as well as from the traffic density at Bitung Toll Gate 1, people using Bitung Toll 1 are not felt comfortable while driving, due to the density at the toll gate, and also many big sized vehicles pass through this toll highway, makes the traffic relatively hampered. The traffic performance before the booth addition using the modeling application of VISSIM is seen more crowded, showing a significant difference from the condition in the field (Figure 1).

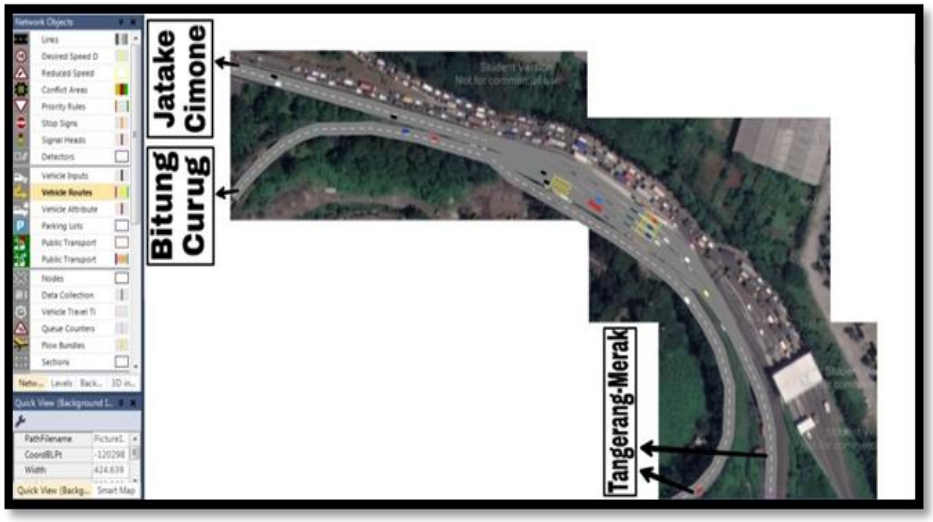

Figure 1: Condition before the Booth Addition at Bitung Toll Gate 1 (5 Toll Booths).

3.4 Booth Addition at Bitung Toll Gate 1

As known, the condition of highway in each area varies depends on the physical condition of the road as well. The addition of toll booth using VISSIM modeling will be more effective, if supported by the lane to the toll gate, the type of vehicle passing through, as well as the drivers' behaviour. In a simulation implemented at seven toll booths, only traffic flow becomes the focus of discussion. Traffic flow is determined mainly by the processing time at the toll booth and the ratio between the number of lanes to the toll booth and the number of active toll booths. The simulation shows that the expected traffic density is very much determined by the traffic flow that has been defined before. With the booth addition from 5 to 7 toll booths, it is felt more effecetive to spread the traffic density. With this booth addition, it is seen that there is a significant difference between the condition of Bitung Toll Gate 1 and the VISSIM modeling (Figure 2).

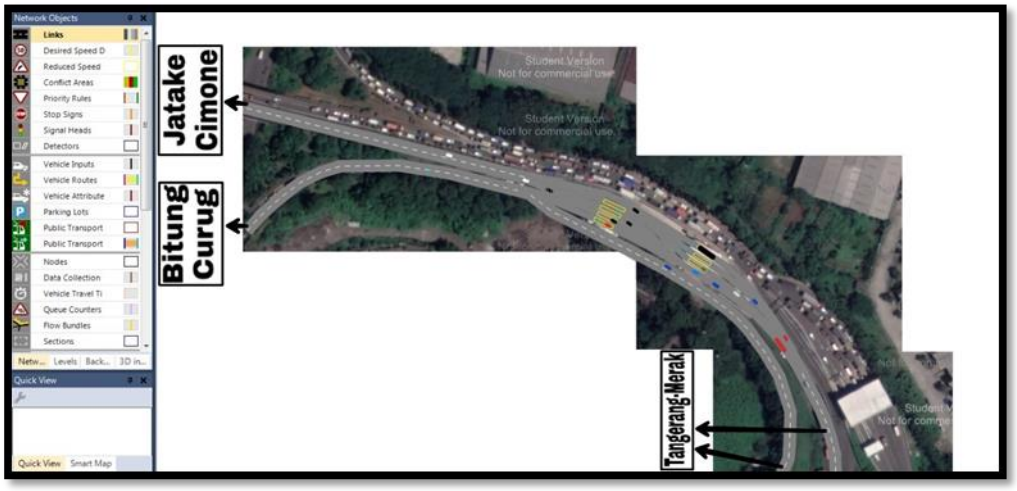

Figure 2: The Condition after the Booth Addition at Bitung Toll Gate I (7 Toll Booths).

This research which uses VISSIM model supports the research performed by Dong, et al., (2019). Their result of numeric simulation using VISSIM model in Malaysia shows that the guidance strategy significantly improves the efficiency and safety. This research also supports the finding in China obtained by Zhandong, et al., (2016), Lin et al., (2013) and Xue, Zheng, & Jin, (2019). This research also supports the finding in India by Abou-Senna, et al., (2013), and Siddharth & Ramadurai, (2013). The result of this simulation with VISSIM also supports some studies in the USA carried out by Boxill, (2007) and Aycin, (2006). The calibration of traffic simulation model using VISSIM on Kebon Nanas Toll, Tangerang has also been carried out by Raharjo, et al., 2013). Another research leads to significant change by booth addition using VISSIM modeling, although another more research shows that there is no significant difference between the result of program simulation and the result of field survey (Andriyanto & Munawar, 2012). Some of the limitations in this research are that there are two adjacent booths, only five booths exist and due to limited area, only two booths can be added.

4. CONCLUSIONS

The traffic condition at Bitung Toll Gate 1 is seen to be fairly crowded during the rush hours. The crowd happens from 7 to 9 am due to many toll users' activities. The crowd at Bitung Toll Gate 1 in the rush hours is dominated by Class 1 vehicles. From afternoon until evening, there is an increase of traffic volume, but it is not so crowded as in the morning. Concerning the traffic performance at Bitung Toll Gate 1 which originally has 5 automatic booths (before the toll booth addition), the traffic volume of vehicles entering the toll gate is seen to be more crowded, so it needs longer time. The result of field survey and the result of using VISSIM modeling application makes significant difference. Based on GEH Test calibration and the model, validation using statistical test of Chi Square which compares the traffic volume using VISSIM model with the data of field survey, it is found that the value of GEH Test calibration is under the standard, that is <5, thus the result is accepted. The value of validation is smaller than the value of calibration, meaning that there is a significant difference between the model calculation and the field data. The field survey at Bitung Toll Gate 1 and the simulation show a significant difference of value, because VISSIM modeling has indicated the real condition of traffic at Bitung Toll Gate 1. The addition of two Automatic Toll Booths much helps increase the traffic density in the rush hours. Seeing the condition and characteristics of Bitung Toll 1, there has been a significant change with the booth addition using VISSIM modeling. In addition, using VISSIM model at the Toll Gate which compares the previous Toll Booths with the two additional Toll Booths, it can be treated as a different research.

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