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Effect of Median Application on Section Road Performance Based on Degree of Saturation and Speed at Road of Small Town in Lombok, Indonesia

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Abstract Road traffic safety is a global concern for people and governments. This is because unsafe roads are among the major causes of traffic accidents, which can result in severe injury and even death. One of the significant ways to minimize traffic movement problems, especially those related to road safety and comfort, is to build a median. Therefore, this research was carried out to determine the performance of roads with and without the median application using the TGH Ibrahim Kholidi road segment, West Lombok Regency, Indonesia. The road section is located in a small town with characteristics such as pedestrians, light and heavy vehicles, as well as traders who use the available inadequate parking spaces, thereby causing high side friction. A quantitative research with data collected by surveying the road section was subsequently employed to determine the traffic volume, speed, side friction, road geometric, and population from the 1997 Indonesian Road Capacity Manual (MKJI-1997) guidelines. The collected data were analyzed using the Separation Planning Procedure. The results showed that using the median increased performance by 45.7% compared to no median. This is in addition to a decrease in the Degree of saturation (DS) from 0.7 to 0.38 or from LOS C to B. Furthermore, the average speed increased from 32.4 km/h (without median) to 33.92 km/h (with median).

Keywords Road Performance, Median, Degree of Saturation, Speed

1. Introduction

Transportation of commodities and people is a fundamental concern of modern society. The urban transportation industry involves an effective system for road traffic management and infrastructure to compensate for user behavior [1][2]. Road traffic safety is increasingly becoming a serious social problem for people and governments globally. This is due to a large number of traffic incidents, especially those that result in the death or serious injury of participants. Therefore, to improve infrastructure, more emphasis should be placed [3] to minimize accidents at high-intensity locations [4]. One of the ways to minimize traffic movement problems by vehicle users, especially regarding road safety and comfort, is through the application of a median [5]. Besides providing safety, the median affects on-road performance, including its capacity. It is part of the road infrastructure installed in the middle of the road that physically separates traffic flows in opposite directions. When installed as a road divider, a median is needed to prevent head-on collisions and reduce driver stress. Furthermore, it contributes to the calculation of road capacity regardless of the difference in the type [6][7].

Every city must make plans to prevent the occurrence of traffic problems through the adequate assessment of

any larger investment plans that may impact traffic [8]. This means that the use of the road median on the highway is very influential on the smooth traffic flow and can reduce the number of accidents due to its ability to separate the flow on each lane. Therefore, applying the median on the section of the road can improve users' safety, smoothness, and comfort [3][7]. In this regard, this research aims to determine the effect of the median in improving road performance on the TGH Ibrahim Kholidi road segment, West Lombok Regency, Indonesia. The road section is located in a small town with characteristics of road users, such as pedestrians as well as light and heavy vehicles. The existence of street vendors who use roads and parking spaces comprising of high side friction results in a decrease in road capacity between 14.37% and 26.60% [9]. Furthermore, this research was carried out on a two-lane road without a median and not separated by two directions (Type 2/2 UD). Meanwhile, a road with a median has four separate lanes in two directions (type 4/2 D).

2. Research Method

2.1. Research Procedure

This is a quantitative research with data collected to determine the traffic volume, speed, side obstacles, and geometric road data through the survey method using the procedures in the MKJI-1997 guidelines [10]. Survey data was collected on the same road segment, before (October 9-11, 2021) and after (February 20-22, 2022) using the median. This is in addition to using secondary data, namely population [11]. From the analysis results, a discussion was carried out to determine how to compare road performance with and without the median. The collected data were analyzed using provisions and formulas to calculate the road performance parameters at MKJI 1997. The median research refers to the Separation Planning Procedure [12]. Furthermore, the effect of the median on performance was discussed by comparing the performance of the section road with and without the median.

2.2. Traffic Volume Analysis

Volume is the number of vehicles that pass an observation point during a certain period (unit of time). [5][13][14]. The volume of vehicles is calculated using equation 1.

$$Q = \frac{N}{\mathrm{T}} \quad (1)$$

With:

Q = volume of vehicles (vehicles/hour), N = number of vehicles (vehicles), T = observation time (hours)

2.3. Side Friction Analysis

The side friction factor is defined as any activity on the side and lane of the traffic lane capable of affecting its normal flow [15]. This factor is the impact on traffic performance from roadside activities such as parking, Parking, and Slow Vehicles (PSV), Exit and Entry of Vehicles (EEV), and Slow Moving of Vehicles (SMV).

2.4. Free Flow Speed Analysis

Traffic flow is the number of motorized vehicles that pass through the road and is measured in a specific time interval [5]. The free flow speed is the desired speed the driver can ride without being hindered or influenced by other users. However, it may be affected by other factors such as vehicle characteristics, drivers, road conditions, weather, and speed limits [10][16][14]. The free flow speed of light vehicles (FV) is defined as the speed at which the current level approaches zero. It is the speed at which the driver chooses to drive a motor vehicle without being influenced by other road users. The free current velocity can be calculated using equation 2.

$$FV = (FVo+FVw) \text{ X } FFV_{SF} \text{ X } FFV_{CS} \quad (2)$$

Where:

FVo denotes the Basic free flow speed of light vehicles (km/hour), FVw is the effective traffic lane width adjustment (km/hour), FFV_{SF} represents Side obstacle adjustment factor, and FFV_{CS} is the City size adjustment factor.

2.5. Capacity Analysis

Road segment capacity is the maximum stable traffic movement on a road cross-section under geometrics, direction separators, traffic composition, and environmental conditions [10][17].

$$C = Co \text{ x } FC_W \text{ x } FC_{SP} \text{ x } FC_{SF} \text{ x } FC_{CS} \quad (3)$$

Where:

C denotes Capacity (pcu/hour), Co represents Basic capacity (pcu/hour), FC_W is the Adjustment factor due to traffic lane width, FC_{SP} signifies Directional separation adjustment factor (only for undivided roads), FC_{SF} is the Adjustment factor due to side friction, and FC_{CS} represents City size adjustment factor

2.6. Degree of Saturation Analysis

The Degree of saturation (DS) is the ratio of the volume (flow value) of traffic to its capacity or the ratio of traffic volume Q (pcu/hour) to capacity C (pcu/hour). This is used to illustrate whether a road is problematic or not, and based on the assumption that when it gets closer to its capacity, it becomes the increasingly limited ease of movement [18][10].

$$DS = Q/C \quad (4)$$

2.7. Space Mean Speed Analysis

Space Mean Speed is the road speed based on the average time of all vehicles traveling a certain distance on the road [19][10].

$$Vs = \frac{nd}{\sum ti} \quad (5)$$

Where:

Vs, n, d, and ti denote Space Mean Speed (km/hour), number of data samples, Distance traveled (m or km), and Travel time of the i-th vehicle in seconds, minutes, or hours.

2.8. Level of Service Analysis

The level of service (LOS) is a qualitative measure used to relate geometric features and road segment's cross-sectional properties with the quality of traffic operating characteristics [10]. It comprises the LOS characterized by the operating conditions of vehicles on the road in terms of travel speed, time, freedom of maneuver, density, delay, disturbance, convenience, and passenger comfort. Service levels are grouped into five categories and marked with letters A to F. Where service level A is the facility with the least traffic jams, and F is the most congested facility. LOS is required when planning new construction, rehabilitating, and reconstructing existing road facilities [14][20]. Table 1 shows the road segment's limiting conditions for each level of service.

3. Results and Discussion

3.1. Data and Analysis of Data without Median (type 2/2 UD)

3.1.1. Road Geometric Data

Based on the direct measurement survey in the field, the geometric conditions of the research site were obtained with flat terrain and asphalt pavement. The width of the traffic lane in both directions =is 9.5 m, while the width of each shoulder on both sides is 2.0 m.

3.1.2. Traffic Flow Data

Traffic flow is used to determine the highest amount of traffic flow that passes through the reviewed road in the busiest period in accordance with the passenger cars unit (pcu) per hour, as shown in Table 2. Figure 1 shows the traffic conditions on the section road being reviewed.

Table 1. Level of services index and road conditions limits [14][20]

Level of Services	Q/C	Flow condition	Travel speed	Driving comfort
A	0,00 – 0,19	Smooth flow, low volume, high speed	Drivers decision	Very high physical and psychological
B	0,20 – 0,44	Stable flow, limited speed, service volume used for out-of-town roads	Slightly reduced due to limited freedom to maneuver	Relatively high
C	0,45 – 0,74	Stable flow, speed is affected by traffic, volume is suitable for city roads	Governed by the speed of other drivers and roadway characteristics	Decreased perceptibly
D	0,75 – 0,84	Approaching unstable current, low speed	Severe restrictions caused by frequent stops	Poor
E	0,85 – 1,00	Unstable current, low speed, dense volume, or near capacity	Low	Very poor
F	>1,00	Delayed flow, low speed, volume over density	Very low speed caused by stop and go	Extremely poor

Note: Q = traffic flow, C = capacity

Figure 1. Condition of section road without median type 2/2 UD

Table 2. Total traffic flow for section road condition type 2/2 UD at peak hours (pcu/hour)

Day/Date	Time	West-East (pcu/hour)			East-West (pcu/hour)			Total both directions (pcu/hour)			Total flow (pcu/hour)
		HV 1,2	LV 1,0	MC 0,25	HV 1,2	LV 1,0	MC 0,25	HV	LV	MC	
Saturday, October 9, 2021	07.00-08.00	55	219	597	37	173	712	92	392	1308	1793
	08.00-09.00	24	166	399	47	219	728	71	385	1127	1583
	12.00-13.00	7	341	494	31	245	469	38	586	963	1587
	13.00-14.00	4	393	530	46	298	473	49	691	1003	1743
	17.00-18.00	38	287	931	26	317	636	65	604	1567	2235
	18.00-19.00	24	267	764	14	277	524	38	544	1288	1871
Sunday, October 10, 2021	07.00-08.00	64	188	387	62	162	518	126	350	905	1381
	08.00-09.00	54	178	394	56	164	394	110	342	789	1241
	12.00-13.00	53	224	373	42	171	367	95	395	740	1230
	13.00-14.00	42	270	394	52	270	384	94	540	778	1412
	17.00-18.00	34	260	746	59	267	535	92	527	1281	1900
	18.00-19.00	25	261	588	22	248	461	47	509	1049	1604
Monday, October 11, 2021	07.00-08.00	23	181	522	20	148	614	43	329	1135	1507
	08.00-09.00	26	215	531	20	204	524	47	419	1055	1520
	12.00-13.00	53	315	373	20	250	399	73	565	772	1410
	13.00-14.00	22	303	470	17	291	464	38	594	934	1567
	17.00-18.00	16	279	746	26	282	823	42	561	1569	2172
	18.00-19.00	8	249	588	14	258	702	23	507	1290	1820

Table 3. Form UR-2 MKJI 1997 without median (2/2 UD)

Line	Vehicle type	Light vehicle		Heavy vehicle		Motorcycle		Total flow (Q)		
1,1	Pce direction 1	LV:	1,00	HV:	1,20	MC:	0,25			
1,2	Pce direction 2	LV:	1,00	HV:	1,20	MC:	0,25			
2	Direction	Vehicle/ hour	Vehicle/ hour	Vehicle/ hour	Vehicle/ hour	Vehicle/ hour	Vehicle/ hour	Direction %	Vehicle/ hour	pcu/ hour
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
3	E-W (1)	317	317	22	26	1816	636	40 %	2155	979
4	W-E (2)	287	287	32	38	2660	931	60%	2979	1256
5	(1)+(2)	604	604	54	64	4476	1567		5134	2235
6	Directional separator, SP = Q1/(Q1+Q2)								40 %	
7	Factor-pcu (Fpcu)									0,44

Note: HV= heavy vehicle; LV= light vehicle; MC= motorcycle; E= East; W= West; passenger car equivalent (Pce) ; passenger car unit (pcu)

Table 2 shows that the highest traffic flow value is obtained during rush hour, which can then be entered in Form UR-2 MKJI Urban Road 1997. Direction separation (SP) is determined from the comparison value between the total flow direction 1 (vehicles/hour) and the total flow direction 1 + direction 2 (vehicles/hour). The passenger car unit factor is obtained using equation 6.

$$\text{Fpcu} = \frac{Qsmp}{Qkend} \quad (6)$$

$$\text{Fpcu} = \frac{2235}{5134} = 0{,}44$$

Table 3 shows the total traffic flow obtained from the survey of the calculation of vehicles crossing the road at the research location with a peak hour period of 17.00 to 18.00. From the survey results, the number of vehicles that pass is 2155 vehicles/hour in direction 1 East-West and 2979 vehicles/hour in direction 2 West-East. The analysis results have a two-way total flow value of 5134 vehicles/hour, which is changed by passenger car units to 2235 pcu/hour.

3.1.3. Side Friction Class

The side obstacle class table on the UD type 2/2 road section at the current peak hour conditions was obtained on Saturday, October 9, 2021, from 17.00-19.00.

3.1.4. Moving Vehicles

Table 4 shows that the classification of side friction for road type 2/2 UD is moderate (M). The total weight of occurrence per 200 meters is at 300 to 499, such as industrial areas, and roadside shops, where in special conditions.

3.1.5. Vehicle Space Average Speed

Table 5 shows the data recapitulation of the survey results for measuring the average speed of the vehicle space. It consists of travel time and the number of vehicles from East (E) to West (W) and vice versa. The average vehicle speed (km/hour) was calculated using equation 5.

Table 4. Determination of the frequency of road events type 2/2 UD

Side friction type	Symbol	Influence factor	Frequency of occurrence/hour. 200m	Weighted frequency
Pedestrian	PED	0,5	102	51
Parking, vehicle stops	PSV	1,0	92	92
Vehicles in and out	EEV	0,7	217	152
Slow vehicle	SMV	0,4	17	7
		Total		302

Note : PED=Pedestrian

Table 5. Total travel time and number of vehicles and space average speed 2/2 UD from both directions

No	Type of road	Σ way E-W (seconds)			Σ way W-E (seconds)			Number of E-W vehicles (/hour)			Number of W-E vehicles (/hour)		
		MC	LV	HV	MC	LV	HV	MC	LV	HV	MC	LV	HV
1	2/2 UD Saturday 17.00-18.00	785.21	381.80	115.51	1016.12	645.87	84.37	154	68	20	206	106	14

No	Direction	Type of Road	Day/Hour	Vs (km/h)			Average vehicle speed (km/h)
				MC	LV	HV	
1	East West	2/2 UD	Saturday 17.00-18.00	35.30	32.06	31.17	32.84
2	West East	2/2 UD	Saturday 17.00-18.00	36.49	29.54	29.87	31.96

3.1.6. Free Flow Speed

The free flow speed is defined as the speed at the zero flow level. At condition 2/2 UD that is before the installation of the road median, analysis was carried out in both traffic directions. Calculations based on the provisions of the MKJI-1997 guidelines[10], obtained the basic free flow speed (FV_0) of 44 km/hour, with a lane width adjustment factor (FV_w) of 5 to obtain $FV_0 + FV_w$ values of 49 km/hour. FFV_{SF} side drag and FFV_{CS} city size adjustment factors are 0.99 and 0.95. Therefore, the free flow velocity (FV) of 49 x 0.99 x 0.95 equals 46.08 km/hour.

3.1.7. Road Segment Capacity

Based on the provisions of the MKJI-1997 guidelines [10], the Basic Capacity (C0), the Adjustment factor for lane width (FCw), Directional separator (FCSP), Side friction (FCSF), and City size (FCCS), are 2900 Smp/hour, 1.27, 0.94, 0.98, and 0.94. Therefore, using equation 3, the capacity is obtained by multiplying the values of these guidelines such as, 2900x1.27x0.94x0.98x0.94, to obtain 3189 pcu/hour.

3.1.8. Degree of Saturation

The Degree of Saturation (DS) is obtained from the comparison value between the total traffic flow and the capacity of the road segment. From the data analysis results, the value of the DS on the road conditions of the research location (type 2/2 UD) was 0.7. This value is close to the eligibility standard threshold.

3.2. Road Data and Analysis with Median (type 4/2 UD)

3.2.1. Road Geometric Data

Based on the direct measurement survey in the field, the geometric conditions of the research site roads were obtained. The road section under consideration has a flat terrain type with asphalt pavement. Traffic lane width per lane E-W and W-E is 3.25 and 3.25, respectively. The median width is 0.5 meters, with the road facility as a curb. The distance between the curb and the barrier for each side of the road is 1.0 meters.

Figure 2. Section road condition with median type 4/2 D

Table 6. Total traffic flow at peak hour type 4/2 D

Day/Date	Time	Per lane (W-E) (pcu/hour)			Per lane (E-W) (pcu/hour)			Total
		HV	LV	MC	HV	LV	MC	
Saturday, February 20, 2022	07.00 -08.00	13	209	437	13	155	746	1573
	08.00-09.00	35	265	429	34	197	546	1505
	12.00-13.00	48	377	399	44	280	325	1474
	13.00-14.00	23	236	331	24	204	327	1145
	17.00-18.00	24	320	726	48	305	415	1838
	18.00-19.00	24	259	538	17	291	366	1495
Sunday, February 21, 2022	07.00 -08.00	2	94	309	8	102	472	987
	08.00-09.00	40	144	392	32	127	406	1140
	12.00-13.00	29	328	370	22	265	357	1370
	13.00-14.00	23	300	329	14	290	338	1294
	17.00-18.00	16	312	628	19	348	615	1938
	18.00-19.00	8	262	503	2	292	592	1660
Monday, February 22, 2022	07.00 -08.00	12	234	419	14	405	739	1823
	08.00-09.00	38	252	442	20	313	589	1654
	12.00-13.00	17	200	403	14	278	369	1282
	13.00-14.00	26	283	379	22	304	416	1430
	17.00-18.00	37	326	810	42	371	462	2048
	18.00-19.00	25	303	671	18	276	488	1781

3.2.2 Traffic Flow Data

The highest amount of traffic flow that passes through the reviewed road segment in the busiest period was obtained on Monday, 11 October 2021, using passenger cars per hour, as shown in Table 6. Figure 2 shows the traffic conditions on the section of the road being reviewed.

Table 6 shows that the highest traffic flow values during peak hours can be entered in Form UR-2 Urban Roads Indonesian Road Capacity Manual (1997). Directional separation (SP) is obtained from the comparison value between the total current direction 1 (vehicle/hour) with the total current direction 1+direction 2 (vehicle/hour). The passenger car unit factor is calculated using equation 7.

$$\text{Fpcu E-W} = \frac{Qpcu}{Qvehicle} \quad (7)$$

$$\text{Fpcu E-W} = \frac{2048}{5849} = 0{,}35$$

Traffic flow per lane is obtained by surveying the calculation of vehicles crossing the road at the research location, where the peak hour period occurs on Monday from 17.00-18.00 (February 22, 2022). The survey results found that the number of vehicles passing by was 3,597 vehicles/hour in the West-East direction. Conversion into passenger car units is 1,173 pcu/hour, while for the East-West lane, the number of vehicles passing is 2,252 vehicles/hour, with passenger car units of 875 pcu/hour. Therefore, the total traffic value of the four-lane two-way road is 2,048 pcu/hour (see Table 7).

3.2.3. Side Friction Class

Side friction class on type 4/2 D roads at peak hour conditions, namely Monday, 22 February, 2022 at 17.00-18.00, is shown in Table 8. Therefore, it can be concluded that type 4/2 D is classified as moderate (M), with the number of incidents per 200 meters from 300 to 499 in special conditions, namely industrial areas and some roadside traders.

Table 7. Form UR-2 MKJI 1997 for roads with a median of 4/2 D

Line	Vehicle type	Light vehicle		Heavy vehicle		Motorcycle		Total flow (Q)		
1,1	Pce direction 1	LV :	1,00	HV:	1.20	MC:	0.25			
1.2	Pce direction 2	LV :	1.00	HV:	1.20	MC:	0.25			
2	Direction	Vehicle / hour	Vehicle / hour	Vehicle / hour	Vehicle / hour	Vehicle / hour	Vehicle / hour	Direction %	Vehicle / hour	pcu/ hour
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
3	E-W (1)	371	371	35	42	1,846	462	40 %	2,252	875
4	W-E (2)	326	326	31	37	3,240	810	60 %	3,597	1,173
5	(1)+(2)	697	697	66	79	5,086	1272		5,849	2,048
6	Directional separator, SP = Q1/(Q1+Q2)								40 %	
7	Factor-pcu (Fpcu)									0,35

Table 8. Determination of the frequency of occurrence of road type 4/2 D

Side friction type	Symbol	Influence factor	Frequency of occurrence/hour. 200m	Weighted frequency
Pedestrian	PED	0.5	120	60
Parking. vehicle stops	PSV	1.0	95	95
Vehicles in and out	EEV	0.7	202	141
Slow vehicle	SMV	0.4	33	13
		Total		310

Table 9. Total travel time and number of vehicles and space average speed 4/2 D from both directions

No	Type of road	Σ way E-W (seconds)			Σ way W-E (seconds)			Number of E-W vehicles (/hour)			Number of W-E vehicles (/hour)		
		MC	LV	HV	MC	LV	HV	MC	LV	HV	MC	LV	HV
1	4/2 D Monday 17.00-18.00	650.23	662.73	101.09	838.63	680.55	62.64	133	123	19	178	112	11

No	Direction	Type of Road	Day/Hour	Vs (km/h)			Average vehicle speed (km/h)
				MC	LV	HV	
1	East West	4/2 D	Monday 17.00-18.00	36.82	33.41	33.83	34.69
2	West East	4/2 D	Monday 17.00-18.00	38.21	29.62	31.61	33.15

3.2.4. Vehicle Space Average Speed

Table 9 shows the data recapitulation of the survey results for measuring the average speed of the vehicle space. The data consists of travel time and the number of vehicles from East (E) to West (W) and vice versa. The average vehicle speed (km/hour) was calculated using equation 5.

3.2.5. Free Flow Speed

The basic free flow speed (FV_0) is 57 km/hour, based on the provisions in the MKJI-1997 guidelines [10]. The lane width adjustment factor (FVw) is -2, hence FV_0 + FVw equals 55 km/hour. The adjustment factor for side resistance FFV_{SF} is 0.97, and the City size adjustment factor (FFV_{CS}) is 0.95. Free current speed (FV) is calculated by multiplying 55x0.97x0.95 to obtain 50.68 km/hour.

3.2.6. Road Segment Capacity

Based on the provisions in the MKJI-1997[10], get Basic Capacity (C0), the Adjustment factor for lane width (FCw), Directional separator (FCSP), Side resistance (FCSF), and City size (FCCS) are1650 pcu/hour, 0.96, 0.97, 0.93, and 0.94. Therefore, using equation 3, the capacity is obtained by multiplying the values 1,650x0.96x0.97x0.93x0.94 to obtain 5,373 pcu/hour.

3.2.7. Degree of Saturation

The data analysis results show that the DS for the research location road type 4/2 D is 0.38.

3.3. Median Effect on Section Road Performance

The analysis results of the research data are the section road performance parameters. Figure 3 compares the performance parameters without and with the median. The distribution of road traffic flow with the median causes the road without the median to have a higher traffic flow. The capacity of the road with the median is higher due to the road's larger geometric size and the path's division. Higher capacity and lower traffic flow on roads with median cause lower DS values. The opposite happens on roads without a median. Therefore, the quality of urban road services is linear with road users' satisfaction when using its infrastructure [21].

In Figure 3, the road with a median entry in LOS B is indicated by the value of DS at 0.38, which is between 0.20 and 0.44. This implies that the traffic flow is stable despite the limited speed. In LOS B, driver comfort is relatively high, with limited driver freedom to maneuver. The level of road service without a median is included in LOS C with a DS value of 0.70, which is between 0.45 and 0.74. The flow characteristics at LOS C are stable, but speed is affected by traffic and regulated by other drivers, thereby reducing driving comfort. The average space speed increased by 4.7% from 32.4 km/hour to 33.92 km/hour, as shown in Figure 3. This is in addition to a 45.7% increase by lowering the DS value from 0.70 to 0.38 or from LOS C to LOS B.

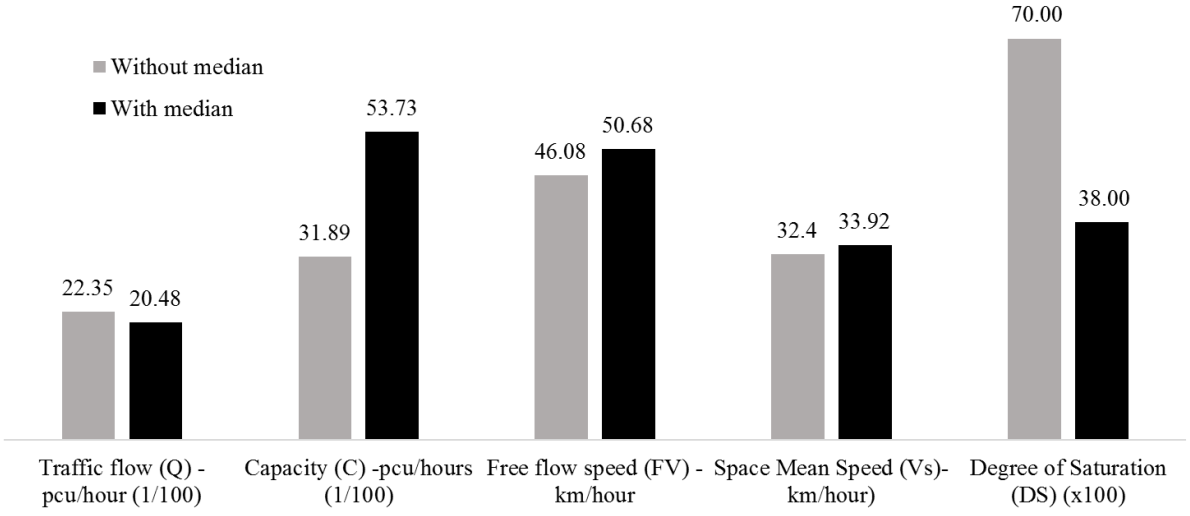

Figure 3. Section road performance parameters with and without median

4. Conclusions

Based on the discussion of the data analysis results, using the median improves performance by 45.7% compared to no median. This indicates a decrease in the DS of traffic flow from 0.7 to 0.38 or from LOS C to B. Additionally, the average speed increased from 32.4 km/hour without a median to 33.92 km /hour with a median.

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