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Spatial Analysis of Accident Rates to Determine Accident-Prone Areas on the Waena–Sentani Road, Jayapura Regency

Erwin
Jurusan Teknik Sipil Fakultas Teknik, Universitas Cenderawasih and tandekerwin@gmail.com

ABSTRACT

The number of traffic accidents in Indonesia is still relatively high, based on data from the Jayapura Regency Traffic Unit, the number of traffic accidents in Jayapura Regency from 2017 to 2019 was 360 incidents. Jayapura Regency which is one of the regencies in Papua Province that is directly related to Jayapura City which continues to experience economic growth and population growth of 2.50% per year (BPS. Jayapura Regency in figures, 2020), thus causing quite high population activity and mobility. The method used in determining blacksite and blackspot areas is the Equivalent Accident Number method, Upper Control Limit and Upper Control Limit to determine the location of the blacksite and the Cumulative Summery (Cusum) method to determine the location of blackspots on Jalan Raya Waena Sentani. Accident-prone areas on the Waena-Sentani Road are located in areas one and area four. Region one with an Accident Number Equivalent value of 155, an Upper Control Limit value of 143.5, and an Upper Control Limit value of 144. Region four with an Accident Number Equivalent value of 155, an Upper Control Limit value of 144.2, and an Upper Control Limit value of 153. with the highest cusum value at location one of 2.56 and location two of 3.34.

***Keywords*:** *Accident Characteristics, Black Site, Black Spot, Upper Control Limit, Jayapura Regency*

1. INTRODUCTION

One of the leading causes of death in Indonesia. The large and increasing number of victims will have significant economic (material losses) and social impacts. The number of traffic accidents in Indonesia remains relatively high. According to data from the Jayapura Regency Traffic Unit, there were 360 traffic accidents in Jayapura Regency from 2017 to 2019 [1].

In general, highways are a route used by people to go to other places, whether to the office, shopping and out of town or out of the region and so on [2], [3]. However, over time, what often happens on highways is traffic accidents resulting in a traffic problem and requiring serious handling considering the very large losses, in the form of injuries to fatalities, as well as material losses. There are three 3 (three) parts that are interconnected and are important factors in traffic operations, namely: drivers, vehicles, and highways. Accident data from Jasa Marga from year to year shows that the biggest cause of accidents is caused by human factors (drivers) [4], [5].

Jayapura Regency, one of the regencies in Papua Province directly connected to Jayapura City, continues to experience economic growth and population growth of 2.50% per, resulting in high levels of activity and population mobility. The increasing traffic flow will indirectly increase the risk of traffic problems, such as congestion and accidents, which will impact the decline in road service performance. The Waena-Sentani Road is one of the roads that connects with high traffic volume and speed, this causes frequent accidents along this road section.

2. LITERATURE REVIEW

According to Law No. 38 of 2004, roads are land transportation infrastructure that includes all parts of the road, including complementary buildings and equipment intended for traffic, which are on the surface of the land, above the surface of the land, below the

surface of the land and water, and above the surface of the water, except for railways, highways and cable roads.

According to Article 1 of the Republic of Indonesia Law No. 22 of 2009, a traffic accident is an unexpected and unintentional incident on the highway involving vehicles with or without other road users which results in human casualties and/or property losses.

According to Article 93 of Government Regulation No. 43 of 1993 concerning Road Infrastructure and Traffic, as an implementing regulation of the Road Traffic and Transportation Law, accident victims are classified as follows:

Fatal Injury or Death Accidents Fatal or death victims are victims who are confirmed to have died as a result of a traffic accident within a maximum of 30 days after the accident.

Serious Injury Accidents Serious injury victims are victims whose injuries result in permanent disability or require hospitalization for more than 30 days after the accident. Permanent disability refers to the loss of a limb or the loss of its use and the permanent disability of a limb.

Minor Injury Accidents Minor injury victims are those who have suffered injuries that are not life-threatening and/or do not require further assistance or treatment at the hospital [6].

[7] stated that traffic control devices can be in the form of markings, traffic signs, control lights and signs placed outside the road, at the side of the road or hanging above the road to increase the safety of road users.

2.1 Accident Rate

Accident rates are typically used to measure the level of accidents on a single road section. Many accident rate indicators are used [8], namely:

The number of traffic accidents per km is the number of accidents per km using the formula in [9] which is:

$$R=A/L$$

Where:

R = Total accident rate per km per year

A = Total number of accidents that occur each year

L = Length of the controlled road section in km

2.2 Ranking by Calculation (Equivalent Accident Number)

Weighting using the Equivalent Accident Number (EAN) value is a ranking with weighting using accident cost conversion, based on the characteristics of each accident. The number of human victims is divided into deaths, serious injuries, and minor injuries. The following is the formula used to find

$$M : LB : LR : K = 12 : 3 : 3 : 1$$

$$EAN = 12MD + 3 (LB+LR)$$

Where:

MD = Death toll (people)

LB = Number of seriously injured victims (people)

LR = Number of victims with minor injuries (people)

K = Number of traffic accidents with material losses

Meanwhile, the control limit values, namely the Upper Control Limit (BKA) & Upper Control Limit (UCL) according to the Department of Settlement and Regional Infrastructure, (2004), can use the following formula:

1. Upper Control Limit (UCL) Method
   $BKA = C + 3\sqrt{c}$

Where:

C = Average number of accidents (EAN)

2. Upper Control Limit (UCL) Method
3. $UCL=\lambda+ \psi \times \sqrt{(\lfloor(\lambda/m)+(0.829/m)+(1/2\ m)\rfloor)}$

Where :

λ = Average accidents in units of accidents per exposure

m = Exposure Unit, in kilometers

In the UCL (Upper Control Limit), road segments with accident rates above the UCL line are defined as accident-prone locations (Department of Settlement and Regional Infrastructure, 2004).

2.3 Cumulative Summery (Cussum)

Cusum is a procedure that can be used to identify blackspots. A cusum graph is a standard statistical procedure as a quality control to detect changes from the mean value. The cusum value can be found using the following formula.

Finding the Mean Value (W)

The calculation to find the mean value of secondary data is as follows:

$W = (\sum xi)/(L \times T)$

Where:

W = Mean Value of Number of Accidents

L = Number of Stations

T = Time / period

$S1=Xi-w$

Where :

S1 = First year of Cussum

Xi = Number of accidents per section in the first year

$S2=(S1+(Xi-w)$

Where:

S1 = First year Cussum

S2 = Second year Cussum

Xi = Number of accidents per section in the first year

$S3=(S2+(X3-w)$

Where:

S2 = Second year Cussum

S3 = Third year Cussum

W = Number of accidents in the third year

3. METHODS

3.1 LocationStudy

The location where the research was reviewed was approximately 12 km away. The location is the Waena-Sentani road section which is located in the Jayapura city and Jayapura district areas, Papua, because traffic accidents often occur in this area.

Field observations are conducted to obtain a more detailed picture of road conditions, vehicle volumes, and traffic behavior. This information is used to support data analysis, particularly to provide an overview of accident-prone areas.

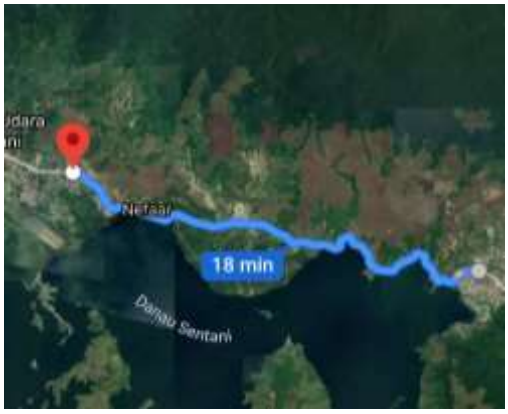

Figure 1. Research Location
Source: Google Earth

3.2 Method of collecting data

In this section, we will describe everything that is part of the problem-solving process and the research analysis methods used to discuss the main problem. We will also explain how to obtain the data that will be used in the calculations. In analyzing the review of the causes of traffic accidents at the research location, supporting data is needed, namely primary data and secondary data obtained directly from the field and from related agencies, including from interviews. Interviews were conducted directly with the East Sentani Police and residents around the research location.

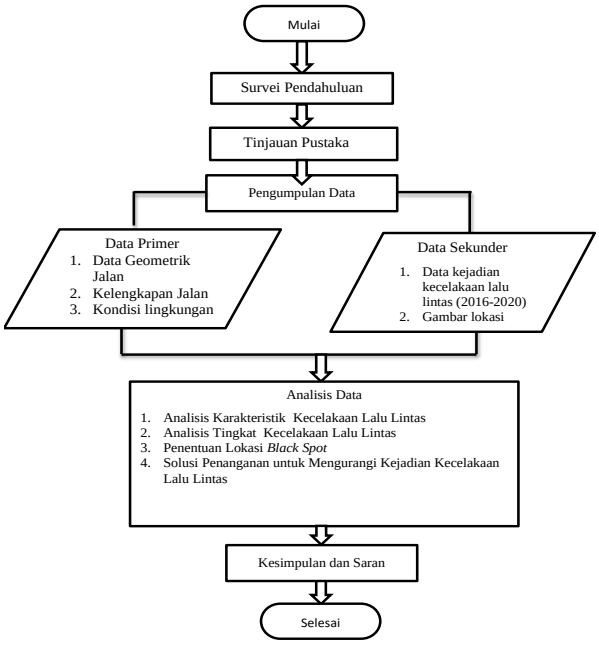

Figure 2. Flow Chart

3.3 Data Analysis Methods

The accident data analysis method was carried out by analyzing the involvement of the most dominant vehicle types involved in accidents on the Waena-Sentani road section with overall road control. The analysis of the characteristics of accidents that occurred on the Waena-Sentani Highway, such as the gender of the victim, the type of accident, the location of the accident, and other data available from secondary data obtained from the Jayapura Police. The data processing process can be explained through the following stages:

1) Stage 1

This stage involves several activities:

a. Divide the research location into four accident-prone areas based on accident data identification.
b. Calculate the number of accidents, number of fatalities, serious injuries, minor injuries, for each segment for each year.

2) Stage 2:

The weighting of the accident equivalent number, in this study, used the weighting based on the Research and Development Agency of the Department of Settlement and Regional Infrastructure, namely 12 MD: 3 LB: 3 LR. The weighting is carried out for each region and each year to obtain the EAN value for each segment and each year.

3) Stage 3: BKA Calculation

a. Calculate the EAN value for each accident-prone area over a period of 3 consecutive years.
b. Adding up the EAN values of all accident-prone areas,
c. Calculate C (average EAN value), namely by dividing the total EAN value by the number of accident-prone areas.
d. Calculating BKA

4) Step 3: UCL Calculation

a. Calculate the EAN value for each accident-prone area
b. Adding up the EAN values of all accident-prone areas
c. Calculate (the average value of traffic accidents).
d. Calculate the UCL value, with the probability factor value used = 2.576.

5) Stage 4: Determination of Blacksite and Blackspot

In both the BKA and UCL methods, blacksite locations are defined as accident-prone areas with an EAN value exceeding the BKA or UCL value for that segment. Blackspots are determined based on accident-prone areas, which are blacksites, using the Cussum method to identify locations with the highest accident frequency. To determine blackspots, each accident-prone area is identified with the highest number of accidents.

4. RESULTS AND DISCUSSION

Figure 3. Research Location Station
Source: Google Earth

4.1 Division of Road Accident Prone Areas

The road to be analyzed and discussed in this study is the Waena-Sentani Highway in Jayapura Regency, a 12-kilometer road that starts at the Jayapura Regency-Jayapura City border monument and ends at the East Sentani-Sentani border. There are four accident-prone areas along the Waena-Sentani road.

The division of accident-prone areas into four parts is based on initial identification of accident data from the Jayapura Police which tends to occur in four different locations for three consecutive years. Area one starts from STA 00+000 to STA 03+000, area two starts from STA 03+000 to STA 06+000, area three starts from STA 06+000 to STA 09+000 and area four starts from STA 09+000 to STA 12+000.

4.2 Accident Characteristics

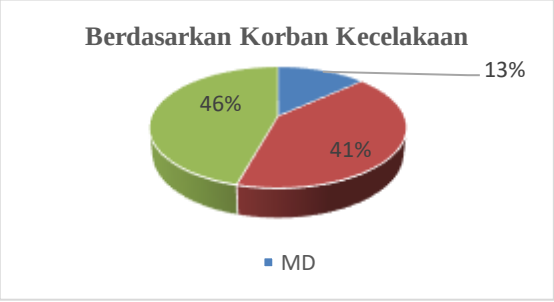

Figure 4. Accident Characteristics Based on Victims

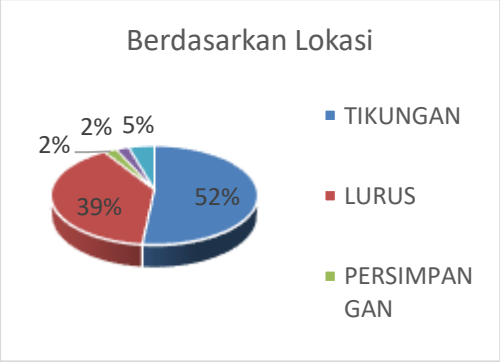

Figure 5. Accident Characteristics Based on Location

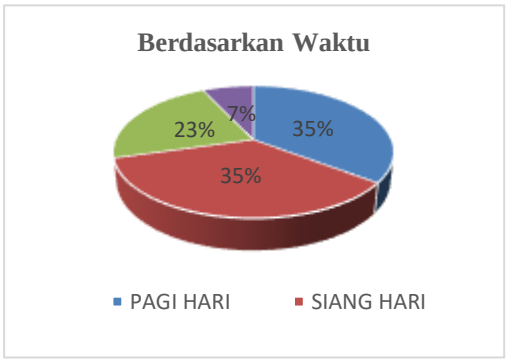

Figure 6. Accident Characteristics Based on Time

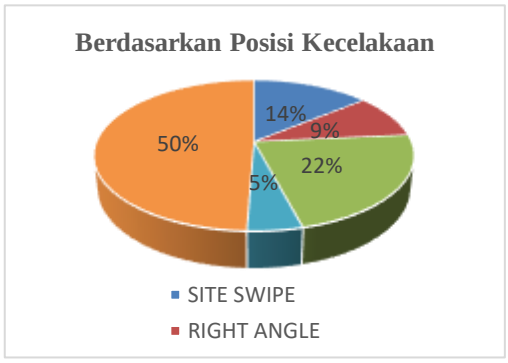

Figure 7. Accident Characteristics Based on Position

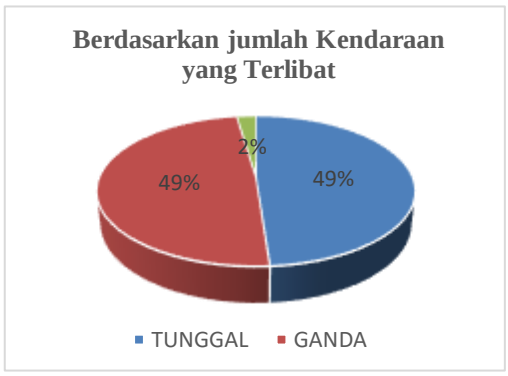

Figure 8. Accident Characteristics Based on Number of Vehicles

4.3 Accident Rate

The accident rate is calculated for each region over a period of one year.

Table 1. Recapitulation of Accident Rates

No	Lokasi	Tahun			Rata-rata
		2018	2019	2020	
1	Daerah 1	2.3	3	2	2.4
2	Daerah 2	1.7	2.7	2.3	2.2
3	Daerah 3	2	2.3	2	2.1
4	Daerah 4	2	4	2	2.7

4.4 Analysis of Accident-Prone Areas (Black Sites)

1. Equivalent Accident Number (EAN) Calculation

The Equivalent Accident Number (EAN) calculation is calculated by adding up the number of accidents in an accident-prone area and then weighting them according to their severity.

The weighting value for each level of severity is 12 for death (MD), 3 for serious injury (LB), 3 for minor injury (LR).

M : LB : LR : K = 12 : 3 : 3 :1
EAN = 12 MD + 3 (LB + LR) + 1 K

Table 2. Recapitulation of EAN Values

Location	EAN
Region 1	144
Area 2	126
Area 3	63
Region 4	153

2. Upper Control Limit (UCL)

$$C = \frac{Angka\ Kecelakaan}{Jumlah\ Daerah\ Rawan\ Kecelakaan}$$
$$= \frac{486}{4}$$
$$= 121.5$$

So the average value of C is 121.5, then the Upper Control Limit value can be calculated as follows:

BKA = C + 3C√
= 121.5 + 3√121,5
= 154.56
= 155

3. Upper Control Limit (UCL)

In determining accident-prone areas, the Upper Control Limit (UCL) method is used, which is based on road areas where the Equivalent Accident Number (EAN) value exceeds the Upper Control Limit value.

$$UCL = \lambda + \psi \times \sqrt{\left[\left(\frac{\lambda}{m}\right) + \left(\frac{0.829}{m}\right) + \left(\frac{1}{2}m\right)\right]}$$

Table 3. Recapitulation of BKA, UCL and EAN values

No	LOKASI	BKA	UCL	EAN	Ket.
1	Daerah 1	155	143.5	144	Rawan Kecelakaan
2	Daerah 2	155	142.1	126	Tidak Rawan
3	Daerah 3	155	136.4	63	Tidak Rawan
4	Daerah 4	155	144.2	153	Rawan Kecelakaan

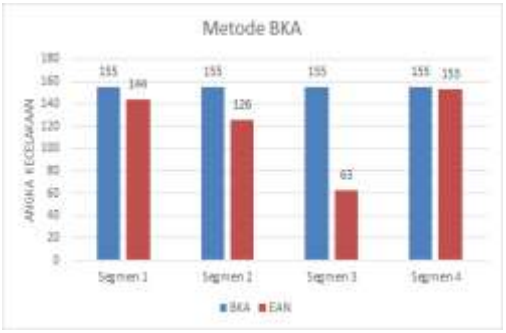

Figure 9. Determination of Black Site Using the BKA Method

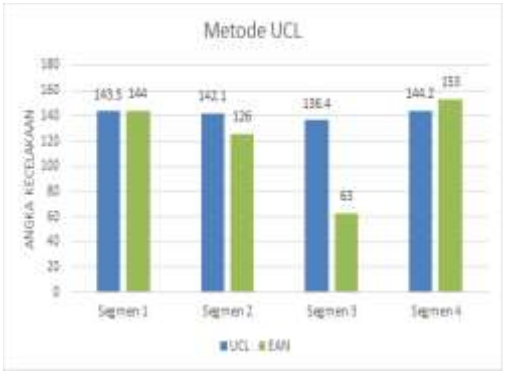

Figure 10. Determination of Black Site Using the UCL Method

4.5 Black Spot Determination

By using the cumulative Summery (Cusum) calculation, the first step is to calculate the mean value by inputting data on the number of accidents.($\sum xi$)divided by the number of accident-prone points multiplied by the observation period (T) in years. The location of the Black Spot is determined from areas identified as Accident-Prone Areas (Black Sites), namely areas one and four, each accident-prone area is further divided into several locations based on the frequency of the number of accidents.

Table 4. Cussum Values for Each Location

Daerah	STA	Tahun		
		2018	2019	2020
Satu	STA 00+000 – STA 01+000	0.56	1.56	2.56
	STA 01+000 - STA02+000	-1.44	-0.44	-2.44
	STA 02+000 - STA 03+000	0.56	0.56	-1.44
Empat	STA 09+000 - STA 10+000	0.34	1.34	1.34
	STA 10+000 - STA 11+000	1.34	3.34	-0.66
	STA 11+000 - STA 12 +000	-2.66	0.66	-2.66

Figure 11.Blackspot Graph of Region One

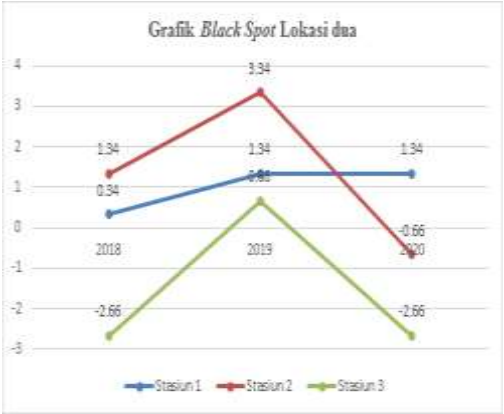

Figure 12.Blackspot Graphics Area Two

Table 5.Alternative Accident Solutions

NO	Penyebab Kecelakaan	Alternatif solusi
1	Mendahului (Menyalip)	· Pemasangan Marka Jalan
		· Pemasangan Rambu Peringatan
		· Perbaikan Bahu dan Badan jalan
		· Penyesuaian Lebar Lajur
		· Penerangan Jalan
2	Malam hari (Gelap)	· Pemsangan Rambu-rambu yang memantulkan cahaya
3	Selip/licin	· Perbaikan tekstur permukaan jalan
		· Perbaikan Bahu dan Badan jalan
		· Melakukan Penjagaan oleh pihak berwenang
4	Kecepatan Tinggi	· Pemasangan rambu rambu peringatan
		· Perbaikan Bahu dan Badan jalan
5	Kehilangan Kontrol	· Marka Jalan
		· Pengendalian Kecepatan
		· Perbaikan Bahu dan Badan jalan

CONCLUSION

Based on the results of data analysis and processing, the following conclusions can be drawn:

1. For the characteristics of accidents that occurred on the Waena-Sentani road section, based on the accident victims, the most victims were slightly injured with a percentage of 46%, based on the location of the accident, the most occurred on bends with a percentage of 52%, based on the time of occurrence, the most accidents occurred in the morning and afternoon with a percentage of 35%, based on the position of the accident, the most were out of control with a percentage of 50% and based on the number of vehicles involved, the majority were single and double accidents with a percentage of 49% each.
2. The rate of traffic accidents that occurred on the Waena-Sentani road section from 2018, 2019 and 2020 had the highest average accident rate occurring in area 4 at 2.7 accidents per kilometer, then area 1 with an average accident rate of 2.4 accidents per kilometer.
3. Accident prone areas (Black Site) on the Waena-Sentani road section are located in areas one and four. Segment one with an Equivalent Accident Number value of 155, an Upper Control Limit value of 143.5, and an Upper Control Limit value of 144. Segment four with an Equivalent Accident Number value of 155, an Upper Control Limit value of 144.2, and an Upper Control Limit value of 153. Accident prone points (Black Spot) in the accident prone areas (Black Site) are at STA 00+000 - STA 01+000 in area one and

STA 10+000 - STA 11+000 in area four with the highest cussum value at STA 00+000 - STA 01+000 of 2.56 and at STA 10+000 - STA 11+000 of 3.34.

4. Alternatives in efforts to handle accident-prone locations (Black Spots) on the Waena-Sentani road section that can be done by completing traffic signs such as maximum vehicle speed limits, accident-prone area signs, improving road markings, adding or repairing road shoulders that are not yet there or are already damaged, especially in accident-prone areas, and providing information about traffic safety to the public. For alternative solutions to accidents in the morning and afternoon which are times when traffic volumes are quite high and accidents most often occur, it is necessary to carry out security by the authorities in certain places so that road users can be more orderly in traffic. For bend areas which are the points with the most accidents, geometric improvements and installation of traffic signs such as maximum speed limits.

SUGGESTION

After conducting various analyses on the Traffic Accident Level Analysis research on the Waena-Sentani road section, the author can provide several suggestions:

1. The limitation of the data used by the author is that it only uses 3 years of data, for greater accuracy it is better to use the last 5 years of data.
2. For further research, it is necessary to review the road geometry in more depth, especially in accident-prone areas.
3. For accident-prone areas, traffic accident-prone area signs need to be installed, especially in accident-prone areas such as bends and guarded by authorities in the morning when traffic volume is quite high.

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