Evaluation of Traffic Performance in Basuki Rahmat Street, Palu City by Using Road Segmentation Method

Arief Setiawan [1, a] , Nopkrialtur Bakti [2, b] , Jurair Patunrangi [3, c]

[1,2,3] *Civil Engineering Department, Faculty of Engineering, Universitas Tadulako*

[a] Corresponding author: ariefsetiawan.untad@gmail.com
[b] nbmesepy@gmail.com
[c] jurair62@gmail.com

Abstract : Basuki Rahmat Street is a National Road with a primary-arterial-function based on the Regional Master Plan of Palu City 2010-2030. The area is focused as a trade and service area which attracts visitors to have economic and social activities. Therefore, each section of the road has other traffic performance. The research was conducted in three road segments: Grand Hero Supermarket, Samsung store, and BCA Bank, and Star Kitchen Electronic Center based on traffic generation of business activity. The study aims to understand Basuki Rahmat street's performance and its activities in each segment. A survey was conducted periodically (early, middle, and end of the month) by taking a workday and a holiday for each period, from 09.00-22.00 WITA. The evaluation method was based on the Indonesian Highway Capacity Manual (IHCM) 1997 urban area on peak hour. The result showed that the Road Segmentation Method (RMS) of Basuki Rahmat street has 0.37 degrees of Saturation (DS) and was included in a B level of service. The differences between DS-RMS and DS on each segment were 0.04. The road segmentation method should be considered to assess the traffic performance of the road link.

Keywords: traffic performance, road segmentation, degree of saturation, level of service

INTRODUCTION

Basuki Rahmat Street in Palu city is a primary arterial road and a national road status [1] for trade and service area [2]. Therefore, the street becomes crowded, and the traffic is jammed . The effect is reduced vehicle speed. The street was chosen because it was connected to Mutiara Sis Al-Jufri, as an access to the airport, which requires vehicles to travel at a high speed (minimum speed of 60 km/hour) [3].

Previous researchers had conducted several research related to the topic. Research and method [4] measured the street performance of Prof. Dr. Satrio Street in DKI Jakarta by taking data on workdays and holidays on an observation point to gain a level of service of traffic performance. In addition, [5] measured the traffic performance of Hassanudin Street in Manado City for a segment. It took a week on an observation point. [6] evaluated the street capacity of Pantura, Brebes Regency, which used data managed from related institutions by dividing sixteen street segments to obtain each capacity. The three researchers measure traffic performance based on each point's volume capacity ratio, but there is no aggregation of the values for several points for the same segment.

IHCM [7] said that the division of segments is differentiated between interurban and urban roads. The significant differences in traffic flow, without interruption of signalized or unsignalized intersections, and similar characteristics of the roads are the criteria of segment dividing. The point at which the road characteristics change significantly becomes the segment boundary. However, the field facts often occur in a section where there are different land-use uses so that there are other traffic generations. The measurement of traffic performance is focused on one critical value, which is considered to represent a road segment. Therefore, this study proposes a road segmentation method to overcome this problem.

Based on some of those experiences, in this study, Basuki Rahmat Street is divided into three segments, with an observation point on each representing data taking of traffic volume. Segment 1 was surveyed by at Grand Hero with a high traffic generation, segment 2 in Samsung smartphone store with a low traffic generation, and segment 3 in Star Kitchen with the middle traffic generation. The evaluation of every segment's performance would then be gained at those places. Evaluation of Basuki Rahmat Street's traffic performance aims to understand the street's current condition, such as speed, degree of saturation or VC ratio, and service level, by using the road segmentation method based on business activities.

RESEARCH METHOD

Location Study

Palu City is located between the Palu valley and Palu Bay, with 0-700 meters above sea level. It is situated at 0º.36"-0º.56" South latitude and 119º.45"-121º.1" east longitude. According to BPS [8], it has a 395.06 km2 area, with 385,619 inhabitants. Figure 1 shows the map of Basuki Rahmat Street and survey locations. Basuki Rahmat Street is located in Palu City, Municipality of South Palu, and some parts are in North Birobuli Village while the other parts are in North Tatura Village. It has a 1.74-kilometer length, 14.7-meter width with four lanes, and two directions undivided (4/2 UD). It is also a primary-arterial-street that connects the center of the regional area and national activity centers such as Port of Pantoloan and Mutiara Sis Al-Jufri Airport. There are housings, prayer facilities, schools, stores, hotels, offices, and service places.


(a)

(b)

(c)

(d)

Data and Survey

Traffic data and field conditions are used to achieve the aim of this research. Data consists of two sources, primary and secondary. The data can be listed below:

1. Secondary data were obtained from data related to the number of Palu City populations, which could affect street capacity, side friction, and land use data from the Regional Planning Department of Palu City [2].
2. Primary data were gained from surveys:
    a. Road geometric condition was measured by length, width, lane width, and pavement width.
    b. Traffic volume survey was conducted using surveys of traffic when stores are opened from 09.00 - 22.00 WITA and by counting on the number of vehicles that passed the observation points. A team of surveyor consisted of 2 persons for two directions.
    c. A surveyor counted on the in-out vehicle into the stores. Later, the data were analyzed to know the effect of business activity on traffic volume.
    d. The survey on vehicle speed was conducted using a stopwatch by a surveyor for each location. The speed was measured at 50 m in front of each site. Each vehicle type was taken a minimum of 20 so that the time-mean speed was obtained.
    e. Side friction survey which used a surveyor was carried out 200 m for each observation location by recording the number of events of pedestrians, vehicles stopping or parking on the road, vehicles entering or exiting the side of the road, and non-motorized vehicles. The data were processed by multiplying the weight factor for each event according to the IHCM 1997. The pedestrian weight factor was 0.5; stop or parked vehicle weight factor 1.0; weight factor for incoming/outgoing vehicles 0.7; the weight factor of non-motorized vehicles is 0.4. The side friction class of each location is detected.

Data Analysis

Basuki Rahmat's performance on each road segment follows the traffic performance procedure's flow chart in Figure 2. The method is based on IHCM 1997 Chapter 5 [7], an urban traffic capacity manual in Indonesia.
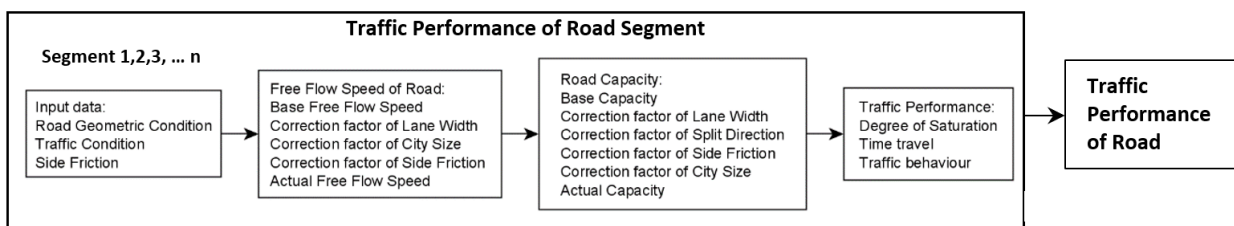
FIGURE 2. Research flow chart

Figure 2 shows the steps to measure the performance of Basuki Rahmat street. The first step was to input data that consists of road geometric, traffic volume, and road site activities that could disturb the traffic. The second step was to find out the free-flow speed based on IHCM 1997 model. The free-flow speed obtained from the model was compared with the actual speed on Basuki Rahmat street. The speed was used to define traffic performance indicators, i.e., time travel. The third step was to calculate Basuki Rahmat street's road capacity, which needs parameters such as base capacity, a correction factor of lane width, a correction factor of split direction, a correction factor of side friction, a correction factor of city size. All the parameters are used to get actual capacity. The fourth step was to define the degree of saturation (DS) or volume capacity ratio (VCR), time travel, and traffic behavior on Basuki Rahmat Street. Finally, VCR was combined with all segments that calculate in one value of VCR's road.

This research proposes an equation to determine the degree of saturation of the road link. The equation is the degree of saturation with the weight factor of segment length. It can be seen in equation 1.

$$DS\ road = \frac{\sum_{i=1}^{n}(DS\ segment_i\ x\ L\ segment_i)}{\sum_{i=1}^{n} L\ segment_i} \tag{1}$$

Where *DS* is the degree of saturation in %, and *L* is the length of a segment in a meter.

The level of service (Los) is converted from the VCR of the street. Operational characteristic and Los according to Regulation of Minister of Transportation No. KM 14 the Year 2006 [9]. It is shown in Table 1.

TABLE 1. Level of Service and Operational Characteristic of Primary-Arterial Road [9]

Level of Service	Related Operational Characteristics
A	Free flow; traffic speed > 100 km/hour; Free visibility to precede is always there; traffic volume reaches 20% of capacity (400 pcu per hour, two directions); and there are about 75% preceding done with little delay or without any.
B	The stable flow condition; traffic speed > 80 km/hour; traffic volume reaches 45% of capacity (900 pcu per hour, two directions).
C	Flow is stable; Traffic speed > 65 km/hour; Traffic volume reaches 70% of capacity (1400 pcu per hour, two directions).
D	The flow will be unstable; traffic speed decreases to 60 km/hour; traffic volume reaches 85% of capacity (1700 pcu per hour, two directions).
E	The condition reaches any capacity with 2000 pcu per hour of volume, two directions; and traffic speed is 50 km/hour on average
F	Flow is restrained; traffic speed < 50 pcu/hour; and volume is under 2000 pcu per hour

## RESULT AND DISCUSSION

1. Road Segment Characteristics

Basuki Rahmat Street was divided into 3 segments and emphasized traffic measurement to represent each segment: Grand Hero Supermarket (segment 1); Samsung smartphone store and BCA Bank (segment 2); and Star Kitchen electronic store (segment 3). Data were taken from November to December 2019 at the early, middle, and end of the month. The segment was identified for its street networking, traffic condition, and surrounding activities of the road. The segment characteristics can be seen in Table 2, and Figure 2 shows the segment's boundary in this study. Figure 3 shows the situation of the segment of the street.

TABLE 2. Road Segment Characteristics

Segment	Description	Distance (m)	Characteristics
1	Intersection 4 (from St. Basuki Rahmat, St. Emy Saelan, St. Towua and St. I Gusti Ngurah Rai) to Intersection 3 (St. Basuki Rahmat and St. Zebra)	805	Have limited access along with the segments; visitors on survey points are very crowd. The side activities are trading and services.
2	Intersection 3 (from St. Basuki Rahmat and St. Zebra) to Hotel Best Western Coco	368	Have many accesses along the segment, and the visitors are in small numbers. The activities are dominated by trade and service centers.
3	Hotel Best Western Coco to Intersection 4 (St. Basuki Rahmat, St. Prof. Moh Yamin, St. Dr. Abdurahman Saleh, and St. Dewi Sartika)	567	Have a medium scale of access along the segment, the moderate number of visitors in the surveyed area. The activities are the trade, services, and also dominated by *warung* (food courts)

FIGURE 2. Segment dividing on Basuki Rahmat Street
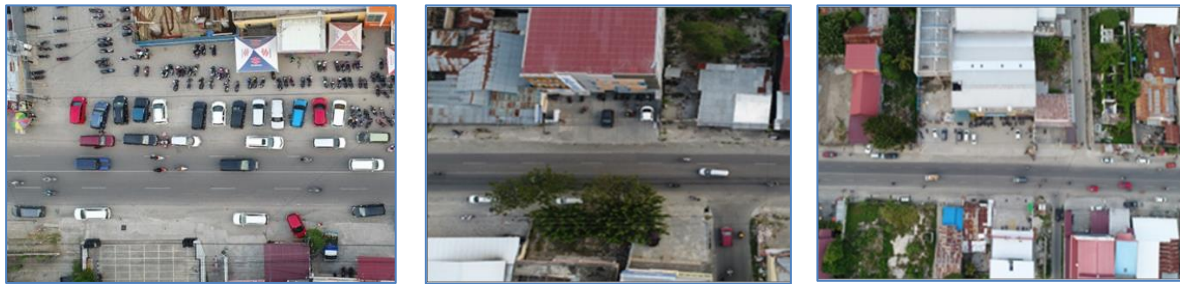
| (a) Grand Hero Supermarket | (b) Samsung Store and BCA Bank | (c) Star Kitchen Electronic store |

FIGURE 3. The situation of Basuki Rahmat Street

A characteristic of the building describes the trip generation potential that affects traffic performance. Three buildings have been chosen, and their features can be seen in Table 3.

TABLE 3. Building Characteristics

Segment	Building Selected	Building Area effective (m2)	Parking Area (m2)	Land Area (m2)
1	Grand Hero Supermarket	2.781,80	834,80	2.128,36
2	Samsung Store and BCA Bank	851,40	110,70	394,5
3	Star Kitchen Electronic store	2.078,95	257,30	3.898,60

According to the building area's effectiveness, Grand Hero supermarket has the most significant trip generation. The trip generation for all the buildings can be seen in Table 5.

2. Selected Traffic Volume

The traffic data were collected at the beginning of the month between 1-10 December 2019, mid-month between 11-20 December 2019, and at the end of the month between 21-30 November 2019. Traffic data collection for working days and holidays was required to determine the difference in the number of trips for that kind of day.

The traffic volumes segment was obtained from the early, middle, and end of the month on workdays and holidays. Table 4 shows the difference in peak hours for each observation time. Samsung store and

BCA Bank have the most comprehensive traffic volume. In the workday, BCA has more visitors than the Grand Hero supermarket and Star kitchen Electronic store.

Grand Hero Supermarket has an enormous traffic volume of a holiday because people go shopping at that time. An interview with 48 respondents shows that 60.1% is *Pegawai Negeri Sipil* (PNS). PNS have paid their salary in the early month, so they schedule to go shopping. Star kitchen has no significant difference in traffic volume for early, middle, and the end of the month. It because people can go to an electronic store anytime they want.

TABLE 4. Traffic Volume during Peak Hour

Time Survey	Segment	Day	Peak Hour (WITA)*	Volume (pcu/hour)
Early of Month	1 (Grand Hero Supermarket)	workday	17.15-18.15	1482.2
		holiday	18.00-19.00	1707.4
Middle of Month		workday	17.00-18.00	1403.7
		holiday	16.30-17.30	1611.7
End of Month		workday	18.30-19.30	1427.7
		holiday	17.00-18.00	1630.7
Early of Month	2 (Samsung Store and BCA Bank)	**workday**	**16.45-17.45**	**1802.9**
		holiday	17.15-18.15	1763.4
Middle of Month		workday	17.00-18.00	1779.3
		holiday	16.30-17.30	1754.4
End of Month		workday	16.30-17.30	1749.9
		holiday	16.45-17.45	1761.1
Early of Month	3 (Star Kitchen Electronic store)	workday	16.45-17.45	1791.9
		holiday	17.15-18.15	1759.6
Middle of Month		workday	17.00-18.00	1776.4
		holiday	16.30-17.30	1753.7
End of Month		workday	16.30-17.30	1756.9
		holiday	16.45-17.45	1764.7

Note: *) WITA: *Waktu Indonesia bagian Tengah* (Middle Indonesian Time Zone)

In this study, the traffic volume is determined at the same time as the three segments. The time had chosen at 16.45-17.45 WITA. Through this method to assess traffic performance, the traffic volume towards Samsung Store and BCA Bank is carried out to follow the other locations. The consideration is the most massive traffic volume on the site.
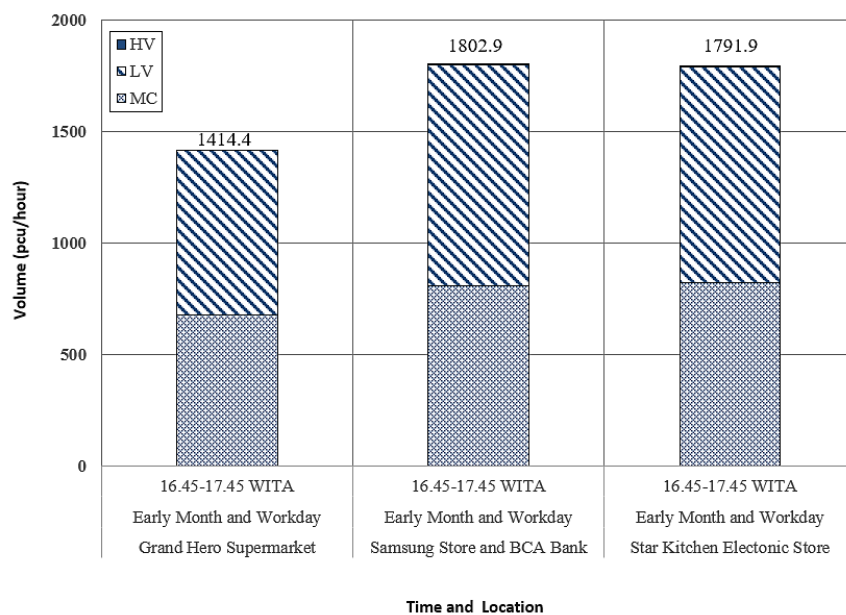
FIGURE 4. Traffic volume of each segment Basuki Rahmat street

Figure 4 showed the fluctuated traffic volumes in Segment 1, 2, and 3. Data were obtained during workdays in the early month, at 16.45-17.45 WITA. The survey result showed that the traffic volume in segment 1 in the early month – workday at 16.45-17.45 WITA was 1414.4 pcu/hour. Samsung store and BCA Bank have the highest traffic volume on Basuki Rahmat Street. Figure 4 shows the total traffic flow and the flow composition, namely MC, LV, and HV in pcu/hour. The HV is the lowest of traffic flow. The number is around one vehicle/hour.

3. Effect of Business Activity on Traffic Volume

Data related to parking due to the generation of visitors in the location was used to measure business activity's effect on the traffic flow, using parking data as an indicator during peak hours, as seen in Table 5. Through in and out data, the generation of business activity can be described [10]. The business activity effect was determined by divided trip generation to traffic volume in percent.

TABLE 5. Vehicle Parking Data

Segment	Peak Hour (WITA)	MC In passenger car 0.4	MC Out passenger car 0.4	LV In equivalent 1.0	LV Out equivalent 1.0	Trip Generation (pcu/hour)	Traffic Volume (pcu/hour)	Activity Effect (%)
(1) Grand Hero Supermarket		102	91	26	22	125.2	1414.4	8.85
(2) Samsung Store and BCA Bank	16.45-17.45	22	15	5	3	22.8	1802.9	1.26
(3) Star Kitchen Electronic store		62	49	18	17	79.4	1791.9	4.43

It was found that Grand Hero led to 125.2 pcu/hour of traffic volume or 8.85 % traffic volume, while Samsung Store and BCA Bank affected 1.26% traffic volume and last Star Kitchen with 4.43% of traffic volume. The effect of business activity in Basuki Rahmat Street ranges from 1.26% up to 8.85%. The effect quantification sometimes does not represent the traffic jam in a short period because of some conflict of traffic flow in a small area.

4. Traffic Performance of Basuki Rahmat Street

Determining traffic performance must consider side friction. Side friction is affected not only traffic performance but also a reflection of traffic generation of business activity. Access road along Basuki Rahmat street and on-street parking or maneuver of the vehicle around the building activities will disturb the regular traffic.

Side Friction of Road

Data gained related to the factor on each event was from side friction classification based on Table 6. It is found that Grand Hero supermarket is in the middle level (M) of side friction, Star Kitchen electronic store is on low level (L), and Samsung store and BCA Bank is very low (VL) level. The site friction affects the road's capacity, and as a result, it will also affect traffic performance.

TABLE 6. Side Friction during Peak Hour

Location	Peak Hour (WITA)	Side Friction Event Pedestrian 0.5	Side Friction Event Vehicle Stop or Park 1.0	Side Friction Event Vehicle In/Out 0.7	Side Friction Event Unmotorized Vehicles 0.4	Total Event of Side Friction per 200 m	Level of Side Friction
(1) Grand Hero Supermarket		29	86	299	16	307.1	M
(2) Samsung store and BCA Bank	16.45-17.45	9	14	58	14	60.2	VL
(3) Star Kitchen Electronic store		45	52	218	7	273.2	L

Vehicle in and out of the building has dominated the event of side friction, and parking on-street parking will occur when the parking area is complete. It means the developer must provide the parking area sufficiently, which can accommodate off-street parking.

Unmotorized vehicles on Basuki Rahmat street comprise of gerobak pemulung, gerobak siomay, and bicycle. There is no bicycle lane on Basuki Rahmat street, increasing side friction and reducing its capacity.

Degree of Saturation by Using Road Segmentation Method

A capacity analysis is conducted ever to represent each segment, which is matched with side friction analysis. Here is the result of capacity and DS on each detail:

TABLE 7. Road Segment Capacity dan VC ratio Road Segmentation Method (RSM)

Segment	Co (pcu/hour)	FCw	FCsp	FCsf	FCcs	Volume (pcu/hour)	C (pcu/hour)	DS	DS-RSM
(1) Grand Hero Supermarket				0.95		1414.4	4257.90	0.33	
(2) Samsung store and BCA Bank	6000	0.83	1	0.99	0.9	1802.9	4437.18	0.41	0.37
(3) Star Kitchen Electronic store				0.97		1791.9	4347.54	0.41	

Determination of the capacity of each segment (C), according to Table 7, is adjusted to the factors that influence road capacity based on the IHCM 1997 method. The basic capacity (Co) is the value of the Basuki Rahmat road's basic capacity, which has the road type 4/2 UD. The basic capacity for four undivided lanes is 1500 pcu/hour per lane so that Co Jalan Basuki Rahmat is obtained for 6000. (FCw) of 0.83 is obtained from the extrapolation of the adjustment factor with 2.5 m traffic lane width. The split direction adjustment factor (FCsp) of 1 is obtained from the traffic volume for two directions, in which the direction separation factor is 50% -50%. The side friction adjustment factor (FCsf) has a different value for each segment due to the different side friction levels. FCsf segment 1 is 0.95 for medium, FCsf segment 2 is 0.99 for very low, and FCsf segment 3 is 0.97 for low side friction. The city-size adjustment factor (FCcs) is 0.9. The FCcs value is obtained from the city's size with a population of between 100,000-500,000. The degree of saturation (DS) or VC ratio is obtained by comparing the traffic volume to each segment's capacity. The value of Degree of Saturation (DS) is used to know whether every segment has a problem with capacity or not.

The measurement of Basuki Rahmat Street's street performance through service level could be gained by measuring the degree of saturation's average value. Equation 1 is used to obtain the average service level value of Basuki Rahman Street. The result of the VC ratio of the segmentation method can be seen in Figure 5. The degree of saturation of Basuki Rahmat shows that the representative of DS is 0.37. There is no significant service level between the road segment and the link, but the RSM or performance road link is more realistic.

Regarding Table 1, the street level is B, which means the flow in stable condition. Visual observation showed that road segmentation could be a significant result of DS. In this case (Table 7) shows that DS with and without RSM has 0.04 differences. The critical part of RMS is concluding all locations on the road to predict traffic performance. Road segmentation should be considered to determine the level of service of the road. The traffic performance decides on not only the point location but also the link of the road.
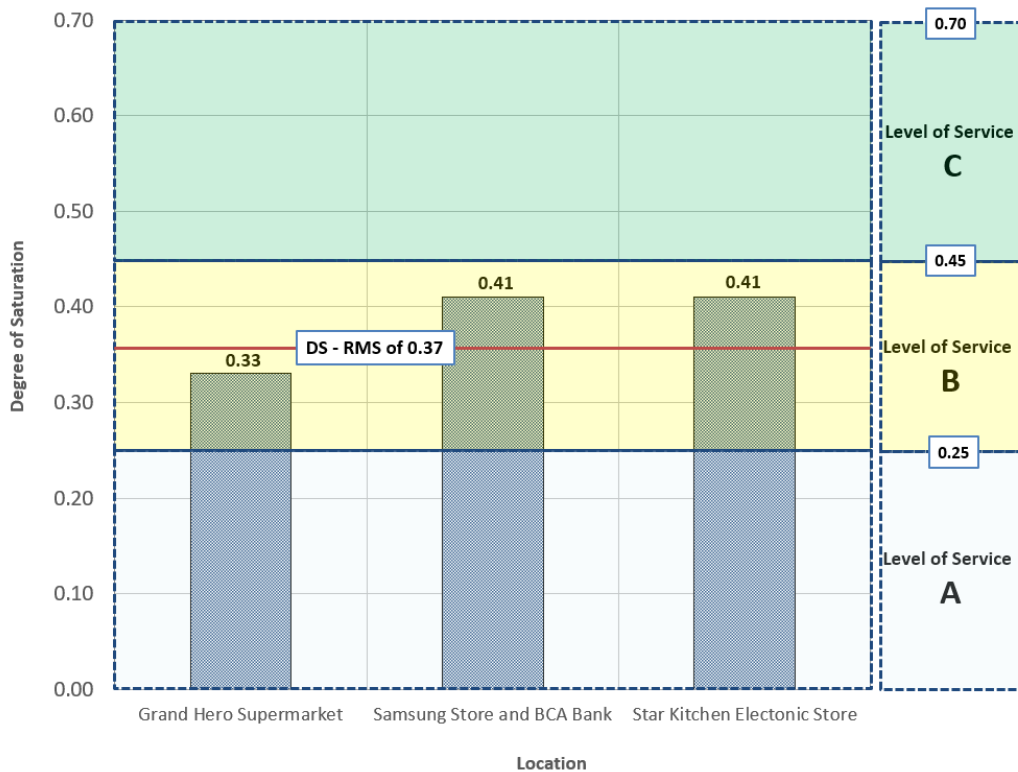
FIGURE 5. DS road segment (location), DS with RMS, and the Level of Service

5. Effect of Business Activity on Time Mean Speed and Free Flow Speed

IHCM 97 uses free-flow speed (FFS) as one of the traffic performance indicators. The higher speed indicates better traffic performance. Free-flow speed is defined as the speed at low traffic volume and absence of traffic control devices, which means that it is the driver's speed to drive his/her motorized vehicle without getting affected by other motorized vehicles on the street. The speed survey was conducted by taking time at a selected short length of the road called spot speed. The spot speed survey has been done on the peak hour of the traffic volume. The arithmetic mean of spot speed is time mean speed (TMS). Data related to speed can be seen in Table 8.

Table 6 and Table 8 show that the lower side friction can increase speed except in segment 2, because the traffic light next to the Samsung store and BCA Bank can reduce the rate. The building activities can affect the speed. Comparing the TMS of MC, LV, and HV, the data shows that MC has the highest speed and the HV speed the lowest one. It means that the dimension of the vehicle affects the speed.

The data relating to FFS could not compare with TMS at peak hours. The free flow speed is represented as the top speed as maintained without signal control or the effect of other vehicles [11]. However, this case study's time-mean speed is the peak hour that represents an actual traffic condition. Table 8 shows that the FFS of LV is the highest. On the other hand, the peak hour's actual state, the highest of speed, is MC.

TABLE 8. The Vehicle Speed

Segment	Speed (km/hour)					
	MC		LV		HV	
	TMS	FFS	TMS	FFS	TMS	FFS
(1) Grand Hero Supermarket	31.917		25.659		21.947	
(2) Samsung store and BCA Bank	35.616	33.063	25.933	43.273	22.779	38.558
(3) Star Kitchen Electronic store	37.246		28.403		22.214	

CONCLUSION

This paper aims to understand the road performance according to the road's dividing segment. Based on the result and discussion, the following conclusions are obtained:

1. The DS of the road segments were 0.33, 0.41, and 0.41 for segment (1) Grand Hero Supermarket, (2) Samsung Store and BCA Bank, and (3) Star Kitchen Electronic store, respectively.
2. The road segmentation method should be considered to assess the traffic performance of the road link. The method showed that Basuki Rahmat street's level of service was B and the DS of 0.37.
3. The effect of business activity due to trip generation was shown to affect the side friction. Increasing side friction will decrease traffic performance. Seeing those findings, Palu City's government should manage the traffic flow on trading and services on the location.

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