Modeling an Unconventional Intersection by Using Single-Point Urban Interchange with PTV.VISSIM

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Abstract*—An intersection is a place where traffic congestion from each arm always happens. In Yogyakarta, one of intersections having the traffic congestion at peak hours is at Kentungan Intersection. The traffic congestion mostly occurs by high volume of vehicles exceeding the intersection capacity. Commonly, a type of this intersection is a plot of intersection. Thus, an evaluation from geometric views by changing the type of the intersection to an elevated intersection (interchange) is needed. The elevated intersection consists of conventional and unconventional intersection. The elevated conventional intersection is commonly applied in Indonesia like flyover or underpass. Hence, this study chose one of the unconventional intersections called Single-Point Urban Interchange (SPUI) because the SPUI could provide more vehicle flows and be more efficient than other types. This study aimed to propose the best model from some intersection conditions. A method of this study used PTV.VISSIM 9 software. This study modeled three conditions: existing condition, default and modified SPUI intersection. Based on the result of the existing models, Level of Service (LOS) was F with 104,79 seconds of vehicle delay average. In the model of default SPUI model, value of LOS was D with 32,54 seconds of vehicle delay average. Next, in the modified SPUI model, the LOS was D with 30,3 seconds of vehicle delay average. Therefore, based on the results, the modified SPUI can reduce 74,49 seconds of the delay.

Keywords--Intersection, SPUI, Unconventional, VISSIM

I. BACKGROUND

Congestion is one of the most influencing factors in traffic. It usually occurs at an intersection. The congestion at the intersection is influenced by several factors: high volume of vehicles, road capacity, driver behavior to traffic signs, inappropriate geometric designs of vehicle volume, and etc. Kentungan Intersection is one of intersections in Yogyakarta that is always jammed during peak hours. This intersection experiences congestion from various directions. The high volume of the vehicles makes this intersection over capacity. Moreover, geometric conditions of its cluster cross are too small. Intersection is not a plot consisting of conventional and unconventional intersections. Unconventional intersections are flyovers and underpasses. Intersection is not an unconventional plot rarely used because of its complicated shape. The researcher changed the type of the intersection at Kentungan to be a Single Point Urban Interchange (SPUI) because the SPUI could have some advantages to provide more volume of vehicles efficiently. Three later intersection conditions would be modeled into a PTV program,VISSIM 9.

Types of conflict at the intersection consisted of primary conflict and secondary conflict. The primary conflict was a conflict that occurred between traffic flows moving straightly from intersecting road segments. Secondary conflict was a conflict where a right traffic flow with other direction traffic flows and or traffic turns left with pedestrians [1]. Previously, Lestari [2] analyzed performances of signalized intersections at Kentungan Intersection and concluded that service levels of the Kentungan Intersection were at the Level of Service (LOS) F with a delay value of 213,357 seconds. Consequently, it recommended to make flyovers on the west arm to the east arm and to add effective widths on the north arm and on the interline. Therefore, this study aimed to create model of implementation of flyover with SPUI (Single Point Urban Interchange).

This study questioned how the modeling results of the Kentungan Intersection are, how the modeling results of the Default SPUI Intersection are, and how the modeling results of the Modified SPUI Intersection are. This study aimed to obtain the modeling results of the Kentungan Intersection, the modeling results of the Default SPUI Intersection, and the modeling results of the Modified SPUI Intersection. By the study it was hope to increase knowledge in analyzing performances of a signalized intersection and applying the knowledge obtained directly in the field.

II. SINGLE POINT INTERCHANGE (SPUI)

According to Jones and Selinger [3], Single-Point Urban Interchange was one kind of intersections where all lines met into one intersection equipped with flyovers or underpasses as major traffic flow lines. This intersection was operated by a single traffic signal, and it usually operated with a three-phase timing pattern. The shape of the SPUI could be seen in Fig. 1.

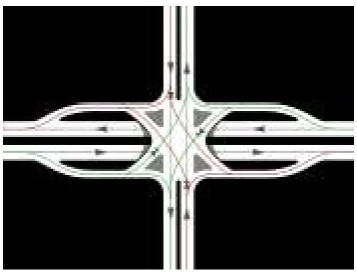


Fig. 1. Single Point Urban Interchange

The type of this interchange consisted of two undisturbed traffic flows; they were the left turn and the main intersection traffic flow above. It was called a single-point because all directions of the traffic flows were regulated by one set (single-point) of traffic signals. Efficiency of SPUI space requirements depended on volume of traffic that can be handled [4]. Advantages of using this type of SPUI intersection were to increase its efficiency and to operate its safety compared to other interchanges. The SPUI intersection also had a wide enough bend, making it easier for large vehicle movements [5].

The SPUI also required less space than other types of elevated intersections. Turning right from both junction directions could turn simultaneously because the junction was controlled by a single sign, so the vehicle could pass through the intersection faster than the diamond interchange [6, 7]. A main disadvantage of this SPUI intersection was its increasing cost because it needed bridges that were longer and wider. Also, the SPUI intersection used an unfamiliar signal phase, so it might make the drivers little bit confused about the direction [8].

A. Methodology

Observing the studied area was conducted to determine its real condition in the field. The location of this study was at Kentungan Intersection, Kaliurang Street, Depok Subdistrict, Sleman Regency, Yogyakarta Province. Primary data of this study include vehicle volume, intersection capacity, intersection dimensions, and conflict points. The Kentungan Intersection could be seen in a picture below.

Fig. 2. Location of the Study

Surveying the location was conducted for one day on Wednesday, and for 6 hours from 6:00 am to 12:00 pm. While conducting the survey, the researcher recorded a number of vehicles passing through the intersection. The vehicles were calculated and categorized based on their types by using classification of Bina Marga [9]: light vehicles (LV), medium heavy vehicles (MHV), long bus (LB), long truck (LT), motorcycles (MC), and non-motorized vehicles (UM).

The study was to model three conditions: the existing condition, the condition with SPUI in actual size and the condition with SPUI in modified size. Furthermore, stages of the modeling process of PTV. Vissim could be seen in a figure below.

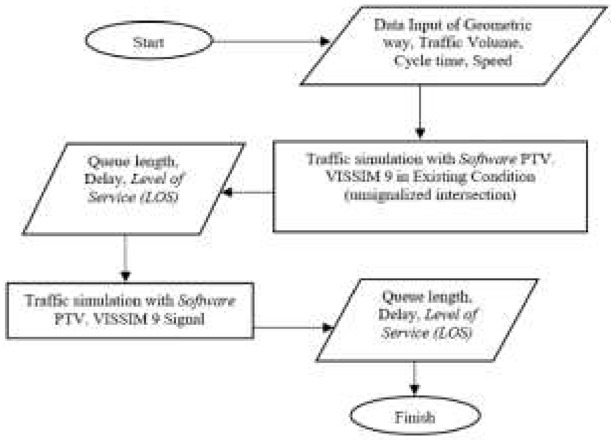


Fig. 3. Stages of Modeling in PTV. VISSIM

III. Result And Discussion

A. Result Data

The following data were some of inputted data used as input for micro simulation program of modeling by PTV. VISSIM based on primary data of this study.

B. Inputted Data

- Geometric Condition

The geometric condition of the intersection could be seen in the following figure.

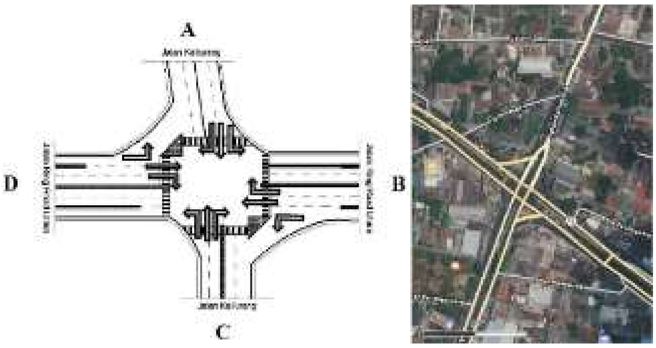


Fig. 4. The Geometric Condition of the Intersection

TABLE I. DATA OF ARM WIDTH

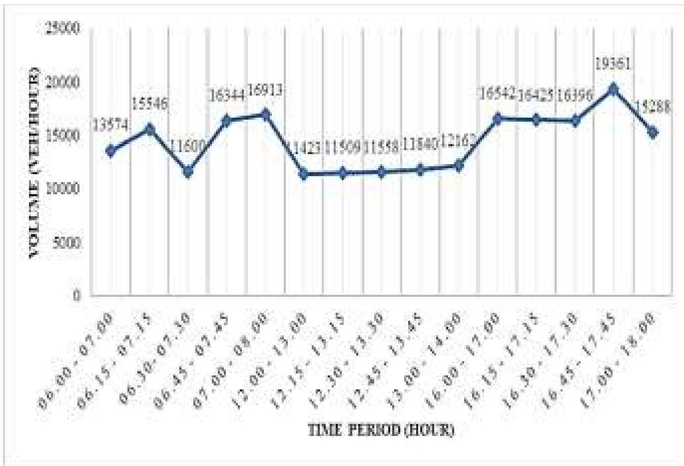
	Entering at the Intersection			Exit at the Intersection		
	Lane 1 (meter)	**Lane 2 (meter)**	**Motorcycle Lane (meter)**	**Lane 1 (meter)**	**Lane 2 (meter)**	**Motorcycle Lane (meter)**
North (A)	2	3	0	3.5	3.5	0
East (B)	4	3	4	3	3.5	3.5
South (C)	4	3	0	3	5	0
West (D)	3.5	3.5	4	3	3	3.5

TABLE II. TYPES OF ENVIRONMENT AROUND THE INTERSECTION

Arm Code	Type of Land-used	Type of Environment
Kaliurang Street (A)	Shops	Commercial
Ringroad Utara Street (B)	Shops	Commercial
Kaliurang Street (C)	Shops, Office Space	Commercial
Ringroad Utara Street (D)	Shops	Commercial

- Traffic Volume

Surveying traffic volume in the Kentungan Intersection was conducted directly at each the intersection. It was conducted for two hours at peak hours, exactly at 06.00-08.00 a.m., 12.00-14.00 p.m., and 16.00-18.00 p.m.. The results of the survey can be seen in a graph below.



Based on the data above, the highest peak hour of the traffic occurred at 16.45 – 17.45 WIB, and its total volume was 19361 veh/hour. Below was table of the volume at peak hours based on the vehicle classification by Bina Marga [9].

TABLE III. TRAFFIC VOLUME AT PEAK HOURS BASED ON EACH DIRECTION

Arm	Direction	Types of Vehicles					
		LV	HV	MHV	LT	MC	UM
	LT	77	4	0	9	274	0
A	ST	201	4	2	15	1915	0
	RT	164	7	0	19	875	0
	LT	87	4	1	4	387	0
B	ST	842	85	20	80	2286	0
	RT	191	0	1	6	557	0
	LT	220	7	0	12	1331	0
C	ST	311	1	2	25	3285	0
	RT	195	5	13	11	1155	0
	LT	98	1	5	3	322	0
D	ST	770	60	7	48	2463	0
	RT	189	2	0	5	698	0

- Cycle Time of Traffic Lights

Cycle time of traffic lights was needed to simulate the real existing condition. The cycle time had important role to rule the signalized intersection. Too long or too short cycle time could affect delay, queue length and other performance in the intersection. Therefore, determining the cycle time should be ideal, not too long and too short. The table below was the cycle time based on the existing condition.

TABLE IV. THE CYCLE TIME BASED ON THE EXISTING CONDITION

Phase	Arm	Type of Approach	Time (second)			
			Red	Green	Amber	All Red
Phase 1	North	Protected	168	30	3	3
Phase 2	West	Protected	138	60	3	3
Phase 3	South	Protected	168	30	3	3
Phase 4	East	Protected	138	60	3	3
Cycle Time (second)			204			

- Vehicle Speed

Surveying vehicle speed was conducted directly at each intersection based on the types of vehicles by using a speed gun. The survey used a random sample with 20 determined vehicles for each type of vehicles. After that, the data from the survey were analyzed to determine cumulative vehicle speed by dividing them into some intervals. Below was the graph of the cumulative vehicle speed.

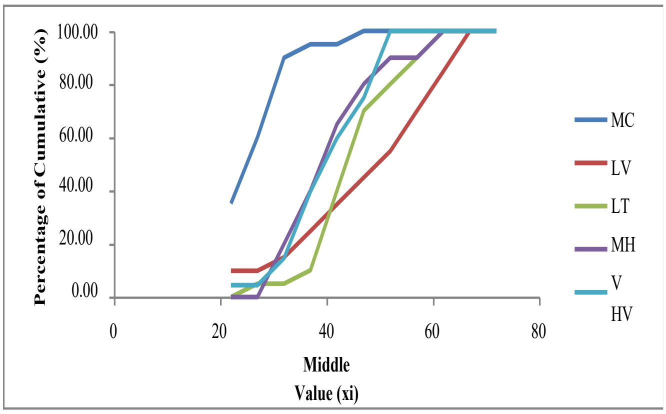


Fig. 6. Distribution of Cumulative Vehicle Speed

- Calibration

According to Irawan and Putri [10] calibration was significant to equalize a modeling with real conditions in the field. The calibration only focused on the driver behavior. The driver behavior was an individual trait that likely occurred in the field because of some interactions with other factors such as vehicle distance, acceleration, deceleration, and existing traffic rules. Thus, this study used Irawan and Putri's study [10] of calibration trial on driving behavior as an approach for this study. Fig. 6 and Table V demonstrated how driving behavior had changed from the default.

TABLE V. CALIBRATION OF DRIVING BEHAVIOR IN PTV. VISSIM 9 [8]

Trial of Calibration	Parameter changed	Before	After
1	a. Desired position at free flow b. Overtake on same lane: on the left and on the right	Middle of lane is off	Any is on
2	a. Distance standing in meter b. Additive part of safety distance	1 meter 1 meter	20 centimeters 0,4 meter
6	a. Average of standstill distance b. Additive part of safety distance c. Multiplicative part of safety distance	0,5 meter 0,5 meter 1	0,6 meter 0,6 meter 1

Fig. 7. The Differences between Before and After Calibration

C. *Modeling Results*

i. Modeling in Existing Condition

Based on several input parameters from the primary data, the next step was modeling. This process was done by making a node from the studied area to be analyzed in a form of a polygon. Based on the running process, the node result would be obtained. The node result would display parameter values in the intersection performance included in the polygon. Some important values were Level of Service (LOS), vehicle delay, queue length and some parameters about pollutants such as NOX, CO, and etc. However, this study only used traffic parameters.

ii. Modeling of SPUI Intersection in Default Size

The modeling stage of SPUI intersection in default size was the same as the stage of modeling at the existing intersection. This modeling used the SPUI intersection type with a default size based on the existing size condition. The design of SPUI based on the default size from the existing condition could be seen in the following figure.

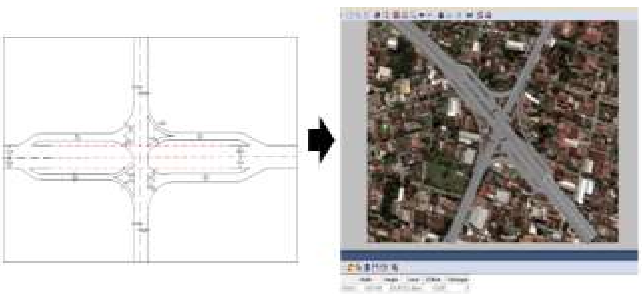


Fig. 8. Default Design of SPUI Based on the Existing Size Condition

iii. Modeling of SPUI Intersection in Modified Size

At this stage, the size of each road was modified to achieve the best modeling result. Some road widths were added 3 to 5 meters. Widening the roads was done by trial and error method to increase performance parameters in the intersection until the ideal widening results were obtained.

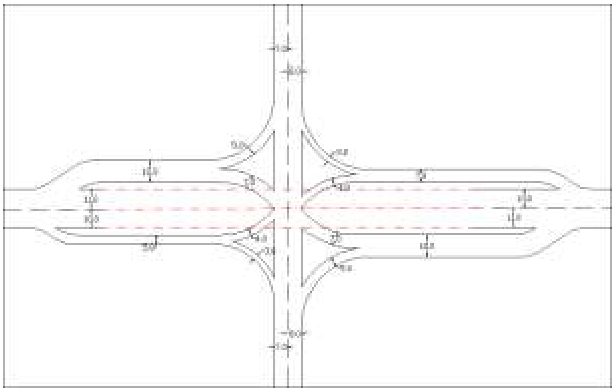


Fig. 9. Modified Size of the SPUI intersection

IV. DISCUSSION

A. *Data Validation*

In the discussion of data validation, a comparison of the volume of the survey results and the volume of the modeling results was made. The data validation aimed to test the modeling that had been made. Specifically, it was evaluated by making a correlation between the number of real vehicles and the number of vehicles captured in the model by determining correlation coefficient based on the value of R squared (R2) [11]. The data validation was demonstrated in the table below.

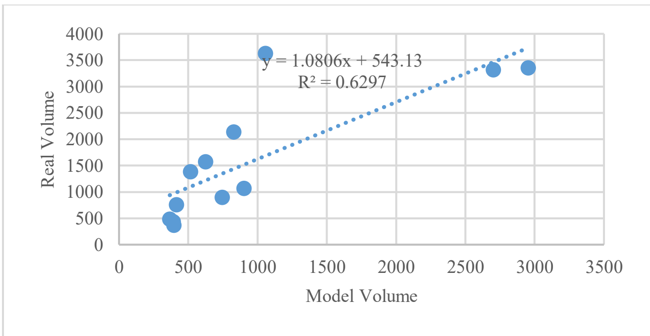


Fig. 10. Data Validation with Linear Regression Method

The result of R square or correlation coefficient was 0,623, meaning that the differences between the real and the model volume was below 0,5 and have a moderate relationship. The result might be because this study used the method of volume type in VISSIM was stochastic. The stochastic method made the volume flow randomly; therefore, the volume captured in the model was more various. Unlike an exact method, the modeling volume was almost same as the real volume results, but it depended on the distribution of real routes.

B. Comparison Results

Based on the three condition models, comparison of important parameters from PTV. VISSIM output could be seen in the table below.

TABLE VI. NODE COMPARISON RESULTS

No	Node Result Condition	Queue Length (m)	Delay (sec)	LOS
1	Existing Condition	82,08 meters	104,79 seconds	F
2	SPUI in *Default* Size	39,46 meters	32,54 seconds	D
3	SPUI in Modification	21,89 meters	30,3 seconds	D

Based on the table above, the best modeling result was the third model, the SPUI with modified size. The modification of the size was by widening each arm. Therefore, the main roads, Ring-road and Kaliurang Street, were still in the same width as the existing condition.

V. Conclusion

A. The Advantage and Disadvantage of the SPUI

Single Point Urban Interchange (SPUI) is quite rare to use in Indonesia because it may more expensive than a conventional intersection. Therefore, explanations below were several reasons about advantages and disadvantages of the SPUI implementation.

a) Advantages:

i. Having aesthetic value
The shape of SPUI was beautiful and unique as it represented a flower in a city. Some countries have used SPUI as an icon for certain cities.

ii. Reducing traffic delay
It could reduce the value of delay because installations of traffic lights were only one. However, in the existing condition in the form of a plot, there were 4 traffic lights. This condition would be effective if the traffic volume still stabled and flowed.

iii. Suitable for urban area
In urban areas, the increasing of vehicles could occur faster than in the rural area. This growth should be accommodated by implementing appropriate infrastructures. The SPUI could be an appropriate plan for the infrastructures because its size and effectiveness could be proper in the urban areas.

b) Disadvantages:

i. Requiring large areas
The SPUI required a wider area than the conventional form. This was because each frontage-road had length of more than 50 meters.

ii. Important need of traffic signs
This consideration referred to concepts of traffic circulations as directions of movement must be followed by installing some signs; therefore, they could facilitate drivers to pass.

iii. More expensive cost to construct
The cost of this model was more expensive because the area was larger than ordinary underpasses or flyovers.

c) Summary

Based on the modeling results by using the PTV program, VISSIM 9, on the Kentungan Intersection, it could be concluded that:

- The modeling results at the existing conditions of Kentungan Intersection showed that the highest traffic volume was at 16.45 - 17.45 p.m. on all arms. The type of vehicles that mostly passed the intersection was motorcycle (MC). Modeling results of the existing condition indicated that the level of road service (level of service) was at the value of F (> 60 seconds) based on the delay value of 104.79 seconds and the queue length of 82.08 meters.
- Modeling by changing the geometric design of the plot of the intersection to be a junction was not in the form of Default SPUI. The results obtained from the Default SPUI Intersection model were at the level of service that changes to D (25.1 - 40.0 seconds). Based on the value of the delay produced is 32.54 seconds and the queue length is 39.46 meters.
- Modified SPUI Intersection Model, redesigned and modification shape geometry by changing the dimensions of several roads using trial and error methods, so that it could have better results than default SPUI Intersection. The results obtained that the level of service that changes to D (25.1 - 40.0 seconds) based on the value of the delay produced is 30.3 seconds and the queue length is 21.89 meters.

References

[1] Idyanata, D., (2013), Evaluasi Geometrik dan Pengaturan Lampu Lalu Lintas pada Simpang Empat Polda Pontianak, Jurnal Teknik Sipil Universitas Tanjungpura, 13(1), 191-201.

[2] Lestari, M. D, (2016,) Analisis Kinerja Simpang Bersinyal pada Simpang Empat Ring Road Jalan Kaliurang, Bachelor Thesis, Universitas Muhammadiyah Yogyakarta, Yogyakarta, Indonesia.

[3] Jones, E. G., and Selinger, M.J., (2003), Comparison of Operations of Single-Point and Tight Urban Diamond Interchanges, Transportation Research Record 1847, 03(2611), 29-35

[4] Bared, J. G., Powell, A., and Kaisar, E., (2003), Traffic Planning Models for Single- Point and Tight Diamond Interchanges, Transportation Research Record 1847, 52-57.

[5] Bonneson, J.A., (1992), Change Intervals and Lost Time at Single-Point Urban Interchanges, Journal of Transportation Engineering, 118(5), 631-650.

[6] Fang, F.C., dan Elefteriadou, L., (2005), Some Guidelines for Selecting Microsimulation Models for Interchange Traffic Operational Analysis, Journal of Transportation Engineering, 131, 535-543.

[7] Fang, F. C., (2009), Simulation Modeling of Traffic Operations at Single Point and Diamond Urban Interchanges, Proceeding of the 8th International Conference of Chinese Transportation and Logistics Professional., Chengdu, 31 July-3 August, 3810-3815.

[8] Bared, J., Powell, A., Kaisar, E., and Jagannathan, R., (2005), Crash Comparison of Single Point and Tight Diamond Interchanges, Journal of Transportation Engineering, 131(5), 379-381.

[9] Bina Marga, (1997), Highway Capacity Manual, Direktorat Jenderal Bina Marga, Jakarta.

[10] Irawan, M. Z., and Putri, N. H., (2015), Kalibrasi VISSIM untuk Mikrosimulasi Arus Lalu- Lintas Tercampur pada Simpang Bersinyal (Studi Kasus: Simpang Tugu, Yogyakarta), Jurnal Penelitian Transportasi Multimoda, 13(03), 97-106.

[11] Muchlisin, M., Yusup, M., & Mahmudah, N. (2018). Congestion Cost Analysis of Condongcatur Signalized Intersection Sleman, DI Yogyakarta using PTV. Vissim 9. In MATEC Web of Conferences (Vol. 181, p. 06003). EDP Sciences.