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An Analysis of the Performance of Unsignalized Intersection and the Impact of Vehicle Exhaust Emissions at Selokan Mataram Street

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ABSTRACT

In transportation, Sleman Regency faces quite prevalent traffic issues, particularly traffic congestion and pollution that are caused by a surge in population mobility without being offset by sufficient development of traffic facilities and infrastructure. Therefore, a traffic management approach is needed as an alternative solution for unsignalized intersections. The technique used to collect data was traffic counting. The data were processed into an intersection performance value by using the 2014 Indonesian Highway Capacity Guidance (IHCG) and PTV VISSIM 9 Student Version software. The analysis of the 2014 IHCG produced saturation, delay, and queue probability values that met the requirement of degree saturation (≤0,8), while the analysis results of VISSIM 9.0 were obtained after modelling the simulation of vehicle traffic flow and showed delay, length of queue, level of service, even vehicle exhaust emissions values that met requirement (Level Of Service < E). Result of VISSIM simulation deviates from IHCG due to differences in calculation system characteristics which are an interesting aspect to elaborate on. The existing condition showed the worst traffic performance with a saturation value of 1.15 and level of service E. Thus, several alternatives were made to improve the intersection performance. The second alternative shows good results for exhaust emissions.

Keywords— exhaust emissions, intersection performance, PKJI 2014, unsignalized intersection, VISSIM 9.0

1. INTRODUCTION

Increase in population mobility that is not offset by sufficient development in traffic facilities and infrastructure can lead to many issues. Increase in vehicle volume can also negatively affect the environment, particularly traffic-related air pollution, due to emissions as well as other traffic problems. It is proved by the increase of traffic volume that occurs every year during busy hours.

Unsignalized intersections are an at-grade junction where two or more roads meet that is not regulated by any form of Traffic Signals [1]. It is commonly found in in urban areas, especially on minor roads and/or roads where turning movements are relatively small. Unsignalized intersections are widely tolerated in low-volume traffic, with vehicle movement at unsignalized intersections is quite complicated as shown in Fig. 1. There are several general solutions for unsignalized intersections such as geometric reconstruction of formatter will need to create these components, incorporating the applicable criteria that follow. Roads to reduce queue, increasing road capacity, and enforcement of traffic management [2].

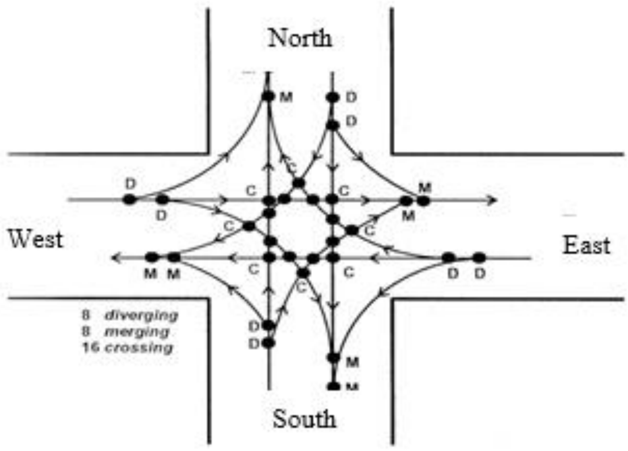

Fig 1. Movement of Intersection traffic.

There are three kinds of data that should be established to conduct an analysis of intersection performance, namely geometric data obtained from of direct observation in the field, traffic data obtained from traffic flow passing through the intersection, normally including type of vehicle within a certain period of time which is then recapitulated using an internal form [3], and intersection environment data obtained from observation and literature study, normally comprising population, city size, neighborhood type and side friction [4].

Capacity refers to maximum total traffic flow entering an intersection that can be maintained for at least an hour during existing weather and geometric conditions, in units of vehicle/hour. Intersection capacity calculation serves to identify the total flow entering from all segments.

Intersection traffic performance is obtained from an analysis related to capacity and delays so as to allow changes in the intersection design in the form of road geometry and traffic system regulation [5]. There are three parameters in the analysis, namely saturation level (DS), delay (T) and queue probability (PA). The determination of the performance of an intersection in relation to saturation value (DS) uses a DS standard of ≤ 0.85. If the DS value exceeds 0.85, a redesign to the intersection is needed to improve the operational service by the way of frontage extension or traffic management.

In Sleman Regency, the Special Region of Yogyakarta, specifically at Selokan Mataram street, also faces traffic problems at intersections. Upsurge in traffic volume occure during busy hours every year. Increase in traffic volume leads to worsening air pollution due vehicle emissions. The most effective solution to this problem is implementing traffic management planning using accurate data that have been carefully analyzed.

Traffic management is the organization, planning, direction, and monitoring of the state of traffic movement, including pedestrians, cyclists, and all types of vehicles, according to Underwood [6]. Traffic management is aimed to meet transportation needs, both present and in the future, by streamlining people/vehicle movement and identifying necessary improvements to the technical side of traffic, public transport, law, road pricing and the operation of the existing transportation system.

VISSIM is a microscopic simulation based on time and behavior developed for urban traffic models [7]. VISSIM is also defined as a traffic simulation software or tool that are used for traffic engineering, transportation planning, and microscopic city planning which are presented visually. The analysis results in the PTV VISSIM 9 software show intersection performance parameters such as average queue length (QLen), level of service (LOS), vehicle delay (VehDelay). The level of service (LOS) is the capability of a road or intersection to accommodate traffic under certain circumstances. The determination of level of service aims to define the level of service of a road or intersection with criteria by [9] as shown in Table I.

Table I. Level of Service Criteria

Level of Service	**Average Control Delay (second/vehicle)**
A	0 – 10
B	> 10 – 15
C	> 15 – 25
D	> 25 – 35
E	> 35 – 50
F	> 50

Source: [9]

Air pollution refers to the infusion or presence of substance, energy or other components into ambient air by human activities causing the air quality to decrease to a certain level, rendering it useless to fulfil its function as an important component in human life, organisms and other environmental elements [10]. Air pollution is caused by combustion/exhaust emissions from vehicles that merge with ambient air/free air causing smoke from vehicles to spread freely and damage the environment and can even endanger human health. Emission itself refers to substances, energy or other components discharged by an activity to open air, whether it has the potential as a pollutant or not. The analysis results of emissions in PTV VISSIM 9 Student Version obtain levels of carbon monoxide (CO) and nitrogen oxides (NOx) pollutants. These are compounds that pose negative consequence on human health such as respiratory problems, weakening of the body's defense system, slowing reflexes and even death.

2. RESEARCH METHOD

This study is organized systematically and in order as expected. It is organized as follows:

2.1. Data collection

A traffic survey was carried out directly or indirectly which included data on geometric conditions, traffic conditions, environmental conditions as well as location and population data located at an unsignalized intersection of Selokan Mataram street with Wahid Hasyim street, Condongcatur, Sleman for two days.

2.2. Analysis and modelling

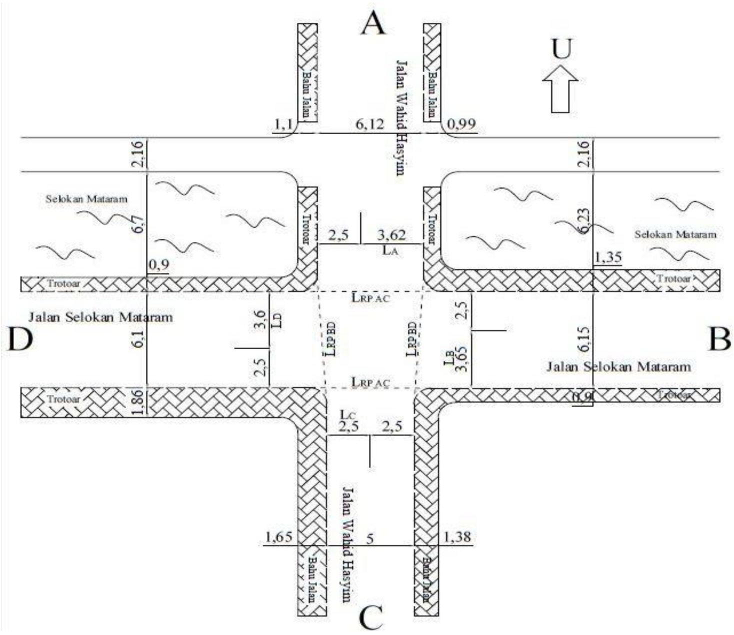

Fig 2. Geometric Intersection of Selokan Mataram Street

Fig. 2 describes the existing conditions of the intersection to be carried out by the research. The east and west side are 6.1m slightly wide, and the south side is 5 m. The north side is 6.12 m bigger. Uniquely the north side has other arms on the west and east sides by 2.1 m, respectively.

2.3. Analysis and modelling

A calculation analysis was carried out using the results of the traffic survey recapitulation with the 2014 IHCG 2014 as the reference and traffic simulation modeling was carried out using the PTV VISSIM 9 Student Version software and the data were processed to obtain the intersection performance analysis results. VISSIM analysis also provided results of the impact of vehicle exhaust emissions.

2.4. Alternative planning

If the intersection performance has not met the criteria set, plan various alternative solutions for traffic problems and analyze the data using the 2014 IHCG and model them in PTV VISSIM 9 Student Version.

2.5. Discussion and conclusions

If the intersection performance analysis data processing has met the criteria and achieved the desired results, then a discussion of the results in this study is conducted, one of which is by comparing the results of the analysis from the two guidelines, namely the 2014 IHCG and VISSIM 9.0.

3. RESULTS AND DISCUSSION

3.1. The 2014 IHCG Intersection Performance Analysis

Stages of the unsignalized intersection performance analysis for existing conditions are as follows:

3.1.1. Determining peak hours

The analysis was carried out for two study days by determining the busy hours from traffic volume (skr/hour). It was summarized in Fig. 3 and Fig. 4.

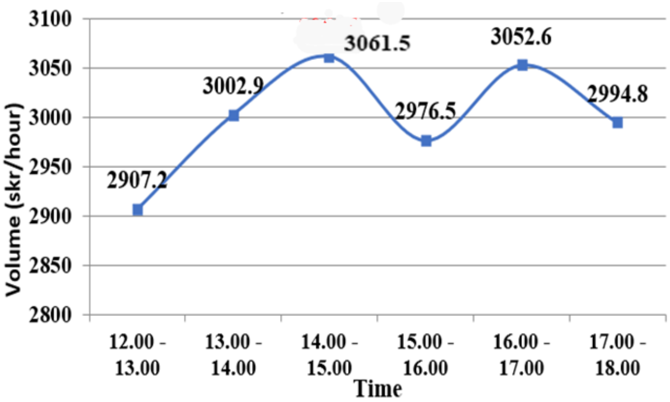

Fig 3. First day fluctuation

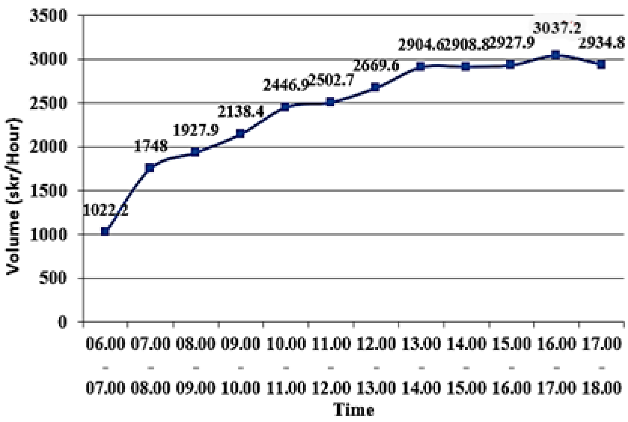

Fig 4. Second day fluctuation

Thus, we obtained the peak hour for the first day which was 14:00 to 15:00 and 16:00 to 17:00 for the second day.

3.1.2. Inputting data

The data inputted in the analysis process were geometric data of Selokan Mataram intersection as seen in Fig. 2, Traffic data using peak hour data from the data collection by the method of traffic counting in the field, and environmental data showing based on the observation showing that the intersection was located in a commercial area with moderate side frictions.

3.1.3. Calculating capacity

Identifying intersection capacity value (C) using equation 1 and the results obtained from 2-day study were presented in Table II.

Table II. Intersection Capacity Value

Value	First Day	Second Day
C_0 (skr/hour)	2900	2900
F_{LP}	0.989	0.989
F_M	1.00	1.00
F_{UK}	0.94	0.94
F_{HS}	0.938	0.936
F_{BKi}	1.156	1.168
F_{BKa}	1	1
F_{Rmi}	0.910	0.914
C (skr/hour)	2661.991	2696.253

3.1.4. Determining traffic performance

Parameters used to define the intersection traffic performance studied were as follows:

a) Saturation level *(D_S)*, calculated using Equation 1 with the results presented in Table III.

$$D_S = \frac{q}{C} \quad (1)$$

Table III. Saturation Level

Value	First Day	Second Day
DS	1.150	1.126

b) Delay (T), divided into two namely traffic delay (TLL) dan geometric delay (TG) that were calculated using the equation in Table IV. Then, delay values in Table V were obtained.

Table IV. Delay Value Equation

Value	Equation
T (sec/skr)	$T = T_{LL} + T_G$ (2)
T_{LL} (sec/skr)	DS≤60: $T_{LL} = 2+8.2078DS - (1 - DS)^2$ (3) DS>60: $T_{LL} = \frac{1.0504}{(0.2742-0.2042 \times DS)} - (1-DS)^2$ (4)
T_{LLma} (sec/skr)	DS≤60: $T_{LLma} = 1,8+5,8234DS - (1 - DS)^2$ (5) DS>60: $T_{LLma} = \frac{1.0503}{(0.3460-0.2460 \times DS)} - (1-DS)^2$ (6)
T_{LLmi} (sec/skr)	$T_{LLmi} = \frac{q_{TOT} \times T_{LL} - q_{ma} \times T_{LLma}}{q_{mi}}$ (7)
T_G (sec/skr)	DS<1: $T_G = (1 - DS)\times\{6R_B+3(1 - R_B)\} +4DS$ (8) DS<1: $T_G = 4$ (9)

Table V. Delay Value

Value	First Day	Second Day
T (sec/skr)	30.669	27.760
T_{LL} (sec/skr)	26.669	23.760
T_{LLma} (sec/skr)	16.617	15.221
T_{LLmi} (sec/skr)	43.104	38.592
T_G (sec/skr)	4	4

c) Queue probability (P_A) obtained upper and lower threshold values calculated using equation 2 and 3 and the results were presented in Table VI.

Upper limit : $P_A = 47.71DS - 24.68DS^2+56.47DS^2$ (10)
Lower Limit : $P_A = 9.02DS - 20.66DS^2+10.49DS^2$ (11)

Table VI. Queue Probability Value

P_A	First Day	Second Day
Upper Limit	108.128	103.142
Lower Limit	53.658	51.370

d) Intersection traffic performance analysis that was based on standard value degree saturation (DS) of ≤ 0.85. It was known the intersection of Selokan Mataram street and Wahid Hasyim street did not meet the requirements for proper operational service of an intersections.

3.2. Modelling and VISSIM 9.0 Simulation

Modelling using PTV VISSIM 9 Student Version was performed in several stages using prepared input data with the input in the form of intersection performance. The data consist of satellite maps of the location, geometric intersection, vehicle types, vehicle speed limits, and traffic volume. The modelling stages were:

2) Create background using satellite maps (Google Earth) of the Selokan Mataram intersection.
3) Create road network in accordance with the road geometric data.
4) Create vehicle routes based on movements on the intersection using 'Vehicle Routes' in VISSIM.
5) 'Conflict area' controlled vehicles so they do not collide with each other in the simulation with specified flow priority.
6) Determining and adding vehicle type model into the simulation based on vehicle type classification. Then arranging vehicle types using features like Vehicle Types, Vehicle Classes, Vehicle Compositions.
7) Filling out Vehicle Input to enter the vehicle traffic flow volume obtained.
8) Defining driver behaviors in the simulation using 'Driving Behaviors'.
9) Determining analysis area using 'Node' then initiating the simulation process with 'Simulations'.

The intersection performance analysis results from the simulation for two days of study were obtained and shown in Table VII and Table VIII. The intersection performance for the existing conditions from the VISSIM 9.0 simulation results was considered poor because it did not meet the (LOS < LOS E) requirement.

Table VII. The Result Of First Day Analysis

MOVEMENT	Q LEN (m)	VEHS (ALL)	LOS (ALL)	VEHDELAY (ALL)
Wahid Hasyim Street (A) to Selokan Mataram Street (B)	12.14	42	LOS B	11.13
Wahid Hasyim Street (A) to Wahid Hasyim Street (C)	20	27	LOS_B	13.8
Wahid Hasyim Street (A) to Selokan Mataram Street (D)	20.29	29	LOS D	29.83

MOVEMENT	Q LEN (m)	VEHS (ALL)	LOS (ALL)	VEHDELAY (ALL)
Selokan Mataram Street (B) to Wahid Hasyim Street (A)	168.9	42	LOS_F	132.05
Selokan Mataram Street (B) to Wahid Hasyim Street (C)	155.7	34	LOS_F	126.62
Selokan Mataram Street (B) to Selokan Mataram Street (D)	155.7	28	LOS_F	106.25
Wahid Hasyim Street (C) to Wahid Hasyim Street (A)	153.7	62	LOS_F	59.25
Wahid Hasyim Street (C) to Selokan Mataram Street (B)	152.8	50	LOS_F	66.28
Wahid Hasyim Street (C) to Selokan Mataram Street (D)	140	49	LOS_F	57.98
Selokan Mataram Street (D) to Wahid Hasyim Street (A)	0.84	89	LOS_A	3.55
Selokan Mataram Street (D) to Selokan Mataram Street (B)	0.84	76	LOS_A	4.33
Selokan Mataram Street (D) to Wahid Hasyim Street (C)	2.72	80	LOS_A	7.59
Result	82.71	608	LOS_E	42.13

Table VIII. The Result Of Second Day Analysis

MOVEMENT	Q LEN (m)	VEHS (ALL)	LOS (ALL)	VEH DELAY (ALL)
Wahid Hasyim Street (A) to Selokan Mataram Street (B)	17.95	39	LOS_C	16.41
Wahid Hasyim Street (A) to Wahid Hasyim Street (C)	33.19	26	LOS_C	22.31
Wahid Hasyim Street (A) to Selokan Mataram Street (D)	32.26	22	LOS_E	43.64
Selokan Mataram Street (B) to Wahid Hasyim Street (A)	52.34	98	LOS_E	43.5
Selokan Mataram Street (B) to Wahid Hasyim Street (C)	36.97	80	LOS_D	32.13
Selokan Mataram Street (B) to Selokan Mataram Street (D)	36.97	70	LOS_D	33.22
Wahid Hasyim Street (C) to Wahid Hasyim Street (A)	165	26	LOS_F	210.33
Wahid Hasyim Street (C) to Selokan Mataram Street (B)	164.1	22	LOS_F	241.02
Wahid Hasyim Street (C) to Selokan Mataram Street (D)	139.4	17	LOS_F	283.29
Selokan Mataram Street (D) to Wahid Hasyim Street (A)	2.34	100	LOS_A	6.49
Selokan Mataram Street (D) to Selokan Mataram Street (B)	2.34	90	LOS_A	6.92
Selokan Mataram Street (D) to Wahid Hasyim Street (C)	7.68	87	LOS_B	11.67
Result	65.12	677	LOS_E	43.15

3.3. Traffic Problem Alternatives

Looking at the results of the analysis of the existing traffic performance conditions at the intersection of Selokan Mataram street with Wahid Hasyim street, both references showed a poor assessment. Therefore, it was necessary to implement alternative traffic problems in order to improve the performance of intersections in accommodating the volume of vehicle traffic passing in high volume conditions.

3.3.1. Alternative 1

Vehicle movement traffic engineering in frontage C or south segment by diverting Wahid Hasyim Street into a one-way road heading north. The results of the intersection traffic performance analysis based on the 2014 IHGC and VISSIM 9.0 were presented in Table IX.

Table IX. The Result Of Alternative Analysis 1

Reference	Value	First Day	Second Day
PKJI 2014	Ds	1.070	1.065
	T (sec/skr)	22.838	22.537
	PA (%)	46-92	46-91
VISSIM 9.0	LOS	LOS_E	LOS_E
	VEHDELAY (sec)	37.120	41.250
	QLEN (meter)	61.490	63.220

3.3.2. Alternative 2

Vehicle movement traffic engineering in frontage D or west segment by diverting Wahid Hasyim Street into a one-way road heading east. The results were presented in Table X.

Table X. The Result Of Alternative Analysis 2

Reference	Value	First Day	Second Day
PKJI 2014	Ds	0.862	0.870
	T (sec/skr)	10.689	10.866
	PA (%)	30-59	30-60
VISSIM 9.0	LOS	LOS_D	LOS_C
	VEHDELAY (sec)	30.130	20.560
	QLEN (meter)	41.230	27.640

3.3.3. Alternative 3

Combination of reduction in sidewalk width in major roads and vehicle movement traffic engineering on frontage D by diverting Selokan Mataram street into a one-way road heading east similar to the second alternative. The results were shown in Table XI.

3.4. Comparison of the IHGC 2014 and VISSIM Analysis

Analysis using two different references produced different results in the same conditions for two days of study. Because of this reason, the results of the analysis that had been carried out show differences in the characteristics of the calculation analysis. From the two references, it can be seen from the delay in Fig. 5 and Fig. 6.

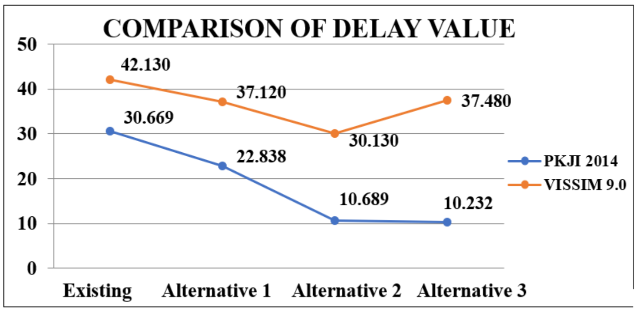

Fig 5. Delay comparison on first day

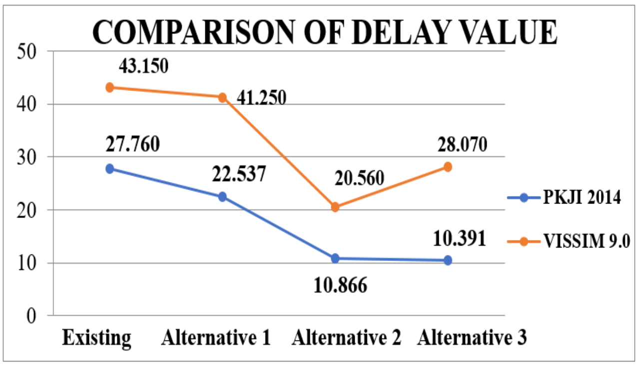

Fig 6. Delay comparison on second day

3.6. Exhaust Emissions Analysis

The values of vehicle exhaust emissions impact obtained from the traffic modelling simulation analysis with VISSIM 9.0 for each condition in two days were presented in Table XII The data above showed that alternative 1 showed the worst exhaust emission substance value and fuel consumption from vehicle traffic activities.

Table XI. Comparison Of Intersection Services On The First Day

Condition	PKJI 2014			VISSIM 9.0		
	Ds	*T (Sec/skr)*	*P_A (%)*	*LOS*	*VEH DELAY (Sec)*	*QLEN (meter)*
Exsisting	1.150	30.669	54-108	LOS_E	42.130	82.710
Alternative 1	1.070	22.838	46-92	LOS_E	37.120	61.490
Alternative 2	0.862	10.689	30-59	LOS_D	30.130	41.230
Alternative 3	0.841	10.232	28-56	LOS_E	37.480	46.410

Table XII. Comparison Of Intersection Services On The Second Day

Condition	PKJI 2014			VISSIM 9.0		
	Ds	*T (Sec/skr)*	P_A (%)	*DS*	*T (Sec/skr)*	QLEN (meter)
Exsisting	1.126	27.760	51-103	LOS_E	43.150	65.120
Alternative 1	1.065	22.537	46-91	LOS_E	41.250	63.220
Alternative 2	0.870	10.866	30-60	LOS_C	20.560	27.640
Alternative 3	0.849	10.391	29-57	LOS_D	28.070	37.990

Table XIII. Result Exhaust Gas Emissions

Condition	First Day			Second Day		
	***Emissions CO* (gr)**	***Emissions NOx* (gr)**	***Fuel Consumptions* (gal)**	***Emissions CO* (gr)**	***Emissions NOx* (gr)**	***Fuel Consumptions* (gal)**
Exsisting	905.676	176.212	12.957	964.372	187.632	13.796
Alternative 1	1010.049	196.519	14.45	1078.661	209.868	15.431
Alternative 2	780.966	151.948	11.173	634.581	123.466	9.078
Alternative 3	981.556	190.975	14.042	808.122	157.231	11.561

4. CONCLUSION

Based on the results of unsignalized intersection between Selokan Mataram street and Wahid Hasyim street, Depok, Sleman, the Special Region of Yogyakarta, the following conclusions were drawn:

1) The unsignalized intersection performance analysis that used the 2014 Indonesian Highway Capacity Guidance (IHCG) showed poor results with DS value of 1.15 and 1.13 for the first and second day, respectively.

2) The unsignalized intersection simulation modelling using the PTV VISSIM 9 Student Version software showed level of service (LOS) of E or poor, average queue length (QLEN) of ± 42 meters and vehicle delay (VEHDELAY) of ± 73 seconds that are summarized for two days of study.
3) The solution to the traffic performance problems at the Selokan Mataram street intersection is presented in three alternatives. Based on the 2014 IHCG, the best alternative is the third alternative with a DS value of 0.84 and 0.85 for the first day and the second day, respectively. Based on VISSIM 9.0, the best alternative is the second alternative with service levels (LOS) D and C for the first day and the second day, respectively.
4) The second alternatives shows the best exhaust emission analysis results compared other alternatives.
5) The comparison of the results of the intersection traffic performance analysis using the two references implies that the way the 2014 IHCG analysis does not really take into account how much traffic flows in and out of the intersection, what counts is the overall performance of the intersection. The VISSIM 9.0 analysis takes into account the traffic flow in and out of the intersection.

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