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Research Article

Analysis of Accident Rate in *Kolonel Sugiono* Street, Malang City

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Abstract

Kolonel Sugiono street is included in the administrative area of Mergosono Sub-Village, Kedungkandang District, Malang City and is a connecting route between Malang Regency and Malang City. In addition, it is also one of the routes that connects Malang City and Surabaya City, with the road function being a Secondary artery and a national road. Kolonel Sugiono street is one of the lanes with a quite high flow of vehicles every day. Kolonel Sugiono street is an area that has quite a lot of blackspot due to the frequent occurrence of traffic accidents. Based on Malang City Traffic data, there were 51 accidents occurred in 2014-2016 and 40 accidents in 2017-2021, both on Kolonel Sugiono street. This study aimed to determine the traffic's characteristics, identify blacksites and blackspots, as well as solutions and efforts to improve road safety. According to the analysis results, the service level of Kolonel Sugiono street is 0.98 that is categorized as criterion E, namely the traffic volume is approaching or at its capacity, the flow is unstable with frequently stop conditions. Furthermore, based on the Z-Score and Cusum analysis, Kolonel Sugiono road is identified as a Blacksite and Blackspot because it has a positive Z-Score value, namely segment I is 3.1 and in segment II is 5, has a Cusum value, namely in segment 1 is 32 and in segment II has a value of 28.2. Solutions and efforts to improve road safety are paying attention to, repairing, and installing traffic signs, traffic signaling devices, and other road complementary factors.

Keywords: *blacksite and blackspot, safe roads, traffic characteristics*

1. INTRODUCTION

Growth can cause an increase in transportation needs. Advances in science and technology, especially in the field of transportation, is needed to facilitate human movement. The number of vehicles increases as the living standard of the people increases. In this case, the increase of vehicles can also affect the number of traffic accidents.

Traffic is defined as the movement of vehicles and people within a traffic space. Road Traffic space is an infrastructure for the movement of vehicles, people, and goods in the form of roads or cargo buildings [1]. A traffic accident is an unexpected and unintentional incident on the road involving a vehicle with or without other road users, resulting in loss of human life or loss of property [1].

Such incident can lead to adverse situations such as congestion, accidents, pollution, and constraints on facilities and infrastructure. Traffic volume density and other factors such as weather, environment, road conditions, road facilities and the driver's own factor are the most frequent causes of traffic accidents.

Kolonel Sugiono Street stretches from north to south and is included in the administrative area of Mergosono Sub-Village, Kedungkandang District, Malang City [2]. Kolonel Sugiono Street is a route that connects Malang Regency and Malang City and is one of the routes that connects Malang City and Surabaya City.

Kolonel Sugiono Street is a road with the function being secondary arterial road and a national road status. In addition, Kolonel Sugiono Street is one of the main routes in Malang City that has quite high flow of vehicles every day.

Kolonel Sugiono Street is an area that has quite a lot of blackspot due to the frequent occurrence of traffic accidents, thus causing casualties. Based on Malang City Traffic data, there were 51 accidents in 2014 to 2016, and 40 accidents in 2017 to 2021 on Kolonel Sugiono Street.

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Efforts to improve road safety are conducted by implementing inspections based on the AKJ checklist through the 2005 PDT and paying attention to the 5 sector pillars that affect the handling of road safety [3].

2. METHOD

Accident Prone Areas

Accident-prone areas or blackspots are areas that have a very large and high number of traffic accidents, risking an accident on a road section [4]. An area is declared as a traffic accident-prone area if:

1) It has a high accident rate
2) the area is relatively stacked
3) The accident are in the form of intersections or road segments of 100-300 meters for urban roads
4) The accidents occur in relatively the same space and span of time
5) The cause of the accident is specific.

According to the data issued in 1998, Land Transportation Training Center Accident Prone Areas are grouped into three including: [5]

1) Accident Prone Locations (*Hazardous Sites*)
   Hazardous site can be grouped into:
   - Blacksite / Section
   - Blackspot is a point on a traffic accident-prone section (0.03 – 1.0 KM)
2) Accident Prone Routes (*Hazardous routes)*
   The criteria used in finding accident-prone routes are as follows: [6]
   - The number of accidents exceeds a certain value regardless of variations in route length and accident volume
   - The number of accidents perkilometer exceeds a certain value regardless of the value of the vehicle
   - The accident rate (vehicle-kilometers) exceeds a certain value.
3) Accident Prone Areas (*Hazardous Area*)
   Ground Transportation Training Center 1998, [6]
   - The number of vehicles per KM² per year regardless of variations in road length and traffic volume variations
   - The number of vehicles per inhabitant regardless of variations in road length and accident volume variations
   - Number of accidents per kilometer of road regardless of traffic volume. Number of accidents per vehicle owned by residents in the area.

Identification of Accident-Prone Locations

Z-Score is a Z number or a Standard score. The Z-score is obtained based on the samples of size n, X1, X2, X3, ..., Xn data with the average X at standard deviation S, so that new data can be formed into Z1, Z2, Z3, …, Zn with an average of 0 standard deviation of 1 [7][8]. The calculation steps are as follows:

- Find the mean value

$$\overline{X} = \frac{\sum x}{n} \quad (1)$$

where:
$\overline{X}$ = Mean value
$\sum x$ = Amount of data
n = Amount of data

- Find the standard deviation value

$$S = \frac{\sqrt{(\sum x - \overline{x})^2}}{n} \quad (2)$$

where :
S = Standard deviation
$\sum x$ = Amount of data
$\overline{X}$ = Mean value
n = Lots of data

- Find the Z-Score value

$$Z = \frac{Xi - \overline{X}}{s} \quad (3)$$

where:
Zi = Z-Score value in road accidents
Xi($\sum x$) = Total accident data at the location
$\overline{X}$ = Mean accident value
S = standard deviation

Blacksite Determination Classification

Table 1 shows the Z- score criteria, namely:

Table 1. Blacksite determination classification

Z-Score	Criteria
Positive + (>0)	Accident-Prone
Negative - (<0)	Not Prone to Accidents

Cumulative Summary

This Cussum diagram is used to monitor changes. Cussum (*Cumulative Summary*) is a procedure or method that can be used to identify blackspot. Cussum is a standard statistical procedure as a quality control to detect changes from the mean value [9].

- Finding the Mean Value (W) of secondary data, namely:

$$W = \frac{\sum xi}{L \times T} \quad (3)$$

where:
W = Mean value
$\sum$xi = Number of accidents

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L = Number of segment
T = Time/period (year)

- Find the cumulative value of the first year's accident.

$$So = (X_1 - W) \quad (4)$$

where :
So = Accident cumulative value for the first year
X_1 = Number of accidents in the first year
W = Mean Value

- Find the accident value for the following year

$$S_1 = \{S_0 + (X_1 - W)\} \quad (5)$$

where:
S_1 = The cumulative value of the following year's accident
S_0 = Accident cumulative value for the first year
X_1 = Number of accidents in the first year
W = Mean value

Blackspot Determination Classification

The following Table 2 shows the Cussum Value criteria, namely:

Table 2. Classification of blackspot determination

Cusum value	Criteria
Positive + (>0)	Accident-Prone
Negative - (<0)	Not Prone to Accidents

This research was conducted on Kolonel Sugiono Street, Kedungkandang District, Malang City. The type of this road section is four lanes in two directions (4/2 UD), this road section has a length of 3 KM and a width of 12 M with a commercial land use type. Kolonel Sugiono Street is a national road with a primary arterial road and class II road.

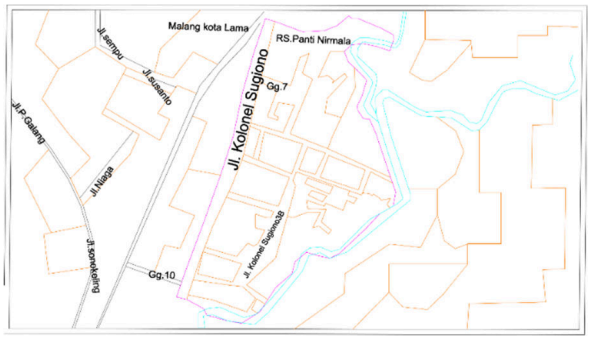

Figure 1. Research location

This study was carried out through quantitative research. Such design was applied aiming to test theories and build facts on research problems [10]. In addition, such research was also carried out to answer the problem to be studied, to describe the research results by not changing the object studied and focusing only on the causes and effects of the traffic characteristics, knowing and determining locations that are prone to accidents, and knowing solutions to improve road safety in accident-prone areas.

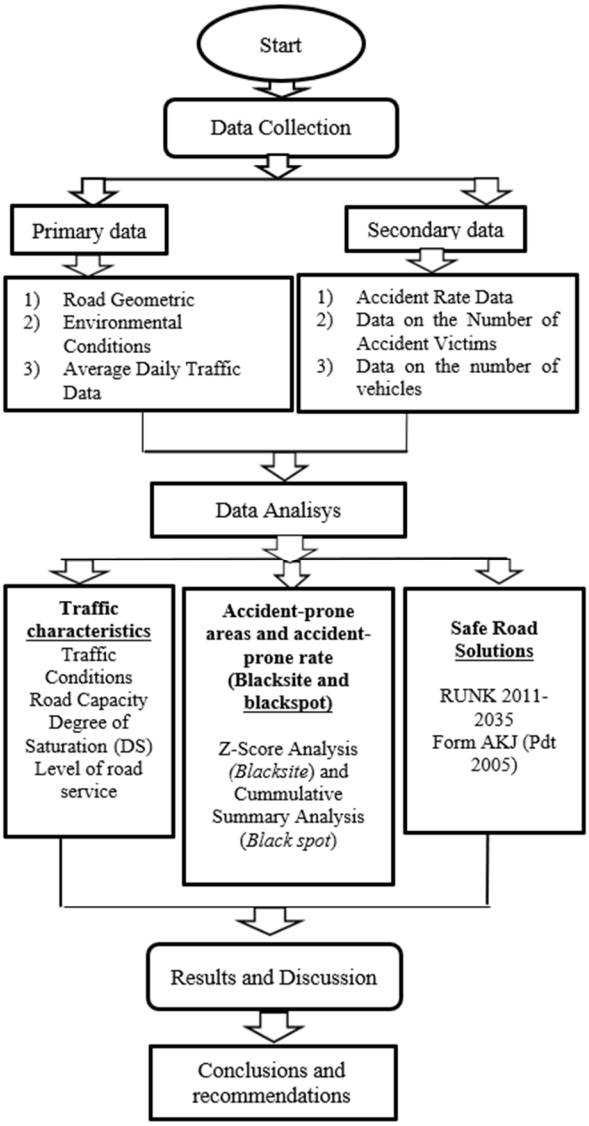

Figure 2. Research flow chart

3. RESULTS AND DISCUSSION

Existing Condition of Road Section

Kolonel Sugiono Street is a route that connects Malang Regency and Malang City. Judging from the situation, conditions as well as road and traffic infrastructure and facilities on Kolonel Sugiono street, it seems that they are still inadequate. Colonel Sugiono Street is a street with a commercial area since there are many shops, schools, housing, and others located. In this study, 3 km of the street were studied and divided into 2 road segments of 1500 M or 1.5 KM.

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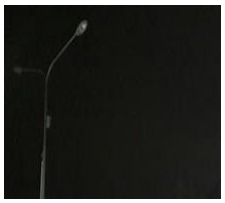
Table 3. Condition of Colonel Sugiono's Road

No	Condition	Location Picture
1	Segment I does not have parking facilities, lacks of traffic signs (prohibition and warning signs) and have directions/ recommendation signs	
2	There are no kerbs and sidewalks (No facilities for pedestrians)	
3	Faded road markings that need to be repainted	
4	Some public street lighting does not work properly	
5	No safety fences or crash barriers are available	
6	Lack of traffic signaling devices and road transport	
1	Lack of traffic signaling devices and road transport,	
2	Road markings are faded and barely visible	
3	There are no curbs, sidewalks, and road median	
4	Lack of traffic signs and their placement is less effective to be reached properly	
5	There are public street lighting lamps that do not work properly	
6	No safety fences or crash barriers are available	

Road Geometry

Based on the results of the research survey carried out by measuring the research location, the existing conditions in the research area are as follows.

Table 4. Existing condition of Colonel Sugiono's Road, Malang City.

Element	Size
Road length	3 KM
Lane width	12 M
Road type/class and function	4/2 UD/ Secondary Artery Road
Lane width	3 M
Roadside width	1 m (to the right and left of the road)
Land Use	Commercial
Side Resistance Class	Tall
Alignment type/ median condition	Straight/Flat

Traffic Conditions

The following figures shows a vehicle graphic and a table of peak vehicle hours.

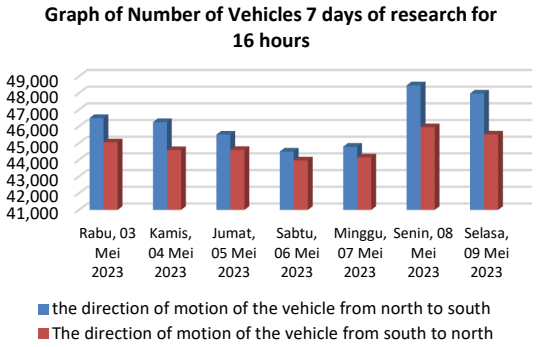


Figure 4. Vehicle graphics

Table 5. Vehicle Peak hours for 1 hour from 2 lanes

South – North					
	Class				
Time	MC	LV	HV	UM	Total
08:00 – 08:15	704	164	45	20	933
08:15 – 08:30	721	158	48	16	943
08:30 – 08:45	734	160	38	23	955
08:45 – 09:00	690	155	43	14	905
Total	2849	640	174	73	3736
North - South					
	Class				
Time	MC	LV	HV	UM	Total
17:00 – 17:15	745	168	41	19	973
17:15 – 17:30	806	175	26	20	1027
17:30 – 17:45	731	172	28	9	942
17:45 – 18:00	722	159	37	14	932
Total	3004	679	129	62	3874
Total for two lanes					7610

Based on the research conducted for 7 days from 06:00 –21:00, the analysis results show that the peak traffic time occurred on Monday, 8th May 2023 (as seen in the graphic figure) and the peak traffic hour occurred on Monday, 8th May 2023 on 08:00 – 09:00 WIB for the South to North direction and 17:00-18:00 WIB for the North to South direction (as seen in Table 5).

Capacity

The calculation for road capacity value is as follows:

$$C = Co \times FCw \times FCsp \times FCsf \times FCcs \quad (6)$$

where:

Co = Base capacity
FCw = Road width adjusment factor
FCsp = Direction splitting adjustment factor
FCsf = Side resistance adjustment factor and roadside width or obstacle curb distance
FCcs = city size adjusment factor

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Table 6. Capacity adjustment factor

Adjustment Factor for capacity					
Co	Fcw	FcSP)	FcSf	FCcs	C
6000	0.92	1.00	0.93	0.94	4825.6

The calculation results show that the road capacity value is 4825.6 smp per hour.

Degree of Saturation (DS)

The results of the Saturation degree calculation is shown as follow:

$$DS = \frac{Vtotal}{c} = \frac{4777.4}{4825.6} = 0{,}98 \quad (7)$$

Based on the calculations above, the service level of the road studied is E.

Table 7. Service level

Volume	C	Ds	Service Level	Information
4777.4	4825.6	0.98	E	Traffic volume is approaching or at its capacity, the flow is unstable with frequently stop conditions.

Summary of Accident Data for Two Segments of Colonel Sugiono's Road

Table 8 presents a Summary of Accident Data on Kolonel Sugiono Street

Table 8. Recapitulation of accident data

Type	Unit	Segment	
		I	II
Accident	Accident	10	29
Accident victim:			
a. minor injuries	people	12	35
b. serious injuries	people	1	1
c. death	people	4	9
Number of vehicle involved	unit	17	51

Source: Malang City Traffic Traffic

Z-Score and Cusum Analysis to Identify Blacksites and Blackspots

The following are calculations to determine the Z-Score:

1) Z-Score

Segment I

- Finding the mean value

$$X^{-} = \frac{\sum x}{n} = \frac{1+1+4+1+3}{5} = \frac{10}{5} = 2$$

- Finding the Standard Deviation Value (S)

$$S = \frac{\sqrt{(\sum x - \overline{x})^2}}{n} = \frac{\sqrt{(10-2)^2}}{5} = 1.6$$

- Finding the Z-Score value (Zi)

$$Zi = \frac{Xi - \bar{X}}{s} = \frac{10-2}{1.6} = 3.1$$

Segment II

- Finding the mean value

$$X^{-} = \frac{\sum x}{n} = \frac{16+5+3+2+3}{5} = 5.8$$

- Finding the Standard Deviation Value (S)

$$\frac{\sqrt{(\sum x - \overline{x})^2}}{n} = \frac{\sqrt{(29-5.8)^2}}{5} = 4.64$$

- Finding the Z-Score value (Zi)

$$Zi = \frac{Xi - \bar{X}}{s} = \frac{29-5.8}{4.64} = 5$$

2) Cumulative Summary (Cussum)

The Cussum calculations are explained as follows:

Segment I

- Finding the mean value (W)

$$W = \frac{\sum xi}{L\,x\,T} = \frac{10}{2\,x\,5} = 1$$

- Finding the cumulative summmary value of the first year's accidents (S_0)

$$S_0 = (X_1 - W) = (17 - 1) = 16$$

- Finding the accident value for the following year (S_1)

$$S1 = \{ S_0 + (X1 - W) \} = \{ 16 + (17 - 1) = 16 + 16 = 32$$

Segment II

- Finding the mean value (W)

$$W = \frac{\sum xi}{L\,x\,T} = \frac{29}{2\,x\,5} = 2.9$$

- Finding the cumulative summary value of the first year accident (S_0)

$$S_0 = (X_1 - W) = (17 - 2.9) = 14.1$$

- Finding the accident value for the following year (S_1)

$$S_1 = \{ S_0 + (X1 - W) \} = \{ 14.1 + (17 - 2.9) = 28.2$$

The Z-score value for segment I is 3.1, while for segment II is 5. Furthermore, the cusum value for

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segment I is 32.2, while for segment II is 28.2. Based on the accident-prone classification table, Kolonel Sugiono Street is an accident-prone area because it has a Z-Score and Cusum value more than 0 or positive. The accident-prone areas and points are in segment II because it has a higher value than segment I. In this case, Sawahan Block and Gadang VIII Block become the blackspot. Based on the accident data of 2017-2021, segment II has a higher accident rate of 29, while segment I has 10. The results of this analysis are in accordance with the results of the previous research [11] [8].

Accident Cause Indicator

The following table shows indicators of accident causes, namely:

Table 9. Indicators for the causes of accidents based on the Pdt Road Safety Audit [12]

No	Checklist		Condition
1	General condition	Kerb	No kerbs and separators
		Landscape	The trees are quite disturbing view, especially for tall vehicles
2	Road alignment	Plan Speed	Lack of warning signs and speed limit signs
		Leading lane	The lane width is 3m and the standard lane width is 3.5m where the lane width is quite narrow for vehicles with a width of >2.5m. And cross paths with other large vehicles.
		Roadside	The roadside width of the road is 1 m and can only be passed by pedestrians and motorbikes.
3	Intersection	Warning sign	There are no warning signs to reduce speed for drivers
		Intersection marks	No intersection marks persimpangan
4	Additional lanes/lanes for turning Direction	Lane width	Lane width is not wide enough to turn around
		Sign	There are no road signs and markings, the placement is not according to standards, and there are no warning signs when approaching intersection
5	Non-motorized traffic	Crossing track	No lanes available or adequate for pedestrians
		Safety fence	No safety fences or crash barriers are available
		Bike lane	No lanes for bicycles
6	Vehicle/Bus Stop	Bus Bay	No bus stop available, so the roadside is often used as a bus stop parking lot
		Vehicle Parking Lot	No vehicle parking space. Vehicles often park on the road sections such as roadside and even road bodies
7	Road auxiliary building	collision barrier	No Crash Barrier
8	Road signs and markings	Sign	Some signs that are less effective and do not yet exist (complete)
		Mark	Road pavement has been installed with markings but at some point, it has faded, and is not visible

In general, accidents often occur as a result of several factors, namely vehicle factors, environmental factors, and human or driver factors. However, other factors such as road signs, complementary facilities, and conditions also greatly influence the technical standards of roadworthiness.

Solutions to Improve Road Safety

Solutions to improve road safety based on the results of the Road Safety Audit survey [12] is by paying attention to the Road Safety Audit and RUNK LLAJ [13].

Segment I

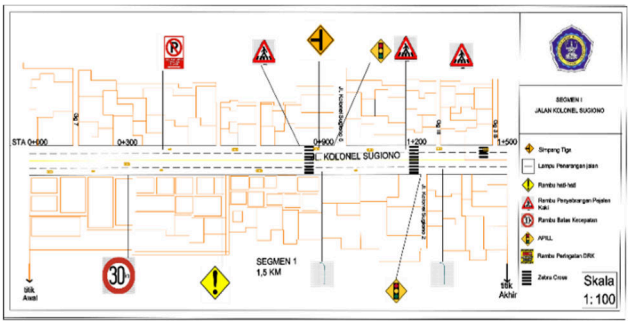

Figure 5. Layout of proposed solutions to improve road safety for segment I

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Segmen II

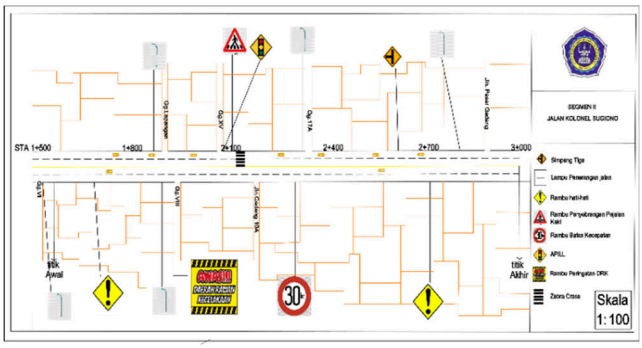

Figure 6. Layout for improving road safety on segment II of Kolonel Sugiono Street

Solutions and efforts to improve road safety to reduce the number of accidents based on the survey results that has been conducted on Colonel Sugiono's road Malang City to improve the road safety in segments I and II are as follows:

1) Repairing and installing the public street lighting so that the road users can clearly see the street conditions at night. Based on SNI 7391:2008, the minimum distance between the lamp poles is 30 m [14].
2) Installing warning signs for Accident-Prone Area at Sta 1+800-2+100 so that road users and motorists can be careful and aware of the surrounding conditions and can reduce vehicle speed.
3) Installing caution signs such as the Safe Zone at Sta 2+100 in segment I and at Sta 1+500 in segment II to control traffic activities by regulating speed by placing markings and signs around the school environment (such as zig-zag markings, Zebra Cross, as well as signs such as caution signs and crossing signs) as explained before [15].
4) Installing warning signs (speed limit) so motorists can be more careful when driving. As stated in the regulations of the Minister of Transportation, the installation of signs is at a minimum distance of 50 m before the crossing or hazardous area.
5) Installing warning signs at an intersection before entering the intersection so that drivers can be more careful, reduce speed and find out the situation ahead, namely 50 m before the intersection as explained in the previous studies [15] [16].
6) Installing the warning sign at accident-prone area at sta 1+800-2+100 so that road users and motorists can be careful and aware of their surroundings and can reduce vehicle speed.
7) In addition to the proposed alternative solutions to improve the road safety on Kolonel Sugiono Street, a rowdy tape needs to be installed at a distance of 50 m from the intersection in order to regulate the vehicle speed [17]. Adding or installing special lanes for bicycles or other slow vehicles in order to increase traffic performance faster as described in the Ministerial Regulation [18] is also necessary whereas secondary arterial roads are roads with fast traffic that cannot be disturbed by slow vehicles and are equipped with sidewalks to improve road safety, especially for pedestrians.
8) Additional infrastructure on Kolonel Sugiono Street by fulfilling the number of Traffic Signaling Equipment, Signs, Public Street Lighting, and Monitoring Equipment which is less than the number required on Kolonel Sugiono Street.
9) Carrying out road widening and adding sidewalks so as to reduce the degree of saturation in accordance with applicable rules and regulations

4. CONCLUSION

1) The traffic characteristics of the Kolonel Sugiono Street show that it has high traffic volume and flow, high side barriers, and high road capacity value with an E level of service.
2) Kolonel Sugiono Street is identified as an accident-prone are seen from the road segment which has a Z-Score value of 8 in segment I and 5 in segment II, where it is positive > 0. Meanwhile, the Cusum value in segment I is 32 and 28.2 in segment II, which is positive and > 0. Based on the classification, it states that if the Z-Score and Cusum values are positive or > 0, then it is identified as accident-prone area.
3) Solutions in an effort to reduce accidents and to improve road safety, are:
   - improving and installing adequate traffic signs, Traffic Signaling Equipment, Monitoring Equipment and Public Street Lighting that are accessible to road users and users in order to improve road safety.
   - Carrying out repairs and adding additional road facilities so that traffic conditions remain stable and to improve road safety and minimize accidents.
   - Carrying out periodic and scheduled checks, inspections and monitoring at locations or points that have the potential for frequent accidents.

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5. RECOMMENDATION

Based on the results of the analysis carried out on the Kolonel Sugiono street, the suggestions that can be given are:

1) The need to carry out repairs and checks both on the geometric conditions of the road, on infrastructure, facilities and road complementary buildings so that problems that exist on the road can be minimized.
2) Installing warning signs (accident prone) in areas and points indicated as accident prone.
3) Conducting socialization and counseling from authorized parties such as the transportation service to the community as road users and users so that they are always obedient and careful to the regulations for the sake of comfort and safety for fellow road users and users.
4) Giving directions and repairs on the street so that the authorities can carry out planning according to the road safety.

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