Analysis of Signalized Intersection Performance Improvement on PHH. Mustofa Road Section, Bandung City Based on Coordination Intersection Modeling

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ABSTRACT

The rapid population growth in the city of Bandung has an impact on increasingly complex problems, especially the increase in traffic flow that is not balanced with the availability of road capacity. This will certainly cause congestion, one of which is at the intersection point. On Jalan PHH. Mustofa several signalized intersections are close to each other which often cause congestion. Data was collected through direct surveys in the field and obtained from third parties. The calculation of signalized intersection performance was carried out using Microsoft Excel, PTV Visum and PTV Vissim software. The vehicle growth rate that occurred in the city of Bandung in 2040 was 3.133%. And the number of vehicles in the city of Bandung in 2040 was 3,339,659 vehicles. The most effective cycle time in improving intersection performance on Jalan PHH. Mustofa with coordination modeling is 51 seconds. Based on the results of the development of signalized intersections on the PTV Vissim application, the results obtained decreased queue length and delay so that the level of service at the North Cikutra Intersection received a class A service level, the South received a class B service level and the West received a class C service level. For the Cimuncang Intersection, the North arm service level received a class A service level, the South received a class C service level and the West received a class C service level. And for the Padasuka Intersection, the North arm service level received a class B service level and the West received a class C service level.

Keywords: intersection performance; signalized intersection; coordination intersection; cycle time; population growth.

INTRODUCTION

Nowadays, transportation has become one of the most important means of human needs. With the increasing density of urban population, transportation is very much needed to meet a person's needs in carrying out activities or moving from one place to another. Transportation is an important part of national development to facilitate the flow of people, goods and information as a support for achieving optimal allocation of economic resources, for that transportation services must be sufficiently available evenly and affordable for people's purchasing power.

Traffic is defined as the movement of vehicles and people in traffic space. Road traffic space is an infrastructure that is intended for the movement of vehicles, people, and/or goods in the form of roads and passenger facilities (Undang-undang Repuplik Indonesia, 2009). The movement of these vehicles must always be in good and smooth condition because the smoothness of this traffic can determine the development of the economy, social, education, and technology in a city.

With the rapid population growth in a city, it certainly has an impact on increasingly complex problems, especially the increase in traffic flow that is not balanced with the availability of road capacity, which will certainly cause congestion, one of which is at the intersection. This also happened in Bandung City, which is the largest metropolitan city in West Java Province with an area of 167.67 km² with 30 sub-districts and 151 villages. Bandung City is estimated to have a population of 2,461,553 people consisting of 1,239,053 male residents and 1,222,500 female residents in 2023 with an annual population growth of 0.35%. Bandung City itself has 1,133.06 km of roads with

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860.58 km of good roads, 210.75 km of moderate conditions, 29.33 km of damaged conditions, and 32.40 km of severely damaged conditions (BPS Bandung City, 2023).

An intersection is a meeting point of two or more intersecting roads (Manual Kapasatisa Jalan Indonesia, 1997). This intersection is an area with the potential for conflict between several vehicles. An intersection that is not properly organized will cause problems such as queues and delays. On Jalan PHH. Mustofa there are several signalized intersections that are close to each other, namely the intersection of Jalan A. Yani with Jalan PHH. Mustofa (Intersection I), the intersection of Jalan PHH. Mustofa with Jalan Padasuka (Intersection II). These two intersections are 182 meters apart. After that there is the intersection of Jalan PHH. Mustofa with Jalan Cimuncang (Intersection III) and the intersection of Jl. PHH. Mustofa with Jl. Cikutra (Intersection IV). Intersection II with Intersection III is 419 meters away and Intersection II with Intersection IV is 740 meters away. These intersections are located in commercial areas and surrounded by several important places, including terminals, offices, schools, and shopping centers so that the volume of vehicles passing through is very high and causes congestion on the road.

RESEARCH METHODS

The analysis in this study was conducted using PTV VISUM, PTV VISSIM and Microsoft Excel software. The Vissim modeling analysis technique is as follows.

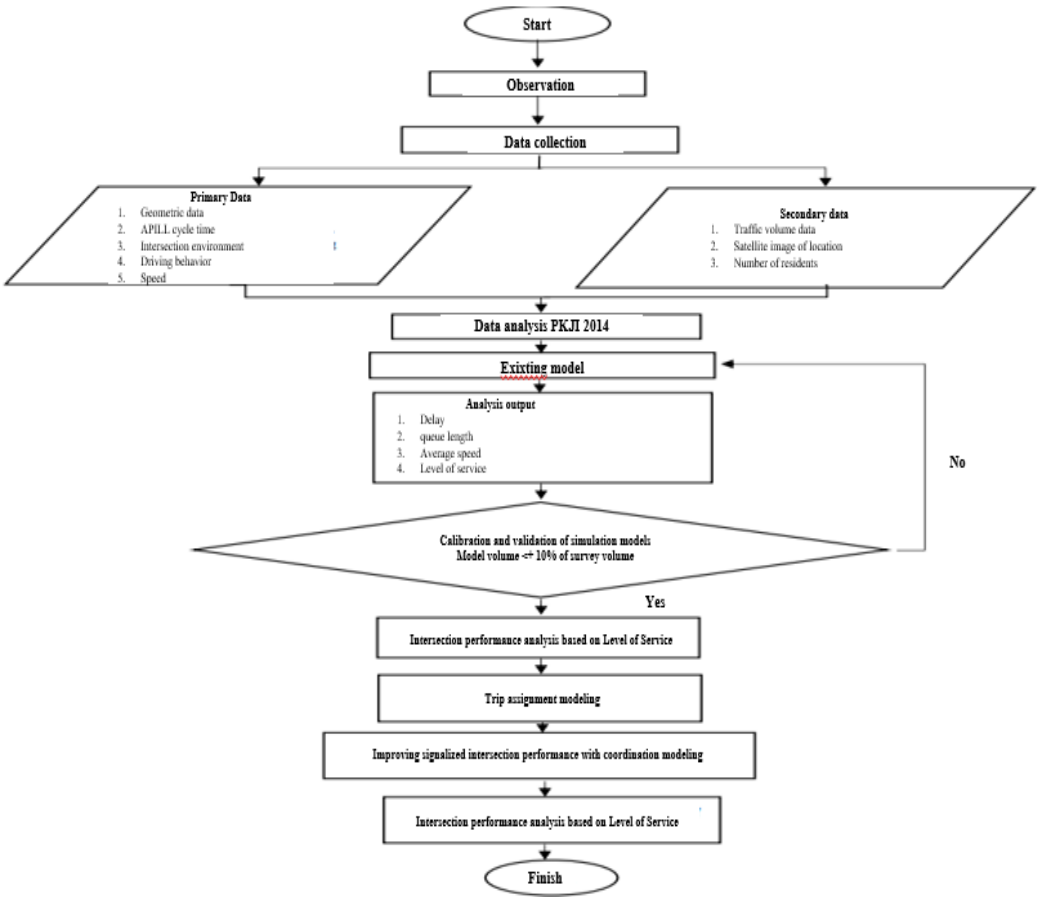

Figure 1. Flow chart

Method

The research location is located at four signalized intersections on Jalan PHH. Mustofa, Kec. Cibeunying Kidul, Bandung City, West Java. The population used in this study is the speed of vehicles and driving behavior of drivers passing through the intersection of Jalan PHH. Mustofa. The samples taken in this study were divided into two, namely vehicle speed with motorcycle

samples, light vehicle samples, and heavy vehicle samples. The next sample is driving behavior. Analyzing existing traffic conditions first using Microsoft Excel software and the (Prayitno et.al, 2019; Departemen Pekerjaan Umum, 2014) method. The analysis steps include finding input data, signal usage, determining signal times, determining capacity, and finally obtaining traffic performance.

Data Analysis

This study uses a quantitative descriptive method because the purpose of descriptive research with a quantitative approach is to explain a situation to be studied with the support of literature studies so as to further strengthen the researcher's analysis in making a conclusion, where the research results are obtained from the calculation results of research variable indicators and then presented in writing.

RESULTS AND DISCUSSION

Analysis of Existing Intersection Performance

To analyze the performance of signalized intersections, it is calculated during the morning peak period with the highest number of vehicle volumes. The performance of this intersection will be used as a better cycle time planning. The calculation is done with the form from PKJI 2014. An example of the calculation recapitulation can be seen as follows.

Table 1. Performance of the Cikutra Intersection Existing Condition

Intersection	Approacher	CT (second)	GT (second)	DS	QL (meter)	DELAY (second)
Cikutra	North	70	16	0.75	133	40.8
	South	70	16	0.51	114	27.6
	East	70	26	1.53	207	1016.0
	East	70	58	0.42	249	3.0
	West	70	26	0.51	228	20.4

Based on PKJI calculations, the average intersection delay for the Cikutra Intersection was 419.19 seconds or 6.98 minutes.

Table 2. Performance of the Cimuncang Intersection Existing Condition

Intersection	Approacher	CT (second)	GT (second)	DS	QL (meter)	DELAY (second)
Cimuncang	North	90	13	0.73	70	56.0
	South	90	13	0.62	54	45.0
	East	90	26	1.59	1171	1148.9
	East	90	43	0.59	70	20.8
	West	90	26	0.62	68	32.1

Based on PKJI calculations, the average intersection delay for the Cimuncang Intersection was 482.51 seconds or 8.04 minutes.

Table 3. Padasuka Intersection Performance Existing Conditions

Intersection	Approacher	CT (second)	GT (second)	DS	QL (meter)	DELAY (second)
Padasuka	North	75	24	0.56	107	26.8
	East	75	37	0.75	134	21.5
	West	75	21	0.82	97	36.6
	West	75	37	0.56	115	18.1

Based on PKJI calculations, the average intersection delay for Padasuka Intersection is 24.18 seconds or 0.40 minutes.

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Table 4. Performance of Cicaheum Intersection Existing Conditions

Intersection	Approacher	CT (second)	GT (second)	DS	QL (meter)	DELAY (second)
Cicaheum	South	150	14	0.29	51	20.8
	East	150	25	1.36	572	708.1
	West	150	25	0.30	37	19.0

Based on PKJI calculations, the average intersection delay for Padasuka Intersection is 328.51 seconds or 5.47 minutes.

Modeling with Vissim Software

In this investigation, Vissim-based software is used to examine how well the intersection performs under current conditions.

Tabel 5. Hasil Validasi VISSIM Setelah Kalibrasi pada Simpang

Inrtersection	Arm	VOLUME (vehicles/hours)		GEH (%)
		VISSIM	Field	
CIKUTRA	North	1675	1680	0.15
	South	1202	1202	0.00
	East	10239	10679	2.10
	West	3789	3966	2.28
CIMUNCANG	North	954	954	0.00
	South	827	827	0.00
	East	9132	9416	1.53
	West	4065	4065	0.00
PADASUKA	North	1573	1597	0.76
	East	9287	9831	2.85
	West	4785	4785	0.00
CICAHEUM	South	2533	2533	0.00
	East	11898	11996	0.41
	West	4158	4158	0.00

Based on the data above, it can be seen that the difference between the number of vehicles entered and those exiting has a difference of less than 10% so that it is still acceptable and tolerable. The results of the existing intersection performance based on Vissim modeling can be seen in the following table.

Table 6. Delay Value, Queue Length, and LoS Existing Conditions

Intersection	Arm	Long queue	Queue Delay (all) (s)	Level of Service (LoS)
CIKUTRA	North	94	38.3	D
	South	159	43.1	F
	East	650	47.1	E
	West	396	70.3	F
CIMUNCANG	North	93	30.7	D
	South	103	19.1	C
	East	672	58.2	E
	West	229	16.6	C
PADASUKA	North	88	37.3	F
	East	595	51.2	E
	West	333	18.6	C
CICAHEUM	South	115	5.5	A
	East	301	15.7	C
	West	247	14.6	B

Vehicle Growth Analysis

Analysis of intersection performance for the next 21 years is conducted to project the feasibility conditions of the intersection based on its performance. The study uses 2019 data so that the vehicle projection that will be carried out is until 2040. To determine the performance of the intersection in 2040, a vehicle growth analysis is needed to estimate the number of vehicles that will pass through the intersection.

Table 7. Bandung City Data

Year	Vehicles	Total population
	Y	X
2013	1336450	2458503
2014	1539409	2470802
2015	1617022	2481469
2016	1716698	2490622
2017	1811498	2497938
2018	1738672	2503708
2019	1747255	2507888

Linear regression analysis of the population (X) both simultaneously and individually can affect the vehicle growth rate (Y) to describe vehicle growth. The following equation is obtained:

Y1 = -19298779.54 + 8.4199 X

To find out the population (X) you must know the interest rate (i%) from 2013 to 2019 with the formula below:

$$i\ \% = \sqrt[2019-2013]{\left(\frac{F_{2019}}{P_{2013}}\right)} - 1$$

- Total population (X)

$$\% = \sqrt[6]{\left(\frac{2507888}{2458503}\right)} - 1 \qquad = 0.332$$

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After obtaining the interest rate value from the population (X1), the next step is to calculate the value of this variable for 2040 using the formula below:

$F_{2040} = P_{2019}(1+i)^{(2040-2019)}$

- Total population ($X_{1)}$

$F_{2040} = 2507888\ (1+0.332)^{(2040-2019)}$

$F_{2040} = 2688679$

Next, we can calculate the vehicle growth rate for 2040 using the previous equation, which is as follows:

Y1 = -19298779.54 + 8.4199 X

Y1 = -19298779.54 + 8.4199 (2688679)

Y1 = 3.339.659 vehicles

So the interest rates from 2019 to 2040 are as follows:

$$i\ \% = \sqrt[2040-2019]{\left(\frac{F_{2040}}{P_{2019}}\right)} - 1$$

$$i\ \% = \sqrt[21]{\left(\frac{3339659}{1747255}\right)} - 1$$

$$i\ \% = 3.133$$

Trip Assignment Using PTV Visum

Seeing the results of previous calculations where the performance of the four intersections studied by the author had quite poor Level of Service results, it is necessary to carry out an innovation to solve the problem. For this reason, in this study, a simulated route change will be carried out using the PVT Visum application..

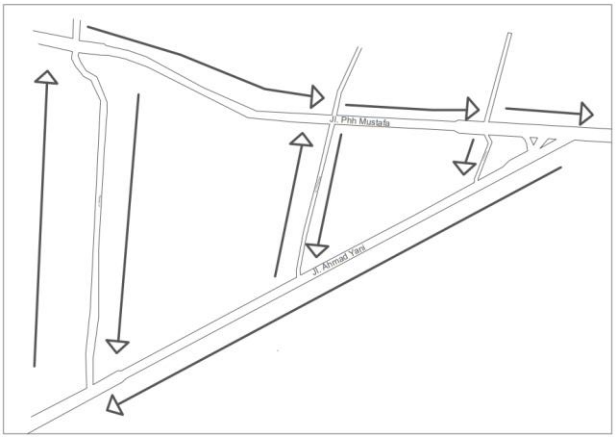

Figure 2. One-Way Street Scheme

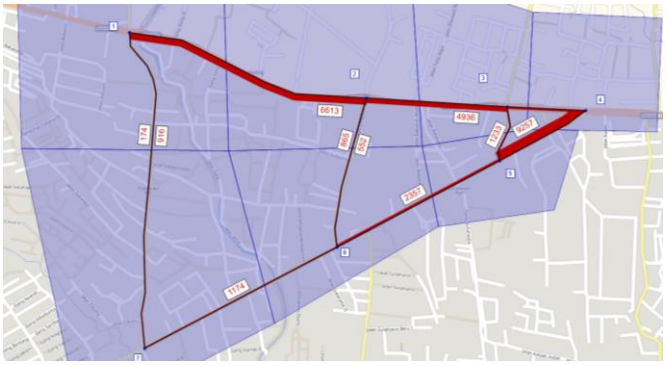

Figure 3. Trip assignment Do Something planning year 2040 LHR Total

The loading data taken is the loading taken from the sum in each direction/lane to represent one road section. The road service level is calculated by calculating the road capacity using the PKJI 2014 formula. The calculation results are then presented in the table below.

Table 8. Road Service Level in 2040 LHR Total (Do Something)

Road name	Type	C	Volume (smp/hour)	LoS (v/c)	Grade
Jl. PHH Mustafa	4/2 UD	4969	13574	2.73	F
Jl. Cikutra	2/2 UD	1445	1090	0.75	D
Jl. Cimuncang	2/2 UD	2245	1445	0.64	C
Jl. Padasuka	2/2 UD	1445	1233	0.85	E
Jl. Ahmad Yani	4/2 UD	4969	12788	2.57	F

The results of the change in one-way roads where Jalan Cikutra decreased one level of road service from B to D. However, Jalan Cimuncang improved one level from class D to C. Therefore, a possible solution to improve the level of service on Jalan PHH. Mustofa and Jalan Ahmad Yani is to increase the number of public transportation to be used. It is assumed that 80% of the total volume of traffic per hour are motorcycle users (MC), where the remaining 20% are light vehicle users (LV) and heavy vehicle users (HV). The obstacles caused by the volume of motorcycle vehicles are very large, therefore motorcycle users will be converted as much as 75% of motorcycle users switch to using public transportation, namely buses. The following is an example of a calculation on Jalan PHH. Mustofa. Total Volume skr/day = 13574 skr/hour

Motorcycle users = 13574. 80% = 10859.2 skr/hour

Assuming 75% of motorcycle users switch to using public transportation Bus.

Public transportation users = 10859.2 . 75% = 7944.4 skr/hour

Furthermore, 1 Bus unit can accommodate a volume of 50 people, then, = 7944.4 / 50 = 159

Emp of Bus vehicles is 1.3, then = 159 . 1.3 = 207 skr/hour

Then the total volume skr/hour after conversion is 3996 skr/hour

The same calculation is carried out on the Ahmad Yani Street section, the following results are obtained for the Road Service Level.

Table 9. Road Service Level in 2040 LHR Total (Do Something)

Road name	Type	C	Volume (smp/hour)	LoS (v/c)	Grade
Jl. PHH Mustafa	4/2 UD	4969	3996	0.73	C
Jl. Cikutra	2/2 UD	1445	1090	0.75	D
Jl. Cimuncang	2/2 UD	2245	1445	0.64	C
Jl. Padasuka	2/2 UD	1445	1233	0.85	E
Jl. Ahmad Yani	4/2 UD	4969	3815	0.71	C

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New Cycle Time Planning

Some plans are created based on the cycle times that have been previously determined in the new cycle time planning step. The cycle time that produces the best average deviation performance from the planning is the cycle time that should be selected.

a. Planning 1

Table 10. Alternative Cycle Time of Distancing 1

Phase	Signal Time (seconds)				Cycle Time
	Green	Yellow	All Red	Green	Yellow
A	29	3	1	18	51
B	18	3	1	29	51

a. Planning 2

Table 11. Cycle Time of Alternative Intersection 2

Phase	Signal Time (seconds)				Cycle Time
	Green	Yellow	All Red	Green	Yellow
A	35	3	1	21	60
B	21	3	1	35	60

a. Planning 3

Table 12. Cycle Time of Alternative Intersection 3

Phase	Signal Time (seconds)				Cycle Time (Seconds)
	Green	Yellow	All Red	Red	
A	25	3	1	11	40
B	11	3	1	25	40

The following are the results of the evaluation of the delay value of signal coordination between signalized intersections to the assessment of service performance (Level of Services (LoS) from the fourth arm of the intersection can be seen as follows.

Table 13. Recapitulation of VISSIM Evaluation Result Delay

Intersections	Approacher	Alternative 1		Alternative 2		Alternative 3	
		Delay (s)	Level of Service (LoS)	Delay (s)	Level of Service (LoS)	Delay (s)	Level of Service (LoS)
CIKUTRA	North	4.8	A	8.8	B	9.7	B
	South	9.9	B	17.2	C	18.1	C
	West	17.7	C	24.9	C	18.5	C
CIMUNCANG	North	4.9	A	5.3	B	4.8	A
	South	16.2	C	16.8	C	16.3	C
	West	19.4	C	23.6	C	19.9	C
PADASUKA	North	11.4	B	13.6	B	12.8	B
	West	17.5	C	20.4	C	16.9	C

CONCLUSION

The vehicle growth rate that occurred in Bandung City in 2040 was 3.133%. And Bandung City vehicles increased quite significantly where vehicles in 2019 were 1,747,255 vehicles to 3,339,659 vehicles in 2040. The most effective cycle time in improving intersection performance on Jalan PHH. Mustofa with coordination modeling is 51 seconds (alternative 1). This alternative produces

significant reductions in queue length and delays so that the service performance of the three intersections is better than the existing conditions. Based on the results of the development of signalized intersections on the PTV Vissim application, the results obtained were a decrease in queue length and delay so that the level of service at the Cikutra Intersection, the North arm received a class A service level, the South received a class B service level and the West received a class C service level. For the Cimuncang Intersection, the North arm service level received a class A service level, the South received a class C service level and the West received a class C service level. And for the Padasuka Intersection, the North arm service level received a class B service level and the West received a class C service level.

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