THE EFFECT OF ON-STREET PARKING ON U-TURN AREA TOWARDS URBAN ROAD PERFORMANCE (STUDY CASE: AFFANDI STREET, YOGYAKARTA)

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Abstract*: Affandi St was on high economic activity area. A consequence was the presence of on-street parking at the turning facility (U-turn) caused a conflict in the form of congestion. This research was intended to determine the performance of the road segment, queue length, delay and proposed alternative solutions for improvement. The research was conducted with the field survey method. The analysis was using VISSIM microsimulation refers to Reverse Planning 06/BM/2005 and the level of performance of road performance refers to the Minister of Transport Regulation number PM 96 of 2015. The result indicated that the average vehicle speed of existing conditions VISSIM analysis was 29,26 km/hour for the North to South and 41,43 km/hour for the South to North, the average queue length was 22,23 meters, the average delay time was 13,66 seconds. Three alternative solutions were implementing prohibited on-street parking at the U-turn area. From the three solutions, the best one was a solution with a decreasing percentage was 27,84% for the queue length and 46,53% for the delay, while the speed increases were 38,54% for North to South and 20,20% for South to North.*

Keywords: *Microsimulation, parking, u-turn, vissim*

INTRODUCTION

As a fast-growing city, Yogyakarta has swift improvement especially in the education, trade, and tourism sector. These developments affected the high traffic growth. In this context, traffic becomes busier and transport problems arise, such as insufficient parking spaces. Therefore, many motorists park their vehicles on street [1]. On-street parking had caused the reduction of road capacity [2], traffic conflict [3], traffic delay [4], and deterioration of traffic performance [5, 6, 7, 8].

The deterioration of traffic performance was indicated by the number of congestion-sensitive points. One of the congestion-sensitive points as a result of the parking space on the road body was on a U-turn. U-turn is turning round facilities for maneuvers of vehicle performing that aims to travel to the opposite lane [9] and can be found in the median opening [10]. Limited land and on-street parking restricted the freedom of vehicles [7] to do the U-turn movement directly. One of the streets in Yogyakarta that had a vulnerable point because of on-street parking at turning round (U-turn) facilities was Affandi St.

Affandi St was on a high economic activity level area because there were hotels, restaurants, schools, offices, and shops. According to Yogyakarta RTRW Regional Regulations of 2010, Affandi St was included in the secondary collector road [11]. Affandi St had a separate building (median) with a reversal facility (U-turn). The existence of high economic activities in Affandi St resulted in a demand increase for parking space [12] so that at certain times there was an imbalance between the needs of parking and parking capacity [7]. Therefore, many motorists parking on-street that influenced the traffic disruption such as the reduction in stream speed or capacity of the road [13, 14, 15], especially at locations that happened to be at the U-turn when the vehicle makes a turn.

The purpose of this study was to know the performance of existing road conditions and propose alternative solutions to improve road performance, reduce queues and delays due to on-street parking at the U-turn area.

RESEARCH SIGNIFICANCE

This paper analyzed the performance of road segment, U-turn, and solutions of on-street parking effect by using VISSIM microsimulation refers to Reverse Planning 06/BM/2005 [16]. The performance level of the road refers to the Minister of Transport Regulation number PM 96 of 2015 [17].

METHODOLOGY

The research was conducted with a field survey method including traffic volume, on-street parking characteristics, vehicle speed, driving behavior, queue length, and delay.

A. REVOLVING PLANNING GUIDELINES (U-TURN)

According to the Directorate-General of Highways (2005), median openings are planned to accommodate the vehicle to perform reversal movements on shared road types, cutting and turning movements can be performed.
The reverse plan (U-turn) was based on the 06/BM/2005 Revolving Planning Guidelines (U-Turn) [16].

B. U-TURN TYPE

U-turn in the middle of the segment with ideal median width that can accommodate the U-turn movement of the vehicle from the inner lane to the second lane of the opposite lane can be seen in Figure 1.

C. DELAY

The delay caused by a vehicle making U-turn to the opposite lanes that effect the original lanes can be seen in Table 1.

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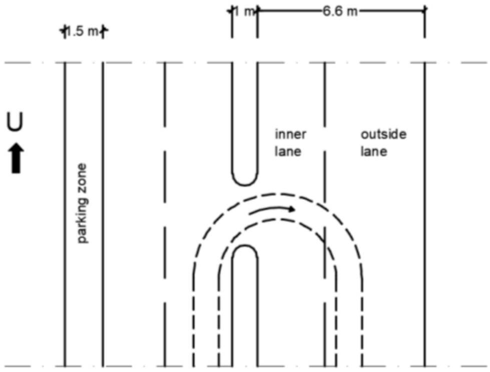

Figure 1. U-Turn Type

Table 1 Vehicle delay [16]

Volume Of Average Traffic Each Lane on the Opponent Lane (Vehicle / hr)	Delay Because 1 Rotating Vehicle (sec)	
	4/2D	6/2D
600	7,32	6,19
1000	9,36	8,95
1400	12,04	13,63
1600	13,62	16,69

D. QUEUE LENGTH

The queue length (4/2-way lanes divided) was calculated using the formula below.

Queue Length = -1,29706 + 0,09778 U-turn vehicle waiting time + 0,00214 vol. al (1)

In Equation (1), the median unit in meters (m), the unit of U-turn vehicle waiting time in seconds, and the unit volume a1 in pcu/hour.

E. VISSIM

According to PTV-AG (2011), VISSIM is a multimodal simulated microscopic flow traffic software that can analyze the functioning of private vehicles and public transport with problems such as path configuration, vehicle composition, traffic lights, etc. To make VISSIM a device that is useful for the evaluation of alternative measures [18]. Basis of transport technical measures and effectiveness planning. VISSIM modeling must reflect field conditions, so calibration and validation must be performed. Validation based on vehicle volume that comes with vehicle volume entered in VISSIM. According to Collins (2009), Validation does not meet the requirements if the comparison of data in the field and the simulation has experienced a deviation of more than 15% [19]. Calibration is performed if the result of the validation does not meet the requirements.

ANALYSIS AND DISCUSSIONS

A. TRAFFIC CHARACTERISTICS

One of the useful parameters in the analysis of lane performance was the composition and traffic volume. The composition of Affandi St vehicles during peak hours can be seen in Figure 2 and Figure 3 as follows.

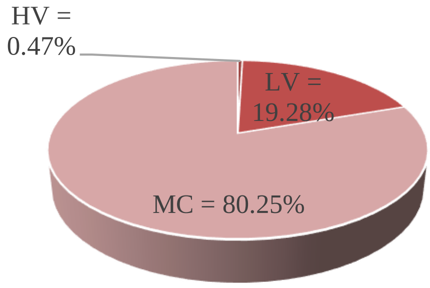

Figure 2 Vehicle Composition at the Peak Hour North to South

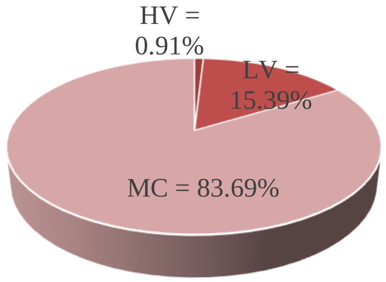

Figure 3 Vehicle Composition at the Peak Hour South to North

B. ANALYSIS OF U-TURN USING REVERSE PLANNING METHOD (U-TURN) 06/BM/2005

Directorate General of Highways has a special regulatory guideline for reversing rounds to create uniformity in planning a reverse cycle and providing safety to road users. In the guidelines, there is a subsection about the impact of a reversal on a non-eligible median that will result in long queues and delays [20].

C. VOLUME

Volume a1 is the deepest lane volume on the same lane with the vehicle that is turning to calculate the length of the row in units of pcu/hour [16]. The illustrations of the analyzed can be seen on Fig 4-6.

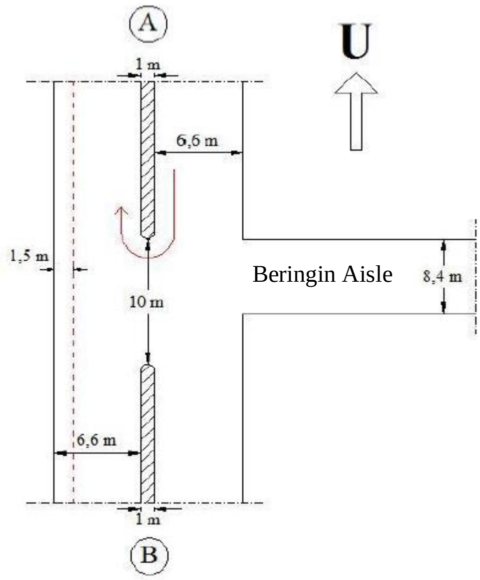

Figure 4 First u-turn (U1)

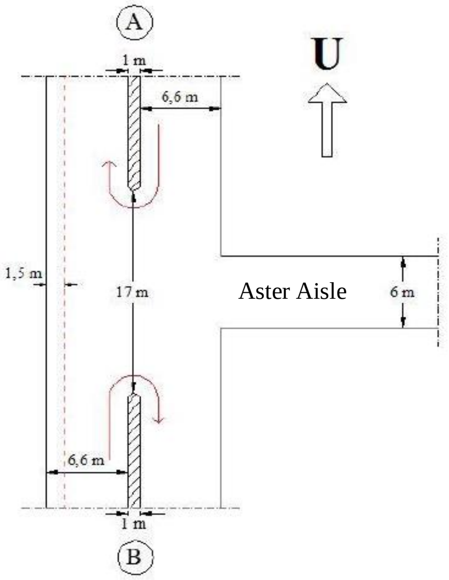

Figure 5 Second u-turn (U2)

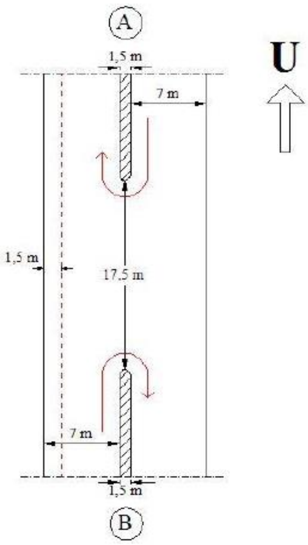

Figure 6 Third u-turn (U3)

The average traffic volume per runway on the opponent's path is stated in vehicle/hour unit. The volume of the inner row (volume a1) is shown in Table 2 and the average volume in the opposite row is shown in Table 3.

Table 2 Volume a1

U-Turn Location	Volume a1 (pcu/hour)
U1-A (U-S)	1102,6
U2-A (U-S)	943,1
U2-B (S-U)	595,05
U3-A (U-S)	819,5
U3-B (S-U)	340,9

Table 3 The average volume in the opposite row

U-Turn Location	The average volume in the opposite row (vehicle/hour)
U1-A (U-S)	1208
U2-A (U-S)	994
U2-B (S-U)	1726
U3-A (U-S)	757
U3-B (S-U)	1076

D. U-TURN WAITING TIMES

U-turn waiting times were used in the calculation of the queue length and obtained from field study results which can be seen in Table 4 as follows.

Table 4 U-turn waiting times

U-Turn Location	U-Turn Waiting Times (s)
U1-A	18,20
U2-A	15,95
U2-B	14,37
U3-A	12,08
U3-B	14,58

E. QUEUE LENGTH

Flow a1 U1-A = 1102,6 pcu/hour
U-turn waiting times U1-A = 18,20 seconds
Queue Length = -1,29706 + 0,09778 U-turn waiting times + 0,00214 volume a1
= -1,29706 + (0,09778 x 18,20) + (0,00214 x 1102,6)
= 2,84 meters

The calculation results of Queue Length at other U-turn can be seen in Table 5.

Table 5 Queue length of reverse planning plan method

U-Turn Location	Queue Length (m)
U1-A (U-S)	2,84
U2-A (U-S)	2,28
U2-B (S-U)	1,38
U3-A (U-S)	1,64
U3-B (S-U)	0,86

F. DELAY

The average flow in the opposite row = 1208 pcu/hour
The delay is calculated based on the interpolation of the delay value in Table 1.

$$\text{Delay} = 9,36 - \frac{208}{400} x(9,36 - 12,04)$$

= 10,75 seconds

The calculation results of Delay at other U-turn can be seen in Table 6.

Table 6 Delay of reverse planning plan method

U-Turn Location	Delay (s)
U1-A (U-S)	10,75
U2-A (U-S)	9,32
U2-B (S-U)	14,61
U3-A (U-S)	8,12
U3-B (S-U)	9,86

G. ANALYSIS OF U-TURN USING SOFTWARE VISSIM

The modeling stages using Software VISSIM are as follows.

1. Network Setting
   The driver behavior and units were changed according to Indonesian standards, which were vehicle behavior to left side traffic (Figure 7) and units to all metrics (Figure 8).

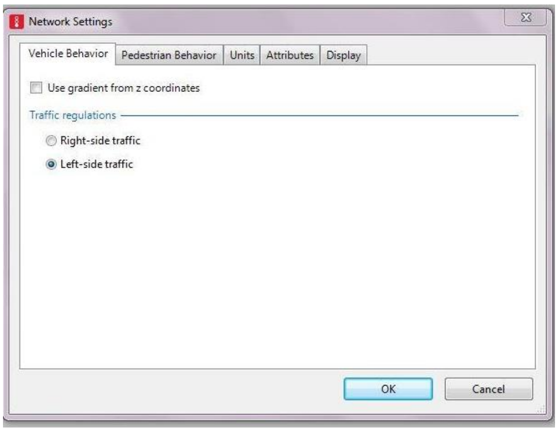

Figure 7 Vehicle behavior settings

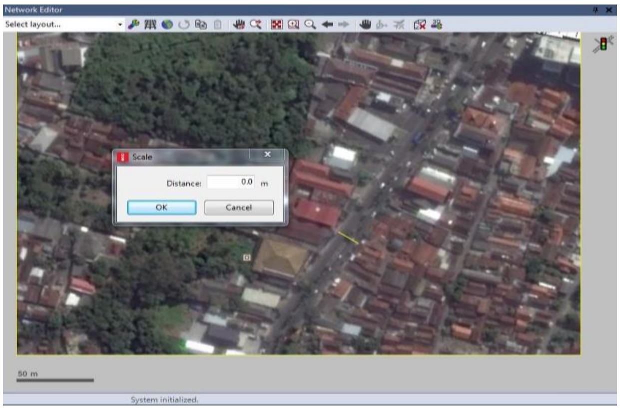

Figure 9 Background image input and set scale

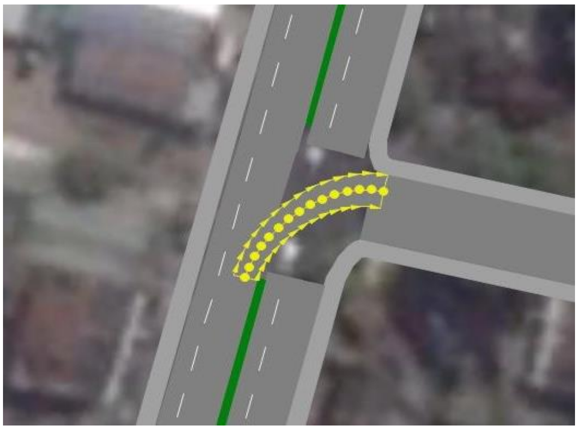

Figure 11 Connectors settings

2. Background Image
   The background image was inputted using a survey location map obtained from Google Earth and can be seen in Figure 9.
3. Links and Connectors
   Link is road lane at segment or minor road/alley. Connector is a liaison between links. Link settings can be seen in Figure 10 and connector settings can be seen in Figure 11.
4. Traffic Volume and Speed
   Traffic volume data that inputted to Vehicle Input setting on Software VISSIM was traffic volume at peak hour on every segment and alley (Figure 12). The vehicle speed from the survey was inputted to the Vehicle Composition setting (Figure 13). After that, the

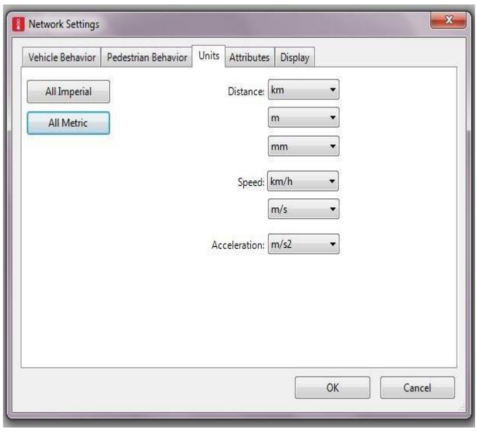

Figure 8 Units settings

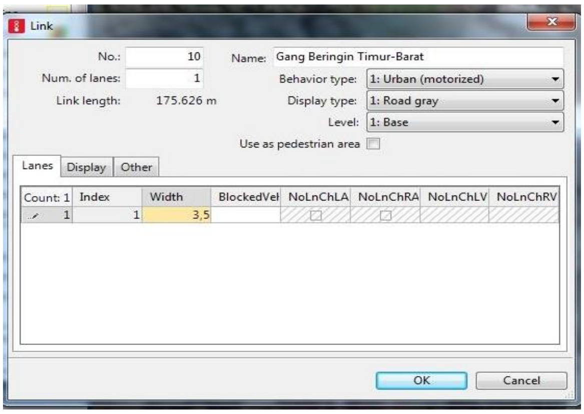

Figure 10 Links settings

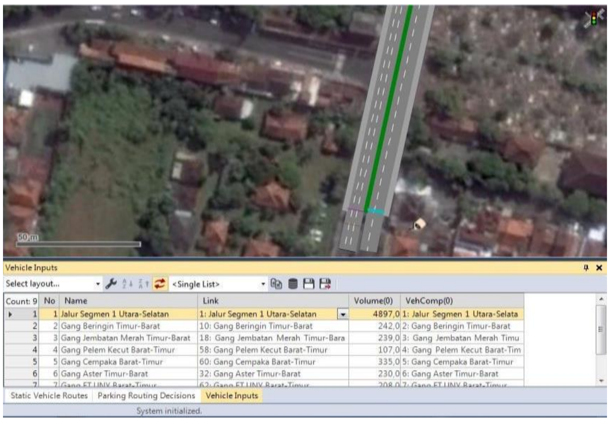

Figure 12 Vehicle inputs

vehicle movement modeling was carried out at the Vehicle Routes setting.

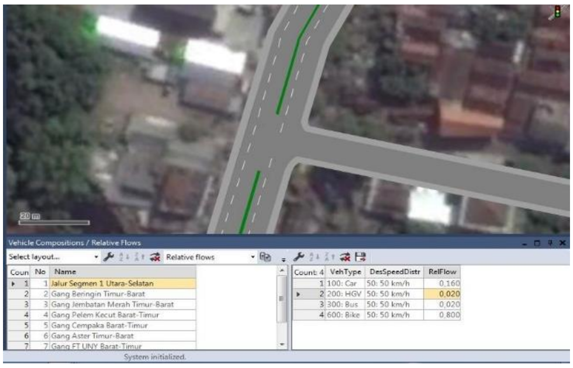

Figure 13 Vehicle composition settings

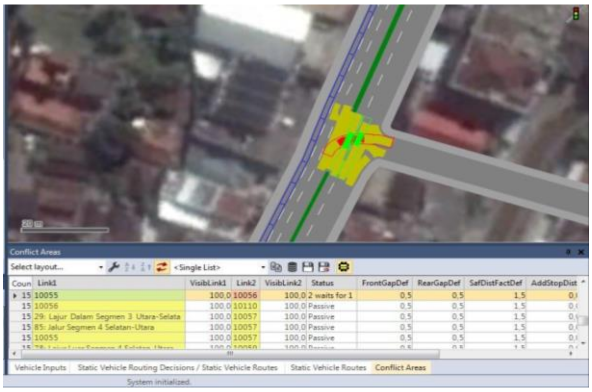

Figure 14 Conflict areas

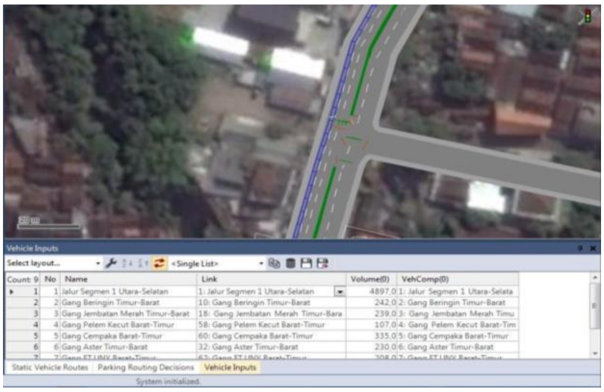

Figure 15 Priority rules settings

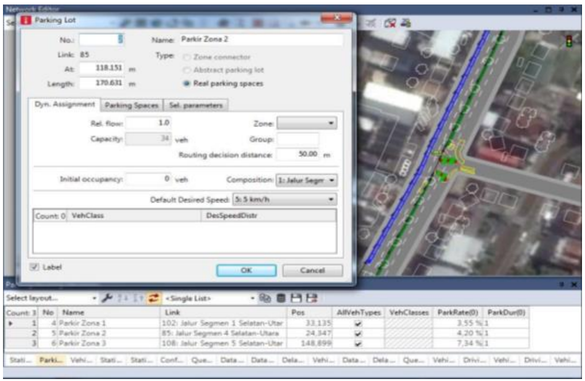

Figure 16 Parking lots settings

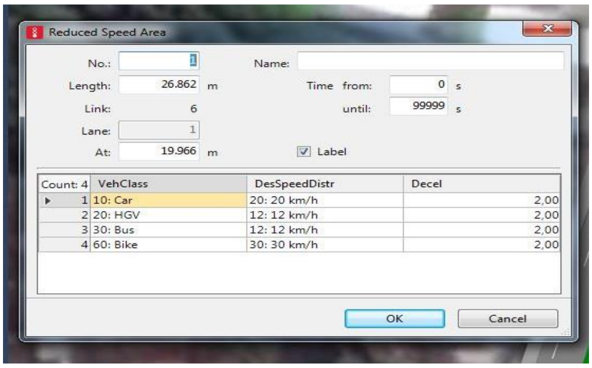

Figure 17 Reduce speed areas settings

Table 7 Field Observations Result for Calibration Input

Parameters	Value	
	Before	After
Desired position at free flow	Middle of lane	Any
Overtake on same lane	Off	On Right and Left
Minimum distance standing (at 0 km/h) (m)	1	0,6
Minimum distance driving (at 50 km/h) (m)	1	0,8
Average standstill distance	2	0,5
Additive part of safely distance	2	0,8
Multipliactive part of safety distance	3	1

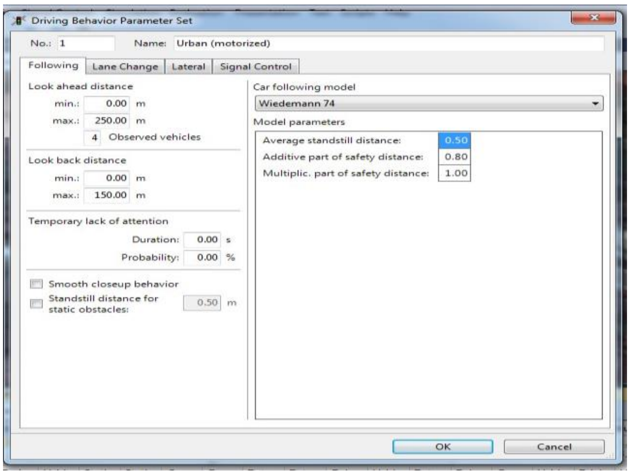

Figure 18 Driving behavior settings

5. Conflict Area
   The conflict areas in this study were at the intersections of segments, alleys, and U-turns. The conflict areas can be seen in Figure 14.
6. Priority Rules
   Priority rule is not controlled by signals and is used in a situation when vehicles in different links or connectors need to consider each other [21]. The priority rules settings can be seen in Figure 15.
7. Parking Lots
   Modeling a parking area on the street by adjusting the percentage composition of the parking volume with the traffic volume and the parking duration. The parking lots settings can be seen in Figure 16.
8. Reduced Speed Areas
   The areas were located at 20 meters of the intersections, turning area, and U-turn area. The reduced speed areas settings can be seen in Figure 17.
9. Driving Behavior
   The driving behavior settings of this study can be seen in Table 7 and Figure 18.
10. Evaluation
    This parameter was the last stage of VISSIM Modeling. The used tools were vehicle travel time and queue counters on U-turn areas to know the delays and queues length. The evaluation settings can be seen in Figure 19.
11. Validation
    The validation result can be seen in Table 8.

Table 8 Volume validation result using software VISSIM

Location	Volume Input (vehicle/hour)	Volume Output (vehicle/hour)	Deviation	Percentage (%)
Affandi St. (N-S)	4897	4769	128	2,68
Affandi St. (S-N)	2410	2436	26	1,07
Beringin Alley	242	248	6	2,42
Jembatan Merah Alley	239	250	11	4,40
Pelem Kecut Alley	107	100	7	7,00
Cempaka Alley	335	349	14	4,01
Aster Alley	430	421	9	2,14
FT UNY Alley	708	698	10	1,43
Alamanda Alley	320	309	11	3,56

Table Information:
Deviation : the deviation of volume input and volume output on Software VISSIM
Percentage : Percentage of the deviation of volume input and volume output on Software VISSIM

Table 9 Evaluation result of queue length and vehicle delay in existing condition using VISSIM

SimRun	TimeInt	Location	Queue Length (m)	Veh. Delay (s)
Average	0-3600	UI-A Same Lane	28,79	10,94
Average	0-3600	UI-A Opposite Lane	17,49	14,67
Average	0-3600	U2-A Same Lane	27,44	17,73
Average	0-3600	U2-A Opposite Lane	14,70	12,30
Average	0-3600	U2-B Same Lane	15,99	11,15
Average	0-3600	U2-B Opposite Lane	18,20	9,25
Average	0-3600	U3-A Same Lane	27,25	17,09
Average	0-3600	U3-A Opposite Lane	19,30	11,53
Average	0-3600	U3-B Same Lane	27,70	14,91
Average	0-3600	U3-B Opposite Lane	25,45	17,05
Average			22,23	13,66

Table 10 The comparison of queue length

Location	Survey Data (m)	06/BM/2005 (m)	Software VISSIM (m)
U1-A	19,86	2,84	28,79
U2-A	8,55	2,28	27,44
U2-B	14,90	1,38	15,99
U3-A	15,00	1,64	27,25
U3-B	14,10	0,86	27,70

Table 11 The comparison of delay

Location	Survey Data (m)	06/BM/2005 (m)	Software VISSIM (m)
U1-A	14,95	10,75	10,94
U2-A	8,88	9,32	17,73
U2-B	9,68	14,61	11,15
U3-A	9,92	8,12	17,09
U3-B	8,88	9,86	14,91

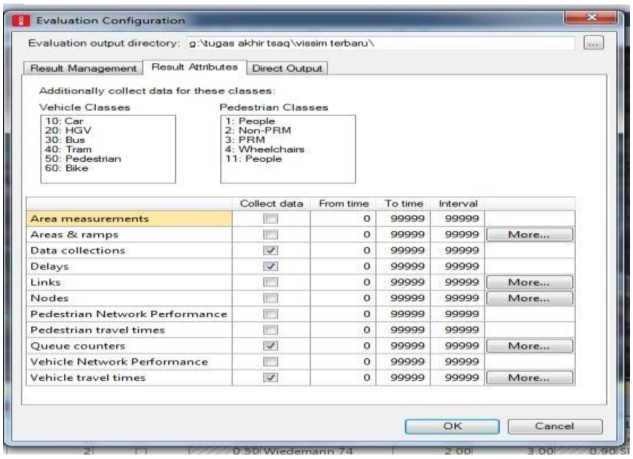

Figure 19 Evaluation settings

Based on Table 8, all deviations were below 15%, so it was concluded that VISSIM modeling can represent conditions in the field and be used in the analysis.

H. EVALUATION RESULT USING SOFTWARE VISSIM

The results were queue length and delay time that can be seen in Table 9. The running evaluation was running for 3600 seconds and used 5 times random seed.

I. COMPARISON OF U-TURN ANALYSIS BETWEEN SURVEY DATA, 06 / BM / 2005 REVERSE PLANNING METHOD (U-TURN), AND SOFTWARE VISSIM

The comparative variables were the queue length and the delay which can be seen in Table 10 as follows. Table 10 shows the length of the queue between the three data had a significant difference. The result of the length of the queue with the Reversal Planning Method 06 / BM / 2005 was smaller than the VISSIM output result. It was because the reverse cycle planning method 06 / BM / 2005 calculated the length of the queue based on the row with one row, while the VISSIM simulation calculated the length of the queue based on the queue of two lanes in the same path.

Between the two results of the queue, the VISSIM output results were closer to the results of the field study (primary data). Based on Table 11 shows that the delay varies between the two methods. The result of the delay of method 06 / BM / 2005 was obtained by interpolation of delay data, while the delay of the VISSIM method was the average delay of the queue of vehicles to perform a reversal.

J. PERFORMANCE ANALYSIS OF THE STREET OF EXISTING CONDITION

The speed used was the average vehicle speed. The speed of the vehicle was also calculated based on the direction of travel of the

Table 13 Comparison of queue length between existing condition, alternative I, II and III

Location	Existing condition VISSIM (m)	Alternative Solutions (VISSIM)					
		Alternative I		Alternative II		Alternative III	
		Result (m)	Decrease (%)	Result (m)	Decrease (%)	Result (m)	Decrease (%)
U1-A Same Lane	28,79	20,58	28,52	19,90	30,88	18,32	36,37
U1-A Opponent Lane	17,49	16,77	4,12	16,84	3,72	13,82	20,98
U2-A Same Lane	27,44	17,43	36,48	13,88	49,42	15,11	44,93
U2-A Opponent Lane	14,70	12,12	17,53	14,18	3,54	14,00	4,76
U2-B Same Lane	15,99	16,21	-1,38	14,66	8,32	13,79	13,76
U2-B Opponent Lane	18,20	17,83	2,03	15,39	15,44	14,74	19,01
U3-A Same Lane	27,25	21,11	22,53	16,99	37,65	12,62	53,69
U3-A Opponent Lane	19,30	18,73	2,95	18,63	3,45	18,32	5,08
U3-B Same Lane	27,70	19,58	29,31	15,12	45,42	12,22	55,88
U3-B Opponent Lane	25,45	26,11	-2,62	20,59	19,09	19,35	23,94
Average	22,23	18,65	13,95	16,62	21,69	15,23	27,84

Table information:

Decrease : Percentage decrease of queue length of alternative solution due to the existing state of VISSIM

- : There was an increase in the length of the queue (meters) of the solution alternative results of the existing state of VISSIM

Table 14 Comparison of delay between existing condition, alternative I, II and III

Location	Existing condition VISSIM (m)	Alternative Solutions (VISSIM)					
		Alternative I		Alternative II		Alternative III	
		Result (s)	Decrease (%)	Result (s)	Decrease (%)	Result (s)	Decrease (%)
U1-A Same Lane	10,94	7,69	29,75	7,78	28,95	7,59	30,60
U1-A Opponent Lane	14,67	10,36	29,38	13,95	4,88	12,47	15,00
U2-A Same Lane	17,73	7,98	54,99	5,25	70,37	5,18	70,81
U2-A Opponent Lane	12,30	10,51	14,59	10,92	11,25	11,20	8,92
U2-B Same Lane	11,15	10,23	8,29	10,38	6,90	10,23	8,30
U2-B Opponent Lane	9,25	7,56	18,24	5,07	45,22	5,05	45,41
U3-A Same Lane	17,09	16,81	1,64	4,96	70,95	4,65	72,78
U3-A Opponent Lane	11,53	10,89	5,55	4,26	63,05	3,93	65,92
U3-B Same Lane	14,91	14,12	5,33	4,45	70,15	4,10	72,50
U3-B Opponent Lane	17,05	15,25	10,56	4,48	73,70	4,25	75,07
Average	13,66	11,14	17,83	7,15	44,54	6,86	46,53

Table information:

Decrease : Percentage decrease of queue length of alternative solution due to the existing state of VISSIM

Table 15 Comparison of vehicle speed between existing condition, alternative I, II and III

Traffic Direction	Vehicle Speed							
	Survey Data (km/h)	Existing VISSIM (km/h)	Alternative I		Alternative II		Alternative III	
			Result (km/h)	Decrease (%)	Result (km/h)	Decrease (%)	Result (km/h)	Decrease (%)
North to South	29,53	29,26	42,46	31,09	47,51	38,25	47,61	38,54
South to North	35,36	41,43	51,22	19,11	51,44	19,45	51,92	20,20

Table information:

Decrease : Percentage decrease of queue length of alternative solution due to the existing state of VISSIM

vehicle. Speed value VISSIM obtained from the result of the data collection on each installation of the data collection point. The output results of the speed of the existing state in VISSIM can be seen in Table 12.

Table 12 Performance of Affandi St in existing condition

Traffic Direction	Survey Data (km/h)	Level of Service	Output VISSIM (km/h)	Level of Service
North to South	29,53	E	29,26	E
South to North	35,36	E	41,43	E

K. ALTERNATIVE SOLUTIONS

Three alternative solutions were used to improve road performance and reduce the length of the queue and delay.

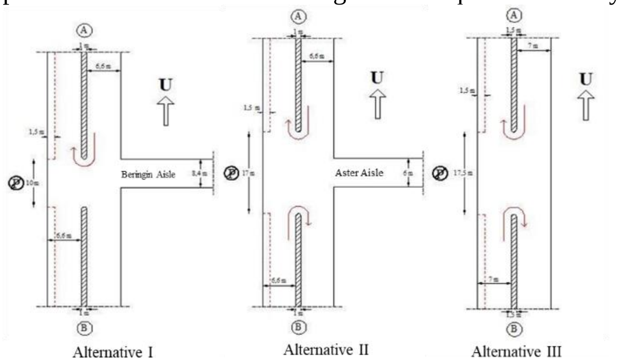

Figure 20 Alternative I, II, and III

Alternative I was to prohibit on-street parking at a median opening along the width of the median opening itself. Alternative II was to prohibit on-street parking at 5 meters before opening the median to 5 meters after opening the median and Alternative III was to prohibit on-street parking at 10 meters before opening the median to 10 meters after the median opening. The comparison of the existing condition and the alternative solutions can be seen in Table 13 for the parameter of queue length, Table 14 for the parameter of delay, and Table 15 for the parameter of vehicle speed. The figure of each alternative can be seen in Figure 20.

Alternative solutions succeeded in reducing the queue length of the existing condition with the largest average percentage of decline found in alternative III was 27,84%.

Alternative solutions succeeded in reducing the value of delay from the existing condition with the largest average percentage of decline found in alternative III was 46,53%.

The result of alternative analysis succeeded in increasing the speed value of the existing condition of VISSIM with the highest percentage increase in alternative III was 38,54% for the North to the South direction with the existing condition of 29,26 km/h increased to 47,61 km/h and level of service E. For the South to the North direction, the percentage increase in alternative III was 20,20% with the existing condition of 41,43 km/h increased to 51,92 km/h and level of service D.

Based on Table 13, Table 14, and Table 15, the result of the three alternative solutions showed similar results which were reducing the length of the queue, the delay, and the average speed. As a road performance parameter, it indicated an increase in speed. The increase of parking ban showed a good result in increasing the road performance. The recommendation is to use alternative III, because it showed the largest decrease in queue length and delay, and showed the greatest speed increase.

CONCLUSIONS

The performance of the Affandi St segment based on the speed parameter for the existing situation was lower than the specification of the Regulation of the Minister of Transportation Number 96 of 2015, which was obtained the level of service of C. The analyzed result using VISSIM software showed that the average vehicle speed of the existing situation was 29,26. km/h for the North to the South with the level of service E and 41,43 km/h for South to North with the level of service E.

The alternative solutions to increase road performance were devised with VISSIM Software. The obtained solutions were three alternatives that prohibiting parking in the street body in the U-turn area. Alternative I along the width of the median opening itself, alternating II over the width of the median opening plus 5 meters per side and the alternative III over the width of the median opening plus 10 meters per side. The best alternative from the three solutions was alternative III with the average decrease rate of the existing condition of VISSIM equal to 27,84% for queue length and 46,53% for delay value while vehicle speed increases. The existing state of VISSIM with a percentage increase rate of 38,54% for the North to South with the level of service E and 20,20% for the South to the North with the level of service D. It can be concluded that the parking ban on the road body can improve the performance of the road.

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