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The Analysis of Traffic Delay and Queue due to the Shunting Activities of Pertamina Trains of Tegal City

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Abstract: A crossing is a meeting point between roads and railways, where this often causes delays and traffic queues, as happened at the crossing on Jl. Abimanyu, Tegal City. This study aimed to analyze the volume, delay and queue length of traffic on each road which occured due to the closing of the railroad crossing. Apart from that, this research was also intended to provide reasonable alternative input for both the management of Pertamina and the road users. This research used the analysis method of v/c ratio, queue and delay with reference to the Manual for Indonesian Road Capacity. Results of the analysis show, the highest queue occurred on the Abimanyu road, which was of 70.5 pcu with the delay of 581.5 seconds/pcu. On the segment of Jl. Menteri Supeno I, the traffic queue was reported to have reached 47.8 pcu with the delay time of 441 seconds/pcu; on the segment of Jl. Semeru, the queue was reported to reach 17 pcu with the delay of 395.6 seconds/pcu, and the last one was the queue at the segment of Jl. Menteri Supeno II which was of 10.8 pcu, with the delay time of 368.5 seconds/pcu. Ones of the keys to overcome problems of traffic queues and delay were by dividing the shunting time into 2 phases according to the results of alternative analysis II where the traffic queue became smaller of 35.3 pcu with the delay time of 290 seconds/pcu and by changing the shunting schedule at off peak time.

Keywords: *V/C ratio; delays; length of queue*

1. Introduction

Transportation is an important means of supporting economic activity in most of regions. In terms of function, it has become a basic need for everyone, especially in relation to the efforts to meet the needs for life. On average, each person travels more than once in a day with different destinations; For example work, school, shopping center, recreational places etc. In order to make the intended journey, a means of transportation is required either in the form of vehicles or roads.

In fact, transportation activities do not always run smoothly. Congestion and obstacles on the road are the factors which trigger the emergence of these problems which ultimately harm the perpetrators, such as loss of time and opportunity, being exposed to air pollution, and waste of vehicle fuel. Therefore, this kind of issue must be resolved immediately by finding a way out in the hope of minimizing the congestion which occurs, although it is understood that congestion cannot be eliminated one hundred percent.

From the observations, the traffic flow in the city of Tegal was classified smooth. The traffic congestion only occured in certain segments such as at the intersections and the railroad crossings and at certain times, such as the time when people started returning from work. Due to such condition, queues and traffic delays were inevitable. From the existing congestion prone areas due to the train traffic, the railroad crossing area located on Jalan Abimanyu became the worst one with the delay time of 13-15 minutes with the traffic queue of up to 200 meters. (Field observation result, 2019)

Jl. Menteri Supeno I, Jl. Semeru and Jl. Menteri Supeno II were the roads affected by these shunting activities. During the shunting process, the railroad crossing was closed and so the traffic flow around the location became congested and had the potential to cause losses to its users. Therefore, it was necessary to have an in-depth study related to these conditions. Departing from the existing phenomena, this research would focus on analyzing the traffic delay and queue due to the shunting activities of the train in the city.

2. Literature Review

2.1. Railroad Crossing

A railroad crossing or also known as a level crossing is a road point with a railroad, crossing each other. In Indonesia, the intersection of a level road between a railroad and a highway is known as a crossing. The lower frequency crossings are usually used for safety reasons of road users and railroad users, so the tracks are equipped with "stop" or "cross bugs" signs. However, when the flow volume becomes large (both incoming and outgoing traffic), the installation of a control system becomes indispensable.

2.2. Shunting Activities

Shunting is the movement of a series of trains, wagons, or just a train to change rail lines. Line switching is mainly needed to separate or assemble trains or wagons. Since the shunting process requires special expertise to be carried out safely, the shunting is usually guided by a shunter. The shunter can go down directly to the shunting area or control from the shunting room. Meanwhile, the steering is controlled by a machinist who sits in the train by moving it following the instructions from the shunter. The length of time spent for shunting can also be determined by the expertise and skills of the machinist and parking attendant.

2.3. Objectives of Shunting

Shunting activities were very possible to happen either at the station, at the depot (train garage) or at the other train stops, in general, the aimed of these activities were as follows:

a. Set together the train series
b. Increase or decrease the number of wagons in a series
c. Clear the sequence for trains returning to the train depot.

The aims of shunting on Jl. Abimanyu, Tegal City were to take the empty tank wagons and put the tank wagon filled with fuel into the yard of the depot of Pertamina.

2.4. Shunting Time

In one day, there were 3 (three) shifting activities carried out by Pertamina trains, first at 10.00 am until completion, second at 01.30 pm until completion, and the third at 06.30 pm until completion.

2.5. V/C Ratio Analysis

VC ratio was one of the aspects used in measuring road performance parameters, which was done by comparing between the flow of busy times on the roads and the road capacity. Traffic volume is defined as the number of vehicles passing a certain point or line in a cross-section of the road (Sukirman, 1994).

a. Traffic Volume

The traffic volume can be searched by classifying the type of vehicle before being converted into a Passenger Car Unit (pcu). For more details, see table 2.1 below:

Table I. PCE value description [1]

Types of Vehicles	Passenger Car Equivalent (pcu/hour)
Heavy Vehicle (HV)	1.3
Light Vehicle (LV)	1
Motorcycle (MC)	0.4

b. Road Capacity

Capacity is the maximum volume of vehicle that can be expected for a road cut in a certain period of time and for certain conditions. The capacity is better known as the "maximum capacity" of a road to the volume of traffic it passes.

Road capacity has different capabilities depending/ influenced by road width and use (one or two directions). The value of the capacity/ capacity of a road segment is expressed in pcu/ hour (Passenger Car Unit per hour). The capacity calculation for urban roads is as follows:

$$C = C_0 \times FC_w \times FC_{sp} \times FC_{sf} \times FC_{cs} \quad (1)$$

where:
C : Capacity (pcu/hour)
C_o : Basic capacity (pcu/hour)
FC_w : Adjustment factor for the traffic lane width
FC_{sp} : Adjustment factor for the direction separation
FC_{sf} : Adjustment factor for the side barriers
FC_{cs} : Adjustment factor for the city size

Table 2. Service Levels based on V/C Ratio [1]

V/C Scope Limits	Service Level	Traffic flow characteristics
0.0-0.19	A	Free flow conditions with a speed of at least 80 km/hour, very low traffic density, drivers can maintain the speed as desired without or with a little delay.
0.20-0.44	B	Current conditions are stable with a speed of at least 70 km/hour, low traffic density, internal traffic obstacles have not affected the speed, drivers still have enough space to determine the speed and use the lane of road.
0.45-0.69	C	Flow is stable but vehicle movement is affected by higher traffic volume, speed of at least 50 km/hour, moderate traffic density due to the increased internal traffic resistance, drivers are not free to determine the speed, change the lanes or overtake.

0.70-0.84	D	The flow is approaching unstable with high traffic volume, speed of at least 50 km/hour, moderate traffic density but experiencing fluctuation of traffic volume, temporary obstacles having the potential to cause a very large decrease in speed, the drivers are not free to control the speed of their vehicle, however this condition can still be tolerated for a short period of time.
0.85-1.0	E	Flow is approaching unstable with the traffic volume approaching the road capacity with the speed of at least 30 km/hour on the intercity roads and at least 10 km/hour on the urban roads, traffic density is high due to high internal traffic resistance, drivers start to feel congestion of short duration.
> 1.0	F	The flow is approaching unstable with traffic volume approaching the road capacity with speed of at least 30 km/hour; high traffic density; long duration of congestion; in queues, the speed or volume drops to zero.

2.6. Vehicle Queue

The queue length was measured since the track gate was closed until the door was opened, while to calculate the average number of queues the following formula was used:

$$NQ = \frac{\sum n}{n} \tag{2}$$

Where:
NQ = Average number of queue (pcu)
Σn = Total number of vehicles in the queue (pcu)
n = Number of tracks closed

2.7. Ratio of Stopped Vehicle

The stopped vehicle ratio Nsv, was the ratio of vehicles which had to stop due to a red signal before passing through an intersection, i was calculated as:

$$N_{sv} = Q \times NS \tag{3}$$

Where NS was the stop number and an approach, while Q was the traffic flow (pcu/hour).

2.8. Delay

The average traffic delay on an approach j could be determined by the following formula (Akcelik 1988):

$$DT = c \times A + \frac{NQ_1 \times 3600}{C} \tag{4}$$

$$A = \frac{0.5 \times (1 - GR)^2}{(1 - GR \times DS)} \tag{5}$$

Where:
DT = Average traffic delay (sec/pcu)
c = Cycle time adjusted (sec) from the form of SIG-IV
GR = Green ratio (g/c)
DS = Degree of saturation
NQ_1 = Remaining number of pcu from previous green phase
C = Capacity (pcu/hour)

3. Research Method

3.1. Site of Research

The research was conducted in the surrounding of the railroad crossing near PT. Pertamina, the city of Tegal. Field observations and surveys were carried out at several location points or road sections which had been divided into segments:
Segment 1 : Jl. Abimanyu in front of PT. Pertamina Tegal
Segment 2 : Jl. Semeru
Segment 3 : Jl. Menteri Supeno I (towards SMA 1 Tegal)
Segment 4 : Jl. Menteri Supeno II (towards Yos Sudarso stadium)

Figure 1. Road segments affected by the shunting activities

3.2. Data Requirement

There were 2 (two) types of data required in this study:

a. Secondary Data
Secondary data were obtained through a variety of ways including literature review, scientific articles, government agencies, the private sector, or even through either print or electronic media. Secondary data in this study included shifting schedules, road network maps, images / image maps.

b. Primary Data
Primary data in this study were obtained through observation and survey at the research site where the shunting activities took place. The required data included:

1. Traffic volume survey
This was done by calculating the amount of traffic volume on the affected road sections (the number of vehicles passing through the road sections were counted and classified based on the type of vehicle.

2. Road inventory survey
Checking the road conditions by directly measuring the road and its accessories using a measuring instrument such as roll meter. The road condition data were then used to calculate the capacity of the existing road sections.

3. Delay and queue survey
Data collection on queuing and delay was done during the shunting process. All progresses were recorded, counted and measured in accordance with the real conditions.

3.3. Data Analyses

Data analyses were made by:

a. Calculating the amount of traffic volume on the affected roads due to the shunting activities. This calculation was done by classifying the vehicle based on its type.

b. Calculating the road capacity on the road sections affected by the shunting activities; calculating the capacity by carrying out an inventory of the road and its accessories in accordance with the actual conditions such as lane width, road shoulders, sidewalks, etc. There were several factors to consider while calculating the road segment capacity like mentioned in Eq. (1).

c. Calculating the queue of vehicles when there was a shunting activity during the closing of the crossing arm gate, then making an alternative phase related to the closing time of the crossing. For example, the first phase was calculated when a train entered the depot to transport or pull an empty wagon/ tank out of the depot, then after the last series of wagons had passed through the crossing gate, the door would be reopened.

$$NQ = NQ_1 + NQ_2 \tag{6}$$

In the second phase, the train re-entered the depot of Pertamina carrying 16 series of wagons which had been filled with fuel, then the crossing gate was re-closed, 8 carriages could be first removed to line 1 then 8 wagons were pulled back until they passed through the crossing, when the last series passed through the crossing gate, then the arm gate was reopened to release the queue.

$$NQ_1 = 0.25 \times C \times \left[(DS - 1) + \sqrt{(DS - 1)^2 + \frac{8\times(DS-0.5)}{C}}\right] \tag{7}$$

In the third phase, the remaining 8 of wagon series were brought back into the depot, and the crossing gates were re-closed. The wagon entered the second lane then the train left the depot. The arm gate was re-opened once the train passed through the crossing gate, then the shunting was complete.

Calculating delay in each phase and so each phase had its own value of delay.

$$DT = c \times \frac{0.5\times(1-GR)^2}{(1-GR\times DS)} + \frac{NQ_1\times 3600}{C} \tag{8}$$

d. Selecting the best phase with the least value of queue and delay. This option would later become a reasonable recommendation for implementation during the shunting process.

e. The alternative option method was carried out through interview involving 2 elements, road users and the management of Pertamina as the organizer of the shunting activities.

3.4. Alternative Determination

1. 3.4.1.Alternative distribution

In conducting the analysis, the researcher divided the shunting activity into several alternatives based on the shunting activity and the length of the shunting. Alternative I - the existing shunting activity, Alternative II – diving the shunting activity into 2 cycles (taking the empty kettle wagon, entering the fuel-filled wagon), Alternative III - dividing the shunting activity into 4 cycles (taking the empty kettle wagons in the first 8 series, taking empty kettle wagon in the second 8 series, placing the kettle wagons in the first 8 series, placing the kettle wagon in the first 8 second series). Performing the alternative distribution which aimed to find the queues and delays ideal for shunting activities of Pertamina Train.

2. Alternative option

The alternative option method was carried out by interview involving 2 elements; road users and Pertamina as the organizer of the train shunting activities.

4. Result and Discussion

This section presented the result of discussion and analyses carried out using predetermined analytical methods. The results of the analyses would determine types of recommendations to deal with the existing issues as addressed by this study.

4.1. V/C Ratio Analyses

V/C Ratio was a calculation method used to measure road performance, where the traffic volume on the road would be divided by the existing road capacity in the real conditions. From the calculation of volume and capacity using the V/C Ratio resulted follows:

Table 3. Calculation V/C Ratio

Road	Co	FCw	FCsp	FCcf	FCcs	C	V	V/C Ratio
Jl. Abimanyu	2900	1.14	0.97	0.94	0.9	2.713	2090.1	0.77
Jl. Menteri Supeno I	2900	1.25	1	0.92	0.9	3.002	1308.0	0.44
Jl. Semeru	2900	0.87	1	0.92	0.9	2.089	857.0	0.41
Jl. Menteri Supeno II	2900	0.87	1	0.96	0.9	2.180	682.8	0.31

From the calculation result of V/C Ratio above, the lowest road performance was on Jl. Abimanyu with the value of 0.77. assuming that the result of which (V/C Ratio value) was approaching 1.00. Looking at Table 2., the Road Service Level belonged to category D. Otherwise, Jl. Menteri Supeno II based on the study was indicated to have the best performance with V/C ratio value of 0.31 that it belonged to category B, in term of service level.

4.2. Traffic Queue

The traffic queue due to the closing of the railroad crossing as the result in the shunting activities occured 3 times a day; in the morning, in the evening and at night. Shunting activities in the morning occured at 09.30 am, in the afternoon at 04.30 pm, and in the evening at 08.30 pm. The following are data obtained from the field observations and surveys:

Table 3. Analysis Result of Queue and Delay

Road section	Time schedule	duration	Length of queue	Amount of queue (pesenger car equivalency)				
				Motor-cycle	Light Vehicle	Heavy Vehicle	Un-motor-cycle	Total of Queue
Jl. Abimanyu	09.30 a.m	900	177	44.7	20	2.6	16.4	83.7
	04.00 p.m	780	110	49.8	14	2.6	0.4	66.8
	08.30 p.m	720	90	32.1	26	1.3	1.6	61
	Average	800	126	42.2	20	2.2	6.1	70.5
Jl. Menteri Supeno I	09.30 a.m	900	79	15	21	3.9	0	39.9
	04.00 p.m	780	182	23.7	43	3.9	2	72.6
	08.30 p.m	720	92	10.8	20	0	0	30.8
	Average	800	118	16.5	28	2.6	0.7	4.8

Jl. Semeru	09.30 a.m	900	30	6	7	0	2	15
	04.00 p.m	780	15	6.9	11	1.3	2.8	22
	08.30 p.m	720	10	5.4	6	0	1.6	13
	Average	800	18	6.1	8	0.4	2.1	16.7
Jl. Menteri Supeno II	09.30 a.m	900	30	3	4	1.3	1.6	9.9
	04.00 p.m	780	15	4.2	6	0	1.6	11.8
	08.30 p.m	720	10	2.1	5	1.3	2.4	10.8
	Average	800	18	3.1	5	0.9	1.9	10.8

4.3. Delay

Below are the amounts of the traffic delays and queues due to the shunting activities of Pertamina train:

Table 4. Alternative Choice of Jl. Abimanyu

Matrix	Abimanyu Street			Priority
	Queue (pcu)	**Stopped vehicle (pcu/hour)**	**Delay (sec/pcu)**	
Alternative 1	70.5	285.5	581.5	-
Alternative 2	35.3	142.8	290.8	-
Alternative 3	17.6	71.4	145.4	-
Lowest	Alt III	Alt III	Alt III	Road user
Highest	Alt I	Alt I	Alt I	Relevant Institute
Median	Alt II	Alt II	Alt II	Road user & relevant institute

Tabel 5. Alternative Choice of Jl. Menteri Supeno I

Matrix	Jl. Menteri Supeno I			Priority
	Queue (pcu)	**Stopped vehicle (pcu/hour)**	**Delay (sec/pcu)**	
Alternative 1	47.8	193.5	441	-
Alternative 2	23.9	96.7	220	-
Alternative 3	11.9	48.4	110	-
Lowest	Alt III	Alt III	Alt III	Road user
Highest	Alt I	Alt I	Alt I	Relevant Institute
Median	Alt II	Alt II	Alt II	Road user & relevant institute

Tabel 6. Alternative Choice of Jl. Semeru

Matrix	Jl. Semeru			Priority
	Queue (pcu)	Stopped vehicle (pcu/hour)	Delay (sec/pcu)	
Alternative 1	17	42.8	395.6	-
Alternative 2	8	21.4	197.8	-
Alternative 3	4	10.7	98.9	-
Lowest	Alt III	Alt III	Alt III	Road user
Highest	Alt I	Alt I	Alt I	Relevant Institute
Median	Alt II	Alt II	Alt II	Road user & relevant institute

Tabel 7. Alternative Choice of Jl. Menteri Supeno II

Matrix	Jl. Menteri Supeno II			Priority
	Queue (pcu)	Stopped vehicle (pcu/hour)	Delay (sec/pcu)	
Alternative 1	10.8	31.3	368.5	-
Alternative 2	5.4	15.7	184.2	-
Alternative 3	2.7	7.8	92.1	-
Lowest	Alt III	Alt III	Alt III	Road user
Highest	Alt I	Alt I	Alt I	Relevant Institute
Median	Alt II	Alt II	Alt II	Road user & relevant institute

From the results of the analysis, the biggest vehicle queues and delays occured on Jl. Abimanyu and the largest alternative option for the value of traffic queues and delay time was in Alternative I.

The results of interviews conducted to the road users and Pertamina companies are presented in the table as follow:

Table 8. Alternative option

Respondent	Status Respondent	First Choice	Second Choice	Reasoning
1	Pertamina	Alternative I	Alternative II	Shortening the fuel loading time, saving more time in order that fuel can be more quickly distributed to gas stations, energy consuming as the shunting process takes a long time
2	Pertamina	Alternative I	Alternative II	
3	Pertamina	Alternative I	Alternative II	
4	Pertamina	Alternative I	Alternative II	
5	Pertamina	Alternative I	Alternative II	
6	road user	Alternative III	Alternative II	Long waiting time, impeding traffic flow, inconvenience for motorcyclist as they are directly exposed to the heat of the sun due to a long wait,
7	road user	Alternative III	Alternative II	
8	road user	Alternative III	Alternative II	
9	road user	Alternative III	Alternative II	
10	road user	Alternative III	Alternative II	

11	road user	Alternative III	Alternative II	disadvantage for online taxibike as order is sometimes canceled, boredom due to a long wait for the shunting process to finish, there is often a rush among motorbike and other vehicles when the arm gate of the railroad crossing is opened
12	road user	Alternative III	Alternative II	
13	road user	Alternative III	Alternative II	
14	road user	Alternative III	Alternative II	
15	road user	Alternative III	Alternative II	

The results of the interview show that Alternative II was the option for recommendation, on the grounds that this option was the choice of the respondents. In addition, it implied that they agreed to have the shunting time be divided into 2 phases.

5. Conclusion

Based on the results of the traffic volume analysis on roads affected by shunting activities in Tegal City, it was reported that peak hours occured 3 times a day; morning, afternoon and evening. On Jl Abimanyu, the density occured during the day at 12.45-13.45 with the traffic volume of 2.774.3 pcu/hour. On Jl. Menteri Supeno I, traffic density occured in the afternoon between 16.30 - 17.30 with the traffic volume of 1,549 pcu/hour. Meanwhile, on Jl. Semeru, the density also occured in the afternoon at 16.00 - 17.00 with the traffic volume of 899 pcu/hour and the last one was the traffic density which occured on Jl. Menteri Supeno II in the afternoon between 16.00 - 17.00 with traffic volume of 866 pcu/hour.

The worst queues and traffic delays due to the shunting activities of Pertamina train took place on Jl. Abhimanyu with the average queue length of 126 meters, and with the average total queue of 70.5 pcu. The amount of delay occurred in the actual conditions on the street was 582 seconds/pcu or equal to 9.69 minutes/pcu with the number of vehicles stopped of 286 pcu/hour.

Alternative I was the condition that reflected the existing phenomena in accordance with the results as stated in the conclusion number 2 above. Alternative II, the highest average queue length occured on Jl. Abhimanyu of 71 meters with the average number of queues of 35.3 pcu, while the value of the delay was 4.85 minutes/pcu with the number of vehicles stopped of 143 pcu/hour. Meanwhile, the lowest queue value occurred on Jl. Menteri Supeno II had the average queue length of 9 meters with the average number of queues of 5.4 pcu, while the value of the delay was 3.07 minutes/pcu with the number of vehicles stopped of 16 pcu/hour. Alternative III, the highest average queue length on Jl. Abhimanyu was 31 meters with the average number of queues of 17.6 pcu, while the value of the delay was 2.42 minutes/pcu with the number of vehicles stopped of 71 pcu/hour, whereas, the smallest value was obtained on Jl. Menteri Supeno II with the average queue length of 5 meters with the average queue of 2.7 pcu, while the value of delay was 1.54 minutes/pcu with the number of vehicles stopped at 8 pcu/hour. From the three alternatives mentioned above, Alternative I had the largest queue and delay value, on the other hand, Alternative III had the smallest queue and delay value, while Alternative II had the queue and intermediate delay value between Alternative I and Alternative III.

References

[1] Direktorat Jalan Bina Kota. (1997). Manual Kapasitas Jalan Indonesia (MKJI). Departemen Pekerjaan Umum. (in Indonesian).
[2] Anonim. (2003). Kota Lampung Dalam Angka. Badan Pusat Statistik. Bandar Lampung.
[3] Amal, A.S. (2003). Pengaruh Penutupan Pada Jalan Raya Malang-Surabaya KM.10, Theses s-2 Universitas Dipenogoro. Semarang.

[4] Hadis, C.S. (2013). Hubungan Tundaan dan Panjang Antrian Terhadap Konsumsi Bahan Bakar Akibat Penutupan Pintu Perlintasan Kereta Api (Studi Kasus perlintasan keretaapi di surakarta). Universitas Sebelas Maret. Surakarta.
[5] Kartika, AG, Wahyuningsih. Pantuan Panjengaruh Penutupan Pintu Perlintasan Terhadap Penjang Antrian Lengan Persimpangan dengan Analisis Gelombang Kejut. *Jurnal Manajemen Rekayasa Transportasi*. Institut Teknologi Sepuluh November.Surabaya.
[6] Morlok, E.K. (1988). *Pengantar Teknik Dan Perencanaan Transportasi*. Jakarta.:Erlangga.
[7] Mujahidin, Muhammad Imammul., Agus Sumarsono. (2014). Hubungan Tundaan dan Panjang Antrian terhadap Konsumsi Bahan Bakar Akibat Penyempitan Jalan (BOTTLENECK) pada Pembangunan Flyover Palur (Studi Kasus : Jalan Raya Palur KM 7,5). *Jurnal Matriks Teknik Sipil*. Surakarta.
[8] Pane, Fanto Pardomuan, Semuel Y.R. Rompis, dan James A Timboeleng. (2018). Analisis Perbandingan Panjang Antrian menggunakan Teori Antrian dan Analisa Gelombang Kejut Di Loket Keluar Kendaraan Kawasan Megamas Manado. Jurnal Sipil Statis Vol6 No.2 (101-112).
[9] Puspitasari, R. (2016). Analisis Tundaan Pintu Kereta Api (Studi Kasus Segmen Ruas Jalan Simpang Urip Sumoharjo – Kimaja)
[10] Rahayu, Gati, Sri Atmaja P. Rosyidi, Ahmad Munawar. (2009). Analisis Arus Jenuh dan Panjang Antrian pad Simpang Bersinyal Studi Kasus di Jalan Dr. Sutomo-Suryopranoto. Jurnal Ilmiah Semesta Teknika Vol. 12, No. 1, 99-108, Yogyakarta.
[11] Sinalungga, B.D. (1999). Pembangunan Kota: Tinjauan Regional Dan Lokal. Universitas Michigan. Amerika Serikat.