Performance of Road Sections on the Road by Adding Traffic Lanes by Utilizing Roadside Drainage

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A B S T R A C T

Along with the rapid development in the Jalan Benteng Pancasila area, Mojokerto City, it has resulted in the emergence of problems, namely the problem of traffic jams along the road. One of the factors that contribute to the problem of traffic jams that occur along Jalan Benteng Pancasila is the presence of side barriers. Studies on the performance of Jalan Benteng Pancasila are needed to find solutions to existing problems. In this study, what was carried out was to analyze the capacity and degree of saturation in the existing and planned conditions. The analysis process was carried out using the Indonesian Highway Capacity Guidelines (IHCG) method. Based on the results of the analysis, the average traffic volume value at peak hours was 1396.90 pcu/hour, while the side resistance class was Medium. The capacity value of the Benteng Pancasila road section is 2480.41 pcu/hour, the Degree of Saturation value is 0.56, and the travel speed value is 39.0 km/hour. Thus the Jalan Benteng Pancasila section of Mojokero City can be stated to be performing well with traffic flow in a stable condition.

1. Introduction

An increase in the volume of traffic flow will cause a change in traffic behavior on a road section, especially on urban roads. This increase was due to the increase in population and ownership of transportation facilities. So sufficient space is needed for traffic infrastructure such as road networks and parking lots [1][2][3].

The Jalan Benteng Pancasila area is an area that has experienced rapid development in Mojokerto City. The area of Jalan Benteng Pancasila at this time has established shopping centers both modern and traditional. In addition, in the area of Jalan Benteng Pancasila also stands hotels, offices, and other public facilities in the form of playgrounds. Along with the rapid development of the area, problems arise on urban roads as often occur in other cities in Indonesia. That is, the problem of traffic

congestion. The existence of transportation problems that occur along Jalan Benteng Pancasila certainly affects the current and future performance of the road.

A study of the performance of the Benteng Pancasila Road section is needed to determine the performance of the Benteng Pancasila Road section in existing conditions, an estimate in what year the performance of the Benteng Pancasila Road section is declared infeasible, and solutions to improve the performance of the Benteng Pancasila road section in the future.

2. Literature Review

A study with the title Capacity analysis of the Adityawarman road section with a road width change plan, with PKJI 2014 existing conditions with a 2/2 UD road type obtained a road capacity of 1433.5 pcu/hour, a saturation degree value of 0.49, and a travel speed of 30 km/hour. With the road widening plan, the road capacity becomes 2559.83 pcu/hour, the degree of saturation value is 0.36, and the travel speed is 34 km/hour. With the road widening, the performance of the Adityawarman road section is still feasible for the next 19 years [4]

Research with the title Analysis of side obstacles to the level of highway Service case study along 200 m on the Imam Bonjol road section of Metro Lampung City, analyzing changes in the perpetrators of activities, intensity, and quality of city activities that result in increased side obstacles on the road section to the level of service of Imam Bonjol road. This research refers to the 1997 Indonesian Road Capacity Manual, obtaining data on side obstacles on Imam Bonjol road in Metro City on Friday amounting to 1,243.2 events, road capacity of 1243.2 pcu/hour, so that the level of service of Imam Bonjol road in Merto City includes category F [5]

The research entitled The effect of the growth of commercial activities on the performance of the Kusuma Bangsa road section of Jombang Regency examines the impact it has on the level of road service. As a result of the emergence of street vendors along this road, the traffic rate has slowed down at certain hours. The results of the analysis with the PKJI 22014 method, the existing capacity of the Kusuma Bangsa road section is 2269.5 pcu/hour, the degree of saturation value is 0.32, and the travel speed is 32 km/hour [6]

Most of the studies above examined the performance of road sections under existing conditions. Along with the increasing growth of vehicles and urban areas, it is necessary to improve a road section, namely road widening. It becomes a problem when there is land acquisition for this purpose. An alternative solution is to utilize the existence of city drainage facilities that are often located beside the road, to improve the road section[7].

Performance Analysis of road sections using the Indonesian Highway Capacity Guidelines (IHCG), 2014 with variables in it including traffic volume, road capacity, free flow speed, and degree of saturation [8][9][10][11].

Traffic volume is the number of vehicles passing through an observation point in units of time (days, hours, minutes). Traffic volume units commonly used in connection with determining the number and width of lanes are average daily traffic, planning hour volume, and capacity[12][13][14]. The Indonesian Road Capacity Guidelines define a passenger car unit (pcu) as a traffic flow unit where the flow of various types of vehicles has been converted into light vehicles using passenger car equivalence (EPC)[15][16]. The equivalence value of light vehicles (er) for road sections can be seen in the following Table 1:

Table 1:   Light Vehicle Equivalence Values (EPC) for Divided and One-Way Roads

Road Type	Traffic Flow per Lane	(car/hour)	Nilai epc	
			HV	MC
2/1, dan 4/2 D	< 1050		1,3	0,40
	≥ 1050		1,2	0,25
3/1 dan 6/2 D	< 1100		1,3	0,40
	≥ 1100		1,2	0,25

Source: PKJI, 2014.

Capacity can be defined as the maximum current through a point on the road that can be maintained per unit hour under certain conditions[17][18]. The amount of urban road capacity is calculated by the following equation:

C = C0 x FCLJ x FCPA x FCHS x FCUK　　　　　　　　　　　　　　　　(1)

The basic road capacity and adjustment factors in the calculation of road capacity can be seen in the tables contained in the Indonesian Highway Capacity Guidelines (IHCG).[19][20]

Free-current speed is the speed at the zero current level, that is, the speed that the driver will choose if driving a motor vehicle without being affected by other motor vehicles on the road [4] [21][22]. The magnitude of the free current velocity is calculated using the following equation:

VB = (VBD + VBL) x FVBHS x FVBUK　　　　　　　　　　　　　　　　(2)

The amount of road base flow speed and adjustment factors can be in the tables contained in the Indonesian Highway Capacity Guidelines (IHCG).

The degree of saturation is the ratio of current to road capacity [4][23]. The magnitude action (DS) is calculated by the equation:

$$D_S = \frac{V}{C}$$　　　　　　　　　　　　　　　　　　　　　　　　　(3)

The Technical Requirement of Saturation Degree (DS) for arterial roads according to the Indonesian Highway Capacity Guidelines (IHCG) is ≤ 0,85 [4][24][25].

Side Frictions

Side frictions are the impact on traffic performance from side activities of road sections, such as pedestrians, public transport, or other vehicles that stop, vehicles entering and exiting the side of the road, and slow vehicles[26][27][28]. The weight value of the effect of side frictions on capacity according to the Indonesian Highway Capacity Guidelines can be seen in Table 2 below:

Table 2:　　　　Side friction weight

Event Type Side Frictions	Symbol	Weight
Pedestrians on the road and those crossing	PED	0,5
Public transportation and other stopped vehicles	PSV	1,0
Vehicles in/out of the side or side of the road	EEV	0,7
Slow vehicle flow (un-motorcycles)	SMC	0,4

Source: PKJI, 2014.

The side resistance criteria have been grouped into five classes very low (VL), low (L), medium (M), high (H), and very high (VH) conditions. This condition is a function of the frequency of occurrence of side frictions along the observed road section. The level of side friction can be seen in the table below:

Table 3.   Side Frictions Class Criteria

Side Frictions Class	Code	The value of the frequency of events (on both sides) multiplied by the weight	Special Features
Very Low	VL	< 100	Residential areas, neighborhood roads (frontage roads) are available
Low	L	100 - 299	In residential areas, there are several public transport
Medium	M	300 - 499	Industrial Area, there are several shops along the side of the road.
High	H	500 - 899	In commercial areas, there is high roadside activity
Very High	VH	> 900	Commercial areas have market activity beside the road

Source: PKJI, 2014

The side friction criterion is established from the total number of occurrence frequency values of each type of side friction taken into account, each of which has been multiplied by its weight. The frequency of side resistance events is calculated based on field observations for one hour along the observed segment.

A. *Analysis of the performance of the Benteng Pancasila road section in the coming year until it is declared unfit*

Analysis of future road performance is based on traffic volume growth figures. Traffic growth is the number of vehicles using the road from year to year which is influenced by regional development, increasing community welfare, and increasing the ability to buy vehicles[29][30]. Traffic growth is expressed in percent/year. The calculation of traffic volume in the coming year is based on traffic volume data in the current year, and variable factors of traffic growth figures as the following equation.[31]

$$Pn = P_0 (1 + i)^n \tag{4}$$

The variable traffic growth rate used in this analysis uses an approach from the data of the Gross Regional Domestic Growth (GRDP) of Mojokerto City. The approach with the GDP figure data of Mojokerto City is used because the GRDP data contains data on the economic growth of the community and it is assumed that along with the economic growth of the community, the number of trips will also increase along with the increase in activities carried out by the community to meet their economic needs.

The performance of the Benteng Pancasila road section in the future is based on the value of the Degree of Saturation (DS) that occurs on the road in the coming years. If the Saturation Degree (DS) value is above 0,85, then the performance of the Benteng Pancasila road is not feasible.

3. Research Method

The location of the study was conducted in Balongsari Village, Magersari District, Mojokerto City. In this study, the object of research is Benteng Pancasila Road, Mojokerto City. At this stage is the stage of data processing obtained both primary data and sounder data. The data obtained can then be determined variables - variables of road section performance and side obstacles. Furthermore, an analysis of the capacity and performance of road sections was carried out using the Indonesian Highway Capacity Guidelines / IHCG (PKJI) in 2014. So that it can be known the performance of existing condition road sections and for the planned time.

4. Results and Discussions

This section contains (concise form) data analysis and interpretation of results. Interpretation of results using theories from articles as used. The descriptions given include theoretical, implicative, managerial, or practical.

Mojokerto City is located in the middle of Mojokerto Regency, lying between 7º 27' 0,16" – 7º 29' 37,11" South Latitude and 112º 27' 24" East Longitude. In general, the area of Mojokerto City has an area of 20,21 km², which is divided into 3 districts, namely Magersari District (8,08 km²), Warrior Kulon District (7,41 km²), and Kranggan District (4,72 km²). Based on data from the Central Bureau of Statistics of Mojokerto City, the total population is 189,423 people, consisting of 69,109 males and 70,314 females. While the boundaries of Mojokerto City are:
- North: Brantas River
- East   : Puri District
- West: Sooko District
- South: Sooko District

A. *Performance Analysis of the Existing Road Section of Benteng Pancasila*

Benteng Pancasila Road in this study was divided into 2 segments. Segment 1 starts from STA 0 + 000 to STA 0 + 935 with West – East direction on line 1 and East–West direction on line 2, while segment 2 starts from STA 0 + 935 to STA 1 + 340 with a South–North direction on line 1 and North–South direction on line 2. Analysis of the performance of the Benteng Pancasila Road section in existing conditions is carried out in each direction for each segment.

The results of observation and data processing from the results of the traffic volume survey on the Benteng Pancasila Road on each segment in each direction can be illustrated in the graph below:
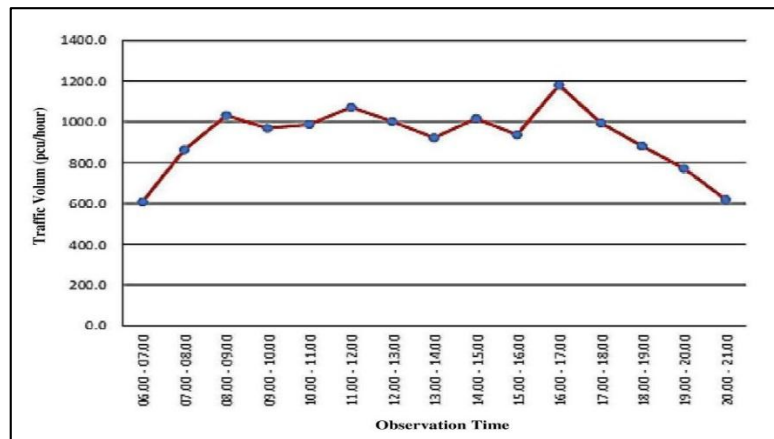

Figure 1. Vehicle flow graph in Segment 1 West to East direction in units of pcu/hour, on Jalan Benteng Pancasila, Mojokerto City.

From Figure 1, the maximum traffic volume of 1275.0 pcu/hr was obtained, which occurred from 04.00 p.m. – to 05.00 p.m.
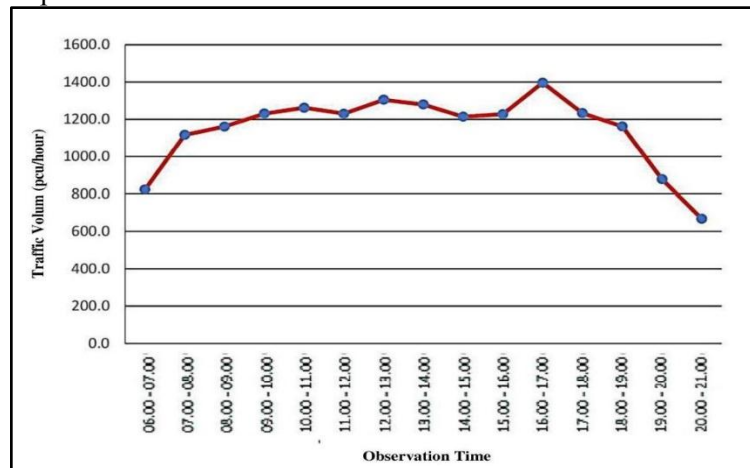
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Figure 2. Vehicle flow graph in Segment 1 East to West direction in units of pcu/hour, on Jalan Benteng Pancasila, Mojokerto City.

Based on Figure 2, the maximum traffic volume value of 1396.90 skr/hour was obtained, occurring at 04.00 pm – 05.00 pm.

In segment 2 south to north direction, with Figure 3, the maximum traffic volume value of 1180.90 pcu/hr was obtained, occurring at 04.00 pm - 05.00 pm.

Figure 3. Vehicle flow graph in Segment 2 south to north direction in units of pcu/hour, on Jalan Benteng Pancasila, Mojokerto City.

In Figure 4 below, the maximum traffic volume value of 1149.90 pcu/hour was obtained, occurring at 04.00 pm - 05.00 pm.

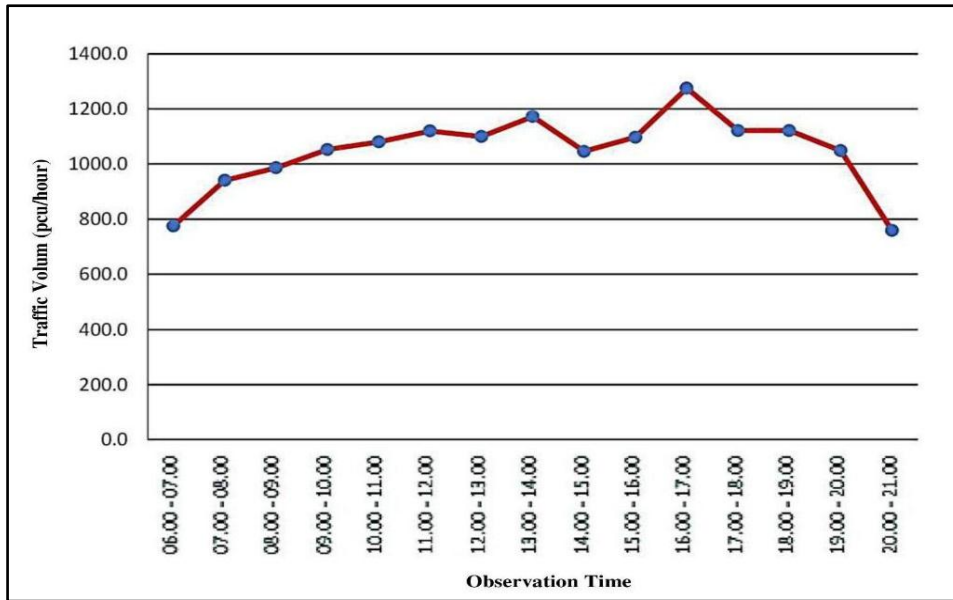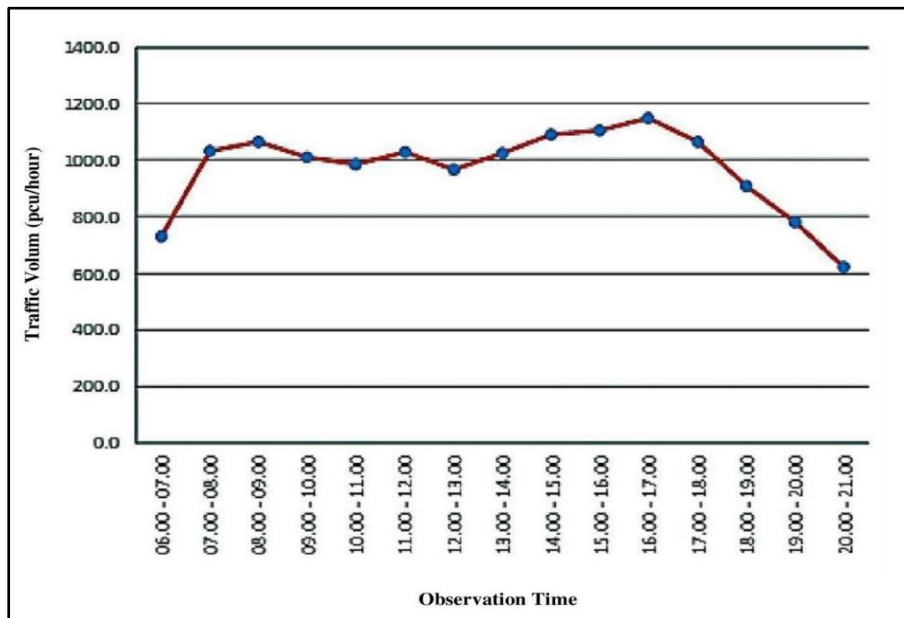**Figure 4.** Vehicle flow graph in Segment 2 North to South direction in units of pcu/hour, on Jalan Benteng Pancasila, Mojokerto City.

Side frictions per hour that occur in each segment based on the results of observations at the research location and data processing can be seen in the following Table 4:

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Table 4. Side Frictions and Weighting in Segment 1 of Benteng Pancasila Road, Mojokerto City

No	Direction	Side Frictions							Amount Σ
		Vehicles in and out		Vehicles Roadside Stop		Pedestrian		Slow Vehicles Flow/ Un Motorcycles	
	Weight	EEV	0,7	PDV	1	PED	0,5	SMV	0,4	
1	West - East	29,63		123,33		18,67		6,93		178,57
2	East - West	22,87		116,00		11,83		4,67		155,37
	2-way									333,94

Table 5. Side Frictions and Weighting in Segment 2 Of Benteng Pancasila Road, Mojokerto City

No	Direction	Side Frictions				Amount Σ
		Vehicles in and out	Vehicles Roadside Stop	Pedestrian	Slow Vehicles Flow/ Un Motorcycles	
	Weight	EEV (0,7)	PDV (1)	PED (0,5)	SMV (0,4)	
1	South - North	23,57	119,00	14,67	5,73	162,97
2	North - South	22,17	111,33	11,83	6,27	151,60
	2-way					314,57

Based on the analysis in Table 5 above, the side obstacles on the Benteng Pancasila Road section are included in the Side Frictions Class of the "Medium" category.

The results of the free flow speed analysis of Benteng Pancasila Road in the current (existing) conditions can be seen in Table 6 below:

Table 6. Free flow velocity existing conditions of benteng Pancasila road Mojokerto city

No	Parameters	Condition	Value
	$V_B = (V_{BD} + V_{BL})$ x FV_{BHS} x FV_{BUK}		
1	Basic Free Current Velocity, V_{BD}	4/2 D	55
2	Speed Adjustment Factor for Road width, V_{BL}	2,50 m	-4
3	Adjustment factors for side frictions (HS), FV_{BHS}	Medium, 1 m curb distance	0,95
4	Adjustment Factor City Size (UK), FV_{BUK}	< 1 million	0,95
	Free current Velocity (km/hour)		46,03

The calculation of the actual/existing capacity of Benteng Pancasila Road in existing conditions can be seen in the following Table 7:

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Table 7.   Capacity of Existing Condition of Benteng Pancasila Road

No	Parameters	Condition	Value
	$C = C_0 \times FC_{LJ} \times FC_{PA} \times FC_{HS} \times FC_{UK}$		
1	Base Capacity, C_0 (pcu/hour)	4/2 D	3300
2	Road Width Correction Factor, FC_{LJ}	2,50 m	0,92
3	Directional Split Factor, FC_{PA}	50 - 50	1
4	Side Frictions Factor, FC_{HS}	Medium, 1 m Curb Distance	0,95
5	Correction City Size Factors, FC_{UK}	< 1 million	0,86
	Actual Capacity, C (pcu/hour)		2480,41

The results of the analysis of the degree of saturation (DS) that occurs in the Jalan Benteng Pancasila existing conditions, in segment 1 west to east and east to west directions obtained DS values of 0.51 and 0.56. Similarly, the DS value in segment 2 for the south-to-north and north-to-south directions obtained DS values of 0.48 and 0.49. From these DS values, it states that the flow in both segments is still stable, considering the DS values <0.85. The results of the degree of saturation analysis can be seen in Tables 9 and 10 below:

Table 8.   Degree of saturation (DS) of existing conditions in segment 1 Benteng Pancasila Road Mojokerto city

No	Parameters	Value
	West - East Direction	
1	Traffic Volume, Q (pcur/hour)	1275,00
2	Actual Capacity, C (pcu/hour)	2480,41
	Saturation Degree, DS	0,51
	East – West Direction	
1	Traffic Volume, Q (pcu/hour)	1396,90
2	Actual Capacity, C (pcu/hour)	2480,41
	Saturation Degree, DS	0,56

Table 9.   Degree of saturation (DS) of existing conditions in segment 2 Benteng Pancasila Road Mojokerto city

No	Parameters	Value
	South - North Direction	
1	Traffic Volume, Q (pcu/hour)	1180,90
2	Actual Capacity, C (pcu/hour)	2480,41
	Saturation Degree, DS	0,48

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	North - South Direction	
1	Traffic Volume, Q (pcu/hour)	1149,90
2	Actual Capacity, C (pcu/hour)	2480,41
	Saturation Degree, DS	0,49

Travel Speed (VT) is the actual speed of the vehicle whose magnitude is determined based on a function of the degree of saturation (DS) and free flow speed (VB). The results of the analysis of existing travel speeds in segment 1 west to east and west to west directions obtained VT values of 41 km / h and 39 km / h. Whereas in segment 2 for the south-to-north direction and the north-to-south direction, the VT value is obtained. In segment 2 for the south-to-north and north-to-south directions, the VT values of 40.50 km/h and 40 km/h were obtained. The travel speed values meet the speed requirements in urban areas. The results of the travel speed analysis can be seen in Tables 10 and 11 below:

Table 10.   Existing Velocity Time in Segment 1 Benteng Pancasila Road Mojokerto City

No	Parameters	Value
	West - East Direction	
1	Saturation Degree, DS	0,51
2	Free Current Velocity, V_B (km/hour)	44,52
	Existing Velocity Time, V_T (km/hour)	41,00
	East – West Direction	
1	Saturation Degree, DS	0,56
2	Free Current Velocity, V_B (km/hour)	44,52
	Existing Velocity Time, VT (km/hour)	39,00

Table 11. Existing Velocity Time in Segment 2 Benteng Pancasila Road Mojokerto City

No	Parameters	Value
	South - North Direction	
1	Saturation Degree, DS	0,48
2	Free Current Velocity, V_B (km/hour)	44,52
	Existing Velocity Time, VT (km/hour)	40,50
	South - North Direction	
1	Saturation Degree, DS	0,49
2	Free Current Velocity, V_B (km/hour)	44,52
	Existing Velocity Time, VT (km/hour)	40,00

B.   Analysis of the performance of the Benteng Pancasila road section in the coming year.

Analysis of the performance of road sections in the future considers the growth of traffic volume and side friction classes. The traffic growth value used in this analysis is using an approach from Mojokerto City's Gross Regional Domestic Growth (GRDP) data. According to data from the Central Bureau of Statistics (BPS) Mojokerto City, the value of GDP is based on constant prices (adhk) In 2020, in the last 3 years (2016 to 2019) the average economic growth value of Mojokerto City was 5.86%, rounded up to 6.00%.

Analysis of the performance of the Benteng Pancasila road section in the next few years was carried out assuming that there is no road widening on the Benteng Pancasila road. By considering the

traffic growth factor (i) of the GDP value of Mojokerto City, it can be estimated the traffic volume in the future, and the performance of road sections in the future can be known.

The results of the analysis of traffic volume growth and performance of Benteng Pancasila Road Mojokerto City in the coming year can be seen in Table 13 below:

Table 12. Results of the Analysis of Traffic Volume Growth and Performance of Benteng Pancasila Road Section in the Next Year

Year of Plan (n)	Rate of Growth, i (%)	Weighted Number Side Frictions	Side Frictions Class	Traffic Volum, Q (pcu/hour)	Road Capacity, C (pcu/hour)	Degree of Saturation, DS
1	6,0	333,93	Medium	1396,87	2480,41	0,56
2	6,0	375,21	Medium	1596,5	2480,41	0,56
3	6,0	446,88	Medium	1869,32	2480,41	0,56
4	6,0	564,17	High	2359,98	2428,19	0,97

From the results of the analysis in the table above, in the 4th year (Year 2025) the performance of the Benteng Pancasila Road section of Mojokerto City does not meet the technical requirements of the road, a saturation degree (DS) value of 0.97 was obtained. So in 2025, the Pancasila Benteng road section needs to increase its capacity.

C. Solutions to Improve the Performance Level of Benteng Pancasila Road Section in the Future.
Based on the results of the analysis, it is known that the performance of the Benteng Pancasila Road Section at this time can be said to be still feasible with a Saturation Degree (DS) below 0.85. However, in the fourth year after this study, in 2025 the performance of the Benteng Pancasila Road Section is no longer feasible because the Saturation Degree (DS) value exceeds 0.85. To overcome these problems, the following alternative solutions can be used:

1. Control of Street Vendors beside the road to reduce vehicles stopping/parking on the side of the road, so that the Side Obstacle Class can be maintained in the medium class;
2. Deployment of officers to manage traffic mainly during peak hours to reduce the level of congestion that occurs;
3. Control and arrangement of motor vehicle parking to reduce side obstacles that occur;
4. Installation of traffic signs prohibited from parking or prohibited from stopping at certain points on the road of Pancasila Fort;
5. Increase road lanes to increase road capacity by utilizing drainage channels beside the Pancasila Fort road in Mojokerto City as road lanes.

5. Conclusion and Suggestion
5.1 Conclusion
Currently, the performance of the Benteng Pancasila Road section can be said to be still feasible with a maximum Saturation Degree (DS) value of 0.56. Meanwhile, in the fourth year or in 2025, the performance of the Benteng Pancasila Road Section in Mojokerto City does not meet the technical requirements of the road. Alternative solutions to increase the capacity of Benteng Pancasila Road Mojokerto in the coming year, are to regulate Street Vendors, traffic engineering management, and add traffic lanes by utilizing roadside drainage as traffic lanes.

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