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Geographic Information Systems (GIS)-Based Visualization for Black Spot Identification on Karanganyar–Matesih Road

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ABSTRACT

The relatively busy traffic movement on Jalan Karanganyar-Matesih causes various transportation problems, including increasing accidents. This study aims to analyze the characteristics of accidents, factors causing accidents, and accident-prone locations (black spots) in Jalan Karanganyar-Matesih which are visualized using A Geographic Information System (GIS). This study uses primary data (road geometric data) and secondary data (data on accident characteristics and factors causing accidents). Black spots can be analyzed and identified by using the Accident Equivalent Number (AEK) and the Upper Control Limit (UCL) method. The results of this study are the type of collision in accidents that often occur on Jalan Karanganyar-Matesih is front-side as many as 72 (42%) incidents, the class of victims with the highest number is minor injuries with a total of 191 (73%) people, the gender and age of drivers who are often involved are male, namely 241 (82%) people, the age of the majority of drivers is 18-30 as many as 128 (43%) people, the type of vehicle that is often involved in accidents is a motorcycle with a total of 272 (92%) vehicles, and the time of the accident often occurs during the day (12.00-18.00) with a total of 61 (37%) incidents. The main factor causing accidents on Karanganyar-Matesih Road is human negligence which totals 154 (94%) incidents. The results of the calculation methods obtained 7 segment locations of black spoy. These findings, visualized using a Geographic Information System (GIS), support data-driven decision-making for planning and implementing accident risk mitigation measures along the road.

Keywords: accident characteristics; black spots; accident equivalent number (AEK); upper control limit (UCL); traffic.

INTRODUCTION

Transportation plays a very important role in driving the development of a region. The movement of people and things must comply with the safety principles that have been regulated in [1]. The safety aspect must be the main focus that needs to be considered. The level of traffic accidents on a road section is the main parameter in assessing the level of safety on that route. The impact of accidents not only results in a significant number of victims but also has an impact on material losses and social impacts that are important [2]. Safety is the main priority in organizing transportation. These principles are often not in line with practices in Indonesia. This can be seen from the increasing number of deaths and accident victims [3].

The World Health Organization (WHO) estimates that by 2030 road traffic accidents will be the seventh leading cause of death globally, with the number of deaths tripling to 3.6 million each year [4]. Losses due to road accidents not only result in loss of life but also result in physical and emotional suffering, as well as significant financial losses [5]. Therefore, analysis of the factors causing accidents is important to be able to develop strategies to reduce the number and fatality rate of these accidents.

The Central Statistics Agency noted that the number of fatalities due to traffic accidents in Indonesia increased in 2020 - 2021 from 23,529 to 25,266 people, which means that 3 to 4 people die every hour due to traffic accidents [6]. The large number of victims will impact the economy (material losses) and society, although many prevention efforts to improve traffic have involved many related parties, the results have not been as expected [7].

Traffic accidents are caused by several factors according to Law Number 22/2009, namely 1) Human factors, including driver behavior such as being careless, sleepy, drunk, disorderly, and unskilled, which contribute to almost 95% of accidents; 2) Pedestrian factors, such as crossing in the wrong place, using a cellphone while crossing, walking in a row, and crossing suddenly; 3) Vehicle factors, including technical problems such as flat tires, brake failure, engine problems, and overloading; 4) Road factors, such as damaged road conditions, ineffective road equipment, and lack of maintenance; and 5) Environmental factors, including climate change, weather, and day and night changes that affect driver visibility [1], [8].

Karanganyar-Matesih Road is geographically part of Karanganyar Regency. The road is a two-lane, two-way road with a length of 10.8 km and several public facilities and shops. The road is the main route for Matesih residents to Karanganyar Regency and an alternative route to the Tawangmangu tourist spot, so so traffic movement on the road is quite high year-to-year and continues to increase. This introduces the need to address potential challenges, such as congestion, road safety concerns, and the strain on existing infrastructure. Traffic accidents on Karanganyar-Matesih Road are increasingly unavoidable and have become one of the roads known to the public as a deadly route because there are often fatalities due to traffic accidents on the road. In 2022, several cases of accidents with high fatalities have occurred as reported by Solopos.com on Sunday, 11th July 2022 at 13:19 WIB, and Kompas.com, an accident that occurred on Sunday, 6th February 2022 at 14:47 WIB [9], [10].

The number of traffic accidents from 2021-2023 on Karanganyar-Matesih Road can be seen in Table 1.

Table 1. Number of accidents (Karanganyar Police Traffic Accident Data, 2021-2023)

Year	**Number of accidents**	
	Number	**Percentage (%)**
2021	43	26%
2022	45	27%
2023	78	47%
Total	**166**	**100%**

From the data in Table 1, it can be seen that the number of fatalities shows an increasing trend from year to year. In 2021, it was recorded at 43 (26%), then this figure rose to 45 (27%) in 2022. Furthermore, in 2023, there was a significant increase in the number of traffic accidents on Jalan Karanganyar-Matesih reaching 78 (47%). The total number of traffic accidents that occurred during the 3 years was 166 accidents.

Geographic Information System (GIS) can provide information to the public about accident-prone areas in the area which functions as an early warning system. By knowing the accident-prone locations, road users are expected to be more careful, thereby reducing the number of accidents. GIS, as a computer-based system, can present data in the form of digital maps, manipulate geographic spatial data, and support learning the concept of location and space. In addition, GIS can handle geographic data, including input, data management, analysis, and output [11].

Geographical Information System (GIS) is an important tool in mapping and analyzing traffic accident rates to determine accident-prone areas. Isvarulita (2019) research which analyzed Balikpapan City using GIS identified 9 accident-prone points and determined the fastest route to the nearest hospital [12]. Yaqin's (2019) research using the Waterfall method produced a GIS that maps accident-prone areas using GPS and Google Maps, helping to manage accident data accurately in Mojokerto [13]. Fadli et al (2020) research, a web-based GIS was created to map accident-prone locations, helping to reduce accidents by providing early warnings [11]. In addition, Saputro (2022) research used a quantitative method with Z-Score to determine blacklinks and Cussum for blackspots, mapping 5 national roads in Sleman Regency as blacklinks and marking the highest blackspot points. Accident data and road attributes are integrated into a web-based ArcGIS application to provide information on accident-prone locations online [14].

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The following are several studies related to the identification and analysis of traffic accident-prone areas (black spots) in different locations. Nisumanti (2018) studied in Palembang, identifying the severity of victims and types of vehicles, with motorcycles as the dominant vehicle and high severity in several segment. Albusin et al. (2019) analyzed the Kalimantan Road section and found that the STA 01+000-04+400 segment was the main accident-prone point, caused by driver factors [15]. Adawiyah (2021) found 5 accident-prone points on Jalan Ahmad Yani using the AEK and UCL methods [16]. Setiyaningsih (2020) used the BAK and UCL methods to determine 8 to 11 black-site locations on Jalan Jogja-Solo, with accidents dominant at intersections [2]. Qubro et al.'s research. (2022) identified 14 accident-prone points on the Palembang-Indralaya Road, with motorcycles as the most frequently involved vehicle in accidents [17]. These studies used a variety of methods to identify accident-prone points and analyze the factors contributing to accidents. The findings from each study provide valuable insights into the characteristics of accidents and the efforts needed to improve traffic safety on these roads.

This study has significant novelty in combining blackspot analysis through Geographic Information System (GIS) based visualization as an effort to reduce the fatality rate of accidents. Previous studies have identified accident-prone points and analyzed factors that contribute to accidents, but this study contributes with a more detailed GIS visualization approach and can provide a deeper understanding of the characteristics of accident-prone areas. By using GIS, this study can provide more accurate mapping and more appropriate solutions in identifying and reducing the fatality rate of accidents in the blackspots studied. This study aims to analyze the characteristics of accidents, factors causing accidents, and accident-prone locations (black spots) in Jalan Karanganyar-Matesih which are visualized using A Geographic Information System (GIS).

RESEARCH METHODS

This research was conducted on Jl. Karanganyar-Matesih KM 0+00 to KM 10+800 is located in Karanganyar Regency, Central Java Province (Figure 1). The data that can be used to conduct this research is historical data on accidents that occurred during a period of 3 (three) years from 2021-2023.

This study uses secondary data from the Karanganyar Police Traffic Unit and primary data in the form of road geometric data to document the location conditions of accident-prone areas. Secondary data includes the number of accident victims, time of accident, type of vehicle, age and gender of victims, type of collision position, and factors causing the accident. Road segments are divided based on the guidelines of the Directorate General of Land Transportation, 2007 into the length of 300 m. An analysis of the Accident Equivalent Number (AEK) and Upper Control Limit (UCL) values is carried out to determine the location of black spots on the road section.

The fatality rate of traffic accident victims is grouped into 3, namely: death (MD), serious injury (LB), and minor injury (LR). Data analysis was carried out using the 5W + 1H approach, namely Where (where the accident occurred), When (when the accident occurred), Why (what caused the accident), Who (who was involved), What (what type of collision), How (vehicle movement) [18].

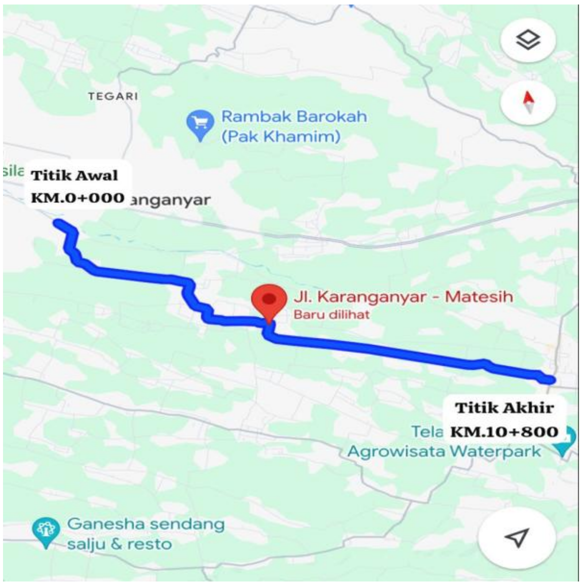

Figure 1. Research location on Karanganyar-Matesih Road (Source: https://maps.google.com/)

Accident Equivalent Number (AEK)

The Accident Equivalent Number (AEK) is used to analyze the highest accident rate or the number for weighting accident classes. The weighting of this study uses guidelines from the Department of Settlement and Regional Infrastructure (2004) which can be seen in equation (1) as follows:

$$\mathbf{MD: LB: LR: K = 12: 3: 3: 1} \quad (1)$$

Meanwhile, the AEK value can be calculated using equation (2) as follows:

$$\mathbf{AEK = 12\ MD + 3\ (LB + LR) + K} \quad (2)$$

Where MD is the number of fatalities, LB is the number of seriously injured victims, LR is the number of lightly injured victims, and K is an accident that only causes material losses.

Upper Control Limit (UCL)

According to the Research and Development Agency of the Department of Settlement and Regional Infrastructure (2004), determining accident-prone locations is done by considering the number of accidents per kilometer of road that have a weight value above a certain limit, which is calculated using the Upper Control Limit (UCL) method. Road segments that have an accident rate above the UCL are identified as accident-prone locations, where the UCL acts as a control limit to determine whether a location can be declared accident-prone based on the number of accidents that exceed the UCL value. Analysis of calculations using the UCL method can be determined using equation (3) as follows:

$$UCL = \lambda + \Psi + \sqrt{[\left(\frac{\lambda}{m}\right) + \left(\left(\frac{0,829}{m}\right) + \left(\frac{1}{2} \times m\right)\right)]} \quad (3)$$

Where UCL is the upper limit control line, λ indicates the average accident rate in units of accidents per exposure or the average number of accidents (AEK), ψ is the probability factor (valued at 2.576), and m is the number of accidents on the section being analyzed (AEK). The formula for UCL is designed to establish a threshold for accident rates. If the number of accidents in a given section of the road (m) exceeds the calculated UCL, it suggests that the accident rate in that section is unusually high, and the area is considered a black spot. The Probability Factor (ψ) cannot be considered a random event so that the probability factor value used is 2.576 with a 99% confidence level in accordance with the guidelines of the Department of Settlement and Regional Infrastructure (2004).

Geographical Information System (GIS)

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The research method using Geographic Information Systems (GIS) involves four main stages, namely data collection from various sources (spatial and non-spatial), data entry into GIS software through digitization or format conversion, data processing and modeling for spatial analysis or simulation, and visualization of results in the form of thematic maps, graphs, or reports that facilitate interpretation and decision making.

RESULT AND DISCUSSION

Traffic Accident Characteristics

Analysis of the characteristics of locations prone to traffic accidents on Jalan Karanganyar-Matesih was carried out using data for three years, namely 2021-2023. Traffic accident data was obtained from the Karanganyar Police Traffic Unit. The characteristics of the accidents analyzed include the type of collision, class of victims, gender and age of the driver, type of vehicle, and time of the accident.

Accident characteristics based on collision type

Table 2 below groups the number of accidents based on the type of collision that occurred on the Karanganyar-Matesih Road in 2021-2023.

Table 2. Accidents by collision type

Collision Type	Year			Total	Percentage (%)
	2021	2022	2023		
Front-Back	4	7	6	17	10
Front-Front	5	2	11	18	11
Front-Side	25	20	27	72	42
Single	6	11	23	40	24
Side-Side	3	5	8	16	10
Consecutive	1	0	3	4	3
Total Per Year	**43**	**45**	**78**	**166**	**100**

(Source: Karanganyar Police Traffic Unit 2021-2023)

Table 2 shows that accidents on the Karanganyar-Matesih road often occur in front-side collisions, 72 (42%) incidents. The highest number of front-side accidents during the 3 years occurred in 2023, which was 27 incidents.

Accident characteristics based on victim class

Table 3 below shows the characteristics of accidents based on victim class that occurred on the Karanganyar-Matesih Road in 2021-2023.

Table 3. Accident based on victim class

Year	Casualty Fatality Rate			Total Per Year
	Victim Class			
	LR	LB	MD	
2021	49	9	10	68
2022	55	9	14	78
2023	87	13	16	116
Total	**191**	**31**	**40**	**262**
Percentage (%)	**73**	**12**	**15**	**100**

(Source: Karanganyar Police Traffic Unit 2021-2023)

Table 3 shows that over the past 3 years, the number of accident victims has increased every year. The peak in 2023 was 16 fatalities (MD), 13 serious injuries (LB), and 87 minor injuries (LR). During the period 2021-2023, the highest fatality rate was minor injuries with a total of 191 (73%) people.

Accident characteristics based on driver gender and age

Table 4 below shows the characteristics of accidents on the Karanganyar-Matesih road based on the gender of the vehicle driver or road user in 2021-2023.

Table 4. Accident based on driver gender and age

Year	Driver Gender		Total Per Year
	Male	Female	
2021	76	6	82
2022	60	17	77
2023	105	31	138
Total	**241**	**54**	**295**
Percentage (%)	**82**	**18**	**100**

(Source: Karanganyar Police Traffic Unit 2021-2023)

Table 4 above shows that the majority of drivers in traffic accidents are male with a total of 241 (82%) while women are only 54 (18%) people. This result is because men do more daily activities outside the home, especially in doing work. The higher number of male drivers involved in traffic accidents, as shown in Table 4, can be explained by the fact that men are more likely to engage in activities outside the home on adaily basis, particularly work-related activities.

Table 5 below shows the characteristics of accidents on Jalan Karanganyar-Matesih based on the age of vehicle drivers or road users in 2021-2023.

Table 5. Accidents by driver age

Year	Age				Total Per Year
	< 18 (Years)	18-30 (Years)	31-48 (Years)	> 48 (Years)	
2021	11	33	22	16	82
2022	15	35	20	7	77
2023	20	60	38	18	138
Total	**46**	**128**	**80**	**42**	**295**
Percentage (%)	**15**	**43**	**27**	**14**	**100**

(Source: Karanganyar Police Traffic Unit 2021-2023)

Table 5 shows that the majority of the age of drivers who had accidents on Jalan Karanganyar-Matesih was between 18-30 years with a total of 128 (43%) people. This age is productive so they do more activities outside the home by driving. Based on accident data recorded at PT. Jasa Raharja also shows harmony with the statement that traffic accidents often occur at productive ages. In 2021, the total number of accident victims at productive ages was 78,660 (40.4%) people.

Accident characteristics based on vehicle type

Table 6 below shows the characteristics of accidents based on vehicle type on the Karanganyar-Matesih Road in 2021-2023.

Table 6. Accidents by vehicle type

Year	Vehicle Type				Total Per Year
	Motorcycle	Passenger Car	Bus	Goods Car	
2021	78	1	0	2	81
2022	71	5	0	2	78
2023	123	8	3	2	138
Total	**272**	**14**	**3**	**6**	**295**
Percentage (%)	**92**	**5**	**1**	**2**	**100**

(Source: Karanganyar Police Traffic Unit 2021-2023)

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Table 6 shows that the type of vehicle most frequently involved in accidents during 2021-2023 was motorcycles with a total of 272 (92%) vehicles. Other types of vehicles involved were passenger cars with a total of 14 (5%) vehicles, buses with 3 (1%) vehicles, and goods vehicles with 6 (2%) vehicles. The results of this analysis are supported by data from the Central Statistics Agency which shows that the number of motorcycle ownership is very high and continues to increase every year. In 2021, the total number of motorcycle ownership was 120,042,298 vehicles and increased in 2022 to 125,305,332 vehicles.

Accident characteristics based on the time the accident occurred

Table 7 below shows the characteristics of accidents based on the time of the accident on the Karanganyar-Matesih Road.

Table 7. Accidents based on the time of the accident

Year	Accident Time				Total Per Year
	Early morning (00.00-06.00)	Morning (06.00-12.00)	Afternoon (12.00-18.00)	Evening (18.00-24.00)	
2021	3	10	25	5	43
2022	4	16	17	8	45
2023	7	32	19	20	78
Total	**14**	**58**	**61**	**33**	**166**
Percentage (%)	**8**	**35**	**37**	**20**	**100**

(Source: Karanganyar Police Traffic Unit 2021-2023)

Table 7 shows that the majority of accidents occurred during the day, namely at (12.00-18.00) as many as 61 (37%). Accidents also often occur in the morning at (06.00-12.00) with a total of 58 (35%) incidents. This time is a productive hour or busy time for people to do activities, resulting in traffic congestion. The Karanganyar-Matesih Road environment has many public facilities such as schools, offices, mosques, food stalls, and shops and is the main road for Matesih residents to Karanganyar city so at that time the traffic flow is relatively busy. The density of traffic flow during productive hours on this road results in a high number of traffic accidents compared to other times.

Factors Causing Traffic Accidents

Table 8 below shows traffic accidents on the Karanganyar-Matesih Road are caused by three factors, namely human, environmental, and vehicle factors.

Table 8. Factors causing traffic accidents

Year	Factors causing traffic accidents			Total Per Year
	Human	Environment	Vehicle	
2021	43	0	-	43
2022	42	3	-	45
2023	71	0	7	78
Total	**156**	**3**	**7**	**166**
Percentage (%)	**94**	**2**	**4**	**100**

(Source: Karanganyar Police Traffic Unit 2021-2023)

Table 9 below shows a description of the factors causing traffic accidents, including:

Table 9. Factors causing traffic accidents

Factor	Description	Total
Human	Changing lanes without caution	23
	Driving while playing with a cellphone	7
	Sudden braking	7
	Mistakes in turning without turning on the turn signal	27

Factor	Description	Total
	Drunk	2
	Drowsy	21
	Entering an intersection carelessly/not carefully	26
	Driving at excessive speed	23
	Overtaking unsafely	13
	U-turns or U-turns carelessly	7
Vehicle	Brake failure	7
Environmental	Potholey roads	3

(Source: Karanganyar Police Traffic Unit 2021-2023)

Table 8 and Table 9 show that the main factor causing traffic accidents on Karanganyar-Matesih Road is human factors with a total of 156 (94%) accidents. The number of accidents caused by road and environmental factors is only 3 (2%) incidents and vehicle factors are 7 (4%) incidents. The majority of human error is the wrong turning maneuver without turning on the turn signal with a total of 27 incidents and entering the intersection carelessly or not being careful, which is 26 incidents.

Analysis of Accident-Prone Areas

Table 10 below is an analysis of calculations based on the weighting of the Accident Equivalent Number (AEK).

Table 10. AEK value of each road segment during 2021-2023

No	Road Segment	Number of Victims			K	Components (Department of Settlement and Regional Infrastructure, 2004)				AEK Value
		MD	LB	LR		MD *12	LB *3	K *1	LR *3	Total
1	KM.0+00-KM.0+300	0	0	0	0	0	0	0	0	0
2	KM.0+300-KM.0+600	0	1	1	1	0	3	1	3	7
3	KM.0+600-KM.0+900	0	0	3	3	0	0	3	9	12
4	KM.0+900-KM.1+200	0	0	2	2	0	0	2	6	8
5	KM.1+200-KM.1+500	0	0	1	1	0	0	1	3	4
6	KM.1+500-KM.1+800	0	0	1	1	0	0	1	3	4
7	KM.1+800-KM.2+100	0	0	0	0	0	0	0	0	0
8	KM.2+100-KM.2+400	2	1	9	9	24	3	9	27	63
9	KM.2+400-KM.2+700	1	3	6	5	12	9	5	18	44
10	KM.2+700-KM.3+000	2	0	3	4	24	0	4	9	37
11	KM.3+000-KM.3+300	1	0	2	2	12	0	2	6	20
12	KM.3+300-KM.3+600	0	0	5	3	0	0	3	15	18
13	KM.3+600-KM.3+900	1	4	8	5	12	12	5	24	53
14	KM.3+900-KM.4+200	1	0	5	5	12	0	5	15	32
15	KM.4+200-KM.4+500	3	2	18	12	36	6	12	54	108
16	KM.4+500-KM.4+800	4	5	22	19	48	15	19	66	148
17	KM.4+800-KM.5+100	2	4	4	9	24	12	9	12	57
18	KM.5+100-KM.5+400	1	0	10	9	12	0	9	30	51
20	KM.5+700-KM.6+000	2	0	2	3	24	0	3	6	33
21	KM.6+000-KM.6+300	0	2	7	6	0	6	6	21	33
22	KM.6+300-KM.6+600	1	0	2	2	12	0	2	6	20
23	KM.6+600-KM.6+900	2	0	2	2	24	0	2	6	32
24	KM.6+900-KM.7+200	3	0	4	4	36	0	4	12	52
25	KM.7+200-KM.7+500	1	0	6	5	12	0	5	18	35

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No	Road Segment	Number of Victims			K	Components (Department of Settlement and Regional Infrastructure, 2004)				AEK Value
		MD	LB	LR		MD *12	LB *3	K *1	LR *3	Total
26	KM.7+500-KM.7+800	4	2	8	7	48	6	7	24	85
27	KM.7+800-KM.8+100	3	2	13	11	36	6	11	39	92
28	KM.8+100-KM.8+400	0	0	2	2	0	0	2	6	8
29	KM.8+400-KM.8+700	0	0	0	0	0	0	0	0	0
30	KM.8+700-KM.9+000	0	0	5	5	0	0	5	15	20
31	KM.8+000-KM.9+300	0	0	1	1	0	0	1	3	4
32	KM.9+300-KM.9+600	0	0	1	1	0	0	1	3	4
33	KM.9+600-KM.9+900	0	0	0	0	0	0	0	0	0
34	KM.9+900-KM.10+200	3	1	22	15	36	3	15	66	120
35	KM.10+200-KM.10+500	1	2	3	2	12	6	2	9	29
36	KM.10+500-KM.10+800	2	2	11	8	24	6	8	33	71
Jumlah		**13**	**9**	**66**	**52**	**156**	**27**	**52**	**198**	**433**

Table 10 shows the highest AEK value in the KM.4+500-KM.4+800 segment, which is 148 with a fatality rate of 4 fatalities, 5 serious injuries, and 22 minor injuries. The second sequence in the KM.9+900-KM.10+200 segment is 105 with a fatality rate of 3 fatalities, 1 serious injury, and 22 minor injuries.

The next step after the AEK value has been obtained is to calculate using the Upper Control Limit (UCL) method to determine the control limit so that it can be known whether the segment location can be declared a black spot location or not. Table 11 below is the result of the identification of black spot locations.

Table 11. Determination of black spots based on UCL and AEK values per 300 m

No	Segment	AEK value	UCL value	AEK > UCL
1	KM.0+00-KM.0+300	0	-	No
2	KM.0+300-KM.0+600	6	44	No
3	KM.0+600-KM.0+900	9	44	No
4	KM.0+900-KM.1+200	6	44	No
5	KM.1+200-KM.1+500	3	45	No
6	KM.1+500-KM.1+800	3	45	No
7	KM.1+800-KM.2+100	0	-	No
8	KM.2+100-KM.2+400	54	51	*Black spot*
9	KM.2+400-KM.2+700	39	49	No
10	KM.2+700-KM.3+000	33	48	No
11	KM.3+000-KM.3+300	18	45	No
12	KM.3+300-KM.3+600	15	45	No
13	KM.3+600-KM.3+900	48	50	No
14	KM.3+900-KM.4+200	27	47	No
15	KM.4+200-KM.4+500	96	55	*Black spot*
16	KM.4+500-KM.4+800	129	59	*Black spot*
17	KM.4+800-KM.5+100	48	50	No
18	KM.5+100-KM.5+400	42	50	No
19	KM.5+400-KM.5+700	6	44	No
20	KM.5+700-KM.6+000	30	47	No
21	KM.6+000-KM.6+300	27	47	No
22	KM.6+300-KM.6+600	18	45	No

No	Segment	AEK value	UCL value	AEK > UCL
23	KM.6+600-KM.6+900	30	47	No
24	KM.6+900-KM.7+200	48	50	No
25	KM.7+200-KM.7+500	30	48	No
26	KM.7+500-KM.7+800	78	53	*Black spot*
27	KM.7+800-KM.8+100	81	54	*Black spot*
28	KM.8+100-KM.8+400	6	44	No
29	KM.8+400-KM.8+700	0	-	No
30	KM.8+700-KM.9+000	15	45	No
31	KM.8+000-KM.9+300	3	45	No
32	KM.9+300-KM.9+600	3	45	No
33	KM.9+600-KM.9+900	0	-	No
34	KM.9+900-KM.10+200	105	56	*Black spot*
35	KM.10+200-KM.10+500	27	47	No
36	KM.10+500-KM.10+800	63	52	*Black spot*

Based on Figure 2, there are 7 segment locations where the Accident Equivalent Number value exceeds the Upper Control Limit value so it can be concluded that the segment is a black spot. For example, in the KM.2+100-KM.2+400 segment with an AEK value of 54 exceeding the UCL value of 51, the segment is categorized as a black spot location.

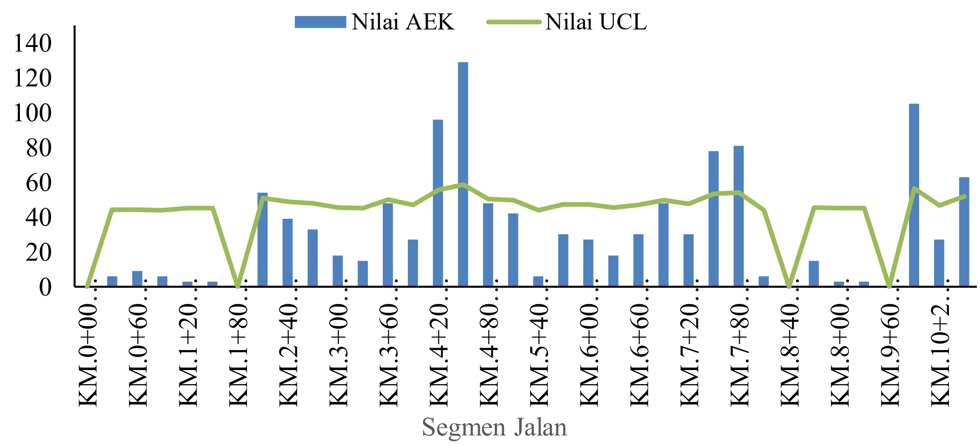

Figure 2. UCL and AEK value graph per 300 m

Figure 3 shows the identification of seven road segment locations whose Accident Equivalent Number (AEK) values exceed the Upper Control Limit (UCL). This indicates that these segments can be categorized as black spots, which are areas with a higher risk of accidents compared to other areas. As an illustration, on the road segment KM.2+100 to KM.2+400. The seven locations are on the segments KM.2+100-KM.2+400, KM.4+200-KM.4+500, KM.4+200-KM.4+500, KM.7+500-KM.7+800, KM.7+800-KM.8+100, KM.9+900- KM.10+200, KM.10+500-KM.10+800. Thus, this segment is included in the black spot category, so it requires special attention for evaluation and corrective actions to improve traffic safety at that location.

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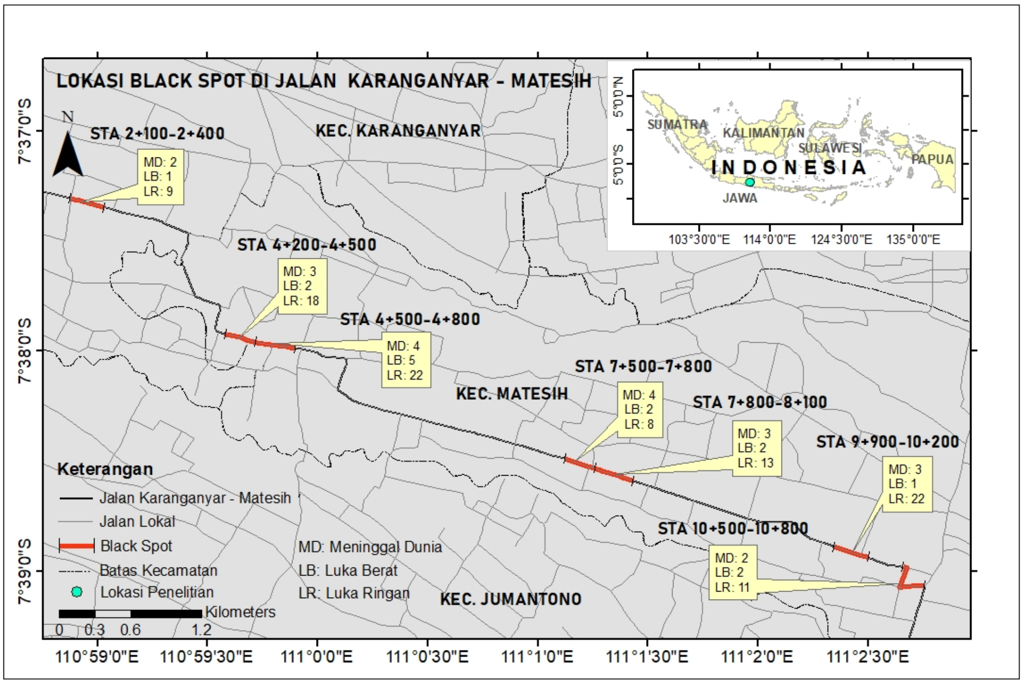

Figure 3. Location of the black spot on Karanganyar-Matesih Road

The black spot identification process utilizes Geographic Information System (GIS)-based analysis. With GIS, spatial and non-spatial data on accidents can be analyzed visually and quantitatively to identify accident patterns and high-risk road segments. GIS also allows for more accurate mapping of black spot locations, thereby supporting data-driven decision-making for planning and implementing accident risk mitigation measures. Once black spots are identified through GIS mapping, authorities can take targeted actions to reduce accident risks in those areas. This could involve changes to road design, better signage, improved lighting, or enforcement of speed limits. GIS helps to ensure that these measures are applied where they are most needed, maximizing their effectiveness in preventing accidents. In Figure 5, black spot locations are marked in red, based on accident data collected over a period of three years. This marking provides a clear visualization of high-risk areas, making it easier to prioritize safety measures at these locations.

CONCLUSION

Based on the analysis of accident data from 2021-2023, this study has successfully identified the characteristics of accidents, factors contributing to these accidents, and accident-prone locations (black spots) along the Karanganyar-Matesih Road. The findings reveal that the most common type of collision is front-side collisions, accounting for 72 incidents (42%). In terms of victim severity, minor injuries were the most frequent, with 191 individuals (73%) affected. Regarding driver demographics, the majority of involved drivers were male (241 individuals or 82%), and the most common age group was 18-30 years, with 128 drivers (43%). The vehicle type most frequently involved in accidents was motorcycles, with 272 vehicles (92%) reported. Accidents most often occurred during the day, particularly between 12:00-18:00, totaling 61 incidents (37%). The primary cause of accidents on the Karanganyar-Matesih Road was human negligence, contributing to 156 incidents (94%). Based on the Accident Equivalent Number (AEK) and Upper Control Limit (UCL) methods, the study identified 7 road segments as black spots, where accidents are more frequent. These black spot locations are at the following segments: KM 2+100-KM 2+400, KM 4+200-KM 4+500, KM 7+500-KM 7+800, KM 7+800-KM 8+100, KM 9+900-KM 10+200, and KM 10+500-KM 10+800.

These findings, visualized using a Geographic Information System (GIS), support data-driven decision-making for planning and implementing accident risk mitigation measures along the Karanganyar-Matesih Road.

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