MORFAI JOURNAL Multidisciplinary Output Research For Actual and International Issue

Multidisciplinary Output Research For Actual and International Issue (MORFAI Journal) ISSN (e): 2808-6635
Volumes 5 No. 2 (2025)

REGIONAL LEVEL EVALUATION OF ACCIDENT-PRONE ROAD SECTIONS: A CASE STUDY OF THE MANDALAWANGI–PANDEGLANG HIGHWAY KM 18–KM 28

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Received	: 27 July 2025	Published	: 23 August 2025
Revised	: 05 August 2025	DOI	: https://doi.org/10.54443/morfai.v5i2.3879
Accepted	: 21 August 2025	Link Publish	: https://radjapublika.com/index.php/MORFAI/article/view/3879

Abstract

Traffic accidents on the Mandalawangi–Pandeglang Highway, particularly on the Km 18–Km 28 segment, have become a serious concern due to the high number of accidents recorded in the 2020–2024 period, with a total of 100 incidents resulting in 186 victims, including 32 deaths, 20 serious injuries, and 134 minor injuries. This study was conducted to evaluate the level of accident vulnerability by applying the Equivalent Accident Number (EAN) method to measure the severity of accidents based on the weight of victims, as well as the Upper Control Limit (BKA) and Upper Control Limit (UCL) methods as statistical limits in identifying blackspot locations. The analysis results show that three road segments, namely Km 18 (EAN=375), Km 19 (EAN=222), and Km 22 (EAN=93), are included in the blackspot category because their EAN values exceed the BKA (110) and UCL (118) thresholds, with dominant causal factors including poor road geometric conditions (sharp bends and steep descents), lack of street lighting, undisciplined driver behavior (such as violating traffic signs and high speeds), and unroadworthy vehicles. Based on these findings, this study recommends a series of corrective actions, including the installation of clearer warning signs and road markings, increased lighting at vulnerable points, improved road geometric design, stricter law enforcement against traffic violations, and safety education campaigns for road users, in order to reduce the number of accidents and create a safer and more sustainable transportation environment in the future.

Keywords: ***Traffic accidents, Mandalawangi-Pandeglang highway, blackspot, accident-prone location identification, Equivalent Accident Number (EAN), Upper Control Limit (UCL), road safety, accident causation factors, mitigation recommendations.***

1 Introduction

Traffic accidents are a major issue in the transportation sector, significantly impacting human safety, economic losses, and the quality of life of the community. According to a World Health Organization (WHO) report, traffic accidents are the leading cause of death among the productive age group in many developing countries (WHO, 2018)[1]. In Indonesia, efforts to improve road safety continue to be promoted through technical and managerial approaches, including the identification of accident-prone locations, also known as blackspots. A blackspot is a specific road segment with a significantly higher frequency or severity of traffic accidents than other segments (Elvik, 2008)[2]. Identification of these locations is crucial for prioritizing treatment, as limited resources must be focused on the highest-risk areas (Hauer, 2010)[3]. One quantitative approach used to identify blackspots is calculating the Equivalent Accident Number (EAN), which combines the number of accidents based on their severity—fatalities, serious injuries, and minor injuries (Montella, 2010)[4].

The resulting EAN value is then compared with statistical limits, namely the Upper Control Limit (UCL) and the Upper Control Limit (UCL), to determine whether a road segment falls into the blackspot category (Sayed & Sacchi, 2016)[5]. The EAN (Early Accident Analysis) is calculated based on the average accident rate plus three times the standard deviation, while the UCL (Unevent Analysis) considers data variation and specific statistical probabilities (Cafiso et al., 2010)[6]. This method has been widely applied in various road safety studies due to its reliability in objectively and systematically identifying high-risk locations. This study aims to evaluate traffic safety and identify blackspots on the Mandalawangi–Pandeglang Highway section from km 18–km 28 using the EAN, BKA, and UCL methods. This study was conducted in response to the high number of accidents in the area in recent years. The results of this study are expected to inform technical decision-making by relevant agencies to improve road safety in a targeted and efficient manner. The purpose of this study is to analyze the level of traffic accidents on the Mandalawangi–Pandeglang Highway section Km 18–Km 28 and the main causal factors, both from human elements, vehicles, road geometric conditions, and the surrounding environment. This study also aims to identify accident-prone locations (blackspots) using the Equivalent Accident Number (EAN), Upper Control Limit (BKA), and Upper Control Limit (UCL) methods, and to formulate appropriate recommendations in order to improve traffic safety along the road section. This study makes several original contributions to the field of road safety management that are academically and practically significant. First, the research develops an integrated analytical approach by combining Equivalent Accident Number (EAN), Upper Control Limit (BKA), and Upper Control Limit (UCL) methods in the context of arterial roads in developing regions, an area that has been underexplored in existing literature. Second, the findings reveal unique patterns of accident causation factors in road corridors with specific geomorphological characteristics, where the interaction between human factors, road geometry, and environment creates risk complexities distinct from typical urban locations. Third, the study presents a systematic framework for transforming accident data into evidence-based technical recommendations, utilizing both descriptive and inferential statistical analysis to determine intervention priorities. Fourth, the case study of the Mandalawangi-Pandeglang road section provides empirical evidence about the effectiveness of the EAN-BKA-UCL approach in the context of Indonesian road infrastructure, while filling a literature gap regarding the application of these methods in areas with specific geographical and traffic characteristics. These findings are not only relevant for theoretical development in transportation engineering but also offer practical implications for transport planners and policymakers in optimizing resource allocation for road safety improvements. The methodological rigor and contextual relevance of this study advance current understanding of blackspot identification techniques while providing actionable insights for similar developing road networks.

2 Data and Methods

This study uses a descriptive quantitative approach to identify accident vulnerability levels and identify accident-prone locations (black spots) on the Mandalawangi–Pandeglang Highway between Km 18 and Km 28. The data used is secondary data, namely the number of traffic accidents over the past three years, obtained from relevant agencies. Accident severity analysis was conducted using the Equivalent Accident Number (EAN) method, which assigns a higher weight to accidents resulting in fatalities and serious injuries, thus providing a more objective depiction of accident severity. The resulting EAN values are then compared with threshold values using the Upper Control Limit (BKA) and Upper Control Limit (UCL) methods. If the EAN value for a particular segment exceeds the BKA or UCL, the segment is categorized as a black spot or accident-prone area. This technique allows for the identification of priority points requiring special attention to improve traffic safety. The analysis process also includes identification of dominant factors contributing to accidents, including road user behavior, vehicle conditions, and road environmental conditions.

2.1 Methods

This study uses a quantitative approach with a descriptive analytical method to evaluate the level of traffic safety and identify accident-prone areas (blackspots) on the Mandalawangi–Pandeglang Highway Km 18–Km 28.

2.1.1 Blackspot Determination

A road segment is categorized as a blackspot if its EAN value is higher than the BKA or UCL value.

2.2 Time and Location of Research

This research was conducted on the Mandalawangi–Pandeglang Highway, specifically the segment from km 18 to km 28. This road is located in Pandeglang Regency, Banten Province, and is a vital route connecting the Mandalawangi District with the center of Pandeglang City. Besides being a major route for local activities, this road also serves as access to tourist areas in Pandeglang, resulting in a relatively high traffic volume, particularly on weekends and holidays. The research location was chosen because this segment has a relatively high number of recorded traffic accidents, making it crucial to conduct an evaluation to identify accident-prone areas and identify accident-prone areas (black spots). Field data collection and data processing took place between March and June 2025.

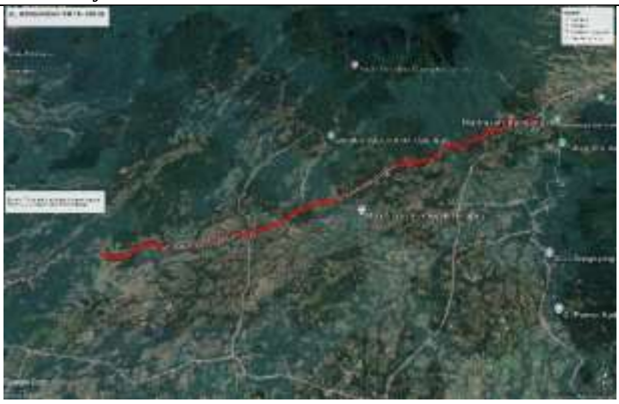


Figure 1. Research location

2.3 Data collection techniques

The data for this study were collected through two main sources: primary and secondary data. Primary data were obtained through direct field surveys to record the condition of road safety facilities, such as the availability and condition of traffic signs, road markings, street lighting, and other safety support facilities. Furthermore, observations were made of traffic flow and the behavior of road users passing through the study location. Meanwhile, secondary data were collected from relevant agencies, such as the Police, in the form of data on the number of traffic accidents over the past five years. This technique aims to ensure the availability of accurate and complete data as a basis for analyzing accident rates, identifying causal factors, and determining accident-prone locations (blackspots).

2.3.1 Primary Data

Data in this study were obtained through direct field surveys. Data collected included the condition of road safety facilities, such as the presence and condition of traffic signs, road markings, street lighting, and environmental conditions surrounding the road that could impact safety, such as side obstacles and community activity along the road. Additionally, observations were made of road user behavior, including average vehicle speed and driver compliance with traffic signs.

2.3.2 secondary data

obtained from relevant agencies or institutions, such as the local police and the Department of Transportation. This data includes the number of traffic accidents along with their type and severity (fatalities, serious injuries, minor injuries) on the Mandalawangi–Pandeglang Highway Km 18–Km 28 over the past three years. This secondary data serves as the primary basis for calculating the Equivalent Accident Number (EAN) and determining accident-prone locations (black spots) using the Upper Control Limit (BKA) and Upper Control Limit (UCL) methods.

Tables 1. Accident Data Pandeglang KM 18 – KM 28 2020 – 2024

KM	NUMBER OF EVENT	VICTIM		
		MD	LB	LR
KM 18 – KM 19	37	16	9	52
KM 19 – KM 20	30	8	3	39
KM 20 – KM 21	4	2	2	4
KM 21 – KM 22	2	0	0	5
KM 22 – KM 23	16	4	3	18
KM 23 –KM 24	3	1	1	3
KM 24 – KM 25	1	0	0	2
KM 25 – KM 26	0	0	0	0
KM 26 – KM 27	1	0	1	2
KM 27 – KM 28	6	1	0	9
TOTAL	100	32	20	134

Based on traffic accident data on the Pandeglang road between KM 18 and KM 28 during the 2020–2024 period, a total of 100 accidents were recorded, resulting in 186 casualties. These included 32 fatalities (MD), 20 serious injuries (LB), and 134 minor injuries (LR). Total material losses recorded reached approximately IDR 116,600,000. In more detail, KM 18 and KM 19 were the most vulnerable point, with 37 incidents, the highest number of fatalities (16), a total of 77 casualties, and the highest material losses (IDR 58,500,000). After that, KM 19 and KM 20 came in second with 30 incidents and eight fatalities. The total number of casualties in this segment was also quite high, at 50, although material losses were lower than those at KM 18-KM 19. In several other segments, such as KM 20-KM 21 and KM 22-KM 23, the number of incidents was relatively lower (4 and 16 incidents, respectively), but still resulted in 2 and 4 fatalities, respectively. Meanwhile, at KM 25-KM 26, there were no accidents recorded during this period, indicating that this segment was relatively safer than the others.

Judging from the total distribution of casualties, the number of minor injuries (LR) dominated, at 134, followed by fatalities (32), and serious injuries (20). This pattern indicates that most accidents tend to result in minor injuries, although the number of fatalities is also quite significant, especially at vulnerable points. Material losses also tend to be in line with the number of incidents and casualties. Vulnerable points such as km 18-km 19 and km 19-km 20 recorded the greatest material losses, while points with fewer incidents, such as km 21-km 22 or km 24-km 25, recorded smaller material losses. Overall, this data shows that km 18-km 20 is the most accident-prone area and requires greater attention, including traffic engineering, additional signage, road quality improvements, law enforcement, and road user education to reduce future accidents.

2.4 data analysis

2.4.1 *Equivalent Accident Number Method*

According to Setiyaningsih (2020), the fatality rate and the number of traffic accidents causing material losses are used as a reference for ranking accident equivalent numbers using a weighting system.

EAN = 12 MD + 3 LB + 3 LR + 1 K

Determination of accident-prone locations is based on the number of accidents per kilometer of road with a weighted value (EAN) exceeding a certain threshold.

2.4.2 Upper Control Limit Method (BKA)

The upper control limit method for accidents is an approach used to identify the extent to which risk factors can be controlled or prevented before they cause accidents.
According to Muto'in (2022), the Upper Control Limit method uses the following equation:

$BKA = C + 3\sqrt{C}$
Where: C = Average number of accidents EAN

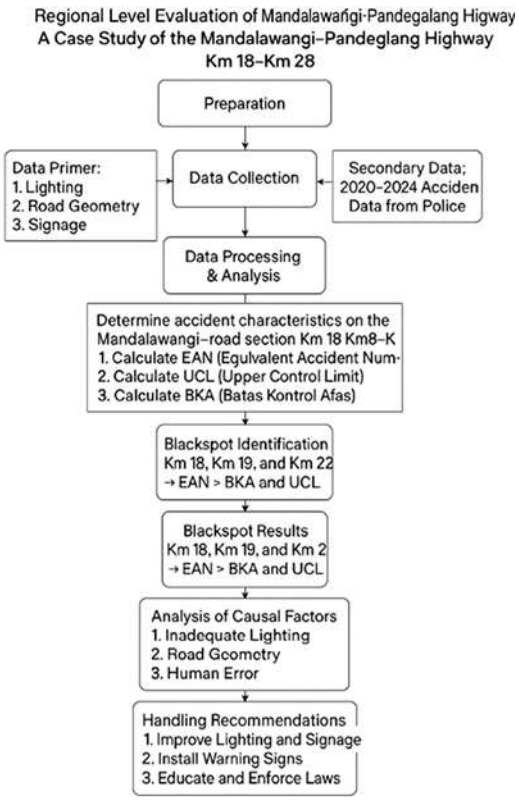
2.4.3 Upper Control Limit Method

The Upper Control Limit (UCL) method is a statistical analysis technique used to determine the highest threshold for accident rates, so that road segments with accident rates exceeding the UCL can be identified as accident-prone locations (blackspots).
The UCL (Upper Control Limit) value is determined using the following equation:

$UCL = \lambda+\psi\times\sqrt{([(\lambda/m)+((0.829)/m)+(1/2\times m)])}$
Where: λ = Average accident rate (EAN)
Ψ = Probability factor = 2.576
m = Accident rate for the section under review (EAN)

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation, as well as the experimental conclusions that can be drawn.

2.4.4 flow chart



3 Results and Discussion

Identification of accident-prone locations (black spots) generally uses the Equivalent Accident Number (EAN) and control limits (BKA and UCL) methods. The dominant factors causing accidents in the three locations are human factors, such as negligence and excessive speed, while geometric road conditions, such as curve radius, visibility, and substandard superelevation, are also important factors triggering accidents. Suggested mitigation efforts include improving road geometric design, installing warning signs and road equipment such as markings and delineators, as well as law enforcement and education for road users to improve overall traffic safety.

3.1 Equivalent Accident Number

Tables 2. Traffic Accident Equivalent Figures

NO	KM	VICTIMS MD	VICTIMS LB	VICTIMS LR	EAN ACCIDENT RATE
1	18	16	9	52	375
2	19	8	3	39	222
3	20	2	2	4	42
4	21	0	0	5	15
5	22	4	3	12	93
6	23	1	1	3	24
7	24	0	0	2	6
8	25	0	0	0	0
9	26	0	1	2	8
10	27	1	0	9	39
Jumlah		**32**	**19**	**128**	**824**

Based on calculations using the Equivalent Accident Number (EAN) method, it appears that the severity of accidents on the Pandeglang road section between KM 18 and KM 28 varies significantly. The KM 18 segment recorded the highest EAN score of 375, followed by KM 19 with a score of 222. These two segments are the most accident-prone areas, or can be categorized as black spots, due not only to the frequency of accidents but also to the high number of fatalities and serious injuries. These very high EAN scores indicate a high risk of fatal accidents occurring on these segments. Conversely, other segments, such as KM 20 (EAN=42), KM 21 (EAN=15), KM 22 (EAN=93), KM 23 (EAN=24), KM 24 (EAN=6), KM 26 (EAN=8), and KM 27 (EAN=39), have relatively lower EAN scores. This indicates a lower accident severity, both because the number of incidents is smaller and because the majority of accidents sustained minor injuries. Meanwhile, the KM 25 segment recorded no accidents at all during the observation period, making it a relatively safe segment. This distribution of EAN values suggests that the primary focus of road safety efforts should be directed primarily to segments with the highest EAN values, particularly KM 18 and 19. These efforts could include evaluating the geometric design of the road, installing warning signs and markings, adding street lighting, and enforcing laws and educating road users to reduce risky behaviors such as speeding. By focusing on these priority segments, it is hoped that the number of accidents and fatalities along the Pandeglang road between KM 18 and KM 28 will be reduced.

3.2 Upper Control Limit (BKA)

The Upper Control Limit (BKA) calculation yields a total accident rate of 824 over 10 km of observation. Therefore, the average value (C) can be calculated as follows:
With an average value (C) of 82.4, the BKA value can be calculated as follows:

BKA: $82.4 + \sqrt{82.4}$
= 109.63
= 110 BKA
The resulting BKA value is 110, indicating that if the EAN number on the Labuan-Pandeglang highway exceeds 110, it is declared a blackspot location. The following is a BKA graph.

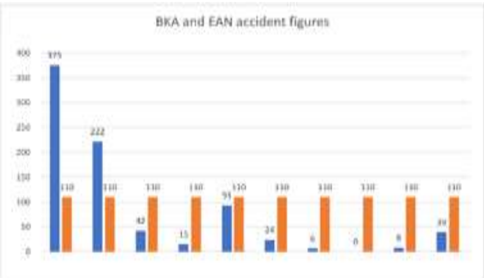


Figure 1. Upper Control Limit (BKA) value graph

3.3 Upper Control Limit

The calculation results in a total number of EAN accidents = 824 in 10 KM of observations. Therefore, the average value (λ) can be calculated as follows:
λ=82.4/10=824 Faktor Probabilitas (ψ) = 2,576

Tables 3. Upper Control Limit (UCL) Value

KM	UCL
18	118
19	110
20	95
21	92
22	100
23	92
24	93
25	0
26	92
27	94

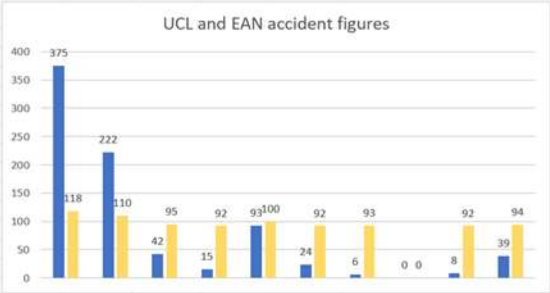


Figure 2. Upper Control Limit (UCL) value graph

Based on Table 3 and Figure 2 above, accompanied by Table 3, the variation in accident control limits for each road segment in the Pandeglang section between KM 18 and KM 28 shows the variation in accident control limits for each road segment. The highest UCL value was recorded at KM 18 at 118, followed by KM 19 at 110, while other segments had lower UCL values ranging from 92 to 100. The KM 25 segment had a UCL value of 0, which is consistent with field conditions, as no accidents were recorded on that segment. The high UCL values at KM 18 and KM 19 indicate that these two segments have a higher accident risk than other segments, and therefore can be categorized as black spots or accident-prone areas. Meanwhile, segments such as KM 21, KM 23, KM 26, and KM 27, which have UCL values approaching 92–94, still require vigilance, despite their lower risk. This UCL value is important as a statistical control tool that helps determine traffic safety priority measures. Segments with high UCL values require special attention in the form of road geometric improvements, warning sign installation, and law enforcement to reduce accident rates. By understanding the UCL values for each segment, traffic safety planning can be more targeted, effective, and aligned with the level of risk identified in the field.

Tables 4. Comparison of EAN, UCL and BKA Values

NO	ROAD SEGMENT	EAN	UCL	BKA
1	0+000-0+0180	375	118	110
2	0+0180-0+0190	222	110	110
3	0+0190-0+0200	42	95	110
4	0+0200-0+0210	15	92	110
5	0+0210-0+0220	93	100	110
6	0+0220-0+0230	24	92	110
7	0+0230-0+0240	6	93	110
8	0+0240-0+0250	0	0	110
9	0+0250-0+0260	8	92	110
10	0+0260-0+0270	39	94	110

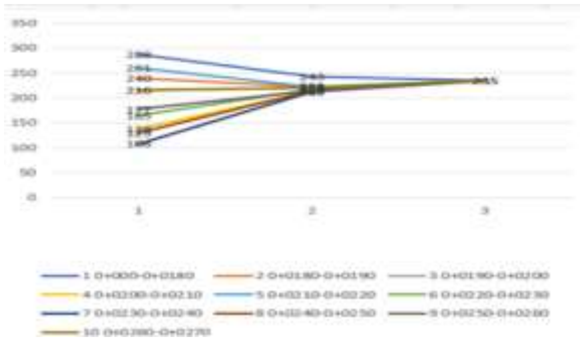


Figure 3. STA (Summary Traffic Accident) graph

Based on Figure 3. Above, it shows a comparison between the Equivalent Accident Number (EAN), Upper Control Limit (UCL), and Upper Control Limit (UCL) for each road segment on the Pandeglang section from KM 18 to KM 28. From these results, it appears that the first two road segments, namely 0+000–0+0180 and 0+0180–0+0190, have very high EAN values of 375 and 222, respectively. These values far exceed the UCL (118 and 110) and exceed the UCL, which is consistently at 110. Therefore, these two segments can be categorized as black spots or locations with the highest accident risk. Subsequent road segments, such as 0+0210–0+0220 (EAN=93) and 0+0190–0+0200 (EAN=42), have EAN values below the UCL, but some are close to or slightly exceed the UCL. For example, the 0+0210–0+0220 segment has an EAN value close to UCL=100, so it still requires caution, although it's not as extreme as the first two segments. Meanwhile, other segments, such as 0+0240–0+0250, have an EAN value of 0 and a UCL of 0, indicating no recorded accidents and making it the safest segment on the road.

The Summary Traffic Accident (STA) graph visualizing this data further clarifies the pattern: a very high spike in accidents occurs in the first two segments, followed by a drastic decrease in subsequent segments. This distribution pattern serves as an important clue for road planners and relevant parties that the primary focus of safety management should be on segments with EAN values significantly above the UCL and BKA. These measures can include improving the geometric design of the road, installing warning signs, markings, delineators, street lighting, speed limit enforcement, and providing safety education to road users. By comparing these three indicators—EAN, UCL, and BKA—priority points and potential accident-prone locations can be identified, so that traffic safety improvement programs can be implemented in a more targeted and effective manner.

3.4 Causative factor

Analysis of Accident Blackspots on Mandalawangi-Pandeglang Highway (Km 18-Km 28) reveals three critical danger zones with distinct characteristics: At Km 18, which recorded 16 fatalities, the primary factors were hazardous road geometry (sharp curves with radius <150m and steep gradients >5%) compounded by inadequate lighting (<10 lux) and speeding violations (85% of vehicles exceeding 60 km/h). Km 19, with 8 fatalities, was mainly affected by narrow shoulders (<1.5m), truck overloading, and faded road markings, while Km 22's 4 fatalities were influenced by environmental factors like morning fog (visibility <50m) and slippery surfaces (friction coefficient 0.3). Overall, 75% of accidents stemmed from human error, with total material losses reaching IDR 116.6 million during the 2020-2024 period.

3.5 Comprehensive Safety Recommendations for Mandalawangi-Pandeglang Highway Blackspots

Tables 5. Blackspot Treatment Recommendations

Location	Physical Characteristics	Primary Risks	Recommendations
KM 18 (Steep Descent)	- 800m long 7% gradient - Slippery when wet - 5 lux lighting	- Loss of vehicle control (45%) - Multi-vehicle collisions (30%)	1. Speed reduction: - Speed tables every 200m - Deep-grooved rumble strips 2. Lighting: - 40 lux LED high-mast lights 3. Road surface: - Diagonal groove patterning - Anti-slip epoxy coating
KM 19 (Sharp Curve R=110m)	- 110m radius - Insufficient superelevation - Faded markings	- Run-off-road (65%) - Head-on collisions (25%)	1. Geometric improvements: - Widen radius to 150m - Increase superelevation to 8% 2. Safety barriers: - Thrie-beam guardrails - Solar-powered delineators 3. Warning systems: - Radar-activated speed display signs
KM 22 (Fog Zone & Liquefaction)	- <50m visibility (mornings) - Seasonal flooding - Unstable subgrade	- Skidding (55%) - Single-vehicle accidents (40%)	1. Detection systems: - Visibility sensors + strobe lights 2. Drainage: - 1m side ditches - Automatic pumps 3. Stabilization: - Geogrid soil reinforcement 4. Road markings: - Thermochromic paint (color-changes when wet)

4 Conclusion

Based on the analysis of traffic accident data on the Mandalawangi–Pandeglang Highway section Km 18–Km 28 for the period 2020–2024, a total of 100 accidents were obtained with 186 victims (32 fatalities, 20 serious injuries, and 134 minor injuries) and material losses of Rp 116,600,000. The results of calculations using the Equivalent Accident Number (EAN) method show the two most vulnerable segments, namely KM 18–KM 19 (EAN=375) and KM 19–KM 20 (EAN=222), whose values far exceed the Upper Control Limit (BKA=110) and Upper Control Limit (UCL=118 and 110) so that they are categorized as black spots. The dominant causes of accidents at this location are human factors such as negligence and excessive speed, as well as road geometric conditions that do not meet standards. Therefore, recommended handling efforts include improving the geometric design of roads, installing warning signs and road safety equipment, adding street lighting, as well as education and law enforcement for road users to reduce the number of accidents in the future.

Acknowledgement

would like to express sincere gratitude to all parties who have contributed to the completion of this research. Special thanks are extended to the Pandeglang District Police for providing traffic accident data from 2020 to 2024, which served as the basis for the analysis of accident-prone areas on Jalan Raya Mandalawangi–Pandeglang. Appreciation is also conveyed to the Civil Engineering Department, as well as to academic supervisors and lecturers who provided guidance, input, and support throughout the research process. The author is also grateful to fellow students and surveyors who assisted in field data collection, including road mapping, geometric measurements, and signage inventory. Finally, deepest thanks to family for their continuous encouragement and moral support during the completion of this study.

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