Performance Analysis of Three-Armed Intersection Capacity on Jalan Raya Sukabumi-Cisaat and Jalan Cibaraja

1st* Lulu Ayu Indriani
Department of Civil Engineering
Faculty of Engineering and Design,
Nusa Putra University
Sukabumi, Indonesia
lulu.ayu_ts20@nusaputra.ac.id

2nd Silvia Rahayu Gunawan
Department of Civil Engineering
Faculty of Engineering and Design,
Nusa Putra University
Sukabumi, Indonesia
silvia.rahayu_ts20@nusaputra.ac.id

3rd Rendi
Department of Civil Engineering
Faculty of Engineering and Design,
Nusa Putra University
Sukabumi, Indonesia
rendi_ts20@nusaputra.ac.id

4th Dio Damas Permadi
Department of Civil Engineering,
Faculty of Engineering and Design,
Nusa Putra University
Sukabumi, Indonesia
dio.permadi@nusaputra.ac.id

5th Utamy Sukmayu Saputri
Department of Civil Engineering,
Faculty of Engineering and Design,
Nusa Putra University
Sukabumi, Indonesia
utamy.sukmayu@nusaputra.ac.id

***Abstract*— Intersections are very important road infrastructure because traffic problems such as delays, traffic accidents and congestion usually occur at segments and intersections. This is because the intersection is a node point where several road sections meet and a conflict point for different road users. One of the points where traffic conflicts often occur is the intersection of Jl Raya Sukabumi-Cisaat and Jl Cibaraja. Traffic conditions on Jl. Raya Sukabumi-Cisaat and Jl Cibaraja have high density, especially at intersections, resulting in congestion on the main roads. The method used in this research is a direct survey method to the field. This method is obtained to obtain primary data. In this survey method, researchers use manual techniques to make observations and collect data in the field, by recording the number of vehicles and types of vehicles used and measuring road geometric conditions. For data analysis, this research uses the Indonesian Road Capacity Guidelines (PKJI) 2023 method regarding Intersection Capacity. The results of the intersection analysis obtained the highest traffic volume occurred on Saturday, August 29, 2023 at 16.00-17.00 WIB with a total traffic flow volume (Qtot) = 2108 smp / hour, with a capacity value (C) = 2286.469 smp / hour, degree of saturation (DJ) = 0.922, delay (T) = 16.25 sec / smp, and queuing opportunities (PA) upper limit = 67% and lower limit = 34%. The level of service of the intersection is included in level of service E.**

Keywords*— *Intersection, Capacity, Degree of Saturation, Queue Length, PKJI 2023

I. INTRODUCTION

The intersection is a very important road infrastructure because traffic problems such as delays, traffic accidents and congestion usually occur on roads and intersections[1]. This is because intersections are nodes where several road sections meet and conflict points for different road users. The increasing number of vehicles with uneven road capacity is one of the causes of traffic conflicts[2][3]. Intersections are divided into two types of intersections to control traffic drivers, namely signaled intersections and unsignaled intersections. An unsignaled intersection is an intersection that does not have a traffic light[4].

The performance of an intersection is a major factor in determining the appropriate handling to optimize the function of the intersection[5]. In contrast to signalized intersections, drivers at unsignalized intersections often take less cautious actions such as tending to precede each other due to the lack of traffic instructions and the absence of traffic lights so these conditions can cause conflicts at the intersection[6]. Traffic conditions on Jl Raya Sukabumi-Cisaat and Jl Cibaraja have high density, especially at intersections, in other words, the existing intersection capacity is not proportional to the large volume of vehicles, resulting in congestion on the main roads.

The unsignalized intersection at Jl.Raya Sukabumi-Cisaat and Jl.Cibaraja is a type 322 intersection consisting of 3 intersection arms, 2 minor road lanes and 2 major road lanes. At the intersection of Jl Raya Sukabumi - Cisaat and Jl Cibaraja, there is frequent congestion caused by side obstacles as well as a high vehicle population that is not matched by the availability of adequate road infrastructure. Because Jl. Raya Sukabumi-Cisaat and Jl. Cibaraja are located in business areas (hospitals, shops, trade) so activities beside the road such as transportation of goods, irregular crossing of people. In addition, the road area does not have a road body and sidewalks so the road and road area directly adjacent to buildings such as hospitals and shops are often used as parking lots, then there are up and down activities of passengers from public transportation, vehicles that stop as well as pedestrians who often walk on the road to cause congestion. The congestion that occurs indicates that the performance of road sections and intersections needs to be re-analyzed.

Based on the description of the problem above, it is the background for researchers to conduct research at the intersection, namely by analyzing the performance of the unsignalized intersection capacity using the Indonesian Road Capacity Guidelines (PKJI 2023) method and as an effort to improve performance at the intersection of Jl Raya Sukabumi-Cisaat and Jl Cibaraja.

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II. Literature Review

A. Road Section

Based on UU RI No. 22 of 2009 concerning Traffic and Road Transportation, the definition of Road is all parts of the Road, including complementary buildings and equipment intended for public traffic, which are on the ground surface, above the ground surface, below the ground surface and / or water, and above the water surface, except rail roads and cable roads[7].

B. Intersection

An intersection is the minimum meeting point of two or more road segments and is an integral part of the road network which is a point of conflict such as queues, accidents traffic delays, all of which will cause traffic congestion at the intersection[6][8].

C. Vehicle Classification

Tabel[9].

TABLE I. PKJI VEHICLE CLASSIFICATIONS AND TYPE

No	Code	Vehicle Type	Typical
1	SM	Motorized vehicles with 2 (two) and 3 (three) wheels with length < 2.5 m	Sepeda motor, kendaraan bermotor roda 3 (tiga)
2	MP	4 (four) seater passenger car, 7 (seven) seater passenger car, small freight cars, medium freight cars medium freight cars with length ≤5.5 m	Sedan, jeep, minibus, microbus, pickup, small truck
3	KS	Medium buses and freight cars 2 (two) axes with length ≤9.0 m	Liability bus, bus metromini, medium truck
4	BB	Large buses of 2 (two) and 3 (three) axles with length ≤12.0 m	Inter-city bus, double decker bus decker city tour bus
5	TB	3 (three) axis freight cars, trucks trucks, and outboard trucks (semitrailer) with length >12.0 m	Tronton truck, semi-trailer truck trailers, articulated trucks
	KTB		Bicycles, tricycles, animal drawn vehicles

D. Level of Service

Level of service is generally used as a measure of the limiting effects of increased traffic volumes[10].

TABLE II. LEVEL OF SERVICE SECTION BASED ON DEGREE SATURATION VALUE

Level of Service	Degree of Saturation	General Description
A	< 0,60	Smooth flow, low volume, high speed
B	0,60-0,70	Steady flow, limited speed, volume suitable for outer city roads
C	0,70-0,80	Stable flow, speed influenced by traffic, volume suitable for urban roads
D	0,80-0,90	Approaching unstable flow, low speed
E	0,90-1,00	Unstable flow, low speed, heavy volume or close to capacity
F	>1,00	Obstructed flow, low speed, volume above capacity, many stops

E. Intersection Capacity

Capacity is the maximum traffic volume that can be sustained along a given road segment or intersection for 1 (one) hour under specified conditions[9].

Intersection capacity can be calculated using the formula :

$$C = C_0 \times F_{LP} \times F_{M} \times F_{UK} \times F_{HS} \times F_{BKi} \times F_{BKa} \times F_{Rmi}$$

Description :

C : the Intersection capacity, in SMP/hour.

C0 : the basic capacity of the Intersection, in SMP/h.

FLP : the approach average width correction factor.

FM : the median type correction factor.

FUK : the city size correction factor.

FHS : the side obstacle correction factor.

FBKi : the left-turn flow ratio correction factor.

FBKa : the right-turn flow ratio correction factor.

FRmi : the correction factor for the flow ratio of the minor road.

F. Intersection Performance

Intersection performance is a condition at an intersection that must be sought to determine the level of achievement of the intersection. Measures of intersection performance can be determined based on the length of queue length, number of stopped vehicles and delay. [11][12].

G. Degree of Saturation

The degree of saturation (Dj) is the ratio of traffic flow (skr/hr) to capacity (skr/hr). The degree of saturation can be written with the equation as follows :

$$D_J = \frac{q}{c}$$

H. Delay on Intersection (T)

Delay on intersection is the average timewaiting time for each vehicle entering the intersection. Delay (T) occurs due to 2 things, namely traffic delay (TLL) and geometry delay (TG)[13][9].

Delay (T) is calculated using the following equation :

$$T = T_{LL} + T_G$$

Traffic delay consists of :

1) AverageTtraffic Delay (T_{LL})

For $D_J \leq 0{,}60$: $T_{LL} = 2 + 8{,}2078\ D_J - (1 - DJ)^2$

For $D_J > 0{,}60$: $T_{LL} = \frac{1{,}0504}{(0{,}2742 - 0{,}2042\ DJ)} - (1 - D_J)$

2) Traffic delay for major roads (T_{LLma})

For $D_J \leq 0{,}60$: $T_{LLma} = 1{,}8000 + 5{,}8234\ DJ - (1 - DJ)^{1{,}8}$

For $D_J > 0{,}60$: $T_{LLma} = 1{,}0503\ (0{,}3460 - 0{,}2460\ D_J) - (1 - D_J)^{1{,}8}$

3) Traffic Delay for Minor Roads (T_{LLmi})

$$T_{LLmi} = \frac{qKB \times TLL - qma \times TLLma}{qmi}$$

4) Geometric Delay (T_G) :

For $D_J < 1$: $T_G(1 - D_J) \times \{6R_B + 3 (1-R_B)\} + 4D_J$ (sec/SMP)
For $D_J \geq 1$: $T_G = 4$ sec/SMP

I. Queuing Opportunity (PA %)

Queuing Opportunit is a chance of queuing vehicles along the approach[9].
Upper limit of opportunity : $Pa = 47{,}71\ D_j - 24{,}68\ D_J^2 + 56{,}47\ D_I^3$

Lower bound of opportunity : $Pa = 9{,}02\ D_J + 20{,}66\ D_J^2 + 10{,}49\ D_J^3$

III. METHODOLOGY

A. Research Location

In this study, the location selection was at a non-signalized triple intersection with vehicles entering and exiting each arm. The intersection taken as a research site is the intersection of Jl Raya Cisaat-Sukabumi and Jl Cibaraja, Sukabumi Regency. The following research location is shown in Figure 1 below.

Figure 1. Research Location

B. Data Collection Methods

The methods used in this research are:

1) Primary Data : Primary data is data obtained directly at the time of research location.

a) Survei Method : The method used in this research is to use the survey method directly to the field or data analysis. In the survey method, researchers used manual techniques to make observations and collect data in the field, by recording the number of vehicles and types of vehicles used and measuring road geometric conditions. Data collection is carried out based on a 15-minute time interval so that data on the number of vehicles passing through is recorded every 15 minutes.

Data generated from the field, consisting of :

- Road geometric conditions in the form of road width and number of lanes only because, at the research location there are no road medians and sidewalks.
- Intersection traffic volume in the form of the number of vehicles moving through the intersection with each direction of movement on each arm and based on the classification of vehicle types.
- Environmental conditions of the intersection in the form of observations around the intersection regarding parked vehicles, pedestrian activities and vehicles entering and exiting the intersection.

2) Secondary Data : Secondary data is additional data obtained from other sources, namely:

a) Map of the research location : Obtained using the google maps application.

*b) Literature study : f*rom PKJI 2023 documents, theses, proceedings and previous research journals.

c) Population data : from each sub-district, namely Cisaat District, Cicantayan District, Caringin District, Kadudampit District and Gunung Guruh District.

C. Data Analysis Method

1) Indonesian Road Capacity Guidelines (PKJI 2023) on Intersection Capacity

This Intersection capacity guideline is included in the Indonesian Road Capacity Guidelines (PKJI 2023), as an update of the Indonesian Road Capacity Manual (MKJI 1997). The Indonesian Road Capacity Guidelines (PKJI 2023) are expected to be a benchmark in the technical implementation of traffic, road organizers, teachers and several related parties at the central level and also at the regional level in preparing and evaluating capacity. The Indonesian Road Capacity Manual (PKJI 2023) focuses on the values of basic capacity (C0), Passenger Car Equivalency (EMP) and other parameters used in MKJI 1997, adopted in PKJI 2023.

In this research, PKJI 2023 is one of the methods used in research for the data analysis stage. The results of data collection obtained during observation and data collection in the field will be analyzed or calculated based on the Indonesian Road Capacity Guidelines (PKJI 2023) ...

IV. RESULT AND DISCUSSION

A. Input Data

1) Geometry Condition

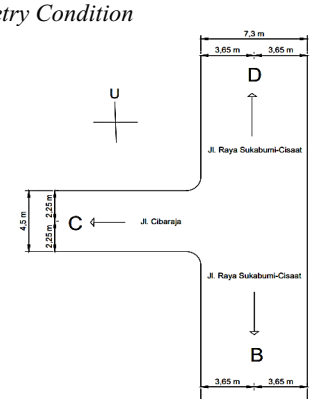

Figure 2. Intersection of Jl Raya Sukabumi-Cisaat and Jl. Cibaraja

From the observations and measurements at the research location, the intersection of Jl Raya Sukabumi-Cisaat and Jl Cibaraja was obtained:

- Westbound lane width of Jalan Cibaraja (minor road) = 4.5 m,
- lane width of Jalan Raya Sukabumi-Cisaat northbound (major road) = 7.3 m.
- Southbound Jalan Sukabumi-Cisaat (major road) = 7.3 m.
- There are no medians and shoulders,
- There are no traffic signs, stop signs and traffic lights.

2) Environmental Conditions

a) City Size Class

Based on data from the Sukabumi District Civil Registration Office (Disdukcapil), the total population of the congestion in the scope of the research location consisting of Cisaat Subdistrict, Kadudampit Subdistrict, Cicantaian

Subdistrict, Gunung Guruh Subdistrict and Caringin Subdistrict amounted to 357,518 people or 0.357 million people. The population data is used to determine the size of the city in accordance with PKJI 2023, thus Jl. Raya Sukabumi-Cisaat and Jl Cibaraja are categorized as small cities.

b) Road Environment Type

After observations at the research site, it was concluded that Jl. Cisaat - Sukabumi and Jl. Cibaraja are included in the commercial road type because the land on the road is used for commercial purposes such as shops, hospitals, offices and used as a direct entrance for both foot and vehicle users.

c) Class of side obstacles

Side obstacles on Jl. Raya Sukabumi-Cisaat and Jl Cibaraja are classified as high because the flow into and out of the intersection is disrupted and reduced due to activities on the side of the road such as up and down activities from public transportation, pedestrians and street vendors along the road.

3) Traffic Volume Data

In taking traffic volume data, the survey was carried out for 3 three days, namely Monday July 24, 2023, Wednesday July 26, 2023 and Saturday July 29, 2023. This study took traffic flow data from three types of vehicles namely Medium Vehicles (KS), Passenger Cars (MP) and Motorcycles (SM). Traffic volumes were recorded per 15 minutes to obtain more accurate data, then processed into hourly traffic volumes. After obtaining traffic volume data for each hour (smp/h) from the observation period (morning 06.00 - 09.00, afternoon 11.00 - 14.00 and afternoon 16.00 - 19.00) respectively for Monday, Wednesday and Saturday, then the next step is to add up all traffic volume data from each movement on each arm of the intersection. From the results of the overall data, to determine the busy time, namely by selecting the highest traffic volume in each period (morning 06.00 - 09.00, afternoon 11.00 - 14.00 and afternoon 16.00 - 19.00). The following are the results of traffic volume at the highest peak hour on each day :

- Monday, July 24, 2023 the highest traffic volume at 16.00 - 17.00 with the number of vehicles amounting to 5080 smp / hour
- Wednesday, July 26, 2023 the highest traffic volume at 07:00 - 08:00 with the number of vehicles amounting to 5801 smp / hour.
- Saturday, July 29, 2023 the highest traffic volume at 16.00 - 17.00 with the number of vehicles amounting to 6485 smp / hour.

The overall traffic volume results are attached in the following table.

TABLE III. PEAK HOUR TRAFFIC FLOW

Period	Monday August 24, 2023	Wednesday, August 26, 2023	Saturday August 29, 2023
06.00 - 07.00	4357	4058	3234
07.00 - 08.00	4602	5801	4135
08.00 - 09.00	3242	3442	3491
11.00 - 12.00	2962	2595	5594
12.00 - 13.00	2890	2942	3903
13.00 - 14.00	3282	3548	4468
16.00 - 17.00	5080	4422	6485
17.00 - 18.00	3769	4942	4664
18.00 - 19.00	3162	3834	4103
calculation	33346	35584	40077

Based on the table above, the peak hour volume on Jl. Cisaat - Sukabumi and Jl. Cibaraja is taken the highest data on Saturday Agustus 29, 2023 at 16.00 - 17.00 WIB with the number of vehicles amounting to 6485 smp / hour.

B. Intersection Performance Analysis

For the calculation of intersection capacity performance, the data that has the highest traffic flow volume among the peak hour periods of the three days is used. Then the calculation of the intersection capacity performance is analyzed using the PKJI (Indonesian Road Capacity Guidelines) 2023 method. The following is an analysis of the intersection capacity at the highest peak hour (16.00 - 17.00 WIB), on Saturday, August 29, 2023.

1) Traffic Composition

Q_{SM} = 1111 smp/hour
Q_{MP} = 829 smp/hour
Q_{KS} = 167 smp/hour
Q_{TOT} = 2108 smp/hour
Q_{KTB} = 7 smp/hour
Q_{MA} = 718 smp/hour
Q_{MI} = 390 smp/hour

2) Left and Right Turn Ratio Analysis

$R_{BKa} = q_{BKa}/q_{KB}$
= 420/2108
= 0,199 smp/hour
$R_{BKi} = q_{BKi}/q_{KB}$
= 598/2108
= 0,284 smp/hour

3) Minor Road Ratio Analysis/ (Major Road + Minor Road) Total

Q_{MI} = 1390 smp/hour
Q_{TOT} = 2108 smp/hour
$R_{MI} = Q_{MI}/Q_{TOT}$
= 718/2108
= 0,341 smp/hour

4) Non-motorized Vehicle Ratio Analysis

Q_{TOT} = 2108 smp/hour
Q_{KTB} = 7 smp/hour
$R_{KTB} = Q_{KTB}/Q_{TOT}$
= 7/2108
= 0,003

C. Intersection Capacity Analysis

1) Determining Approach Width and Intersection

a) Minor Road Approach Width

L_C = C/2
= 4.5/2
= 2,25 m
L_{AC} = 2,25 m

b) Approach width of major Road

L_B = B/2
= 7,3 / 2
= 3,65 m

L_D = D/2
= 7,3/2
= 3,65 m

L_{BD} = (B/2 + D/2) / 2
= (7,3/2 + 7,3/2) / 2
= 3,65 m

c) Minor and Major Average Approach Widths

$L_{RP} = L_{AC} + L_{BD}$ /2
= 2,25 + 3,65 /2
= 2,95 m

d) Number of Lanes

The number of lanes for major roads is 2 lanes and the number of lanes for minor roads is 2 lanes.

e) Intersection Type

Based on the PKJI 2023, this intersection type is 322.

2) Base Capacity (Co)

Based on PKJI 2023, the intersection type is obtained 322, then the basic capacity is obtained 2700 smp / hour

3) Average Approach Width Correction Factor (F_{LP})

For intersection type 322, using the formula :

$F_{LP} = 0,73 + 0,0760 (L_{RP})$
= 0,73 + 0,0760 (2,95)
= 0,9542

4) Median Correction Factor on Major Roads (F_M)

TABLE IV. MEDIAN CORRECTION FACTOR ON MAJOR ROADS, F_M

Intersection Condition	Median Type	Correction Faktor, F_M
No median on major road	No Median	1,00

At the research location there is no median on either major or minor roads, then F_M = 1.00

5) City Size Correction Factor (F_{UK})

TABLE V. CITY SIZE CORRECTION FACTOR (F_{UK})

City Size	Population (in million)	Fuk
Small	0,1 - 0,5	0,88

Based on the population variable from 5 sub-districts, namely Cisaat, Cicantaian, Kadudampit, Gunung Guruh and Caringin, the total population amounted to 357,518 people or 0,357 million people. In PKJI 2023, the F_{UK} value = 0,88

6) Side Obstacle Correction Factor (F_{HS})

Based on PKJI 2023, environment type including Commercial, High side obstacles, R_{KTB} value 0,00, then obtained F_{HS} 0,93

7) Left Turn Correction Factor (F_{BKI})

F_{BKI} = 0,84 + 1,61 (R_{BKI})
= 0,84 + 1,61 (0,284)
= 1,297

8) Right Turn Correction Factor (F_{BKA})

F_{BKA} = 1,09 – 0,922 (R_{BKA})
= 1,09 – 0,922 (0.199)
= 0,906

9) Minor Road Flow Ratio Correction Factor (F_{MI})

F_{MI} = 1,19 x Rmi^2 – 1,19 x R_{mi} + 1,19
= 1,19 x $0,341^2$ – 1,19 x 0,341 + 1,19
= 0,923

10) Capacity

C = $C_0 \times F_{LP} \times F_M \times F_{UK} \times F_{HS} \times$ FBKI $\times F_{BKA} \times F_{RMI}$
= 2700×0,9542×1×0,88×0,93×1,297×0,906×0,923
= 2289,496 smp/hour

D. Intersection Performance

1) Traffic Flow (Q)

Traffic flow is obtained from the total number of all vehicles (Q_{TOT}) = 2108 smp/hour.

2) Degree of Saturation (DJ)

The degree of saturation is calculated using the formula :

D_J = Q/C
= 2108/2289,38
= 0,922

3) Tundaan (Delay)

a) AverageTtraffic Delay (T_{LL})

T_{LL} = 1,0504 (0,2742−0,2042 × D_J) − $(1 - D_J)^2$
= 1,0504 (0,2742 – 0,2042 × 0,922) – $(1 – 0,922)^2$
= 12,211

b) Traffic delay for major roads (T_{LLma})

Because Dj > 60, then :

T_{LLma} = 1,0503 / (0,3460 – 0,2460 x Dj) – $(1 – Dj)^{1,8}$
= 1,0503 / (0,3460 – 0,2460 x 0,922) – $(1- 0,922)^{1,8}$
= 8,798

c) Minor Road Traffic Delay (T_{LLmi})

T_{LLmi} = ($q_{KB} \times T_{LL}$ − qma × T_{LLma}) / q_{mi}
= (2108 × 12,211 – 1390 x 8,798) / 718
= 18,821

d) Intersection Geometric Delay (T_G)

For Dj<1 then :

T_G = (1 − DJ) × {6 R_B + 3 (1 − R_B)} + 4 D_J
= (1 – 0,922)×((6 x 0,48) + 3(1 – 0,48)) + 4×0,922
= 4,035 sec/smp

e) Intersection Delay (T)

$T = T_G + T_{LL}$
= 4,035 + 12,211
= 16,2465 sec/smp

4) Queuing Opportunity (P_a)

a) Lower Limit of Odds

Pa = 9,02 $DJ + 20,66 DJ^2 + 10,49 DJ^3$
= 9,02 x 0,922 + 20,66 $(0,922)^2$ + 10,49 $(0,922)^3$
= 34 %

b) Upper Limit of Odds

Pa = 47,71 DJ – 24,68 DJ^2 + 56,47 DJ^3
= 47,71 (0,922) – 24,68 $(0,922)^2$ + 56,47 $(0,922)^3$
= 67%

The results of the calculation using PKJI 2023 for the three unsignalized intersections Jl. Raya Sukabumi - Cisaat and Jl. Cibaraja, the following conclusions were obtained :

- The total traffic flow volume (q_{TOT}) of mayor and minor roads is 2108 smp/hr.
- The capacity value (C) of the intersection of Jl. Raya Sukabumi - Cisaat and Jl. Cibaraja is 2286,469 smp/hr.
- The degree of saturation (Dj) is 0,922
- Queuing opportunity of 34% - 67%
- Intersection delay (T) of 16,2465 sec /smp

- Level of service of the intersection is included in level of service E, namely with a delay (T) of 16,2465 sec /smp

V. Conclusion and Recommendations

A. Conclusion

- The intersection of Jl Raya Sukabumi - Cisaat and Jalan Cibaraja is currently a type 322 intersection and is an unsignalized intersection with no traffic control.
- The intersection of Jl Raya Sukabumi - Cisaat and Jalan Cibaraja experiences peak traffic flow on Saturday, August 29, 2023 at 16.00 - 17.00 WIB with a traffic flow volume of 2108 smp/hour.
- The performance of the three-arm intersection of Jl Raya Sukabumi - Cisaat and Jalan Cibaraja, based on PKJI 2023 for the intersection capacity value (C) is 2286.469 smp/hour and the degree of saturation (DJ) at the intersection is 0,922
- Based on the total traffic flow volume of 2108 smp/h and the value of the intersection capacity (C) of 2286,469 smp/h, the intersection capacity of Jl Raya Sukabumi - Cisaat and Jalan Cibaraja can still accommodate the large volume of flow at peak hours. However, the degree of saturation (Dj) value at this intersection is 0,922, based on the degree of saturation value, the level of service of the intersection falls into category E which means that the level of service at this intersection is not good, where the flow is unstable, the speed is low and the volume is dense or close to capacity.
- The time delay (T) at the intersection of Jl Raya Sukabumi - Cisaat and Jalan Cibaraja based on PKJI 2023 is 16,25 sec/smp.
- Queuing opportunities (Pa) at the intersections Jl. Raya Sukabumi - Cisaat and Jalan Cibaraja based on PKJI 2023 are 67% (upper limit) and 34% (lower limit).

B. Recommendations

- Due to the level of service at the intersection of Jl Raya Sukabumi - Cisaat and Jalan Cibaraja category E where the flow is unstable, low speed and dense volume or close to capacity, it is necessary to optimize in the form of widening traffic lanes, prohibiting roadside parkits and traffic management by adding traffic lights at the intersection.
- Further research is needed to analyze the use of traffic light at the intersection.

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