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Simulation of Signalless Intersection Handling Using the VISSIM Model at the Punge Intersection, Banda Aceh City, Indonesia

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***Abstract*— the Punge Intersection is one of the four-armed unsignalized intersections in Banda Aceh City without traffic regulations such as traffic lights, roundabouts, or other warning signs. This condition is very troublesome for road users, especially during peak hours. It is considered necessary to evaluate the performance of the intersection along with alternative treatments that produce the best performance to meet the standards. Most of the previous studies relied heavily on tailor-made simulation tools to evaluate control algorithms, but the use of simulation platforms to make system comparisons through modeling is still very rare, especially in Indonesia. Analysis and modeling at the Punge Intersection using the MKJI method and PTV VISSIM 10.00-02 (VISSIM) software. Traffic volume data (plan), road geometric, and environmental conditions are needed in data processing operations using VISSIM. Three modeling scenarios were carried out with the implementation of a one-way road for arm A in the entry direction, installation of a traffic signaling tool, called APILL, roundabout planning and widening of each arm. A roundabout planning simulation with type R10-22 with widening on each road section can make the Punge Intersection with the best LOS and meet the best service levels.**

Keywords— VISSIM, Transportation, Punge Intersection.

I. INTRODUCTION

An intersection is a meeting point or area of at least three main roads, where the meeting point area is shared by various vehicles in turn. It causes frequent traffic conflicts between vehicles which cause various traffic obstacles, which are called congestion [1], [2]. It occurs at the Punge Intersection in Banda Aceh City, which visually looks low in terms of traffic performance (in terms of the degree of saturation, average speed, travel time, and queues between vehicles). Therefore, it is necessary to conduct an evaluation study of the level of service and alternative treatments at this intersection [3]. The Punge intersection is currently an unsignalized intersection with four arms connecting roads such as Sultan Iskandar Muda Street, Punge Blang Cut Street, and Cempaka Punge Jurong Street. The spatial pattern formed at this intersection consists of mixed areas filled with various activities, such as shops, offices, social facilities, and several residential areas [4], [5]. Along with the growth of vehicles and developments in land use, it is feared that the performance of the intersection will decrease in the future. As one of the most important elements in the transportation sector, management requires serious attention [6]–[8]. Therefore, this requires an alternative traffic model to improve the system for better service.

Most of the previous studies relied heavily on tailor-made simulation tools to evaluate control algorithms Quinlan, et al (2010); Li, et al (2015); Niels, et al (2020), but the use of simulation platforms to make system comparisons through modeling still needs to be improved very rarely done, especially in Indonesia [9]–[11]. However, with a standard simulation platform, simulation results are easier to obtain and even to be trusted. In addition, it is known that most existing studies do not have standards for using terms and clear descriptions of setting simulation parameters when presenting evaluation results. For example, when traffic volumes are presented, there is no clarification as to whether they are per lane or whole at the same point [12]. Requirements for determining path configuration, speed distribution, volume, delay, number of passes per experiment, random seed selection, and simulation period were also excluded from the analysis or were not determined consistently in various studies, such as in Zohdy & Rakha's research (2016), Fayazi & Vahidi (2017), Yang & Monterola (2016). The inconsistency is likely due to using various simulation software programs created by researchers instead of standard commercial simulation software [13]–[15].

Several previous studies using VISSIM software to simulate intersection handling in Indonesia have been available. VISSIM offers a variety of functions according to flexible needs to facilitate the creation of various component object models [16]. In contrast to developed countries, road traffic in Indonesia has distinctive vehicle categories and road traffic characteristics, in which traffic flow is dominated by

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motorbikes with a composition of 40-80% [17], [18]. Therefore, traffic simulation software applications such as VISSIM must consider this condition during calibration. In addition, various studies in Indonesia should have considered more stimulation parameters to obtain a comprehensive study. Halim et al. (2019) only included eight parameters in modeling intersections on the road in Makassar City, such as (1) expected position, (2) lane change rules, (3) distance between vehicles on the same lane in an active condition, (4) distance lateral distance between vehicles when stopped, (5) lateral distance between vehicles when active, (6) minimum speed, (7) number of vehicles observed, and (8) average stopping distance [18]. Nugroho & Dwiatmaja (2020) in their research, only considered (1) intersection geometry, (2) traffic volume, (3) vehicle speed surveys, (4) traffic light cycles, and (5) queue lengths [19]. Misdalena (2019), Trilaksono et al. (2019), Hutahaean & Susilo (2021), Wijaya & Susilo (2020), Nur'sila & Widodo (2021), also do not consider more parameters [20]–[24]. This study aims to determine the service level of intersections with several scenarios by adding parameters that have yet to be widely used by previous researchers in the simulation process, such as considering existing conditions by imposing one-way movement on one arm, installing traffic light signals, and roundabouts. By knowing the level of service for each treatment alternative, an alternative that produces maximum performance can be selected. In addition, the level of service obtained can be compared with the difference in performance improvement with the existing conditions. This design research analyzes the service level of intersections with various scenarios using the MKJI method and PTV VISSIM 10.00-02 software. The results obtained are the service level described by the parameters of queue length, delay, and level of service (LOS).

II. METHOD

A. Data Collection

The research was conducted at the Punge Intersection, Banda Aceh City, Indonesia. Figure 1 shows the geometric condition of the intersection, which consists of 4 arms, namely (A) the minor arm of Cempaka Plunge Jurong Street, (B) the major arm of Sultan Iskandar Muda Street (from Ulee Lheu), (C) the minor arm of Punge Blang Cut Street, and (D) The main arm of Sultan Iskandar Muda Street (from the city). Traffic data collection was carried out in 2019. The data needed to analyze intersections includes (1) geometric road conditions such as lane width, curb height, and road length; (2) The calculated traffic volume is motorcycles (MC), light vehicles (LV), heavy vehicles (HV) and non-motorized vehicles (UM); (3) Activities around the intersection (side barriers); (4) Traffic conditions, such as traffic volume, vehicle registration based on the type and direction of movement. Traffic volume was obtained from a survey using CCTV tools. Collecting data with CCTV reduces costs and produces more accurate data than conventional methods [25]. CCTV is placed in locations around the intersection that can record traffic volume and types of vehicles from all arms. This data includes the volume per 15 minutes for 15 hours in 3 consecutive days, which has been converted from units of vehicles to units of passenger cars per hour using the passenger car equivalent value.

An automated computer vision analysis technique was used in this study to extract traffic jams from video (CCTV) recordings. A detailed description of the automated computer vision analysis process, its validation, and its application in safety assessment are presented by Saunier & Sayed (2006), Saunier et al. (2010), Autey et al. (2012), Zaki et al. (2013), Tageldin et al. (2014), and Guo et al. (2018). Camera calibration is performed to map the three-dimensional real conditions and the two-dimensional image space. Thus, the vehicle tracked in the camera image can be related to its position in the real world—the process of tracking distinguishable features on moving objects in a video scene. Features on moving objects are identified and tracked using the implementation of the Kanade-Lucas-Tomasi (KLT) feature tracking algorithm. In feature grouping, features that move with the same speed and movement pattern and satisfy a predetermined spatial proximity are grouped to create objects. Tracking accuracy for road users has been found in previous studies to be between 90% and 94.4%. LV equivalent value is 1.0; 1.3 for HV, 0.5 for MC at an unsignalized intersection, 0.4 for opposing conditions, and 0.2 for protected conditions.

B. Simulation Model: VISSIM

The simulation model used in this research is VISSIM, version 10.00-02. VISSIM 10.00-02 software is used for microscopic simulation, which can display all traffic users and their interactions in one model. The most important part of the accuracy of the simulation results is the approach to the actual vehicle modeling data or the movement of vehicles observed along the site. VISSIM uses the psychophysical driver behavior model developed by Wiedemann. The basic concept of this model considers the driver of a fast-moving vehicle starting to slow down when the road user reaches the threshold of individual perception of a slower-moving vehicle in front of him. Since road users cannot precisely determine the vehicle's speed, the speed will drop below that of other vehicles in the vicinity. This results in repeated acceleration and deceleration processes within a certain period. The input data used for the intersection simulation in this study include geometric conditions, traffic volume, and environmental conditions around the intersection location.

VISSIM is software to help create intersection models and simulate intersection performance in scenarios accurately engineered to suit field conditions. First, the intersection geometry, such as the number of lanes, lane width, and turning radius, is extracted from aerial photographs, and then drawn as an engineering drawing design. Once the geometry engineering drawings are defined in the VISSIM model, all links and connectors are set to their original dimensions. Second, data on conflict areas and areas of decreased vehicle speed around intersections are processed using VISSIM. Available road signs and dash signs for left turning movement are also added to this process. An important part that needs to be considered is the traffic rules in VISSIM that are selected for left-hand traffic. Third, traffic volume and the proportion of vehicles, including the percentage of motorcycles, cars, and other types of vehicles, are entered into the simulation model for every hour. Fourth, the cumulative distribution curve of the desired vehicle speed value is adjusted in VISSIM to match the desired design speed in the field for efforts to improve existing conditions. Traffic signal settings in the VISSIM model for each hour are determined using the Ring Barrier Controller (RBC). In RBC, each phase has a green time, a yellow time, and a red time, minimum-maximum. In the final stage, the simulation model is run and visually inspected to ensure no abnormal movement of the running vehicle.

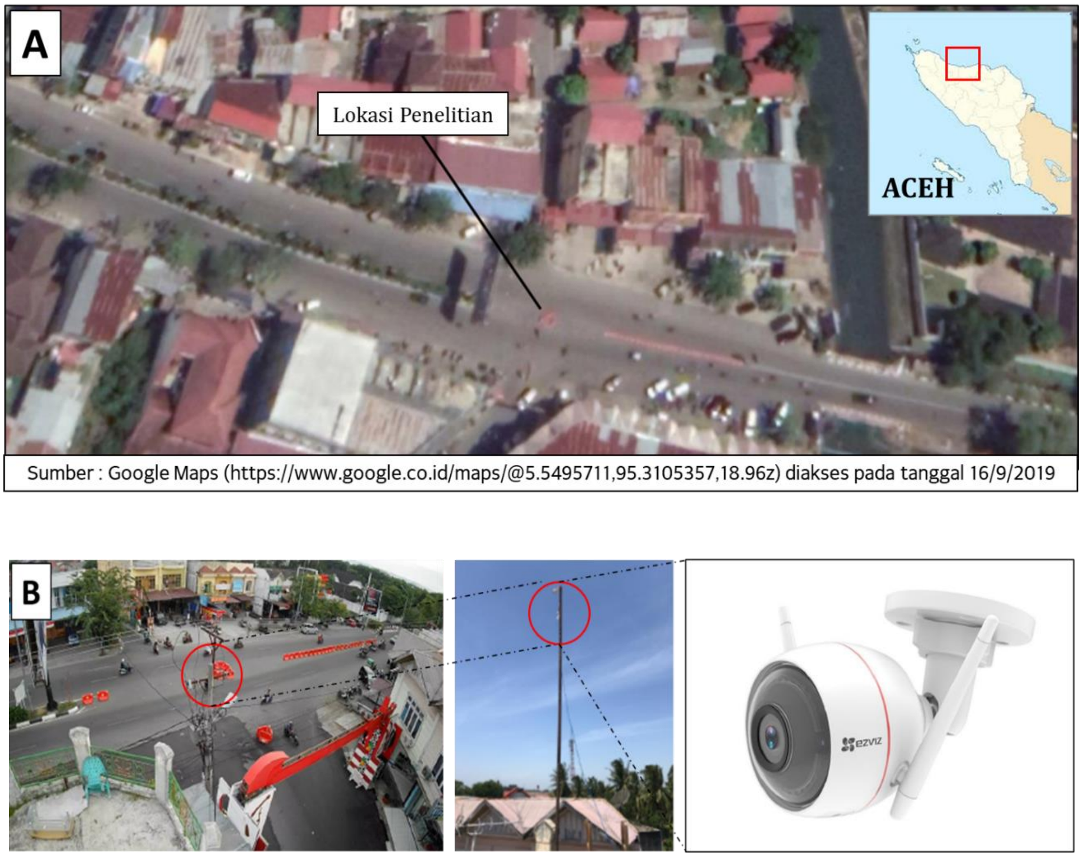

Figure 1. (A) Location location and (B) CCTV to assist the data collection process

C. Calibration and Validation of Simulation Modeling

The VISSIM model can only produce the required results once calibrated and validated. In the simulation process, VISSIM provides many calibration parameters that can be modified, considering the existing conditions at the study site and several other parameters depending on the targeted results. In this study, to produce outputs that are close to real conditions, calibration is carried out by changing the parameters of driver behavior through trial and error concerning the variable values of these parameters[26]–[28]. The parameters and calibration values are shown in Table 1. The calibration results show that several parameters have the same values in each period, as shown in Figure 2. The results before and after the parameters are calibrated. Figure 2 shows the visual appearance of the VISSIM software before and after calibration; where before calibration, the vehicle flow was very regular in the lane, and the distance between vehicles was quite tenuous. Meanwhile, after being calibrated, the flow of vehicles is irregular, side by side, and the distance between vehicles is so tight.

TABLE 1.
SIMULATION CALIBRATION AND VALIDATION

Parameters	Driving Behavior Parameters	
	Negligence	**Variable**
Average stopping distance	2	0.50
Part of the desired safe distance	2	0.50
Part of non the desired safe distance	3	1
Number of vehicles observed	2	2
Lane change rules	Free Path Selection	Free Path Selection
Desired side position	1	Ada
Side distance driving	1	0.75
Standing distance	1	0.65
Safe distance reduction factor	0.65	0.45

Parameters	Driving Behavior Parameters	
	Negligence	Variable
Minimum front clearance	0.50	0.50
Minimum advance	42	42
Simulation	1	10

III. Results and Discussion

A. Junction Environmental Conditions

Environmental conditions around the intersection are used to analyze the performance of the existing intersection. There are three things reviewed in this section, namely the city size class, the type of road environment, and the side friction class. The population of Banda Aceh City based on the Central Statistics Agency (BPS) in 2018 was recorded at 259,913 people. This number is in the range of 0.1-0.5 million people, which is included in the size of a small city class. Judging from the spatial conditions, the Punge Intersection is a meeting point that distributes access to and from the city of Banda Aceh, access to offices, education, historical sites, tourist attractions, and a place for various commercial buildings such as shophouses and street vendors (PKL). The impact on traffic is quite large even though it only occurs during rush hours. Based on the analysis using MKJI 1997, it is found that this type of road environment is classified in the commercial class. The side barriers on each side of the road are high, considering the large number of commercial activities on the side of the road, roadside buildings that function as shophouses and other similar commercial buildings. Obstacles generally occur, especially during peak hours in the afternoon until early evening when many residents return home from office, school, or trading activities. Figure 2 shows vehicles increase in the afternoon and at night.

Location sighting at 8.00-9.00 WIB
(at morning)

Location sighting at 13.00-14.00 WIB
(at noon)

Location sighting at 17.00-18.00 WIB
(at afternoon)

Location sighting at 18.00-19.00 WIB
(at night)

Figure 2. Conditions at the Punge Intersection, Banda Aceh City

B. Geometric and Intersection Traffic Movement.

The geometric conditions of the study location consist of four roads, namely Sultan Iskandar Muda Street (B and D) as the main or major roads, Cempaka Punge Jurong Street (A), and Punge Blang Cut Street (C) as minor roads. Information on geometric conditions in this study is shown in Figure 3 and Table 2.

TABLE 2.
LANE WIDTH ON EACH ROAD SECTION

No	Roadside	Notation	Road Type	Width (m)
1	The minor side Cempaka Punge Jurong Street	A	2/1UD	6
2	The major side of Sultan Iskandar Muda Street	B	6/2D	9
3	The minor side Punge Blang Cut Street	C	2/1UD	7
4	The major side of Sultan Iskandar Muda Street	D	6/2UD	9

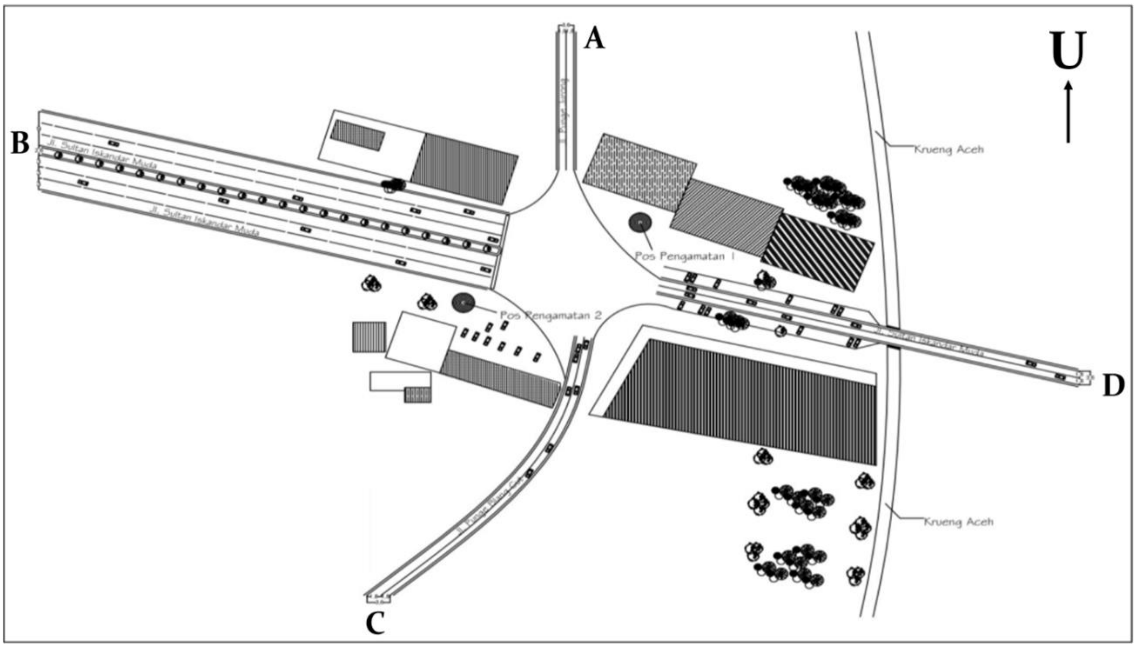

Figure 3. Punge Junction Layout Simulation

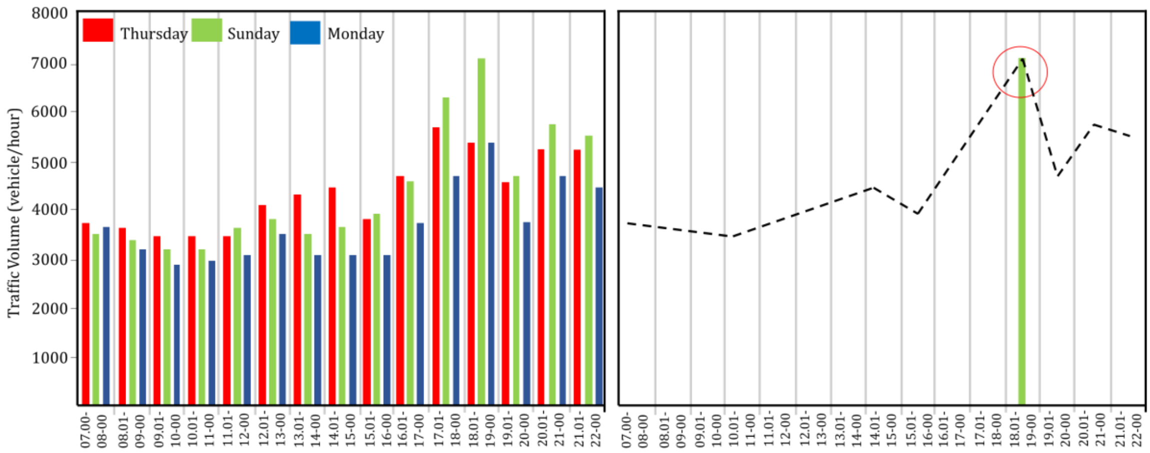

Figure 4. Traffic volume at the Punge Intersection

C. Geometric and Intersection Traffic Movement.

The traffic volume survey was conducted on Thursday (August 22 th, 2019), Sunday (August 25th, 2019), and Monday (August 26th, 2019). It is known that the peak traffic volume occurs on Sunday during the afternoon rush hour at 18.00-19.00 WIB, with a total of 7,000 vehicles during that period. The recapitulation of traffic volume data can be seen in Figure 4. The traffic volume is used as a parameter to determine delays, queuing opportunities, and LOS, which are then processed using VISSIM 10.00-02. to generate simulations and determine intersection performance.

D. Intersection Service Level in Existing Conditions.

The data from the traffic survey results in the field were then continued by simulating using the VISSIM 10.00-02 software to be able to describe the existing traffic conditions at the Punge intersection by inputting the parameters, which can be seen in Figure 5.

From Figure 4, multiplying ten random seeds and running a simulation runs ten times on the parameters of traffic volume, capacity, current of braided sections, and delays to obtain accurate results of Measurement of Effectiveness (MOEs). Recapitulation of running process results in Vissim software to obtain intersection performance simulation results. The output of the Vissim Running simulator results obtained can be seen in Table 3.

From the calculation results above, it can be concluded that the queue length is 71.25 m, the delay is 104.92 seconds, and LOS E. Here, the performance of the existing conditions is very low. Several scenarios or alternative solutions are needed [29].

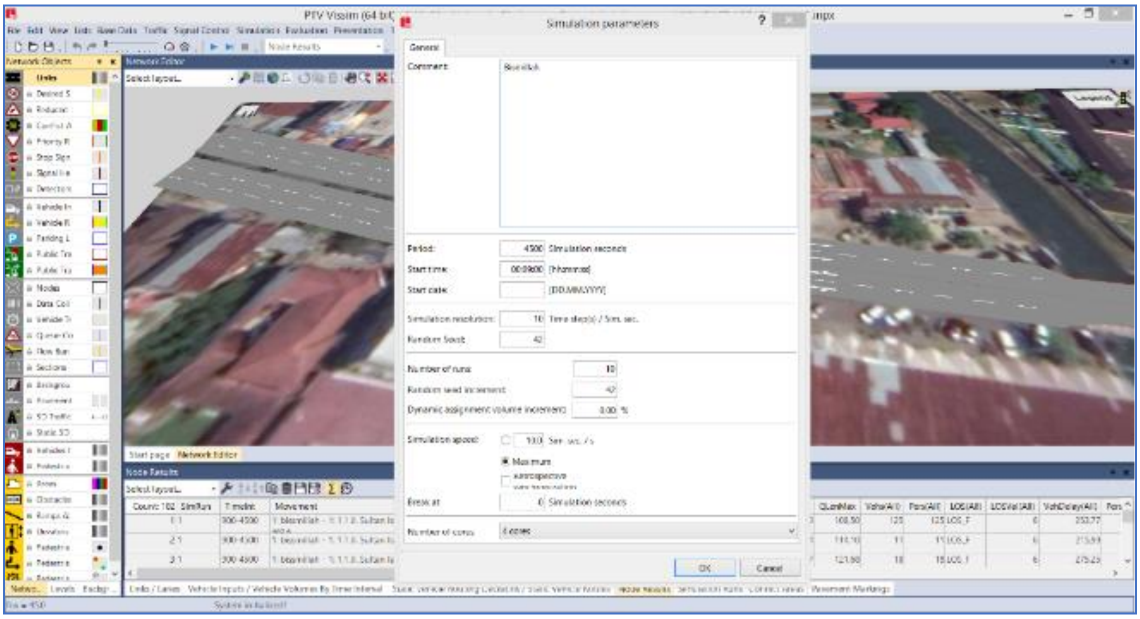

Figure 5. Simulation parameters (input random seed and simulation run)

TABLE 3.
RECAPITULATION OF VISSIM SIMULATION RESULTS FOR EXISTING CONDITIONS

Movement	$Q_{Len\ Max}$	VEH Delay (All)	LOS (All)
B-D	105.14	347.62	LOS F
B-A	110.74	258.08	LOS F
B-C	118.32	316.68	LOS F
D-B	99.89	116.55	LOS F
D-A	99.89	133.53	LOS F
D-C	99.89	117.66	LOS F
A-D	43.83	11.98	LOS B
A-B	44.05	7.08	LOS A
A-C	43.83	11.36	LOS F
C-D	47.62	21.35	LOS C
C-B	47.62	24.92	LOS C
C-A	47.62	19.32	LOS C
Average	71.25	104.92	LOS E

i. Scenario I (Enforcement of one-way, Cempaka Road)

In this scenario, a one-way road for the north arm, namely on the Cempaka Punge Jurong road, is implemented only for the inbound direction with the assumption that the current from arm A will seek the other direction, so the intersection that originally had a 4-phase arrangement was changed to 3-phases. Recapitulation of running process results in Vissim software to obtain intersection performance simulation results. The output of the Vissim Running simulator results obtained can be seen in Table 4.

Based on the calculations on this alternative by designing a one-way road for arm A only to enter from the approach and using the average one-hour condition data, the queue length is 30.38 m, the delay is 25.32 seconds, and LOS D is lower than the existing condition.

TABLE 4.
RECAPITULATION OF VISSIM SIMULATION RESULTS (ONE-WAY DIRECTION, CEMPAKA PUNGE JURONG ROAD)

Movement	$Q_{Len\ Max}$	VEH Delay (All)	LOS (All)
B–D	55.19	3.21	LOS A
B–A	69.80	3.42	LOS A
B–C	55.19	3.17	LOS A
D–B	87.36	21.83	LOS C
D–A	98.13	65.25	LOS F
D–C	97.42	22.25	LOS C
C–D	54.02	3.19	LOS A
C–B	62.35	1380.36	LOS F
C–A	54.25	3.19	LOS A
AVERAGE	30.38	25.32	LOS D

ii. Scenario II (Installation of Traffic Light Control Devices)

Data from the traffic survey results are then continued by simulating using Vissim so that it can describe the traffic conditions at the Punge intersection by installing APILL, with cycle times that can be seen in Figure 6.

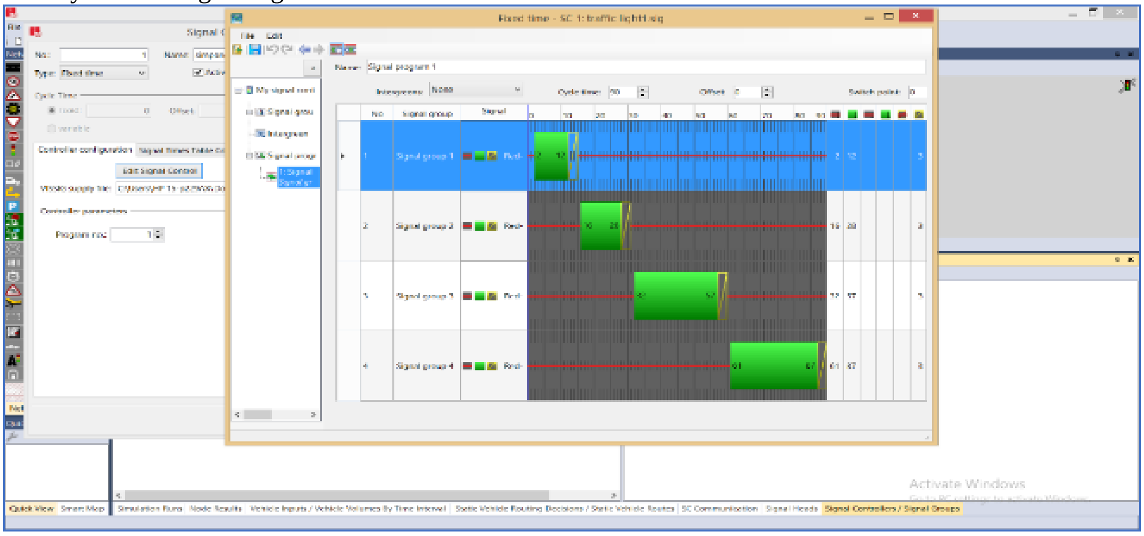

Figure 6. Cycle time on each arm using the VISSIM software.

Recapitulation of running process results in Vissim software to obtain intersection performance simulation results. The output of the Vissim Running simulator results obtained can be seen in Table 5.

TABLE 5.
RECAPITULATION OF VISSIM 10.00-02 (APILL) SOFTWARE SIMULATION RESULTS

Movement	$Q_{Len\ Max}$	VEH Delay (All)	LOS (All)
B-D	107.63	138.82	LOS F
B-A	80.95	118.43	LOS F
B-C	80.95	126.52	LOS F
D-B	97.55	74.72	LOS E
D-A	97.55	74.36	LOS E
D-C	72.14	70.78	LOS E
A-D	43.44	102.93	LOS F
A-B	20.00	90.06	LOS F
A-C	43.44	104.14	LOS F
C-D	26.03	37.28	LOS D
C-B	52.10	50.13	LOS D
C-A	52.10	50.99	LOS D
Average	45.33	99.63	LOS F

Table 5 above explains that the simulation results of the VISSIM 10.00-02 software can be concluded that the average waiting length is 45.33 m, the delay is 99.63 seconds, and LOS F. With the results of this scenario, the intersection performance is still low.

iii. Scenario III

A roundabout planning geometric change was carried out in scenario III experiment. One way is to widen each approach. In this roundabout simulation, the type of roundabout used is type R10-22, which can be seen in Figure 7 and Table 6.

Figure 7. Lay out the Punge Junction plan the roundabout.

TABLE 6.
WIDENING OF THE APPROACH ROAD IN ROUNDABOUT PLANNING

Section	Existing			Planning		
	Pend. 1	**Pend. 2**	**Average (WE)**	**Pend. 1**	**Pend. 2**	**Average (WE)**
A	10	6	8.00	10	10	10.00
B	10	9	9.50	10	11	10.50
C	10	7	8.50	10	10	10.00
D	10	9	9.50	10	12	11.00

Data from traffic survey results in the field were then continued by simulating VISSIM 10.00-02 software to be able to describe the existing traffic conditions at the Punge intersection. The recapitulation of the simulation results in the Roundabout situation using the VISSIM 10.00-02 software can be seen in Table 7. From Table, it can be interpreted that by installing a roundabout with a roundabout radius of type R10-22 and widening each intersection arm, an average queue length of 31.62 m, a delay value of 19.34 seconds, and LOS C is better than the existing condition. Based on the results of data collection and analysis that have been done previously, in this section, a discussion can be made regarding the traffic flow of the Punge Banda Aceh Intersection in the existing conditions and with type R10 – 22 developments planning whose performance has been calculated based on the simulation with software VISSIM to get accurate Measurement of Effectiveness (MOEs) results. From the calculation results of the three scenarios above, it can be concluded that calculations using Vissim as software can be seen in Table 8.

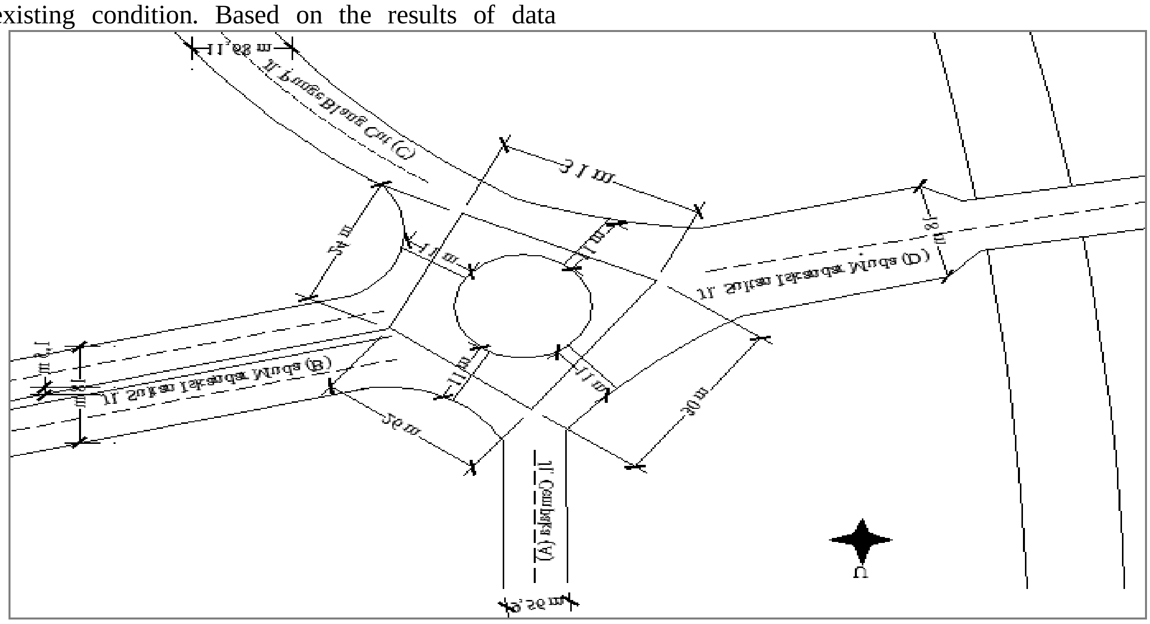

Figure 8. Layout of the Roundabout Planning Punge Intersection

From the three scenarios that have been analyzed using Vissim Software, it can be concluded that the delay values (Delay, D), queue length (queue length, Q), and level of service (Level of service, LOS) meet the standards by widening the lane and planning a roundabout type R10-22.

TABLE 7.
RECAPITULATION OF VISSIM 10.00-02 SOFTWARE SIMULATION RESULTS (ROUNDABOUT)

Movement	Q_{Len} Max	VEH Delay (All)	Los (All)
B-B	80.63	0.00	-
B-D	80.63	47.19	E
B-A	80.63	0.00	-
B-C	80.63	47.30	E
D-B	22.77	3.32	A
D-D	22.77	0.00	-
D-A	22.77	4.95	A
D-C	22.77	0.00	-
D-C (left turn permitted)	22.77	0.57	A
A-D	19.10	0.84	A
A-B	19.10	0.00	-
A-A	19.10	0.00	-
A-C	19.10	0.14	A
C-D	16.20	0.00	-
C-B	16.20	1.00	A
C-A	16.20	0.17	A
C-C	16.20	0.00	-
C - B (left turn permitted)	16.20	0.08	A
B - A (left turn permitted)	19.10	15.43	B
A - D (left turn permitted)	19.49	0.41	A
AVERAGE	31,62	19,34	LOS C

Note: A-Cempaka Punge Jurong Road; B-Sultan Iskandar Muda Road (from Ulee Lheu), C-Punge Blang Cut Road, and D-Sultan Iskandar Muda Road (from city).

TABLE 8.
RECAPITULATION OF CALCULATION RESULTS

No.	Analysis	Queue Length (m)	Delay (seconds)	LOS
1	Existing	71.25	104.92	E
2	One-way	101.72	25.32	D
3	APILL	107.63	99.63	F
4	Boundabout	31,62	19.34	C

IV. Conclusion

In the existing conditions, the Punge Intersection calculated by the MKJI method has a delay (D) = 36.49 seconds, queue length (Q) = 57-115%, and level of service (LOS) F. Meanwhile the results from the VISSIM software simulation 10.00-02 (Vissim) result in a delay (D) = 25.32 seconds, queue length (Q) = 101.12 m, and level of service (LOS) E. 2. If the Punge Intersection is controlled with a Traffic Signal Control Tool (APILL) using the MKJI method then D = 37 seconds, Q = 45%, and LOS D are obtained. Meanwhile, the results from Vissim have D = 99.63 seconds, Q = 107.63 m, and LOS F.3. Roundabout planning at the Punge Intersection with the MKJI method is type R10-22 by widening each road section, the value of D = 2.49 seconds, Q = 6.70-18.13 %, and LOS B is obtained. Meanwhile, the results from Vissim have D = 19.34 seconds, Q = 80.63 m, and LOS C.4 From the three scenarios, it can be concluded that planning to install a roundabout with type R10-22 and widening each road section can result in the Punge Intersection becoming an intersection that meets the standards. In the future it is necessary to conduct research on the socio-economic impacts during construction and post-construction structuring the Punge Junction area using roundabouts 2. There is a need for further research to improve the traffic management system, both management at intersections and roads around intersections, and further research on driver behavior in Banda Aceh City, especially those passing through the Punge Intersection in more detail, regarding the distance of car following, lane change, car lateral, or driver behavior at signalized and unsignalized intersections.

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