

Evaluation of Performance Non-signal Intersection on Telekomunikasi Road Intersection - Terusan Buah Batu Road, Bandung - West Java

Asep Setiawan

Department of Civil Engineering, Faculty of Engineering, Widyatama University, Bandung, East Java, Indonesia

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Abstract Evaluation of performance non-signal intersection on Telekomunikasi Road Intersection – Terusan Buah Batu Road is carried out by considering the geometric conditions of the road, traffic volume, side barriers, and environmental conditions around the intersection. Primary data and secondary data were analyzed by referring to the Indonesian Road Capacity Manual Method (MKJI 1997). From the results of the study, it was found that on Wednesday at 15:20 – 16:20, the maximum capacity value of 9,326/hours exceeded the base capacity of type 324 crossing ($C_0 = 3,200$ pcu / hour). The highest degree of saturation (DS) occurs on Monday at 6:20 - 7:20, which is 0.86. This means that the service level value is in class E (0.85 - 1.00). Namely, unstable traffic flow, solid vehicles, stagnant traffic and intersection volume higher are than its capacity, so that crossing conditions require handling. From the data above, it is known that the Telekomunikasi Road intersection - Terusan Buah Batu Road is not feasible to accommodate traffic flows and it needs to be handled by making stop lines, road signs as vehicle lane separators and warning signs, danger signs or by installing traffic signal lights.

Keywords Non-signalized Intersection, Capacity, Degree of Saturation, Delay

1. Introduction

The Telekomunikasi Road Intersection - Buah Batu Road is a type of non-signalized intersection. The pattern of regulating traffic at this intersection is not optimal; this can be seen from the quite heavy traffic flow and congestion, especially during rush hour in the morning, afternoon, and in the afternoon.

By taking into account the geometric conditions of the road, the volume of traffic flow, side barriers and intersection environment, which is a commercial area, and

then try to evaluate the performance of the three-arm unsignalized intersection of Telekomunikasi Road - Buah Batu Road, Bandung Regency.

The purpose of this study was to determine the traffic behavior at an unsignalized intersection on Telekomunikasi Road - Terusan Buah Batu Road using the Indonesian Road Capacity Manual (MKJI) 1997. The results of this study are expected to be a reference and input for related agencies that are directly or indirectly related directly in traffic to make new planning and steps in accordance with community needs, so that it can be applied in reducing congestion on existing road capacity.

2. Literature Review

2.1. Non-signal Intersection

Non-signalized intersections with road rights arrangements (priority from the left) are generally used in urban settlements and inland areas for intersections between local roads and low traffic flows. For intersections with different classes and/ or functions of roads, traffic on minor roads must be set with a "yield" or "stop" sign.

The 1997 Indonesian Road Capacity Manual (MKJI) distinguishes intersections from signalized intersections (traffic signals) and non-signal intersections (non-traffic signals). Non-signalized intersections are controlled by the basic rules of Indonesian traffic that give way to vehicles from the left, while the signal intersections are controlled by traffic light.

2.2. Intersection Type

The intersection/ Intersection Type (IT) type is determined by the number of intersection arms and the number of lanes on the major and minor roads in the intersection with a three-digit code as shown in table 1.

Table 1. Code Intersection Type (IT)

Code IT	Number of arms intersection	Number Of Minor Road Lanes	Number of Major Road Lines
322	3	2	2
324	3	2	4
342	3	4	2
422	4	2	2
424	4	2	4

Source: MKJI 1997

2.3. Non-signal Intersection Performance

Intersection performance is a condition at the intersection that must be sought to determine the level of achievement of the intersection. The parameter that must be sought to find out the intersection performance is the ratio between capacity (Capacity/ C) and existing traffic flow (Q). From the ratio of capacity, current will be obtained the number of degrees of saturation (Degree of saturation/ DS). With the value of degree of saturation (DS) and capacity value (C), the level of performance of each approach can be calculated as well as the overall level of intersection performance. The level of performance measured in the Indonesian Road Capacity Manual (MKJI 1997) is the delay (Delays/ D) and the chance of queuing.

2.3.1. Traffic Flow (Q)

The traffic flow used in the intersection capacity analysis is used the most congested traffic flow per hour from the overall movement of the vehicle. The total vehicle flow is the vehicle per hour for each movement calculated by% (prosent) conversion vehicles, namely passenger car ekivalents (pce).

$$Q_{PCU} = Q_{keng} \times K_{pcu}$$

Information:

Q_{PCU} = total current at the intersection (pcu / hour)

Q_{keng} = current there are each intersection (pcu / hour)

K_{PCU} = factor pcu

The passenger car unit (pcu) factor for various types of vehicles can be calculated using the formula

$$K_{smp} = (LV\% \times pce LV + HV\% \times pceHV \times MC\% \times pceMC) / 100$$

2.3.2. Non-signal Intersection Capacity

MKJI (1997) defines that capacity is the maximum maintained (fixed) traffic flow on a part of the road under certain conditions stated in vehicles/ hours or junior / hour.

The total capacity of an intersection can be expressed as a result of multiplication between basic capacity (C_0) and adjustment factors (F). The formulation of intersection capacity according to MKJI 1997 is written as follows:

$$C = C_0 \times F_W \times F_M \times F_{CS} \times F_{RSU} \times F_{LT} \times F_{RT} \times F_{MI}$$

Information:

C = Actual capacity

C_0 = basic capacity

F_W = Admission width factor

F_M = Median adjustment factor for the main road

F_{CS} = City size adjustment factor

F_{RSU} = Factor for adjusting the type of road environment, side obstacles and no vehicles motorized

F_{LT} = Ratio adjustment factor turn left

F_{RT} = Ratio adjustment factor turn right

F_{MI} = Minor road flow ratio adjustment factor

2.3.3. Degree of Saturation

Degree of saturation (DS) is the comparison between traffic volume and road capacity, used as the main factor in determining the level of performance of intersections and road segments. The DS value indicates whether the road segment has a capacity problem or not.

The basic equation to determine the value of the degree of saturation as follows:

$$DS = Q_{PCU} / C$$

Information:

DS = Degree of saturation

C = Capacity (pcu / hour)

2.3.4. Delay (D)

Cross traffic delay is the total time the average obstacle experienced by a vehicle when passing a side.

1. Average traffic delay for all intersections (DT_i)

For DS ≤ 0.6 :

$$DT_i = 2 + (8,2078 \times DS) - [(1 - DS) \times 2]$$

For DS > 0.6

$$DT_i = ((1.0504 / [0.2742 - (0.2042 \times DS)]) - [(1-DS) \times 1,8])$$

2. Average traffic delay for major roads (DT_{MA})

For DS ≤ 0.6 :

$$DT_{MA} = 1.8 + (5,8234 \times DS) - [(1 - DS) \times 1,8]$$

For DS > 0.6

$$DT_{MA} = ((1.0504 / [0.346 - (0.246 \times DS)]) - [(1-DS) \times 1,8])$$

3. Minor road average traffic delay (DT_{MI})

$$DT_{MI} = [(Q_{SMP} \times DT_i) - (Q_{MA} \times DT_{MA})] / Q_{MI}$$

Information:

Q_{PCU} = Actual total flow (pcu / hour)

Q_{MA} = Number of vehicles entering at the intersection major road (pcu / hour)

Q_{MI} = Number of vehicles entering at the intersection minor road (junior / hour)

4. Geometric delay intersection (DG)

DG is calculated using the equation:

For DS < 1.0 :

$$DG = (1 - DS) \times (Pr \times 6 + (1 - Pr) \times 3) + DS \times 4$$

For DS > 1.0

$$DG = 4 \text{ sec/pcu}$$

2.3.5. Queue Opportunities (QP%)

The limit of the QP% queue probability value is determined by the empirical relationship between the probability of QP queue% and the degree of saturation of the DS. Opportunities for queuing with upper and lower limits can be obtained using the following formula below

Upper limit :

$$QP_a = (47.71 \times DS) - (24.68 \times DS^2) + (56.47 \times DS^2)$$

Lower limit :

$$QP_b = (9.02 \times DS) + (20.66 \times DS^2) + (10.49 + DS^2)$$

2.4. Level of Road Services

MKJI 1997 explains that the level of road service can be calculated based on the scope of the Q / C road section, as shown in Table 2.

Table 2. Relationship capacity with level

Service Level	Q/C	Characteristics
A	0,00 – 0,19	Free flow, low volume and high speed, the driver can choose the path he wants
B	0,20 - 0,44	The current is stable, the speed is slightly limited by traffic, the volume of service used to design lines outside the city
C	0,45 – 0,74	Stable current, speed controlled by traffic, volume of service used for urban roads
D	0,75 – 0,84	Approaching an unstable, low speed current
E	0,85 – 1,00	Unstable current, easy speed and different volume capacity
F	>1,00	Obstructed currents, low speed volumes above capacity and many stops

Source: Warpani Swardjoko, Rekayasa Lalu Lintas, Brata Karya Aksara, Jakarta 1985

3. Research Methodology

The flow of thought in the research methodology can be described as in Figure 1:

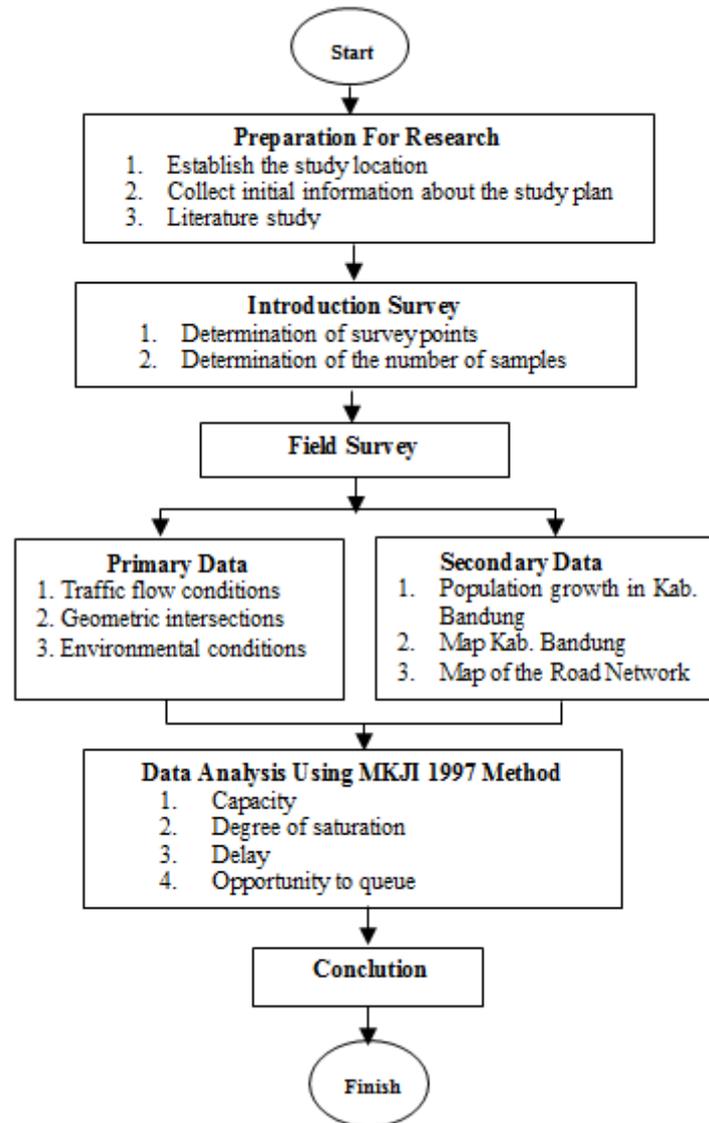


Figure 1. Research Flow Chart

3.1. Research Sites

This research was carried out at the Telecommunication Street unsignalized intersection - on Jalan Terusan Buah Batu, Bandung Regency, West Java Province - Indonesia.

06.20 - 07.20 WIB, noon 11:50 - 12:50 WIB, afternoon at 15:20 - 16 20 WIB; Wednesday 16th January 2019 morning period 06:20 - 07.20 WIB, noon 11:50 - 12:50 WIB, afternoon at 15:20 - 16 20 WIB; and Saturday 19th January 2019 morning period 06:20 - 07.20 WIB, noon 11:50 - 12, 50 WIB, afternoon at 15:20 - 16 20 WIB.

4. Data Processing and Analysis

4.1. Data Collection

Data collection at the intersection that will be analyzed is carried out for 3 days with a one-hour time period in the morning, noon and afternoon. Data retrieval was carried out directly in the field on each intersection arm. From each arm observed all data for morning, noon and afternoon were taken for one hour. Data collection at the Telekomunikasi Road intersection - Terusan Buah Batu Road on Monday 14th January 2019 period morning at

4.2. Data Processing

4.2.1. Intersection Data

Telekomunikasi Road Intersection – Terusan Buah Batu Road is a non-signal three-arm intersection located on the crossing of the Terusan Buah Batu and serves as a major/major road at the intersection. The condition of each road section consists of two directions and two lanes without borders (median). On the main road and minor roads, there are sidewalks on both sides of the road.

Data on Telekomunikasi Road intersection – Terusan Buah Batu Road can be seen in Figure 2.

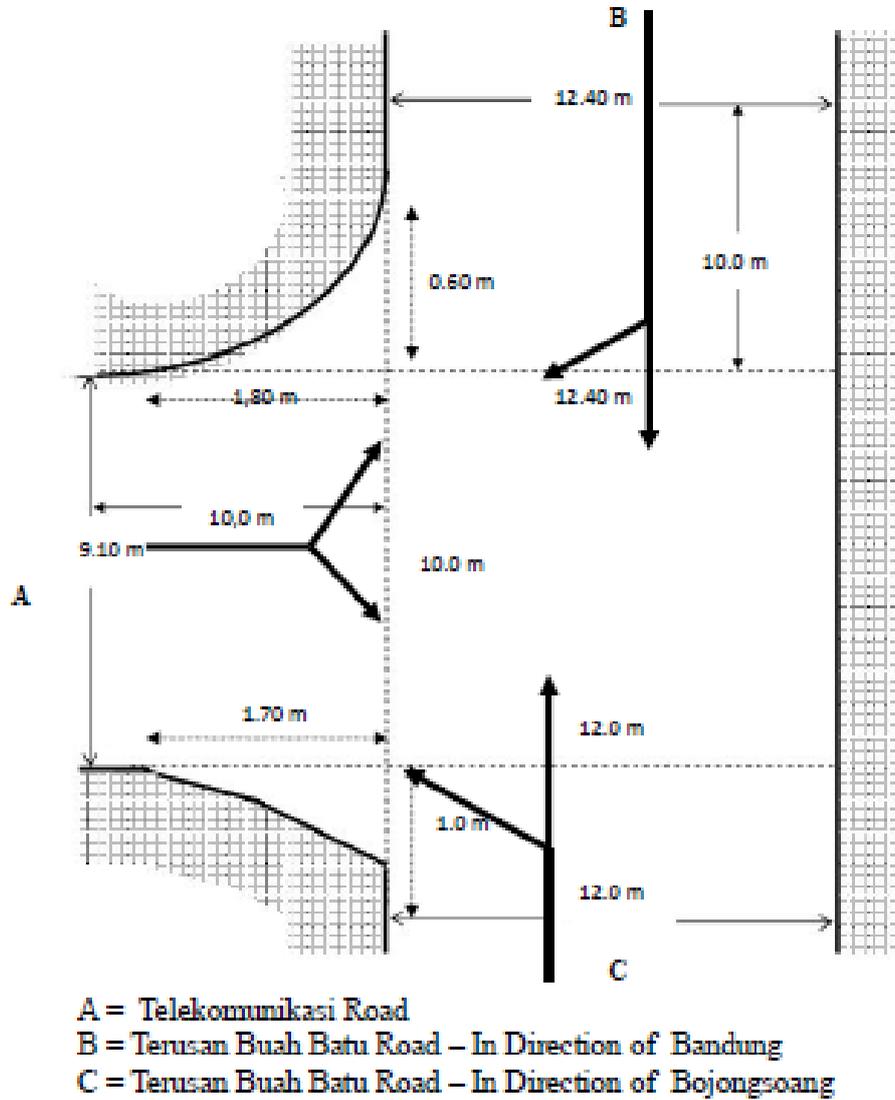


Figure 2. Telekomunikasi Road Intersection – Terusan Buah Batu Road

4.2.2. Traffic Volume

Vehicle volume observed can be seen in the table 3.

Table 3. Vehicle Volume Observation

Vehicle Flow Direction	Transportation type	Period	Day		
			Monday	Wednesday	Saturday
	MC	Morning	788	680	506
		Noon	703	631	495
		Afternoon	701	536	447
	LV	Morning	268	208	109
		Noon	148	136	101
		Afternoon	197	146	80
	HV	Morning	0	0	0
		Noon	1	3	3
		Afternoon	1	0	1
	Σ			2807	2340
Number of Vehicles/Hour			936	780	581
	MC	Morning	1452	1262	1481
		Noon	1625	1327	1441
		Afternoon	2430	2035	2516
	LV	Morning	268	353	469
		Noon	530	521	464
		Afternoon	608	487	743
	HV	Morning	76	68	86
		Noon	170	171	123
		Afternoon	154	113	124
	Σ			7313	6337
Number of Vehicles/Hour			2438	2112	2482
	MC	Morning	2073	1690	1076
		Noon	419	441	347
		Afternoon	452	552	363
	LV	Morning	58	46	27
		Noon	46	50	38
		Afternoon	41	56	20
	HV	Morning	0	1	0
		Noon	1	0	0
		Afternoon	0	0	0
	Σ			3090	2836
Number of Vehicles/Hour			1030	945	624
	MC	Morning	4476	1800	4678
		Noon	1458	1286	1489
		Afternoon	1935	1138	1428
	LV	Morning	649	896	578
		Noon	579	536	360
		Afternoon	720	623	379
	HV	Morning	80	119	69
		Noon	190	210	112
		Afternoon	160	180	56
	Σ			10247	6788
Number of Vehicles/Hour			3416	2263	3050
	MC	Morning	446	441	338
		Noon	728	773	799
		Afternoon	1045	1022	843
	LV	Morning	55	60	39
		Noon	182	175	152
		Afternoon	267	242	149
	HV	Morning	2	1	3
		Noon	2	0	11
		Afternoon	6	1	2
	Σ			2733	2715
Number of Vehicles/Hour			911	905	779
	MC	Morning	424	341	237
		Noon	467	246	242
		Afternoon	684	1254	494
	LV	Morning	14	16	11
		Noon	46	58	57
		Afternoon	51	76	41
	HV	Morning	0	0	0
		Noon	2	0	0
		Afternoon	0	0	0
	Σ			1688	1991
Number of Vehicles/Hour			563	664	361

5. Analysis and Discussion

5.1. Performance of Non-signal Intersection Analysis

Non-signalized intersection performance analysis is done by computerization, where the intersection performance analyzed includes capacity (C), degree of saturation (DS), delay (D) and queuing opportunity (DS) based on the Indonesian Road Capacity Manual (MKJI) 1997.

The flow chart (Flow chart) which will be a reference procedure for calculating and analyzing the data as follows:

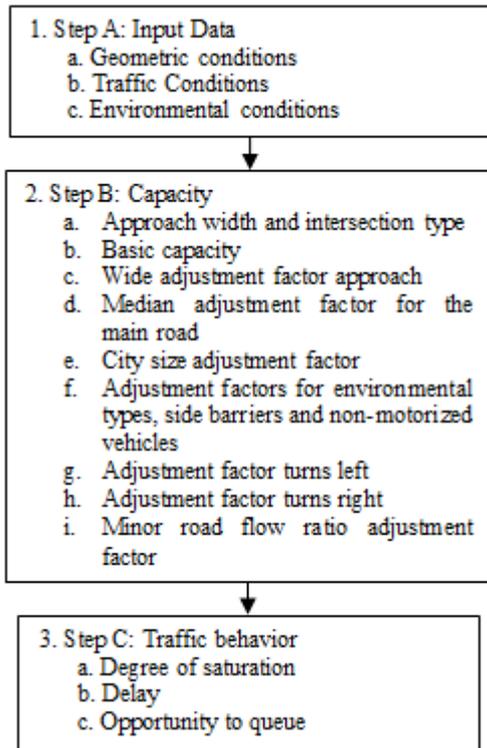


Figure 3. Flow Chart of Operational Analysis Procedures

5.2. Calculation of Survey Data

a. Intersection Capacity C

- 1) The average width of the intersection approach

$$W_{AC} = (W_A + W_C) / 2 = (9.1 + 0) / 2 = 4.55 \text{ m}$$

$$W_{BD} = (W_B + W_D) / 2 = (12.40 + 12.0) / 2 = 12.20 \text{ m}$$

$$W = (W_A + W_B + W_C + W_D) / \text{Number of intersection arms} = (9.1 + 12.40 + 12.0) / 3 = 11.20 \text{ m}$$

2) Intersection type

Code Type Intersection and figure 2 Geometric Plan of Non-Signal Intersection Three Arms of Telekomunikasi Road –Terusan Buah Batu Road then this intersection

includes type 324

3) Basic capacity

The basic capacity is adjusted to the three arm intersection type (code 324), the basic value of $C_0 = 3200$

4) Approach width adjustment factor (F_W)

The F_W value is obtained from the ratio of the average approach width to the intersection type 324 then:

$$F_W = 0.62 + 0.0646 \times W_I = 1.343$$

5) The median adjustment factor for the F_M main road

Median narrow road (<3m). then the F_M value = 1.05.

6) Factors adjusting the size of the city of F_{CS}

The size of Bandung Regency with a population of 3,534,114 inhabitants (data from the Central Bureau of Statistics of Bandung Regency in 2018), so that it belongs to a large category, then the F_{CS} value = 1.00

7) Factors adjusting the type of road environment, side barriers and F_{RSU} non-motorized vehicles

Factors adjusting the type of road environment, side barriers and non-motorized vehicles assuming this intersection is a commercial environmental type (RE) with low side resistance (SF), and the ratio of non-motorized vehicles (p_{UM}) is 0.00, $F_{RSU} =$ taken 0.95

8) Adjustment factor for turning left F_{LT}

$$P_{LT} = (Q_{LT} / Q_{TOT})$$

Q_{LT} value = vehicle volume turn left from the main road and minor road

Q_{TOT} value = overall vehicle volume from the main road and minor road

$$P_{LT} = (1385,3/6356.9) = 0,21789$$

$$F_{LT} = 0,84 + 1,61 \times P_{LT} = 1,191$$

9) Adjustment factor turns right F_{RT}

$$P_{RT} = (Q_{RT} / Q_{TOT})$$

$$P_{RT} = (888 / 6356.9) = 0.13969$$

$$F_{RT} = 1.09 - 0.922 \times P_{RT} = 0.961$$

10) F_{MI} minor road flow ratio adjustment factor

$$P_{MI} = (516,6 / 6356.9) = 0.08127$$

$$F_{RT} = 16.6 \times P_{MI2} - 33.3 \times P_{MI3} + 25.3 \times P_{MI2} - 8.6 \times P_{MI} + 1.95 = 1,510$$

11) Capacity value

$$C = C_0 \times F_W \times F_M \times F_{CS} \times F_{RSU} \times F_{LT} \times F_{RT} \times F_{MI}$$

$$C = 3200 \times 1,343 \times 1.05 \times 1.0 \times 0.95 \times 1,191 \times 0.961 \times 1,510 = 7400 \text{ pcu / hour}$$

b. Work Level

1) Degree of Saturation of DS

$$DS = Q_{TOT}/C$$

$$DS = 6356,9/7400 = 0,859$$

Table 4. Results of Capacity Recapitulation and Intersection Performance Levels

Day	Time Interval	C (pcu/ hour)	DS	DT _I	DT _{MA}	DT _{MI}	DG (sec/ cu)	D (sec/ pcu)	QP%
Monday	06..20-7.20	7400	0,86	10,38	7,55	42,42	4,016	14,39	34,22% - 64,44%
	11.50-12.50	6953	0,68	7,14	5,27	15,88	4,042	11,19	26,52% - 46,87%
	15.20-16.20	7496	0,79	8,93	6,55	18,41	4,020	12,95	31,15% - 57,57%
Wednesday	06..20-7.20	7398	0,67	7,01	5,17	24,51	4,103	11,11	26,12% - 45,93%
	11.50-12.50	7324	0,60	6,24	4,60	13,29	4,079	10,32	23,80% - 40,34%
	15.20-16.20	9326	0,56	5,75	4,30	9,55	4,166	9,92	22,45% - 36,98%
Saturday	06..20-7.20	7204	0,78	8,75	6,42	42,12	3,942	12,69	30,72% - 56,59%
	11.50-12.50	7869	0,51	5,19	3,88	10,11	4,068	9,26	20,68% - 32,50%
	15.20-16.20	7266	0,65	6,75	4,97	14,62	3,983	10,73	25,36% - 44,10%

2) Delays

- a) Total delay (D_{TOT}), which is the average traffic delay for all motorized vehicles entering the intersection

For $DS > 0,6$

$$DT_i = ((1,0504/[0,2742-(0,2042 \times DS)])) - [(1-DS) \times 1,8]$$

$$DT_i = ((1,0504/[0,2742-(0,2042 \times 0,859)])) - [(1-0,859) \times 1,8] = 10,380 \text{ sec/hour}$$

- b) Average traffic delay for the main road (D_{TMA})

For $DS > 0,6$

$$DT_{MA} = ((1,0504/[0,346-(0,246 \times DS)])) - [(1-DS) \times 1,8]$$

$$DT_{MA} = ((1,0504/[0,346-(0,246 \times 0,859)])) - [(1-0,859) \times 1,8] = 7,55 \text{ sec/hour}$$

- c) Minor road / intersection (DT_{MI}) average traffic delay

$$DT_{MI} = [(Q_{TOT} \times DT_i) - (Q_{MA} \times D_{TMA})] / Q_{MI}$$

$$DT_{MI} = [(6356,9 \times 10,380) - (5,840,3 \times 7,546)] / 516,6 = 42,42 \text{ sec/ hour}$$

- d) Geometric delay intersection (DG)

DG is calculated using the equation:

For $DS < 1,0$:

$$DG = (1 - DS) \times (Pr \times 6 + (1 - Pr) \times 3) + DS \times 4$$

$$DG = (1 - 0,859) \times (0,37205 \times 6 + (1 - 0,37205) \times 3) + 0,859 \times 4 = 4,02 \text{ sec/ hour}$$

3) QP% Queue Opportunity

- a) Opportunity to queue I (Bottom)

$$QP_b = (9,02 \times DS) + (20,66 \times DS^2) + (10,49 + DS^2)$$

$$QP_b = (9,02 \times 0,859) + (20,66 \times 0,859^2) + (10,49 + 0,859^2) = 34,22\%$$

- b) Opportunity to queue II (Top)

$$QP_a = (47,71 \times DS) - (24,68 \times DS^2) + (56,47 \times DS^2)$$

$$QP_a = (47,71 \times 0,86) - (24,68 \times 0,86^2) + (56,47 \times 0,86^2) = 64,44\%$$

By using the same method, the recapitulation and deviation performance levels are obtained as shown in table 4.

5.3. Discussion

The results of the calculation can be seen that at the intersection of Telekomunikasi Road - Terusan Buah Batu Road, it is not feasible to accommodate traffic flow as a consideration in controlling and managing future traffic. The maximum value of the maximum capacity at the intersection is 9326 pcu/ hour, occurring on Wednesday 16th January 2019 at 15.20-16.20, already exceeding the basic capacity ($C_0 = 3200$ pcu/ hour). This will continue to increase in line with population growth with the increasing number of vehicles

While based on the calculation of degree of saturation (DS) obtained value of 0.859 occurred on Monday 14th January 2019 at 06.20-207.20, which states that for the service level is in class E (0.85 - 1.00), i.e. the traffic flow is unstable; the vehicle is solid; the traffic is stagnant and the intersection volume is higher than its capacity. This situation results in losses that must be borne by the driver, including increased operational costs, delayed travel time and also impact on comfort,

6. Conclusions

Based on the formulation of the problem and the results of the calculation of non-signal intersections on Telekomunikasi Road - Terusan Buah Batu Road in Bandung Regency by using the 1997 Indonesian Road Capacity Manual (MKJI) Guidelines, the following conclusions can be obtained:

1. Based on the results of the analysis of the level of intersection performance obtained as follows:
 - a. On Monday which shows the highest DS value (Degree of saturation) is at 06.20 - 7.20, which is equal to 0.86, and the value for the service level is in class E (0.85 - 1.00), namely the flow of traffic unstable, solid vehicles, stagnant traffic and intersection volume higher than capacity.
 - b. On Wednesday which shows the highest DS value (degree of saturation) is at 06.20 - 7.20, which is equal to 0.67, and the value for the service level is

- in class C (0.45 - 0.74), namely traffic flow stable, speed is controlled by traffic.
- c. On Saturday which shows the highest DS value (degree of saturation) is at 06.20 - 7.20, which is equal to 0.78, and the value for the service level is in class D (0.75 - 0.84), namely traffic flow unstable, low speed.
 - d. On Wednesday at 15:20 - 16:20, the maximum capacity value of 9326 pcu/ hour exceeded the basic 324 junction capacity ($C_0 = 3200$ pcu / hour).
2. From the above data volume results in a decrease in the level of intersection performance due to the delay experienced by each vehicle and the Telekomunikasi Road intersection – Terusan Buah Batu Road is not feasible to accommodate traffic flows.

The results of this study are suggested as follows:

1. A better traffic control system is needed at intersections, such as making stop lines, road markers as vehicle lane separators and warning signs, danger signs or by installing traffic signal lights. This is deemed necessary to be carried out immediately by the parties concerned in order to improve service and anticipate congestion at the intersection
2. It is necessary to review the geometric compatibility of intersections based on current traffic conditions and predictions for the coming year
3. The government is expected to pay more attention to unsignalized intersections that have been troubled by deploying officers related to traffic control, namely traffic police so that during rush hour the traffic flow remains smooth

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