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Evaluation of Traffic Engineering Management in Semarang City CBD with the Contram Application

Achmad Choliq Anwar*, Rachmat Mudiyono, Soedarsono

Faculty of Engineering, Sultan Agung Islamic University, Semarang, Indonesia

Email address:

Wasmad88@gmail.com (Achmad Choliq Anwar), Rachmat@unissula.ac.id (Rachmat Mudiyono), Soedarsono@unissula.ac.id (Soedarsono)

*Corresponding author

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Abstract: One of the centers of economic activity in Semarang City is the Tugu Muda Central Business District (CBD) area which is located on the Imam Bonjol, Captain Piere Tendean, and Pemuda roads. This area is a center of community movement which has a very high traffic pull generation, causing congestion. The Semarang City Government since 2017 until now (2022) has implemented a One Way System in the area. Therefore, it is necessary to evaluate the existing traffic services after 5 years of implementation. This research was conducted to determine the effectiveness and efficiency of the existing One Way Traffic System during the morning peak hour. The trick is to compare performance using 2 alternative scenarios. Alternative I uses a two-way system without parking lanes and Alternative II uses a two-way system with parking lanes. The method used is a case study based on MKJI calculations and the use of the Contram Release 5.09 application. The results of the analysis show that for the performance of roads (micro), namely V/C Ratio and speed, the One Way System has a better value than Alternative I and Alternative II. For road network performance (macro) which consists of travel time, mileage, network speed, and fuel consumption also has a better value. One Way System after 5 years is still feasible.

Keywords: Evaluation, Traffic Services, One Way System, Contram Release 5.09

1. Introduction

The city of Semarang as the provincial capital is the main city as the economic pulse of the people of Central Java. According to Semarang City BPS (Central Bureau of Statistics) data which was published to the public in September 2020, the population of Semarang City in 2019 was 1,689,655 people [1]. When compared to 2018, the population of Semarang City has increased by around 1.26 percent. One of the causes of this population growth is due to the high level of urbanization in the city of Semarang. The many opportunities in the economic sector make "village" people flock to the city of Semarang to make a living. The large number of residents causes economic activity to become massive so that it affects traffic conditions. Besides that, the large number of movements from outside the city that enter the city of Semarang or just passing by also affect the traffic conditions of the city of Semarang.

As a real picture of traffic conditions in the city of Semarang, according to research conducted by Devi et. al. (2012) [2], the number of daily movements of people on one of the main roads, namely on Kaligawe Road (around Terboyo Bus Station), traffic during the morning peak hour reaches 11,671 vehicles/hour or the equivalent of 3,592 pcu/hour. The average speed of vehicles during traffic jams on the Kaligawe road section (direction from Demak towards Semarang) for a distance of 2,000 m is around 616 seconds or an average of about 10 minutes, while the average speed of vehicles for a distance of 2,000 m is of 13.45 Km/Hour. From these data, we get an overview of high traffic flow but causes low vehicle travel speed on one of the main roads leading to Semarang City. From this, you can imagine how much fuel is needed in a day to serve the community.

Still according to Devi et. al., traffic jams can be triggered by the existence of economic facilities for community needs,

such as facilities in the transportation, industrial and trade sectors [2]. One of the centers of economic activity or the Central Business District (CBD) in Semarang City which is the focus of congestion is the Tugu Muda Area of Semarang City which includes government centers, schools, shopping centers, campuses, offices and hotels. This area is the center of community movement because of its strategic location in the middle of the city. So that this area is a very high traffic-generated area of attraction, as well as a trajectory for the movement of people from the suburbs of Semarang City.

Since 2017, the Tugu Muda Semarang CBD Area has implemented a One Way System arrangement by the Semarang City Government. Precisely on the Imam Bonjol road, the Captain Piere Tendean road and the Pemuda road. As a protocol road which is the main access to the center of community activity, the Semarang City Government is very serious about traffic engineering management on that road. One Way System engineering management is expected to be able to solve existing traffic problems, such as the complicated congestion problem. But the consequence causes longer traffic circulation and high fuel consumption. In the end, a sustainable transportation system cannot occur due to high environmental pollution.

In 2022, after five years of implementing the One Way System traffic engineering management, it is necessary to carry out an evaluation to determine a comparison of traffic services [3]. Evaluation is carried out to find out which traffic engineering management is the best, is it a One Way System or are there other alternatives. On this occasion, research on evaluation will be carried out, by bringing up alternative traffic services for comparison of performance [4]. So that from the measured evaluation, it can be concluded whether the One Way System is the best service or not to be applied to the road network under study.

2. Methodology

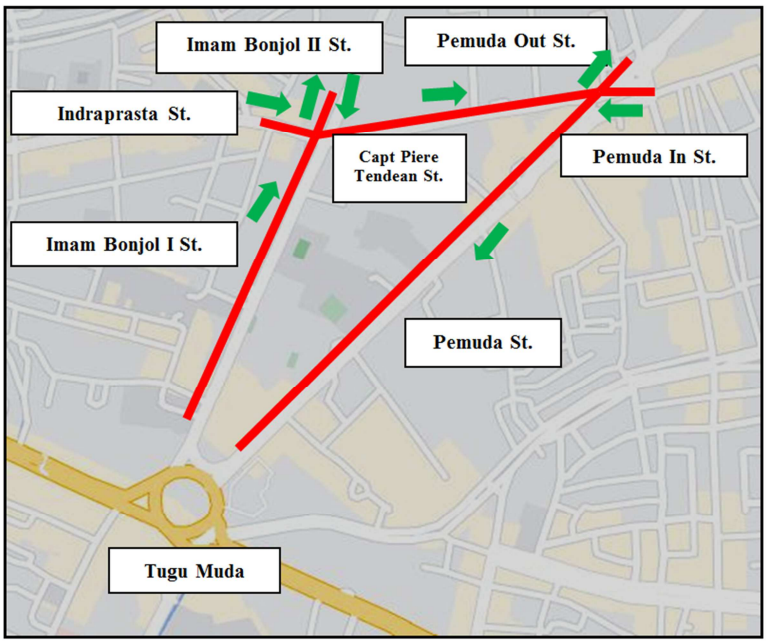
The methodology used in the research consists of:

2.1. Research Approach

The focus of the research is measuring the performance of the road network, so the main instrument used is the standard for measuring roads that apply in Indonesia, namely the Indonesian Highway Capacity Manual (IHCM) 1997 [5-9]. The supporting instrument used in the research is the Contram Release 5.09 application, which is a foreign-made traffic simulation application. the use of which can be adapted to the standards in MKJI 1997 (call name of IHCM) [6]. Because the main instruments and supporting instruments used are aligned, the two instruments can support each other in data processing, both primary data and secondary data [10].

2.2. Research Sites

The research location is the traffic network around the Tugu Muda Semarang CBD which consists of the Imam Bonjol road, the Captain Piere Tendean road, and the Pemuda road and the surrounding roads can be seen in Figure 1 below. The road segments that are one way are Imam Bonjol I, Indraprasta, Captain PiereTendean, Pemuda Out, Pemuda In, and Pemuda. The evaluation process related to the implementation of the One Way System on the road network is a measurement of road network performance in the existing conditions, after which performance is compared with other traffic control models, namely a two-way system without parking lanes and a two-way system with parking lanes.



Source: Google maps processed (2022)

Figure 1. *Existing Road Network Map.*

2.3. Method of Collecting Data

Data collection consists of primary data and secondary data [10]. Primary data is data obtained from observation surveys and direct calculations in the field. This data is in the form of road geometric data to determine the capacity of the road section, the number of vehicles per unit time to determine the volume of the road segment, and the vehicle speed at a point on the road segment. The time for primary data collection was carried out during the morning peak hour, namely 06.30 - 07.30, because this is the time when people start carrying out their daily activities such as going to work, school and other socio-economic activities.

Secondary data was obtained from related agencies, namely from the Semarang City Transportation Office, Semarang City BPS and other literature sources. Secondary data is in the form of city characteristic data, location data, and existing traffic engineering management data.

2.4. Data Analysis

2.4.1. V/C Ratio

In this study, the level of road performance is calculated based on the V/C Ratio (ratio of volume per capacity). To find the V/C ratio, it is determined in advance by measuring the capacity of the available sections and calculating the flow of traffic passing through the sections [6, 11-13]. The general standard that can be used to measure traffic performance is the Indonesian Highway Capacity Manual (IHCM). Traffic volume is the flow of traffic passing through a road section and the nature of mixed vehicles of different sizes and dimensions, it is necessary to use a standard measure, namely the passenger car unit (PCU) [6].

Table 1. *Passenger Car Unit (PCU).*

Vehicle Type	PCU
Light Vehicle	1.00
Heavy Vehicle	1.30
Motorbike	0.30
Non Motorized	0.28

Source: IHCM (1997)

Road capacity is the maximum number of vehicles that can cross a cross-section of a road segment at a certain time. Urban road capacity is calculated using formula (1) based on IHCM 1997 [11].

$$C=Co \times FCw \times FCsp \times FCsf \times FCcs \times FCks \quad (1)$$

Keterangan:
C = Road Capacity (pcu/hour)
Co= Basic capacity for certain or ideal conditions
FCw= Traffic lane width adjustment factor
FCsp= Directional separation adjustment factor
FCsf= Road shoulder adjustment factor
FCcs= Capacity adjustment factor for city size
FCks= Adjustment factor with curb and shoulders

Table 2. *Service Level Characteristics.*

Service level	Characteristics	Scope limit V/C Ratio
A	Free flow conditions at high speed, the driver can choose the desired speed without obstacles	0.00 – 0.20
B	The flow is stable, but the operating speed is starting to be limited by traffic conditions. The driver has sufficient freedom to choose the speed	0.20 – 0.44
C	The flow is stable, but the speed and motion of the vehicle are controlled. The driver is limited in choosing the speed	0.45 – 0.74
D	The current is approaching unstable, the speed can still be tolerated	0.75 – 0.84
E	Traffic volume is approaching/at capacity. The current is unstable, the speed sometimes stops	0.85 – 1.00
F	Forced or stalled current, low speed, volume above capacity. The queues were long and there were major obstacles	> 1.00

Source: Directorate General of Land Transportation – Indonesia DOT, 1997 [14].

2.4.2. Contram Release 5.09 Application

The Contram Release 5.09 application is a computer application program for comprehensive transportation planning that has the ability to model trip assignment forecasting that assesses traffic loading based on the information provided regarding the road network (supply) and traffic demand (demand). Contram uses an iteration process, in which with several iterations a balanced traffic flow pattern is achieved, namely a pattern of vehicles charged to the road network with the same route in successive iterations. Contram requires input data regarding existing traffic conditions, so that it can estimate and forecast in detail regarding:

a. Traffic flow on the road network in the study area.
b. Barriers and queues at every segment and intersection.
c. The average speed on each road segment.
d. Fuel consumption.

The working principle of the Contram Release 5.09 application is basically almost the same as other traffic assignment applications, where the principle of the minimum limit (shortest path) is also used, that is, drivers are assumed to already know the existing traffic conditions, so they will choose the route with the minimum trip [15].

2.4.3. Traffic Simulation Model Validation

According to Sudaryono (2012), the Chi-square test ($\chi 2$) is a statistical technique that makes it possible to obtain probability values to obtain differences between observations or observations with expected results in certain categories [16]. The general formula for the Chi-square test ($\chi 2$) is outlined in formula (2) below.

$$\chi^2 = \sum_{i=i}^{k} \frac{(\text{fo}-\text{fh})^2}{\text{fh}} \quad (2)$$

Formula description:
χ^2= Chi-square
fo= Observation frequency / model simulation results
fh= Frequency of expectations / survey results

2.4.4. Four Steps Model Analysis

The analysis carried out is the application of the four steps model transportation planning method which consists of analysis of trip attraction generation, trip distribution, mode selection and traffic loading. This process is carried out with the help of the Contram Release 5.09 application [17].

2.4.5. Traffic Performance Comparison

The final step is the process of comparability or comparison of road network performance data between the existing One Way System conditions, two-way Alternative I without parking lanes, and two-way Alternative II with parking lanes. The comparison is to compare the value of traffic indicators in each scenario. The indicators for assessing road performance consist of V/C Ratio, section speed, overall travel time, overall travel distance, average speed of the road network, and fuel consumption [15].

3. Analysis and Research Results

3.1. Existing Traffic Analysis and Model Validation

Analysis of the existing One Way System traffic on the road network studied, namely during the morning peak hour conditions (06.30-07.30) the results for the performance of the road sections are obtained in table 3.

Table 3. *Existing Condition Traffic Performance.*

Road Segmen	Flow Type	V/C Ratio	Velocity (Km/Hour)
Imam Bonjol I St.	One Way	0,22	50,7
Indraprasta St.	One Way	0,35	50,0
Imam Bonjol II St.	2/2 UD	0,27	44,9
CaptainPiereTendean St.	One Way	0,49	56,8
Pemuda Out St.	One Way	0,29	29,3
Pemuda In St.	One Way	0,58	48,7
Pemuda St.	One Way	0,54	55.9

Source: Analysis results (2022)

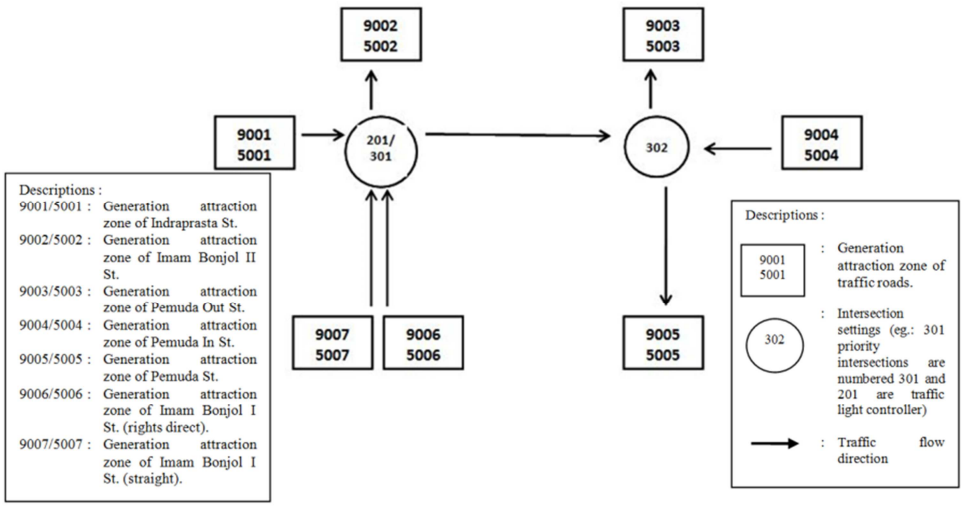
Meanwhile, the calculation of road capacity based on existing conditions is presented in table 4 below.

Table 4. *Existing One Way System Road Capacity.*

Road Segmen	Flow Type	Wide (Meter)	Base Capacity (PCU/Hour)	Adjustment Factor					Road Capacity (PCU/Hour)	Desc.
				FCw	FCsp	FCsf	FCcs	FCks		
Imam Bonjol I St.	OW	13,1	4.950	0,96	1	0,97	1	1,02	4.702	1 Lane Parking
Indraprasta St.	OW	13	4.950	1,08	1	0,97	1	0,98	5.082	No Parking Lane
Imam Bonjol II St.	2/2 UD	13,1	2.900	1,34	1	0,9	1	1	3.497	No Parking Lane
CaptainPiereTendean St.	OW	14,3	4.950	1,04	1	0,9	1	1,02	4.726	1 Lane Parking
Pemuda Out St.	OW	14	4.950	1,08	1	1	1	0,98	5.239	No Parking Lane
Pemuda In St.	OW	15	4.950	1,08	1	1	1	1,02	5.453	No Parking Lane
Pemuda St.	OW	16,8	6.600	1,08	1	0,97	1	1,02	7.052	No Parking Lane

Source: Analysis results (2022)

One of the most important parts of the process for evaluating road network performance is conducting an analysis of travel demand. Where this trip demand is an estimation of the trip for traffic facilities. The evaluation process carried out in this study is an analysis of changes in the level of accessibility of a road network from a One-Way System to a Two-Way System with the criteria of Alternative I without parking space and Alternative II with parking spaces. The existing traffic flow pattern is shown in an imaginary map of One Way System settings in Figure 2 below.



Source: Analysis results (2022)

Figure 2. *Codification of the Existing Condition Road Network.*

The trip demand analysis stage consists of four stages, namely attraction generation, trip distribution, mode selection, and traffic assignment. This analysis process is carried out with the help of the Contram Release 5.09 application. From this application, the road network performance output data is obtained from the model that has been made. The model is said to be in accordance with the conditions in the field if it meets certain significance. The significance usually used is 95% with a margin of error of 5%. To get the significance level, it is necessary to validate it with the Chi-square test [16]. The validation of the contram model is outlined in table 5.

Table 5. *Contram Model Validation.*

Road Segmen	Volume		X^2
	Survey (PCU/Hour)	Contram (PCU/Hour)	
Imam Bonjol I St.	1.034	1.035	0,00097
Indraprasta St.	1.768	1.769	0,00057
Imam Bonjol II St.	943	943	0,00000
Captain PiereTendean St.	2.338	2.339	0,00043
Pemuda Out St.	1.511	1.494	0,19344
Pemuda In St.	3.143	3.139	0,00510
Pemuda St.	3.796	3.984	8,87149
		Total (RU_X^2)	9,07198

Source: Analysis results (2022)

Degree of freedom (df)

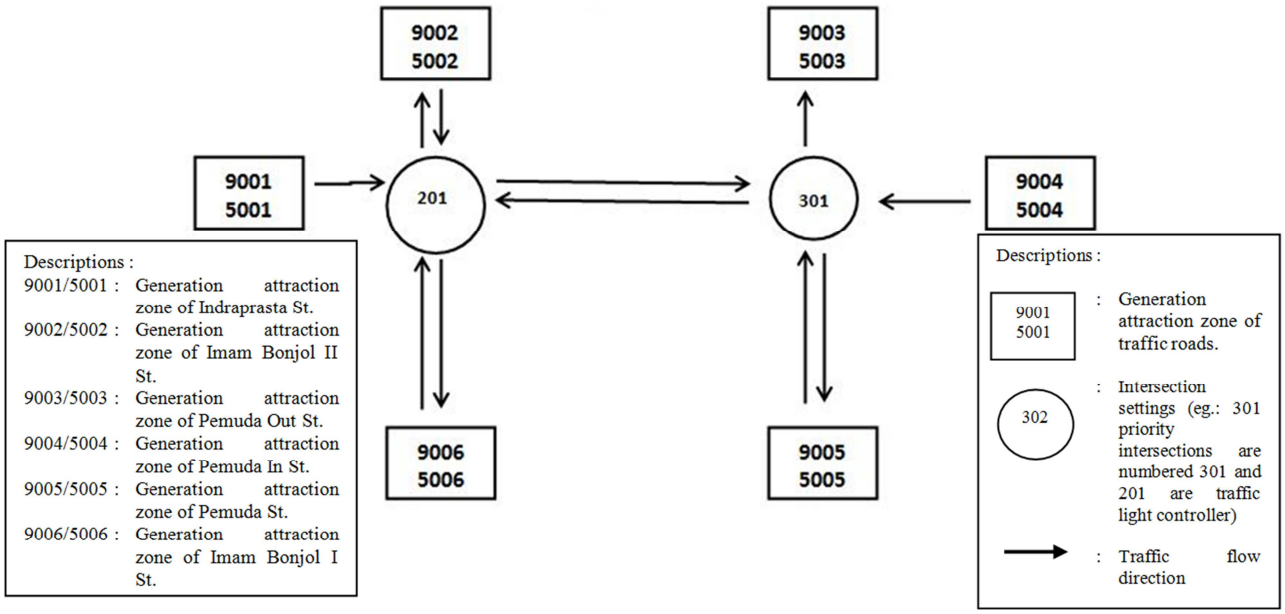
$$df = k - 1 = 7 - 1 = 6$$

The significant level used is 95 %
Chi-square table (0.95;6)= 12,5916
Chi-square model (RU_X^2)= 9,07198

Because the Chi-square value of the model is smaller than the Chi-square value of the table, the model created can be used because it meets the requirements based on the Chi-square Test.

3.2. Traffic Analysis of Alternative I and Alternative II

Alternative I is traffic regulation on the road network under study using a two-way system without parking lanes. This system can be seen in the imaginary map in Figure 3. The value of road capacity is of course different from the existing One Way System, because it changes from a one-way road type to a two-way one. This is based on the calculation of the basic capacity for two-way roads and the adjustment factors are also different, namely the adjustment factor for the type of road / flow and side resistance. Road capacity data in Alternative I settings can be seen in table 6.



Source: Analysis results (2022)

Figure 3. *Codification of Alternative I and Alternative II Road Networks.*

Table 6. *Capacity of Alternative I.*

Road Segmen	Flow Type	Wide (Meter)	Base Capacity (PCU/Hour)	Adjustment Factor					Road Capacity (PCU/Hour)	Desc.
				FCw	FCsp	FCsf	FCcs	FCks		
Imam Bonjol I St.	2/2 UD	13,1	2.900	1,34	1	0,9	1	1,02	3.567	No Parking Lane
Indraprasta St.	OW	13	4.950	1,08	1	0,97	1	0,98	5.082	No Parking Lane
Imam Bonjol II St.	2/2 UD	13,1	2.900	1,34	1	0,9	1	1	3.497	No Parking Lane
CaptainPiereTendean St.	2/2 UD	14,3	2.900	1,34	1	0,9	1	1,02	3.567	No Parking Lane
Pemuda Out St.	OW	14	4.950	1,08	1	1	1	0,98	5.239	No Parking Lane
Pemuda In St.	OW	15	4.950	1,08	1	1	1	1,02	5.453	No Parking Lane
Pemuda St.	4/2 UD	16,8	6.000	1,09	1	0,9	1	1,02	6.004	No Parking Lane

Source: Analysis results (2022)

While Alternative II is a traffic regulation on the road network by using a two-way system arrangement with parking lanes. This system is also the same as Alternative I (Figure 3). The capacity is also different from the calculation of Alternative I road capacity because it uses parking lanes on the Imam Bonjol I road, Captain Piere Tendean road, and Pemuda road. The basic capacity still uses the same basis as Alternative I, while the side resistance due to the parking lane uses the side resistance adjustment factor based on the MKJI standard. Road capacity data in Alternative II arrangements can be seen in table 7.

Table 7. *Capacity of Alternative II.*

Road Segmen	Flow Type	Wide (Meter)	Base Capacity (PCU/Hour)	Adjustment Factor					Road Capacity (PCU/Hour)	Desc.
				FCw	FCsp	FCsf	FCcs	FCks		
Imam Bonjol I St.	2/2 UD	13,1	2.900	1	1	0,86	1	1,02	2.544	2 Lanes R-L
Indraprasta St.	OW	13	4.950	1,08	1	0,97	1	0,98	5.082	No Parking Lane
Imam Bonjol II St.	2/2 UD	13,1	2.900	1	1	0,86	1	1	2.494	2 Lanes R-L
CaptainPiereTendean St.	2/2 UD	14,3	2.900	1,14	1	0,86	1	1,02	2.900	2 Lanes R-L
Pemuda Out St.	OW	14	4.950	1,08	1	1	1	0,98	5.239	No Parking Lane
Pemuda In St.	OW	15	4.950	1,08	1	1	1	1,02	5.453	No Parking Lane
Pemuda St.	4/2 UD	16,8	6.000	0,91	1	0,86	1	1,02	4.790	2 Lanes R-L

Source: Analysis results (2022)

3.3. Research Results

Traffic performance performance data consists of data on traffic variables consisting of V/C Ratio, speed, road network travel time, road network travel distance, average speed, and fuel consumption. Data on the comparison of traffic performance on each road section which includes the performance of the V/C Ratio and the performance of the road speed are presented in table 8. Meanwhile, a comparison of the performance of the road network as a whole is shown in table 9.

Table 8. *Comparison of V/C Ratio and Speed of Existing Conditions, Alternative I, and Alternative II.*

Road Segmen	Existing			Alternative I			Alternative II		
	V/C Ratio	Velocity (Km/Hour)	LOS	V/C Ratio	Velocity (Km/Hour)	LOS	V/C Ratio	Velocity (Km/Hour)	LOS
Imam Bonjol I St.	0,22	50,7	B	0,31	41,7	B	0,43	41,5	B
Indraprasta St.	0,35	50,0	B	0,35	50,0	B	0,35	50,0	B
Imam Bonjol II St.	0,27	44,9	B	0,45	31,0	C	0,62	30,7	C
Captain PiereTendean St.	0,49	56,8	C	0,69	52,1	C	0,85	50,2	E
Pemuda Out St.	0,29	29,3	B	0,29	29,3	B	0,29	29,3	B
Pemuda In St.	0,58	48,7	C	0,59	48,2	C	0,59	48,5	C
Pemuda St.	0,54	55,9	C	0,64	56,0	C	0,80	55,9	D

Source: Analysis results (2022)

Table 9. *Comparison of Road Network Performance with Existing Conditions, Alternative I, and Alternative II.*

Measured Variables	Existing		Alternative I		Alternative II	
Overall Travel Time	48,2	Vehicle-Hours	56	Vehicle-Hours	51,7	Vehicle-Hours
Overall Mileage	2.285,6	Vehicle-Km	2.460,8	Vehicle-Km	2.254,7	Vehicle-Km
Average Speed	47,5	Km/Hours	44	Km/Hours	43,6	Km/Hours
Fuel consumption	233,9	Liter	259	Liter	242,4	Liter

Source: Analysis results (2022)

After doing the data comparison, the following results are obtained:

a. The existing One Way System (OW) traffic service has a road performance on the Imam Bonjol road section V/C Ratio 0.22 (LOS B) and a speed of 50.7 km/hour, the Captain PiereTendean road section V/C Ratio 0.49 (LOS C) and a speed of 56.8 km/hour, and the Pemuda road section V/C Ratio 0.54 (LOS C) and a speed of 55.9 km/hour. While the performance of the road network on the One Way System is a travel time of 48.2 vehicle-hours, a mileage of 2,285.6 vehicle-km, a network speed of 47.5 km/hour, and fuel consumption of 233.9 liters.

b. Alternative I traffic services have a road performance on the Imam Bonjol road section V/C Ratio 0.31 (LOS B) and a speed of 41.7 km/hour, the Captain PiereTendean road section V/C Ratio 0.69 (LOS C) and a speed of 52.1 km/hour, and the Pemuda road section V/C Ratio 0.64 (LOS C) and a speed of 56 km/hour. While the performance of the Alternative I road network is a travel time of 56 vehicle-hours, a mileage of 2,460.8 vehicle-km, a network speed of 44 km/hour, and fuel consumption of 259 liters.

c. Alternative II traffic service has a road performance on the Imam Bonjol road section V/C Ratio 0.43 (LOS B) and a speed of 41.5 km/hour, the Captain PiereTendean road section V/C Ratio 0.85 (LOS E) and a speed of 50.2 km/hour, and the Pemuda road section V/C Ratio 0.80 (LOS D) and a speed of 55.9 km/hour. Meanwhile, the performance of the Alternative II road network is a travel time of 51.7 vehicle-hours, a mileage of 2,254.7 vehicle-km, a network speed of 43.6 km/hour, and fuel consumption of 242.4 liters.

4. Conclusion

Based on the analysis and discussion through comparison of the existing One Way System traffic service data with Alternative I and Alternative II, it is concluded that the One Way System currently implemented has the best level of performance when compared to Alternatives I and Alternative II. This shows that the performance of the micro (road section) and macro (road network) use of the One Way System in Semarang City CBD (Jl. Imam Bonjol - Jl. Captain PiereTendean - Jl. Pemuda) is currently still very good. Further research is needed with the same method with a wider range of research, perhaps in one city so that the traffic profile of a city can be identified.

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